A TREATISE
ON
THE DESIGN AND CONSTRUCTION
OF

MILL BUILDINGS

AND OTHER INDUSTRIAL PLANTS

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PREFACE

This book is the outcome of a smaller one entitled "Mill Building Construction," written in 1896 and given to the publishers in 1900. These books are based on the personal experience of the writer, covering a period of twenty years in designing and estimating buildings, bridges and other structural work, and most of their contents is from his private notes and records.

A separate part on "The Theory of Economic Design" was included in the present work because of the large amount of capital being invested in manufacturing plants. A knowledge of the possibilities and requirements should precede the design, and it is only by the exercise of such knowledge that the best results are obtained. The introduction of Part I has caused some repetition, as subjects discussed generally in this part are treated more fully in Parts III and IV on details. The repetition, however, seems necessary for clearness, as the whole contents of one part would be out of place in the other. This is particularly the case in the chapters on framing of northern light and other roofs.

The table of required wall thickness according to the building laws of different cities, is subject to change, but shows accepted practice. Before designing buildings for any of the cities mentioned, a copy of the latest ordinance should be consulted.

Chapters VI and VII, on the comparative cost of different kinds of manufacturing buildings, contain estimated costs rather than actual ones, for comparisons are then more reliable, as external conditions are considered uniform.

It was at first intended to include chapters on Graphic Statics and Calculations, after those on Loads and Framing, but these were omitted to make room for more important ones. It appears unnecessary, in a book on building construction, to occupy valuable space in reviewing mathematical methods, with which the reader is already familiar and which are fully treated in other books.

Chapters XV and XVI are purposely short, and consist chiefly of illustrations. The arrangement of members for timber framing

(Chapter XV) is similar in many respects to that for steel, which is outlined in other parts of the book, and the subject of Timber Framing has been covered by others. Only a brief review is made in Chapter XVI of a subject which has been completely discussed in recent treatises, but the costs, formulæ and other data given are from the writer's personal records.

Ground floors are well illustrated, for they are important, and although the subject has been much studied, there is but little available literature. The construction of upper floors and especially fireproof ones, is given less space, as they differ little from those in other kinds of buildings. A hundred pages or more might easily be written on the subject, but this would appear unnecessary, as text books on fireproof building construction are abundant.

As modern manufacturing plants represent such large investments, several chapters are given to the preservation of their materials by paint and painting, and in the preparation of these chapters, in order that the directions given might be the best and latest, assistance has been received from The Sherwin Williams Paint Co., of Cleveland and the Lowe Bros. Paint Co., of Dayton.

Part V was prepared especially for students, estimators and draftsmen, and to others it may appear elementary. The costs given are from my own notes, and should be all the more valuable because data of this kind are generally difficult to secure. But approximate costs should be very carefully used, and should be revised to suit the time and place in question, or serious errors may result. To assist in revising them, a table is included giving the wages paid to mechanics in the building trades in all parts of North America, which should also be kept up to date.

Drawings and illustrations are freely used, as they generally convey ideas more easily than text.

Advertising of special goods or makes is not intended, and where manufacturers' names are given, it is only for the benefit of the reader and not in any way to favor one maker above another, excepting as impartial judgment directs.

As extracts have been very freely made by others from the author's writings in the engineering and technical journals of America and Europe (often without credit), foot notes are used, giving the date of the original articles, and other notes refer to extracts from "Mill Building Construction." Tables I, II, III and IV were supplied by the Shaw Electric Crane Co. A number of illustrations are from the pages of Engineering News, Engineering Record, Engineering Magazine, and other papers and journals, and a few from Report No. V of The Boston Manufacturers' Mutual Fire Insurance Co. In writing this book I have been greatly assisted, especially in the preparation of drawings, by my wife, Maude K. Tyrrell, who is a graduate of the Chicago Art Institute and experienced in architecture. H. G. TYRRELL.

Evanston, Illinois, January, 1910.

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PART I
THEORY OF ECONOMIC DESIGN

CHAPTER I.

GENERAL FEATURES AND REQUIREMENTS.

Mill and other industrial buildings, in order to produce at minimum cost, must be carefully planned and suited to their individual needs. There is a difference of 10 to 15 per cent in the cost of labor, resulting from the convenience of these buildings and adaptability to their use. There are many old plants, long out of date, on which enough money has been spent in additions and repairs, to construct new ones. Old buildings which are wrongly located or insufficient to their needs are wasteful in production, and yet it is frequently difficult to decide just when an old manufacturing building should be abandoned and the machinery moved into a new one. Many companies carrying on profitable business are hampered with a plant that is so out of date and so inadequate that competition with more recent ones is difficult. A complete and destructive fire is often the cause of rebuilding modern plants of suitable strength, containing the proper equipment and handling appliances necessary to meet competition.

Before deciding on the general features of a new plant, a careful study must be made of all the conditions and needs, with a view not only to immediate requirements, but also to future extension. Old plants are generally the product of gradual growth and enlargement. Starting with a small building, others have been added from time to time, without regard for the best ultimate arrangement, and often the growth of the plant has been unexpected. There are large iron works in Pennsylvania which are producing under very unfavorable conditions, owing to their wrong location, and because their rapid growth was unforeseen by their owners. If the proprietors of these industries had anticipated the increase of their business, they would not only have made a beginning in a more favorable location, but would also have drawn a plan for the ultimate arrangement of buildings, and developed their plant according to that plan. After years of growth and the construction of numerous buildings filled with heavy and expensive machinery, with the whole site laid out and built upon, little by little, until the plant represents a large investment of capital, removal is then too costly to consider. The best that can then be done is to carry on production in the most economical way possible under these adverse circumstances.

There are, however, many large but old plants producing at too great a sacrifice, and these are being abandoned and new buildings erected on sites with ample room not only for the present needs but for future expansion. In some cases, where the old wooden buildings have been completely destroyed by fire, new ones can be erected on the old location.

Careful study should be given to the requirements of each individual building, to the arrangement of the different ones and their location in reference to each other. They should be so placed that they may be economically reached by one or more lines of railroad, with provision for receiving and storing materials and for storing, loading and shipping the products. Buildings should be so placed in reference to each other that products and materials can be easily transferred, if required, from one building to another. The complete plant should be so planned as to facilitate production with the greatest economy. The experience at other plants in manufacturing similar products or different goods under similar conditions, will doubtless be of great benefit, but it is unsafe to lay out a new plant exactly like some other, without thoroughly examining all conditions and ascertaining definitely if the features are the best suited to the particular industry.

Some modern plants have buildings connected with a system of tunnels or subways for pipes and wires, thereby avoiding frequent trench digging and taking up floors to reach drains or lines of water or steam pipes. The Corn Products plant at Argo, Illinois, and the Sturtevant plant at Hyde Park, Massachusetts (Figs. 307 and 308), are examples of those plants with complete subway systems. The subway for the Sturtevant shops is five feet in width and six and one-half feet in height.

A proposed plan for the arrangement of a set of shops for a complete plant is shown in Fig. 1. The buildings are arranged with their longitudinal axes radiating from a center, and are connected by two circular lines of railway, an inner and an outer one. At the center of the plant is located the executive building, containing the general offices, and the shop offices for the various buildings are located in the shops at the ends adjoining the executive building. With this arrangement, the management is in close touch with the foremen of the shops and can secure personal consultations on short notice, which is difficult where the shop offices are scattered over a large area. While the plan has some

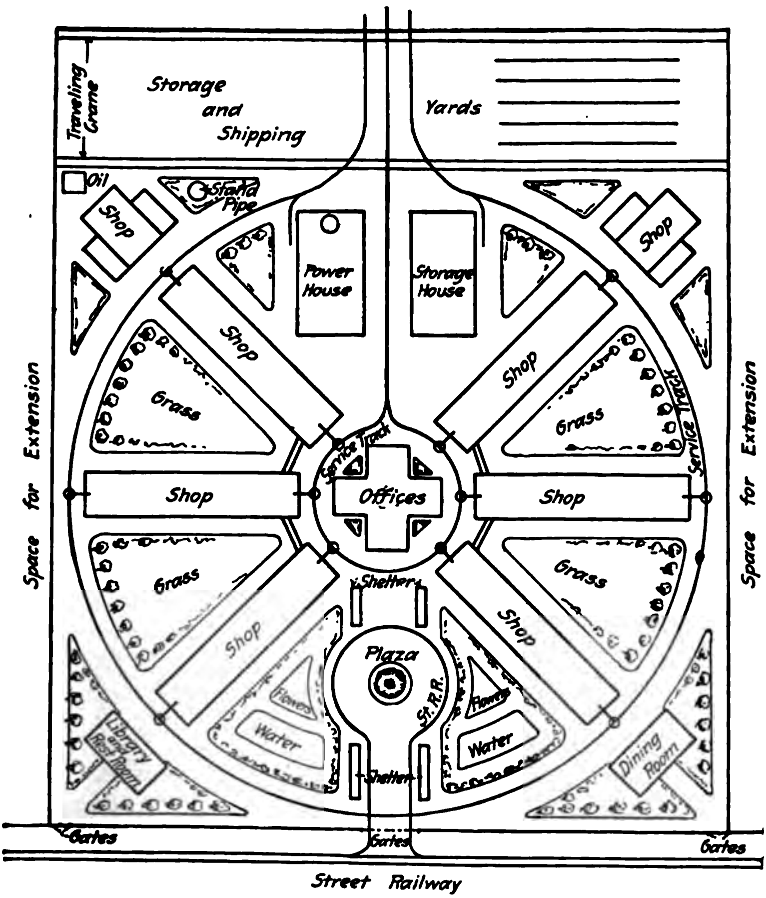


Fig. 1.

points of merit, there are other features, especially that of track service, which cannot be recommended.

A more practical plan, laid out on parallel lines, is shown in Fig. 2. The executive office occupies the center of the plot, with shops at either side, and a power house in the rear adjoining the shipping yards. The plant is served by both rail and water, while street cars pass in front and a branch line joins the city railway system with the storage and shipping yards. At both sides of the plant there is additional space for future expansion if required. The ground in front adjoining the street is laid out in grass plots with ponds and shrubbery, and contains two buildings devoted to welfare features, with a dining-room on one side and a library and rest room on the other. A complete tunnel system

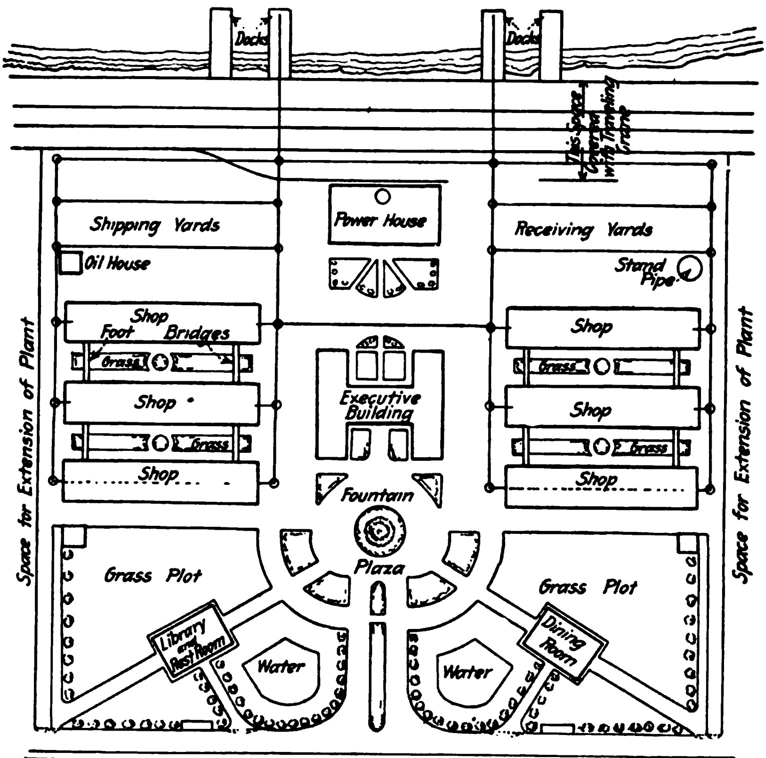


Fig. 2.

connects the buildings with the power house, and foot bridges join the shops at each story. In the plaza directly in front of the executive building is a fountain, and between the shops are beds of flowers, shrubbery and grass. These plans are suggestions for a convenient, symmetrical and artistic arrangement, and would be modified to suit particular demands.

Figs. 3, 4 and 5 show plants actually built, the first being in Germany and the others in America.

CHAPTER II.

LOCATION AND SITE.

Most old plants are not economically located. They have grown from small beginnings, and were built in the vicinity of their owners' residence, without reference to the principles of economic location and production. Their location is, in fact, an accident. Little by little these plants have developed, until large manufacturing industries have resulted, which are not only remote from their source of supplies, but often have poor shipping facilities and insufficient labor. There is, in one of the Eastern States, a large structural iron works on a branch railroad several miles from the main line, which was started twenty years ago as a sheet metal shop with a single wooden building. It was owned and operated by a resident of the adjacent village. A change of management was made, and in ten years the little plant developed into a large and prosperous one, manufacturing all kinds of structural iron work in addition to its original sheet metal products. The nearest labor market was ten to fifteen miles distant, and raw materials were brought largely from Pittsburg. After a dozen or more buildings had been erected, it was decided to remove the entire works to the vicinity of Pittsburg, near the source of supplies and the best market for structural labor. At the old location, dividends were being wasted in useless freight charges, and the market area for manufactured products was limited in comparison to the corresponding area when near the source of raw materials.

In selecting an economical location for a manufacturing plant, the following are the chief considerations:

(1) The amount of ground required for yards and buildings.

(2) Value and availability of land for present needs and extension.

(3) The amount of labor in the vicinity.

(4) Proximity to source of power and cost of same.

(5) Proximity to source of raw materials.

(6) Distance from residence of owners.

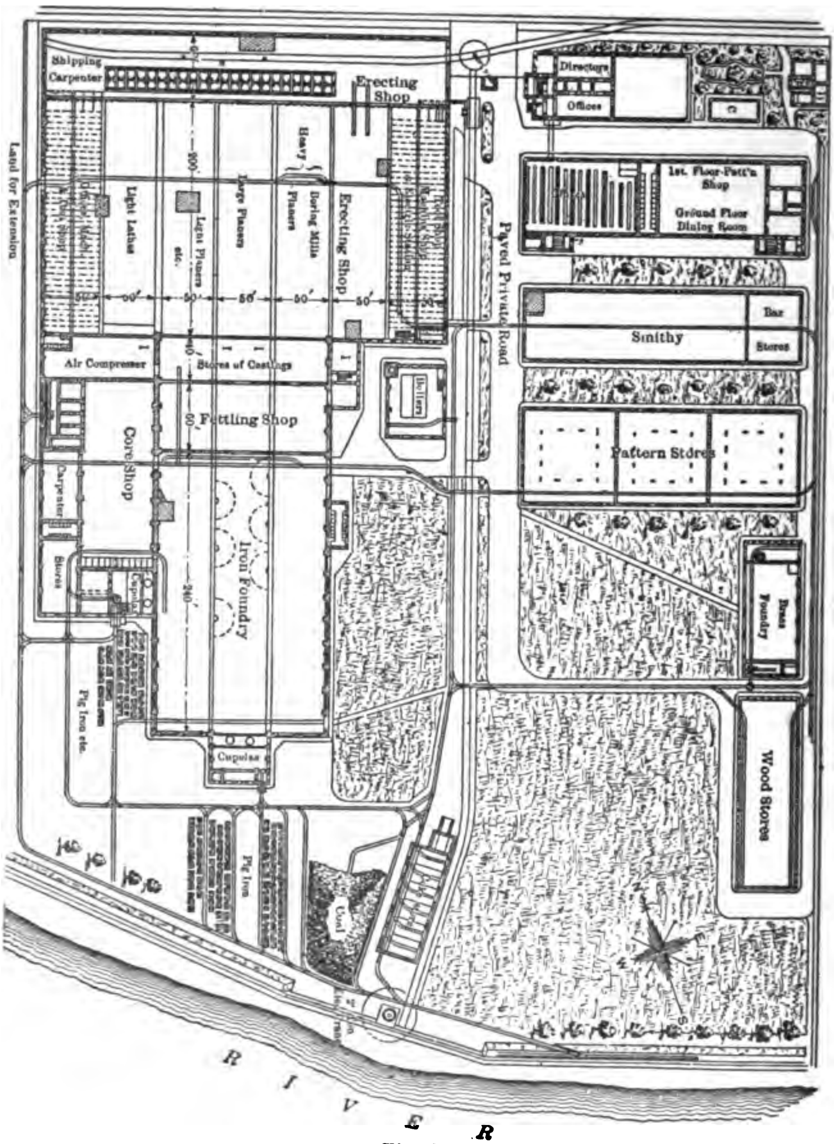

Shipping
Carpenter
Erecting Shop
Light Lathes
Light Planers
etc.
Large Planers
Heavy Planers
Boring Mills
Erecting Shop
Land for Extension
Paved Private Road
Directors
Offices
1st. Floor-Patt'n Shop
Ground Floor Dining Room
Smithy
Bar
Stores
Air Compressor
Stores of Castings
Fettling Shop
Boilers
Core Shop
Pattern Stores
Carpenter
Stores
Iron Foundry
Brass Foundry
Cupolas
Pig Iron etc.
Wood Stores
Pig Iron
Coal
R I V E R

Fig. 3.

(7) Presence of shipping facilities, with rail and water competition if possible.

Some kinds of manufacturing plants, such as car shops, structural mill and iron works, require a large area of land, not only for the storage of materials and products, but also for spreading out their one-story buildings. The contents of these shops are usually too large and heavy to handle on upper floors, and single stories are therefore needed. The amount of land required for such work generally necessitates too great an investment in the

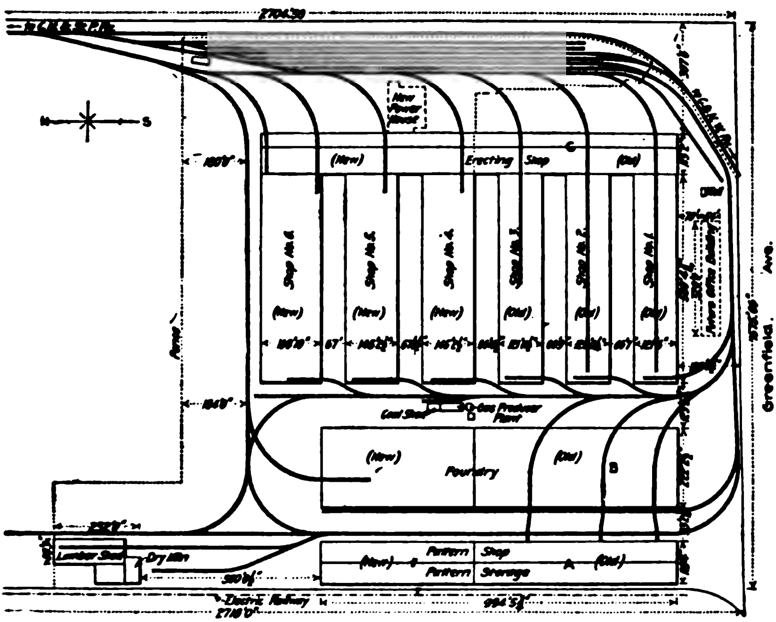


Fig. 4.

land itself, to warrant other than a suburban or country location. There are, however, occasional plants still existing in the large cities, occupying so extensive a ground area that the sale of their city property would more than pay the cost of land and new buildings in the country, where values are low and taxes correspondingly small. The importance of the proper location is therefore evident. A suburb is often most desirable, because, while land values and taxes are comparatively low, it is still in close proximity to a source of supplies and labor. In making a choice, therefore, between a city and its suburb, the selection will depend largely on the comparative land values and the presence of labor.

Land that might cost from $5 to $25 per square foot in the city could probably be secured in a suburb for 10 to 25 cents per square foot. If a suburb be selected, it is probable that an office in the adjoining city may be desirable or necessary, and the additional expense of maintaining the office must be counted in the comparison. A disadvantage of a suburban location is that the manufacturing company may have to invest capital in homes for workmen. This was necessary in connection with the Pennsylvania Steel Company's new plant, the American Bridge Company's works at Ambridge, and the Associated Industries of Sault Ste. Marie, Ontario. When a force of workmen has been secured for the suburban plant and the men with their families are settled in their homes, the manufacturing company will then have much better employees in their shops than would be secured from the migrating class usually found in large cities. Rural workmen, living at home with their families, are usually more reliable and better able to do a full day's work, and they can generally be depended upon for extra work or emergencies. On the other hand, in times of commercial and financial depression, when manufactories are doing but little work, these companies must exercise paternalism with their employees, often at great expense. After workmen have gone through one period of depression and have received the support of their employers, they will generally be more loyal to their companies and will have less desire to seek employment elsewhere. Such experiences tend to establish confidence between employers and employees. If the suburban workmen were dismissed or temporarily laid off when the amount of work in the shops was small, it would probably be difficult to find other men on short notice when business revived. In large cities, these conditions are reversed. Labor can usually be obtained at a lower price, laid off when not needed, and new men employed when required.

When a manufacturing establishment has been located in the country or suburb, and a corps of workmen secured and settled in their homes, if the company then wishes to remove the plant to an urban site, it may be difficult or impossible to persuade the well-trained rural employees to move with them. The better class of skilled labor usually prefers to remain at home rather than to shift about from place to place.

It is much easier to finance a new enterprise for a city location than one in the country, because the buildings in a city can be used for other purposes if the enterprise fails. The suburb

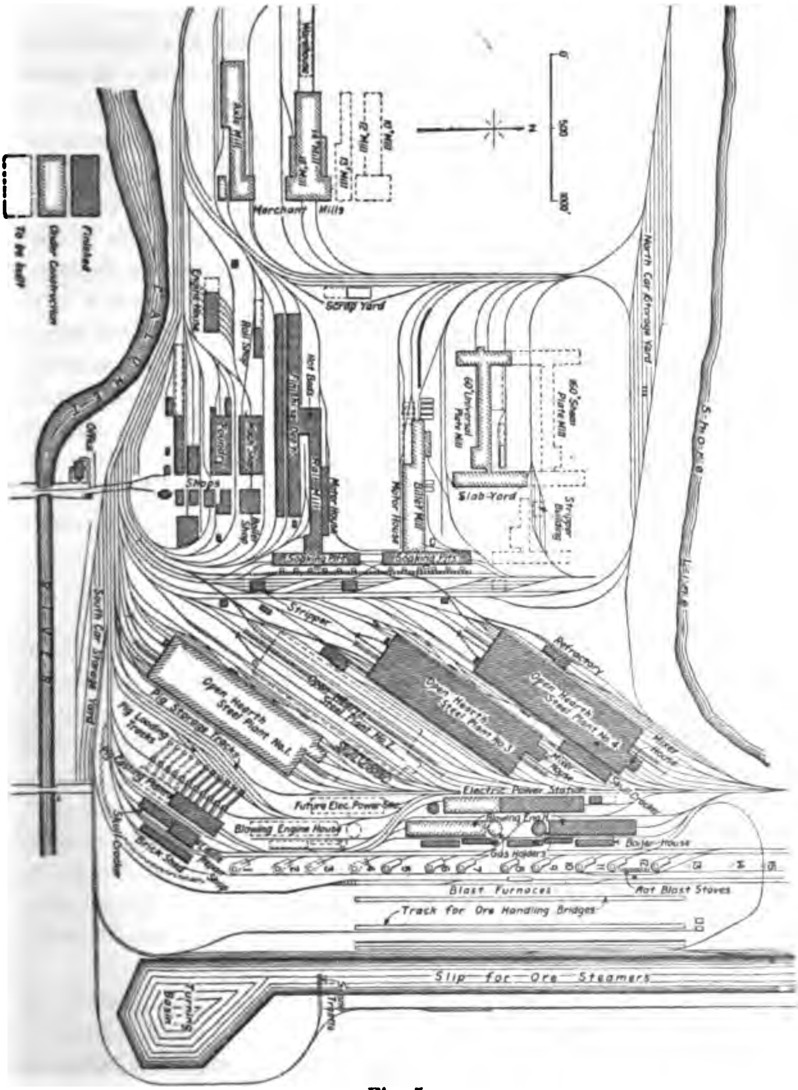


Fig. 5.

or rural site affords a better opportunity for expansion, better light and purer air for its operators and owners, with correspondingly better results. Considered merely as a machine, there is no longer any doubt that a man can and will do better work and more of it, when surrounded by the ordinary comforts and working in good light and pure air, than under reversed conditions.

When the value of manufactures is large in comparison to the place occupied in making them, particularly where work can be economically conducted on several floors, the city may be more convenient and advisable.

In selecting the general location of a plant with reference to the part of the country in which it shall be placed, it should be remembered that in any department of industry, labor is more easily found in districts where there are other manufactures of the same kind. For instance, in starting a new furniture factory, the most abundant source of labor would be found in such a city as Grand Rapids, while for a new hardware industry, the best labor market would doubtless be in some of the manufacturing cities of Connecticut. Skilled labor for the manufacture of shoes would be most easily found at such a place as Lynn or Brockton, Massachusetts, and labor for structural steel work at such cities as Harrisburg or Pittsburg. As stated before, the availability of labor and the nearness to the source of raw material will usually govern.

SITE.

Having decided upon the district in which the plant shall be located, and whether it shall be in a city or in one of its suburbs, the actual site for the buildings must then be chosen. It should, if possible, be accessible both by rail and water and by competing lines of railway, in order to secure the lowest freight rates. There should be ample opportunity for spur tracks or sidings; and the site should be high enough above the neighboring waterways or valleys so it can be thoroughly drained. If located away from a city, it should have convenient trolley connections to the adjoining town, and be reasonably near the source of supplies for both shops, and the workmen and their families.

The ground on which the buildings are to be placed should be graded with a slope of about six inches per 100 feet in the direction in which materials and products will pass in going through the works. With a slight grade, it is easier for the workmen to move small service cars, loaded with material, as products pass through the various buildings in course of manufacture.

The possibility of finding near at hand the various kinds of building material needed, may have weight in choosing a site.

Occasionally land is available where sand and stone are abundant without hauling, and expense of building is thus reduced.

A survey of the ground must be made, the lot lines and other external limitations established, streets laid out, sewers, water and gas pipes shown and all buildings and sidings indicated in their proposed places. Borings should be made, if necessary, to determine the strata and bearing power of the soil.

CHAPTER III.

PURPOSE AND ARRANGEMENT.

The term "mill building" includes a large variety of manufacturing plants, such as rolling mills, car shops, storehouses, sugar mills, car sheds, foundries, machine shops, forge shops, etc. The particular nature of a building will in each case determine its principal features. Each kind will have its own special requirements, and for this reason no rules can be given for the form or size.

MACHINERY ARRANGEMENT.

In undertaking the design of a manufacturing building, the designer must prepare or secure outline drawings showing the space required for the contents. Either the building should be designed in consultation with the mechanical engineer, or if this is not convenient, the building engineer must obtain from the mechanical engineer such complete data in reference to the arrangement of the machinery, the space that it will occupy, and the loads it will cause on any or all parts of the building frame, that he may proceed to develop his design with confidence and accuracy. The mechanical engineer or those familiar with the processes of manufacture in the particular line of work in hand should first arrange all machinery, preferably regardless of the building, so manufacturing can be carried on at least cost. The various machines should be so placed that material in course of manufacture will pass in one direction consecutively from one machine or operation to another, until finally completed and ready for shipment. Each machine must have sufficient space about it for handling and possibly turning material, space for workmen and some for storing small excess material or products.

A mill building is in reality a part of the machinery, and should be designed as such rather than as a work of architecture. Utility must have preference over appearance, but both may usually receive proper attention. The presence of cranes and other appliances for handling materials makes the building a part of the mechanical equipment. The building must, however, be subservient to its use, and its form and shape be made to properly surround and house the machinery and contents. The location of certain machines may make it necessary to omit columns, and to provide especially large bays in side walls for admitting and removing large machines. It is imperative that the machinery be exactly located before plans for the building itself are drawn, to avoid the possibility of columns or other framing being placed

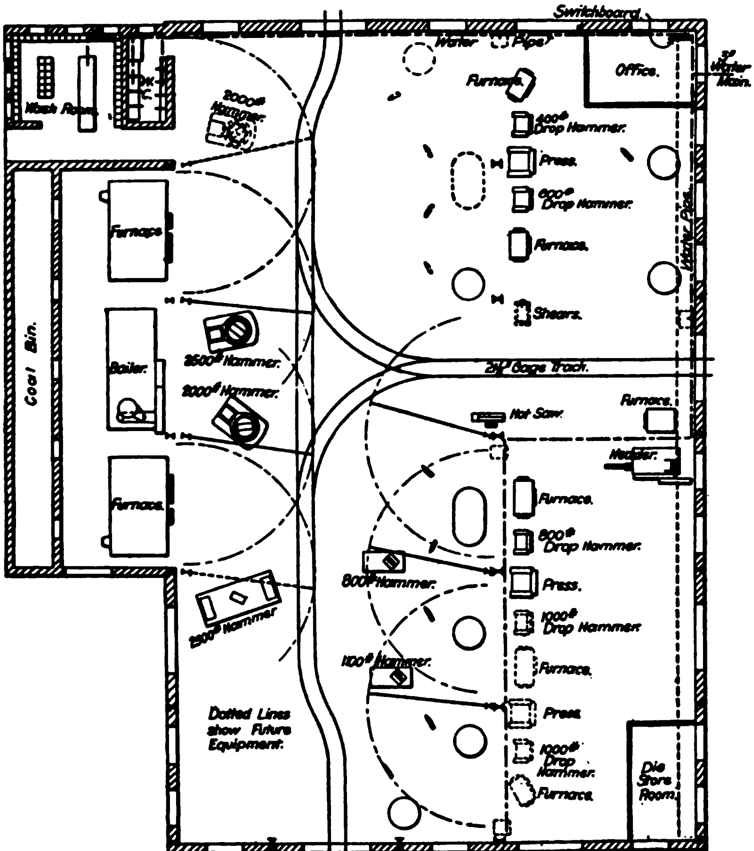


Fig. 6.

in a position where machines must stand. The building must, in fact, be made to fit the mill. (Fig. 6.) The form, length, height and width will then depend upon the contents. If ground is unlimited, there is no difficulty in placing the machines to the best possible advantage and surrounding and covering them suitably, but if the size or form of the lots is limited, the building plan must necessarily conform to its outline.

HEIGHTS AND CLEARANCES.

The equipment and contents of a building must be examined both as to plan and elevation, to ascertain the amount of space required above and around them. The weight and maximum dimensions of all materials and products must be accurately known and the general style of cranes and other handling or conveying appliances selected before the height beneath the trusses can be determined. There must also be ample space allowed for heating and ventilating ducts, belts, hoists, shafting and any other contents. Generally, high buildings are lighter than lower ones, and it is easier to keep leather belts tight when they are long, than when in a lower building. Fig. 7 shows the method of deter-

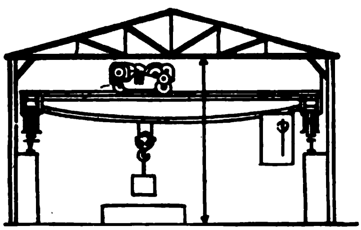


Fig. 7.

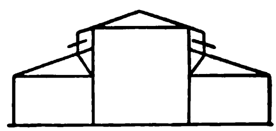


Fig. 8.

mining the required height beneath the trusses. On the floor is first drawn the maximum height of the machines or fixtures over which products or materials must be lifted or conveyed. The maximum outline for any pieces requiring crane service is drawn above this and over this is shown the crane hook with trolley and crane bridge above it. In drawing these heights, clearances should be allowed in each case and the sketch, if to scale, will show accurately the total height required below the trusses.

For further determining the clearances required for traveling cranes, the following four tables are given, which show not only the necessary clearances, but give also the maximum wheel load on the crane girders and the total net weight of the crane in pounds. A method of securing clearance and space for opening swing sash on the monitor side is shown in Fig. 8, in which the sash when open will cause no obstruction to the crane.

PRINCIPAL REQUIREMENTS.

A building that will enable men and machinery to produce results in the most direct and cheapest way, is the best.

If there are several buildings in the plant, they must be so

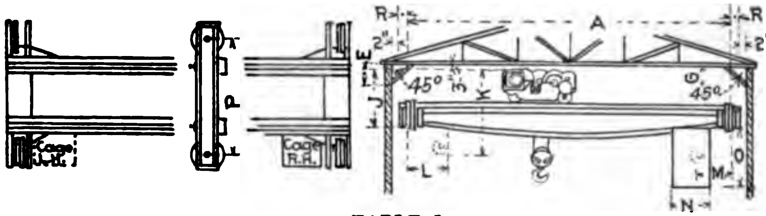


TABLE I.

OUTSIDE DIMENSIONS OF 3½ TO 15 TON STANDARD ELECTRIC TRAVELING CRANES.
Table is for hoist of about 30 ft. Higher hoist may increase wheel base.
Dimension R may be reduced if necessary.

FLUSH BRIDGE.

Capacity in Tons	A	R	J	K	L	M	N	O	P	Maximum Load on each wheel	Total net Weight of Crane	Dia. Bridge Wheel	Runway Rail A.S. C.E., Lbs. per yard.	Max. Brace without limiting Trol. Trav. E	G
	Ft.	In.	Ft.In	Ft.In	Ft.In	Ft.In	Ft.In	Ft.In	Ft.In	Lbs.	Lbs.	In.		In.	In.
3½	30	7½	3 6	4 2	1 6	1 6	6 3	7 1	8 8	9,300	16,700	15	35	7	7
3½	40	7½	3 6	4 2	1 6	1 6	6 3	7 1	8 10	10,200	19,200	15	35	7	7
3½	50	8	3 8	4 2	1 7	1 7	6 3	7 1	9 6	11,300	23,300	18	35	9	8
3½	60	8	3 8	4 2	1 7	1 7	6 3	7 1	10 0	12,600	27,700	18	40	9	8
3½	70	9	3 11	4 2	1 8	1 8	6 3	7 1	11 8	14,300	33,600	21	40	11	10
3½	80	9	4 1	4 2	1 8	1 8	6 3	7 1	13 4	16,000	39,900	21	45	11	10
5	30	7½	3 11	4 8	2 2	1 9	6 3	7 1	10 1	11,600	19,500	15	40	5	9
5	40	8	4 2	4 8	2 1	1 10	6 3	7 1	10 1	12,800	22,400	18	40	5	11
5	50	8	4 2	4 8	2 1	1 10	6 3	7 1	10 4	14,100	26,200	18	40	5	11
5	60	9	4 4	4 8	2 0	1 11	6 3	7 1	10 10	15,500	31,300	21	45	5	13
5	70	9	4 6	4 8	2 0	1 11	6 3	7 1	11 8	17,100	37,300	21	45	5	13
5	80	9	4 9	4 8	2 0	1 11	6 3	7 1	13 4	18,900	43,400	21	45	5	13
7½	30	8¼	4 5	5 0	2 2	2 0	6 3	7 1	10 7	14,900	22,300	21	40	5	8
7½	40	8¼	4 5	5 0	2 2	2 0	6 3	7 1	10 8	16,200	24,900	21	45	5	8
7½	50	9	4 7	5 0	2 1	2 1	6 3	7 1	10 3	17,600	28,800	21	45	5	10
7½	60	9	4 9	5 0	2 1	2 1	6 3	7 1	10 5	19,100	34,100	21	45	5	10
7½	70	10	4 11	5 0	2 2	2 2	6 3	7 1	11 8	20,800	40,700	24	50	7	12
7½	80	10	5 1	5 0	2 2	2 2	6 3	7 1	13 4	22,700	47,000	24	50	7	12
10	30	8¼	4 7	5 8	2 5	2 2	6 3	7 1	10 7	18,500	23,500	21	45	5	10
10	40	9¼	4 10	5 8	2 4	2 1	6 3	7 1	10 9	19,800	28,400	24	50	5	10
10	50	9¼	4 10	5 8	2 4	2 1	6 3	7 1	10 10	21,200	32,400	24	50	5	10
10	60	10	5 0	5 8	2 3	2 3	6 3	7 1	10 11	22,700	37,800	24	50	5	12
10	70	10	5 2	5 8	2 3	2 3	6 3	7 1	11 8	24,500	43,100	24	50	5	12
10	80	10	5 4	5 8	2 3	2 3	6 3	7 1	13 4	26,800	52,100	24	55	5	12
15	30	9½	5 0	6 6	2 7	3 0	6 3	7 1	11 8	25,000	29,600	24	50	6	9
15	40	9½	5 0	6 6	2 7	3 0	6 3	7 1	11 8	26,500	33,900	24	55	6	9
15	50	10½	5 2	6 6	2 6	2 11	6 3	7 1	11 7	28,100	38,600	24	55	6	9
15	60	10½	5 4	6 6	2 6	2 11	6 3	7 1	11 6	29,800	44,000	24	60	6	9
15	70	10½	5 6	6 6	2 6	2 11	6 3	7 1	11 8	31,800	51,200	24	60	6	9
15	80	10½	5 8	6 6	2 6	2 11	6 3	7 1	13 4	34,300	59.800	24	65	6	9

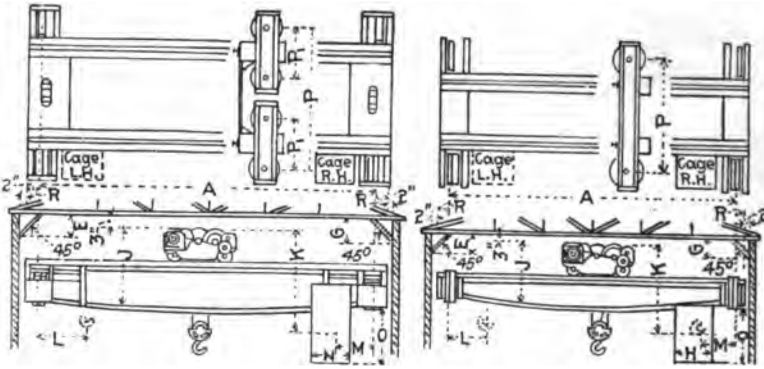


TABLE II.

OUTSIDE DIMENSIONS OF 20 TO 50 TON STANDARD ELECTRIC TRAVELING CRANES.

FLUSH BRIDGE.

Capacity in Tons	A	R	J	K	L	M	N	O	P	Maximum Load on each wheel	Total Net Weight of Crane	Dia. Bridge Wheel	Runway Rail A. S. C. E., Lbs. per yard	Max. Brace without limiting Trol. Trav. E	G
	Ft.	In.	Ft.In	Ft.In	Ft.In	Ft.In	Ft.In	Ft.In	Ft.In	Lbs.	Lbs.	In.		In.	In.
20	30	9½	5 4	8 8	2 8	3 0	6 3	7 1	11 9	31,000	32,800	24	60	10	10
20	40	10½	5 6	8 8	2 7	2 11	6 3	7 1	11 7	32,700	37,600	24	60	10	10
20	50	10¾	5 8	8 8	2 7	2 11	6 3	7 1	11 9	34,600	45,000	24	65	10	10
20	60	10¾	5 10	8 8	2 7	2 11	6 3	7 1	11 4	37,000	50,700	24	65	10	10
20	70	10¾	6 1	8 8	2 7	2 11	6 3	7 1	11 8	39,700	58,200	24	70	10	10
20	80	10¾	6 3	8 8	2 7	2 11	6 3	7 1	13 4	42,800	70,600	24	70	10	10
25	40	10¾	5 11	9 1	2 8	3 1	6 3	7 1	12 2	39,300	43,400	24	70	11	10
25	50	10¾	6 1	9 1	2 8	3 1	6 3	7 1	11 11	41,800	49,500	24	70	11	10
25	55	10¾	6 2	9 1	2 8	3 1	6 3	7 1	12 1	43,100	54,200	24	70	11	10
25	60	11¼	6 4	9 1	2 9	3 1	6 3	7 1	12 5	44,500	58,700	27	70	12	11
25	70	11¼	6 6	9 1	2 9	3 1	6 3	7 1	12 2	47,500	69,100	27	75	12	11
25	80	11¼	6 8	9 1	2 9	3 1	6 3	7 1	13 4	50,800	79,900	27	75	12	11
30	40	11¼	6 3	10 0	2 11	3 2	6 3	7 1	13 0	46,200	49,500	27	75	13	12
30	50	11¼	6 5	10 0	2 11	3 2	6 3	7 1	12 10	48,800	56,800	27	75	13	12
30	60	12¼	6 7	10 0	3 0	3 1	6 3	7 1	13 3	51,700	66,600	30	80	15	12
30	70	12¼	6 10	1Q 0	3 0	3 1	6 3	7 1	13 1	55,000	77,300	30	80	15	12
30	80	12¼	7 0	10 0	3 0	3 1	6 3	7 1	13 4	58,800	90,700	30	85	15	12
40	40	13¾	6 10	11 6	3 2	3 2	6 3	7 1	13 7	60,100	64,200	30	85	18	15
40	50	13¾	7 0	11 6	3 2	3 2	6 3	7 1	13 5	63,400	72,800	30	85	18	15
40	60	13¾	7 2	11 6	3 2	3 2	6 3	7 1	13 2	67,000	84,300	30	90	18	15
40	70	13¾	7 4	11 6	3 2	3 2	6 3	7 1	12 5	71,000	96,800	30	90	18	15
40	80	13¾	7 7	11 6	3 2	3 2	6 3	7 1	13 4	75,600	112,900	30	90	18	15
50	40	13¾	7 6	12 11	3 5	3 7	6 3	7 1	13 0	74,000	76,100	30	90	19	16
50	50	13¾	7 8	12 11	3 5	3 7	6 3	7 1	12 8	77,600	85,700	30	95	19	16
50	55	13¾	7 8	12 11	3 5	3 7	6 3	7 1	12 10	79,800	92,200	30	95	19	16
50	60	11¾	......	12 11	......	......	6 3	7 1	......	41,200	98,500	24	70	19	16
50	70	11¾	......	12 11	......	......	6 3	7 1	......	43,300	112,700	24	70	19	16
50	80	11¾	......	12 11	......	......	6 3	7 1	......	45,900	131,200	24	75	19	16

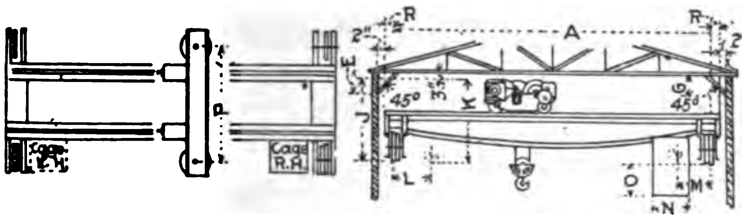


TABLE III.

OUTSIDE DIMENSIONS OF 3½ TO 15-TON STANDARD ELECTRIC TRAVELING CRANES.
Table is for hoist of about 30 feet. Higher hoist may increase wheel base.
Dimensions R and J can be reduced if necessary.

STANDARD BRIDGE.

Capacity in Tons.	A	R	J	K	L	M	N	O	P	Maximum Load on each wheel	Total Net Weight of Crane	Dia. Bridge Wheel	Runway Rail A. S. C. E. Lbs. per yard	Max. Brace without limiting Trol. Trav. E	Max. Brace without limiting Trol. Trav. G
	Ft.	In.	Ft. In	Ft. In	Ft. In	Ft. In	Ft. In	Ft. In	Ft. In	Lbs.	Lbs.	In.		In.	In.
3½	30	7½	4 7	4 2	1 6	1 6	6 3	6 3	7 3	9,300	16,700	15	35	7	7
3½	40	7½	4 8	4 2	1 6	1 6	6 3	6 3	7 4	10,200	19,200	15	35	7	7
3½	50	8	4 11	4 2	1 7	1 7	6 3	6 1	8 4	11,300	23,300	18	35	9	8
3½	60	8	5 0	4 2	1 7	1 7	6 3	6 1	10 0	12,600	27,700	18	40	9	8
3½	70	8¼	5 2	4 2	1 7	1 7	6 3	6 0	11 8	14,300	33,600	21	40	9	8
3½	80	8¼	5 4	4 2	1 7	1 7	6 3	6 0	13 4	16,000	39,900	21	45	9	8
5	30	7½	5 1	4 8	2 2	1 9	6 3	6 3	7 8	11,600	19,500	15	40	5	9
5	40	8	5 4	4 8	2 1	1 10	6 3	6 1	7 11	12,800	22,400	18	40	5	11
5	50	8	5 5	4 8	2 1	1 10	6 3	6 1	8 4	14,100	26,200	18	40	5	11
5	60	8¼	5 8	4 8	2 1	1 10	6 3	6 0	10 0	15,500	31,300	21	45	5	11
5	70	8¼	5 9	4 8	2 1	1 10	6 3	6 0	11 8	17,100	37,300	21	45	5	11
5	80	8¼	5 11	4 8	2 1	1 10	6 3	6 0	13 4	18,900	43,400	21	45	5	11
7½	30	8¼	5 8	5 0	2 2	2 0	6 3	6 0	8 4	14,900	22,300	21	40	5	8
7½	40	8¼	5 9	5 0	2 2	2 0	6 3	6 0	8 5	16,200	24,900	21	45	5	8
7½	50	8¼	5 10	5 0	2 2	2 0	6 3	6 0	8 6	17,600	28,800	21	45	5	8
7½	60	8¼	5 11	5 0	2 2	2 0	6 3	6 0	10 0	19,100	34,100	21	45	5	8
7½	70	9¼	6 3	5 0	2 1	2 0	6 3	5 10	11 8	20,800	40,700	24	50	5	9
7½	80	9¼	6 5	5 0	2 1	2 0	6 3	5 10	13 4	22,700	47,000	24	50	5	9
10	30	8¼	5 11	5 8	2 5	2 2	6 3	6 0	8 4	18,500	23,500	21	45	5	10
10	40	9¼	6 3	5 8	2 4	2 1	6 3	5 10	8 7	19,800	28,400	24	50	5	10
10	50	9¼	6 4	5 8	2 4	2 1	6 3	5 10	8 9	21,200	32,400	24	50	5	10
10	60	9¼	6 5	5 8	2 4	2 1	6 3	5 10	10 0	22,700	37,800	24	50	5	10
10	70	9¼	6 6	5 8	2 4	2 1	6 3	5 10	11 8	24,500	43,100	24	50	5	10
10	80	9¼	6 8	5 8	2 4	2 1	6 3	5 10	13 4	26,800	52,100	24	50	5	10
15	30	9½	6 4	6 6	2 7	3 0	6 3	5 10	9 6	25,000	29,600	24	50	6	9
15	40	9½	6 6	6 6	2 7	3 0	6 3	5 10	9 6	26,500	33,900	24	55	6	9
15	50	9½	6 7	6 6	2 7	3 0	6 3	5 10	9 4	28,100	38,600	24	55	6	9
15	60	9½	6 8	6 6	2 7	3 0	6 3	5 10	10 0	29,800	44,000	24	60	6	9
15	70	10½	6 10	6 6	2 6	2 11	6 3	5 9	11 8	31,800	51,200	24	60	6	9
15	80	10½	7 1	6 6	2 6	2 11	6 3	5 9	13 4	34,300	59,800	24	65	6	9

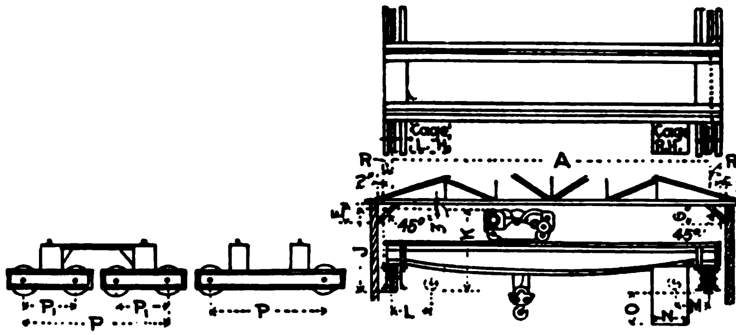


TABLE IV.

OUTSIDE DIMENSIONS OF 20 TO 50-TON STANDARD ELECTRIC TRAVELING CRANES.

STANDARD BRIDGE.

Capacity in Tons.	A	R	J	K	L	M	N	O	P	P_1	Maximum Load on each wheel	Total Net Weight of Crane	Dia. Bridge Wheel	Runway Rail A. S. C. E. Lbs. per yard	Max. [illegible] without Hunting Trol. [illegible] E	G
	Ft.	In.	Ft.In	Ft.In	Ft.In	Ft.In	Ft.In	Ft.In	Ft.In	Ft.In	Lbs.	Lbs.	In.		In.	In.
20	30	9½	6 10	8 8	2 8	3 0	6 3	5 9	9 2	......	31,000	32,800	24	60	10	[illegible]
20	40	10½	7 0	8 8	2 7	2 11	6 3	5 9	9 2	......	32,700	37,600	24	60	10	[illegible]
20	50	10¾	7 2	8 8	2 7	2 11	6 3	5 9	9 2	......	34,600	45,000	24	65	10	[illegible]
20	60	10¾	7 3	8 8	2 7	2 11	6 3	5 9	10 0	......	37,000	50,700	24	65	10	[illegible]
20	70	10¾	7 5	8 8	2 7	2 11	6 3	5 9	11 8	......	39,700	58,200	24	70	10	[illegible]
20	80	10¾	7 7	8 8	2 7	2 11	6 3	5 9	13 4	......	42,800	70,600	24	70	10	[illegible]
25	40	10¾	7 4	9 1	2 8	3 1	6 3	5 9	9 7	......	39,300	43,400	24	70	11	[illegible]
25	50	10¾	7 6	9 1	2 8	3 1	6 3	5 9	9 9	......	41,800	49,500	24	70	11	[illegible]
25	55	10¾	7 7	9 1	2 8	3 1	6 3	5 9	9 11	......	43,100	54,200	24	70	11	[illegible]
25	60	11¼	7 9	9 1	2 9	3 1	6 3	5 7	10 10	......	44,500	58,700	27	70	12	[illegible]
25	70	11¼	7 11	9 1	2 9	3 1	6 3	5 7	11 8	......	47,500	69,100	27	75	12	[illegible]
25	80	11¼	8 2	9 1	2 9	3 1	6 3	5 7	13 4	......	50,800	79,900	27	75	12	[illegible]
30	40	11¼	7 9	10 0	2 11	3 2	6 3	5 7	10 4	......	46,200	49,500	27	75	13	[illegible]
30	50	11¼	7 11	10 0	2 11	3 2	6 3	5 7	10 6	......	48,800	56,800	27	75	13	[illegible]
30	60	12¼	8 3	10 0	3 0	3 1	6 3	5 5	11 2	......	51,700	66,600	30	80	15	[illegible]
30	70	12¼	8 5	10 0	3 0	3 1	6 3	5 5	11 8	......	55,000	77,300	30	80	15	[illegible]
30	80	12¼	8 8	10 0	3 0	3 1	6 3	5 5	13 4	......	58,800	90,700	30	85	15	[illegible]
40	40	13¾	8 6	11 6	3 2	3 2	6 3	5 5	11 4	......	60,100	64,200	30	85	18	[illegible]
40	50	13¾	8 8	11 6	3 2	3 2	6 3	5 5	11 6	......	63,400	72,800	30	85	18	[illegible]
40	60	13¾	8 10	11 6	3 2	3 2	6 3	5 5	11 10	......	67,000	84,300	30	90	18	[illegible]
40	70	13¾	9 0	11 6	3 2	3 2	6 3	5 5	12 0	......	71,000	96,800	30	90	18	[illegible]
40	80	13¾	9 3	11 6	3 2	3 2	6 3	5 5	13 4	......	75,600	112,900	30	90	18	[illegible]
50	40	13¾	9 2	12 11	3 5	3 7	6 3	5 5	11 4	......	74,000	76,100	30	90	19	[illegible]
50	50	13¾	9 4	12 11	3 5	3 7	6 3	5 5	11 6	......	77,600	85,700	30	95	19	[illegible]
50	55	13¾	9 5	12 11	3 5	3 7	6 3	5 5	11 8	......	79,800	92,200	30	95	19	[illegible]
50	60	11¾	9 4	12 11	3 7	3 9	6 3	5 7	11 0	3 10	41,200	98,500	24	70	19	[illegible]
50	70	11¾	9 9	12 11	3 7	3 9	6 3	5 5	11 8	4 0	43,300	112,700	24	70	19	[illegible]
50	80	11¾	10 0	12 11	3 7	3 9	6 3	5 5	13 2	5 1	45,900	131,200	24	75	19	[illegible]

located that material and products may be conveniently transferred from one building to another. The primary requisites are as follows:

(1) One or more working floors of ample area.

(2) Buildings large enough for men, machinery and equipment.

(3) Protection of the contents from the weather and of tools and materials from theft.

(4) Avoidance of useless travel.

(5) Buildings well braced and rigid, and able to safely sustain their maximum loads.

(6) Sufficient space for machinery and goods in process of manufacture.

(7) All floor space, as far as possible, open to view.

(8) The trusses and other framing strong enough, if necessary, to carry shafting or trolleys on the bottom chord.

(9) Departments producing noise, smoke, gas, odors or fire, partitioned from the rest of the shop, but partitions used only where necessary, as they occupy valuable space, obstruct light and make hiding places for workmen.

(10) Separate rooms for drafting or shop offices.

(11) Clothes presses or lockers for the safekeeping of employees' clothing and other effects.

(12) Sanitary toilets and wash rooms.

(13) Buildings properly heated, lighted and ventilated, as required.

(14) Cranes or other lifting, handling or conveying appliances wherever needed.

(15) Space for receiving, storing, loading and shipping materials.

(16) Provision for admitting or removing the largest pieces of machinery that will ever be placed in the building.

(17) Buildings designed with a view to future extension.

(18) Separate floor space for both light and heavy manufacturing if needed.

(19) Provision for fire extinction.

The essentials, therefore, are strength, simplicity, utility and economy. Buildings are for assisting in production and are secondary to their contents. Poor light, a chilly atmosphere and impure air impair man's activity, and it is for the best interests of all that human producers be surrounded with such comforts and conveniences as will permit them to render their best services.

CHARACTER OF BUILDINGS—TEMPORARY OR PERMANENT.

Whether the buildings shall be temporary or permanent, fireproof or otherwise, will depend upon conditions, some of which are as follows:

The amount of money immediately available may not be sufficient to pay for more than a temporary building, or there may be insufficient time for the erection of permanent structures. Frequently valuable contracts are secured which must be completed in a specified time, requiring additional machinery and buildings. In both of the above instances it may be economical to use temporary buildings which can be erected quickly, rather than to wait a longer time for more substantial ones. The site may be a temporary one, to be used for a short time only, the buildings then to be removed and abandoned, as occurs during the construction of large public works where local shops may be needed. During the erection of the Forth bridge in Scotland, a temporary bridge and structural plant was built close to the bridge site, in which much of the fabrication was executed.

When a manufacturing venture is started, the ultimate outcome of which is uncertain, the investors may at first prefer temporary buildings, and even then only such as are absolutely needed, until such time as the success of the business is assured. These and numerous other reasons may arise to determine their character.

FRAMING AND WALLS.

The framing for industrial buildings will consist of either wood, steel or reinforced concrete, inclosed with walls of stone, brick, concrete, reinforced concrete, sheet metal or wood. The roof trusses or beams will rest either on solid walls or on columns with sides of plank, corrugated iron or light masonry curtain walls. The merits and comparative costs of various kinds of walls are discussed in detail under another heading, but a few general features of wall construction are given here.

If the purpose of the building is such that it will require heating, the walls and covering must then have sufficient thickness and be otherwise designed to act as nonconductors. Brick walls, either solid or hollow, are satisfactory for heated buildings, but walls of either stone or concrete, unless hollow, are liable to cause excessive condensation on the inner side. For this reason, hollow concrete blocks are sometimes used, or double concrete slabs from two to three inches thick, each slab being reinforced with a sheet of wire mesh or expanded metal. Buildings where heat is not required may have exterior walls of sheet metal or corrugated iron laid either on girths or over plank sheathing, or the sheathing may be waterproofed with shingles or clapboard. The nature of the walls will also to some extent depend upon the amount of light required from the sides.

As a general rule, steel framing is preferable for trusses and large girders, which are subjected to impact, as, for example, shop girders carrying traveling cranes. Columns, all ordinary floor framing, girders of medium dimensions carrying static loads, and wall lintels, are generally more economical and satisfactory when made of reinforced concrete. This kind of composite construction is well illustrated by the shops at El Paso, Texas, for the Atchison, Topeka and Santa Fé Railroad Company.

FIREPROOF OR OTHERWISE.

There need be no difficulty in making a selection between wood, steel or reinforced concrete framing. For light loads, wood is satisfactory for columns, but not for trusses and other framing where difficulty is experienced in making joints of sufficient strength. Light wooden framing is easily and quickly destroyed by fire, and is therefore unsatisfactory for permanent work. It has been frequently proven that heavy wood columns resist fire much better than unprotected steel or iron. The metal columns fail by bending at a high temperature, while wooden ones are consumed slowly.

Steel columns inclosed in masonry walls are often unsatisfactory and not economical because they must be surrounded by sufficient brick or other fireproofing to make a pier which would be strong enough without the steel. This kind of pier and column construction being less economical, reinforced concrete columns are coming extensively into use. The reinforcing steel is in the form of light angles with just enough compressive strength to temporarily support the roof or other framing during erection, and after the various parts of the metal frame are riveted or bolted together, the concrete of the column is then placed. This type is economical because the entire area of both steel and concrete is considered in resisting the compressive stresses. Unprotected steel framing is lacking in fireproof qualities, and yet to enclose the interior columns or other framing with fireproofing would make the cost prohibitive. As a result, few, if any, manufacturing buildings have their steel framing enclosed.

The fire at the Lewiston (Maine) car barns, the interior of which was made of steel, was so destructive that in seven minutes after the beginning of the fire the roof fell. A similar case occurred October 25, 1904, at the car barns of the Forest Hill Station of the Boston Elevated Railway, at West Roxbury, Massachusetts. In this case the steel trusses and other framing failed fifteen minutes after the beginning of the fire. There are numerous cases on record where fires have taken place in buildings of wood mill construction, and while the buildings were ultimately destroyed, the total collapse did not happen until the cross sectional area of the framing was seriously reduced. This destructive process usually occupies half an hour or more, and therefore gives a greater time for the contents of a building to be removed. With exposed steel framing, a collapse occurs more quickly under excessive heat. In order to give greater protection to the contents of car sheds, it has been proposed to divide them by numerous fireproof longitudinal walls, separating the various tracks; but these walls would evidently be too great an inconvenience to warrant their use. It has been further suggested that the floors of car sheds containing cars valued at from $2,000 to $3,000 apiece shall be laid with a sufficient grade so that in case of fire the cars would run out by force of gravity. The chief reason for not making buildings of fireproof material is the extra first cost of their construction. When the valuable contents of a building and the extra expense for insurance are considered, it is a doubtful policy to carry on any manufacturing business in buildings that are not fireproof or to use such buildings for the storage of material or products.

A table of approximate costs for buildings of various types of construction is given in Chapter VII.

CHAPTER IV.

NUMBER OF STORIES.

One of the first questions that will present itself in planning a manufacturing plant is in reference to the height of buildings or number of stories in them. A decision must be made as to whether work will be done all on one floor or on several. In order to intelligently and economically decide the question, it is necessary to consider—

(1) Size and weight of manufactured products.
(2) Size and weight of machinery.
(3) Space and height required for traveling cranes.
(4) Relative cost of buildings per square foot of floor surface for one or more stories.
(5) Cost of land.
(6) Relative convenience and economy of manufacturing and handling goods on one floor or on several floors.
(7) Lighting.

(1) When the manufactured products and the raw material used in a building are excessively heavy, there will then be little or no choice about the number of floors, for all heavy pieces and assembled products must stand upon the ground. Their size and weight would prohibit handling them on floors above the ground. In this class may be mentioned car and locomotive shops, bridge and structural plants, foundries for heavy castings, etc. There will be certain parts, before the products are assembled, that are not too heavy for upper floors, but the general assembled product, with the need for numerous lines of tracks, will require a single-story building with perhaps galleries for some of the lighter parts. Even in these heavy plants, much light work can be done on upper floors, and for this space it is simply a choice in comparative cost between building a larger ground floor or making one or more upper floors of the needed area.

The relative cost of galleries or upper floors compared to ground-floor space is considered more fully in a later paragraph. The comparison is plainly illustrated in Fig. 9, which shows a building of common form with high center bay and lower side ones. If it is found that there is a sufficient amount of light work and machinery for the gallery floor shown at F, the choice will depend largely, if not entirely, on the cost of this gallery floor compared with the combined cost of the roof R, added to the ground floor G, and the additional land L. If the cost of F is less than R plus G plus L, the gallery floor will then be the more economical.

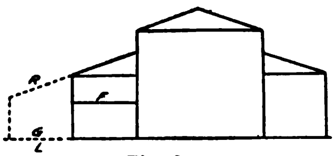


Fig. 9.

(2) The second consideration in choosing between one or more stories is the size and weight of shop machinery. In car shops, bridge plants, etc., heavy machinery, such as punches, planers, steam hammers, etc., requiring heavy and elaborate foundations, must necessarily be upon the ground.

(3) The space and height required for cranes will depend upon the size of the manufactured products. The method of determining this height and clearance has already been described in Chapter III, under the head of "Heights and Clearances." Where high settings are required for the cranes, it is impracticable to use more than a single floor in the crane bay, for the products, being assembled under the runway, must necessarily rest on a solid floor. The upper view of Fig. 10 shows a cross section of the erecting shop for the Worthington Hydraulic Works at Harrison, New Jersey, built in the year 1904. The two interior lines of columns are spaced 60 feet apart on centers, and the clear head room in the center bay is 72 feet. The crane clearance, therefore, in this and other similar cases is the governing factor in deciding on a single floor only, in the erecting shop. There is sufficient light machine work to occupy the three gallery floors on either side of the erecting floor. The lower view of Fig. 10 is the machine shop for the same company. Fig. 11 is a cross section of the machine shop for the General Electric Company at Schenectady, New York. One-half of the building shown is made in three stories with two floors for light machinery above the ground. In the other half, the clearance required for cranes in the erection aisle prohibits the use of any intermediate floors, and the entire space of 62 feet beneath the trusses is therefore left open.

(4) Fig. 12 shows the relative cost per square foot of floor area for ordinary mill construction factory buildings in widths up to 125 feet and heights from one to five stories. The costs given

are for wood construction in floors and roofs, inclosed in brick walls. Buildings of steel and reinforced concrete have a different cost per square foot of floor, but the relative cost for one story or many will be about the same. In the following table, the cost of a one-story building is taken as unity, and the cost of a building, for width of 50 feet, from two to five stories is given in terms thereof.

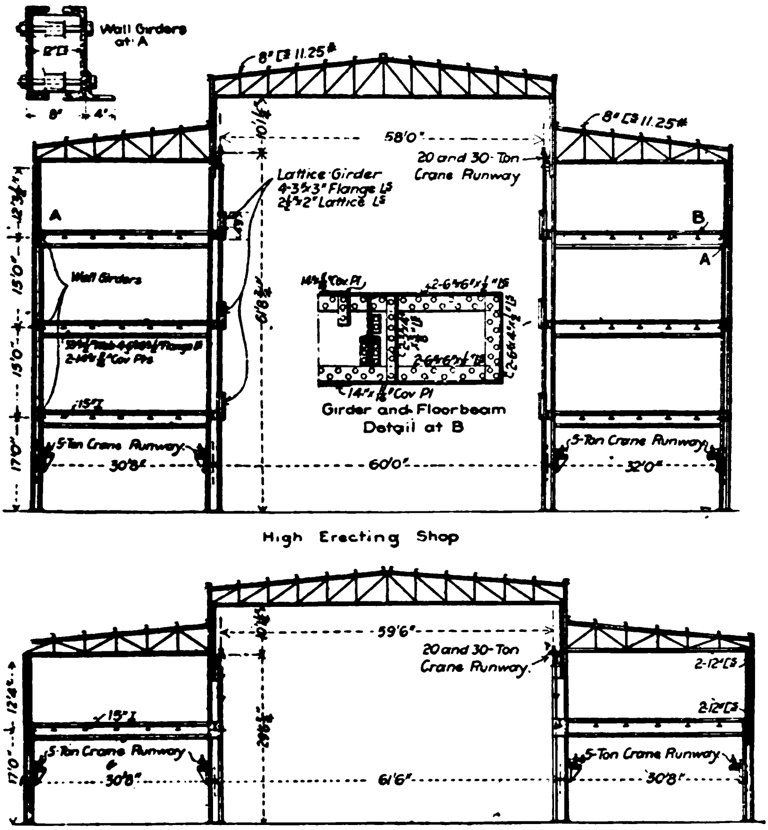
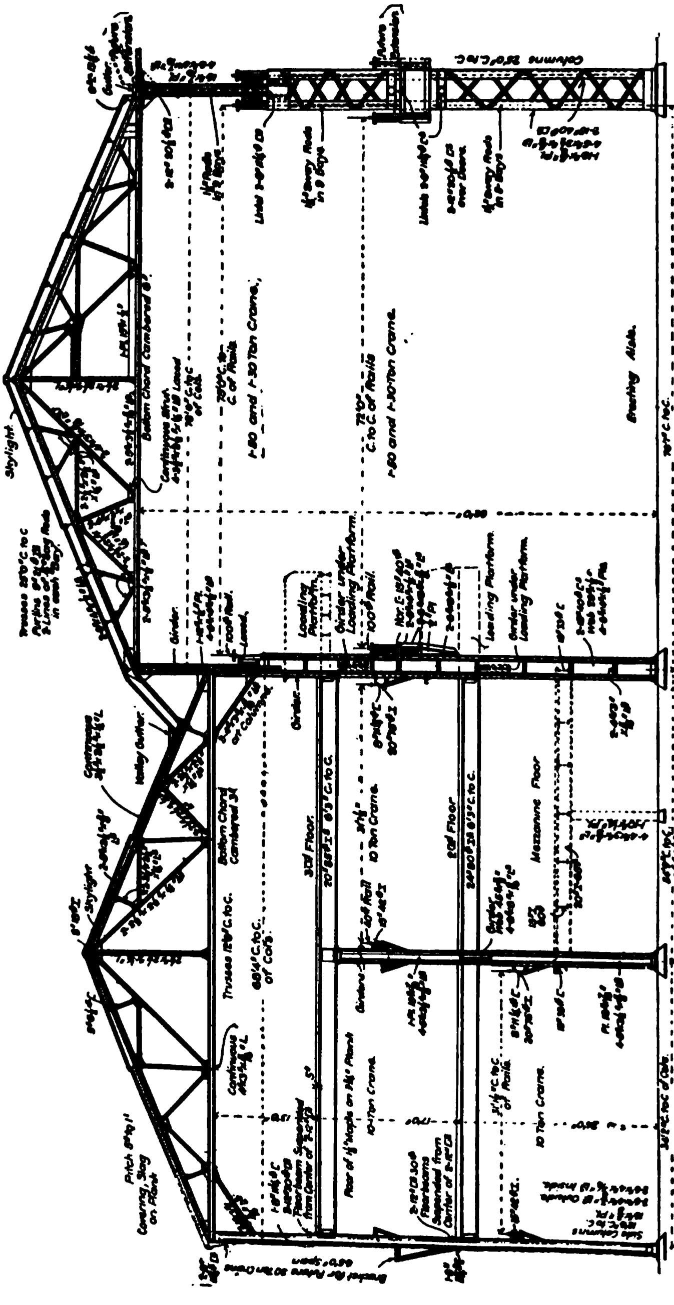


Fig. 10.

RELATIVE COST OF MANUFACTURING BUILDINGS 50 FEET IN WIDTH AND OF VARIOUS HEIGHTS, BUILT OF EITHER WOOD, STEEL OR REINFORCED CONCRETE.

Cost per sq. ft. of total floor area—one story	$1.00
Cost per sq. ft. of total floor area—two story	.92
Cost per sq. ft. of total floor area—three story	.87
Cost per sq. ft. of total floor area—four story	.86
Cost per sq. ft. of total floor area—five story	.85



Skylight.
Valley Gutter.
Bottom Chord Cambered 3".
3rd Floor.
2nd Floor
Mezzanine Floor
10 Ton Crane.
Loading Platform.
Girder under Loading Platform.
1-80 and 1-30 Ton Crane.
Erecting Aisle.

Fig. 11.

It appears, therefore, that buildings of one and two stories cost more than buildings of three, four and five stories, the last being 15 per cent less per square foot of gross floor area than when all floor space is on the ground. For light products, it is therefore economical to make manufacturing buildings not less than three stories in height, for not only is the building itself less expensive, but it also occupies smaller ground space. The only probable reason that might cause the owner of a building for light manu-

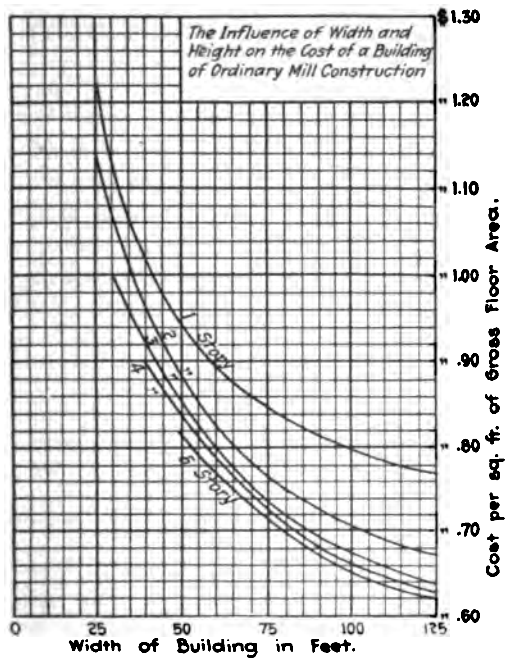


Fig. 12.

facturing purposes to select one floor in preference to three or more would be the relative convenience and economy of carrying on the work on a single floor. Records of certain factories show that the cost of labor is from 5 to 10 per cent less when work is all done on a single floor rather than on several floors. It must, therefore, be ascertained if the saving in the pay roll from better lighting and other conditions in light manufacturing buildings will be enough to pay interest on the cost of extra land and the increased cost of the one-story building. One of the principal reasons for one-story buildings costing so much more per square foot of floor area than those of two or more stories is because of the extra cost of skylights, which are not required in multi-story buildings.

(5) It is assumed that the possibility of using expensive city land as a site for a manufacturing plant is under consideration, and it is desired to ascertain the amount of ground and corresponding investment that is economical.

One-story buildings, whether the products and machinery be light or heavy, can generally be used; whereas buildings of two or more stories are suitable only when a large part of the work is light manufacturing.

Therefore, before making any comparison of the relative cost between buildings of one story or more, it must be definitely known for what proportion of the entire floor surface, solid ground will be required. If a large part of the work can as well be done on upper floors as on the ground, it is then in order to add the number of stories to this ground floor area to equal the total required, and which is the most economical, when the cost of land, building and production is considered. Fig. 13 shows a building

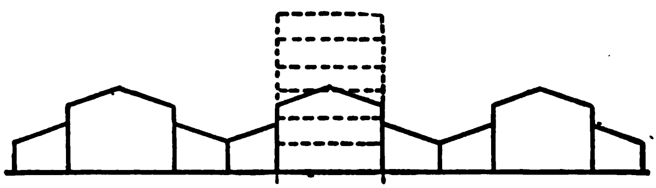


Fig. 13.

with five tiers of floors and a one-story building with the same total floor area. The total cost of securing any required floor space, either one floor or more, may be found by first computing the relative costs of the buildings and to these costs adding the value of the land on which they stand. The sum of these will be the net investment. It can then be decided what saving in production in a low building will pay the interest on the additional investment.

For the purpose of illustrating these operations, the following example is given: A manufacturing company requires a new building with a total floor space of 36,000 square feet, and it is desired to find if it will be more economical to have this all on one floor or on several floors. It is assumed, for comparison, that the one-story building will cost 90 cents per square foot for the building only. The percentages given on page 25 show that buildings of two, three, four and five stories cost, respectively, 92, 87, 86 and 85 per cent of the cost of a one-story building. The cost per square foot of floor surface for buildings of from one to five stories will therefore vary from 90 to 76 cents, and the total cost for 36,000 square feet will vary from $32,400 to $27,360. The ground area required varies from 36,000 square feet for a one-story to 7,200 square feet for a five-story building, and this land, figured at an assumed value of $5 per square foot, would cost from $180,000 to $36,000, making the total investment for the land and buildings vary from $212,400 for the one-story to $63,360 for the five-story building. These figures are all clearly shown in Table V. The difference in cost of land and buildings between the one and the five story building is therefore about $150,000. The annual interest on $150,000 at 6 per cent, is $9,000. Therefore, to decide whether a one-story building is more economical than a five-story building, it is simply necessary to determine whether the yearly saving in production will be equal to or greater than $9,000. If the saving is more than this amount, the one-story building is then economical, even though the building and land on which it stands represent a greater cost.

It has already been stated that cost records from one-story shops show that the saving in production is from 5 to 10 per cent. Therefore, to make a total saving of $9,000, the annual production cost for the assumed shop must be from $90,000 to $180,000.

TABLE V.

COMPARATIVE COSTS OF ASSUMED PLANTS, INCLUDING BOTH LAND AND BUILDINGS FOR HEIGHTS VARYING FROM ONE TO FIVE STORIES.

Number of Stories—	*One.*	*Two.*	*Three.*	*Four.*	*Five.*
Percentage cost...	100.00	92.00	87.00	86.00	85.00
Cost per sq. ft. of floor	$ .90	$ .83	$ .78	$ .77	$ .76
Total cost of building	$32,400.00	$29,880.00	$28,080.00	$27,720.00	$27,360.00
Lot area required, sq. ft..........	36,000.00	18,000.00	12,000.00	9,000.00	7,200.00
Cost of lot at $5 per sq. ft......	$180,000.00	$90,000.00	$60,000.00	$45,000.00	$36,000.00
Total cost of land and building....	$212,400.00	$119,880.00	$88,080.00	$72,720.00	$63,360.00

(6) The relative convenience and economy of manufacturing and handling products all on one floor, or on several floors, is important. Elevator service costs about $25 per day for each elevator, not simply for the service of the operator, or the cost of running the elevator itself, but rather in the amount of em-

ployees' time lost in waiting. The amount of lost time is somewhat reduced by using several elevators, but even then there is waste. There is also loss of time by transferring goods from one floor to another. If an operator desires to transfer an article to a point on the floor directly above him, he may have to walk half the length of the building, wait for the elevator, ascend to the floor above, and walk back again to the place designated. He must then retrace his steps over the same route to his own place. Either the workmen themselves must transfer the products or others must be employed whose duties are devoted to messenger and delivery service. In either case extra expense is involved. In one-story buildings there is a corresponding expense for transferring, with the difference that the delivery distances may be less, and no delay or loss is caused by the maintenance of elevators.

It is claimed by some shop superintendents that when workmen are all on one floor that is unobstructed by partitions, and where they are at all times under the eye of the superintendent or foreman, there is less tendency to loafing and idleness among the employees. It is also claimed by these advocates of one-story buildings that the foreman's office should be so located that every operator on the floor will be directly in view and his presence can at all times be seen from the office. The wisdom of this feature is, however, doubtful, for while the foreman from his office may be able to see all the employees, he has no assurance that their work is being either properly or effectively done, without personally going about the shop and inspecting the products of each man's labor. The theory of the single floor is that there are periods in the day when an entire floor of a many-story factory may be left without a foreman's supervision during hours when his presence is needed on other floors, and at such times there is idleness and ineffective work among the men.

The area of one-story factory buildings is frequently so large that it is quite impossible for a foreman from his office to keep effective watch over the men or their work. He should be out on the shop floor inspecting at close range what is being done. When a single floor is too large for easy inspection from one point, one of the supposed merits of single-floor buildings disappears, for it requires as much time for the foreman to travel about a single floor as it would to travel over several floors, and if he is unable to see through the entire length and breadth of the shop, there appears to be nothing gained by the arrangement.

The one-story building will be most economical in shop labor when the area is not too great.

The experience of some single-story shops is that ventilation is not as good as in narrower buildings, and that workmen become lethargic and do less work.

(7) Lighting. Buildings in several stories can be lighted only from the sides and ends, and as side lighting in low stories is not effective for a greater distance than from 20 to 25 feet, buildings in several stories which require lighting cannot, therefore, be made in a greater width than from 40 to 50 feet. The conditions are quite different in one-story buildings, for abundance of light can then be brought from the roof, and the buildings can be made as long and wide as desired. The chief objection to roof lighting is its increased cost.

CHAPTER V.

WALLS.

In Part IV a detailed description is given for various types of walls, together with their comparative costs. In this chapter it is intended only to outline some possible forms for use when considering the general requirements and features of a manufacturing building. The minimum thickness of walls specified in the building laws of several cities is given in Table VI. In some cases the building laws may determine the kind or thickness of walls to use. Building laws are not so much for the guidance of competent engineers as they are for the restriction of incompetents or

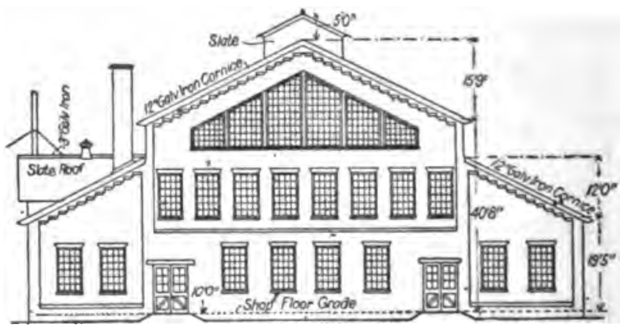


Fig. 14.

those who might knowingly violate the principles of safe construction; and while a building engineer must be governed to some extent by building laws, he should follow the principles of safe construction, as well as law, and walls, like other parts, should be proportioned to their needs. It may be given as a general rule that brick side walls should have thicknesses about as follows:

(a) Upper story, 12 ins. thick.
(b) Next two lower, 16 ins. thick.
(c) Next three lower, 20 ins. thick.
(d) Next three lower, 24 ins. thick.
(e) Next three lower, 28 ins. thick.

The following types are those most frequently used in mill and factory buildings:

(1) Stone walls.
(2) Brick walls.

TABLE VI.

REQUIRED THICKNESS OF WALLS.

According to Building Laws of American Cities.

	Stories.	Boston.	New York.	Chicago.	Minneapolis.	St. Louis.	Denver.	San Francisco.	New Orleans.
Ten	10	16	16	16	12	13	17	..	..
	9	20	16	16	16	18	17	..	..
	8	20	20	20	16	18	17	..	..
	7	20	20	20	16	22	21	..	..
	6	20	24	20	20	22	21	..	..
	5	20	24	24	20	26	21	..	..
	4	24	28	24	20	26	26	..	..
	3	24	32	24	24	30	26	..	..
	2	28	32	28	24	30	30	..	..
	1	28	36	28	24	34	30	..	..
Nine	9	16	16	16	12	13	17	..	..
	8	20	16	16	16	18	17	..	..
	7	20	20	16	16	18	17	..	..
	6	20	20	20	16	22	21	..	..
	5	20	24	20	20	22	21	..	..
	4	20	24	20	20	26	21	..	..
	3	24	28	24	20	26	26	..	..
	2	24	32	24	24	30	26	..	..
	1	24	32	24	24	30	30	..	..
Eight	8	16	16	16	12	13	17	..	13
	7	20	16	16	16	18	17	..	13
	6	20	20	16	16	18	17	..	18
	5	20	20	20	16	22	21	..	18
	4	20	24	20	20	22	21	..	18
	3	20	24	20	20	26	21	..	22
	2	24	28	24	20	26	26	..	22
	1	24	32	24	24	30	30	..	22
Seven	7	16	16	16	12	13	17	..	13
	6	20	16	16	16	18	17	..	13
	5	20	20	16	16	18	17	..	18
	4	20	20	20	16	22	21	..	18
	3	20	24	20	20	22	21	..	18
	2	20	24	20	20	26	21	..	22
	1	24	28	20	20	26	26	..	22
Six	6	16	16	16	12	13	13	13	13
	5	20	16	16	16	18	17	17	13
	4	20	20	16	16	18	17	17	18
	3	20	20	20	16	22	21	17	18
	2	20	20	20	20	22	21	21	18
	1	24	24	20	20	26	26	21	22
Five	5	16	16	16	12	13	13	13	13
	4	20	16	16	12	18	17	17	13
	3	20	16	16	16	18	17	17	18
	2	20	16	20	16	22	21	17	18
	1	20	20	20	20	22	21	21	18
Four	4	16	12	12	12	13	13	13	13
	3	16	16	16	12	18	17	17	13
	2	16	16	16	16	18	17	17	18
	1	20	16	20	16	22	21	21	18
Three	3	16	12	12	12	13	13	13	13
	2	16	16	12	12	18	17	17	13
	1	20	16	16	16	18	17	17	18
Two	2	12	12	12	12	13	13	13	13
	1	16	12	12	12	18	13	17	13

(3) Combination brick and concrete.
(4) Concrete walls with light steel framing.
(5) Concrete block walls (hollow).
(6) Concrete and expanded metal—single or double.
(7) Sheet metal or corrugated iron.
(8) Plank walls or movable wooden panels.

These may be constructed in any one of three general ways, as—

(a) Solid masonry walls without columns.
(b) Light masonry curtain walls between supporting columns.
(c) Curtain walls of wood or metal sheathing between steel or concrete columns.

Solid walls should be built with pilasters having sufficient area to safely sustain the loads without causing a greater compressive stress than 125 pounds per square inch on brick work and 250 pounds per square inch on stone and concrete. Wide pilasters are preferable to narrow ones, as they present the appearance of greater strength than those which are narrower but deeper. Solid masonry walls are satisfactory for buildings in which heavy manufacturing is conducted and where traveling cranes are used, for in such buildings the traveling cranes cause no vibration. Curtain walls are not so satisfactory for buildings with heavy cranes, for they lack rigidity, and when once the framing becomes loosened, it is difficult to stiffen the building. A method that has been found effective for avoiding vibration in buildings where curtain walls are used is to first erect the metal framing and to omit the curtain walls for a month or two, while the cranes and machinery are in operation. The bracing may then be inspected and all loose rods or pieces tightened, and the frame placed in adjustment. The walls are then built in solid between the columns and there is little or no opportunity for vibration to occur. When the pilasters of solid walls would be excessively large, steel columns may be inserted in the piers. A column made of four angle bars connected with a plate or lattice will be the most convenient (Fig. 15). If the side walls or pilasters are brick, the columns should be made the proper width so that brick can be built in and around the column with the least amount of cutting. Whether to use a steel column in a masonry pier will depend principally on the cost of a solid pier compared to the corresponding cost of a smaller pier with a steel center. In some cases a steel column may be used to reduce the size of pier, even though the pier with the

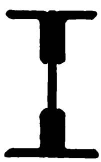


Fig. 15.

steel center would have a greater cost than a larger pier without the steel.

There are many matters of importance that must be carefully weighed when selecting a wall for any prospective building. Certain types are suitable for buildings that must be heated, while others are not. Forge shops or buildings where excessive smoke, gas or odors occur will need so much ventilation that the walls may well be made of movable doors or panels which can be thrown open or removed, and the whole side of the building up to a height of eight or ten feet left open. This arrangement is an excellent one for blacksmith shops, where there is not only excessive smoke, but where workmen are liable to be overheated at the forge. The open sides produce good ventilation and cause an upward draft to carry the smoke away through roof monitors. Buildings in which the walls are made as described above, with continuous doors (Fig. 16) or removable panels, should have a

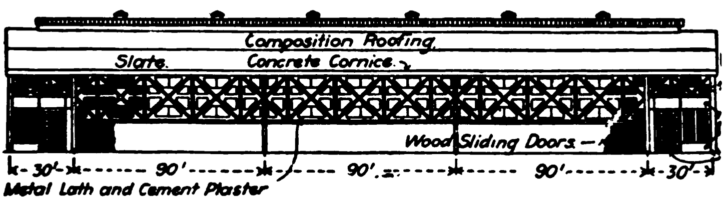


Fig. 16.

continuous line of sash above the doors, for lighting the building when the panels are in place or the doors closed. If the total height beneath the trusses does not exceed about twenty feet, the entire wall space above the movable panels may then be covered with sash; but if the height exceeds this amount, it will be sufficient to use from six to ten feet of sash, with the remaining part of the wall above the windows enclosed with sheathing.

Any kinds of reinforced concrete walls are inconvenient for buildings where extensions or additions are anticipated, unless provision has previously been made. As these walls have continuous metal reinforcement, it is difficult to cut away portions of the wall or to make openings therein. Concrete walls, especially those of a single thickness, are, however, quite economical in the amount of space required.

Where there is any probability of shop walls being rammed by cars at the stub end of tracks, it is a good precaution to insert lintels beneath the eaves, so the roof would not collapse, even if a car or locomotive should be driven through the wall. In proportioning wall lintels, economy may result if careful examination is made to ascertain the actual load that bears upon the lintel. In solid walls, the amount of load will usually not exceed the weight of a small triangular piece of masonry above the lintel, but this will depend upon the position of the adjoining openings.

Extra large doors may have to be provided for the admission or removal of large machines, or framing arranged so a panel can be removed and replaced again without serious inconvenience or injury. This may necessitate the omission of one of the wall columns and the insertion of a truss or girder to carry the roof.

The following table gives the comparative cost, per superficial square foot, for walls of various kinds. The estimates are based on panel lengths of 20 feet and the costs per square foot given include not only the wall between the columns but also the cost of the wall at the pilaster or pier. They are, in fact, the average square foot cost of the entire wall, including columns, pilasters, water table and plain cornice.

TABLE VII.

COST OF WALL PER SQ. FT.	*Per Sq. Ft.*
12-inch stone wall	$0.50
18-inch stone wall	.70
12-inch brick wall (common brick)	.45
8-inch brick curtain wall (common brick), steel columns	.46
8-inch brick wall (common brick), reinforced concrete columns	.37
8-inch brick curtain wall (face brick), reinforced concrete columns	.52
8-inch concrete wall, light steel frame and steel columns	.46
10-inch concrete block wall, steel columns	.37
2-inch concrete and expanded metal lath on steel frame (single)	.33
3-inch concrete and expanded metal lath on steel frame (single)	.36
2-inch concrete and expanded metal lath on steel frame (double)	.54
Galvanized corrugated iron walls on steel frame	.28
Plank walls, sheathed on steel frame	.31

The above walls are those best suited for mill and factory use. Comparative cost of walls finished on the interior and suitable for factory offices are as follows:

	Per Sq. Ft.
Wood stud walls, weather boarded and painted on outside, and lathed and plastered on inside	$0.18
Wood stud walls, with 4-in. face brick veneer, lathed and plastered inside	.38
12-inch solid brick walls, face brick exterior, furred and plastered inside	.62

The cheapest of these walls appears, therefore, to be corrugated iron supported on steel frames. Next in order of cost are weatherboarded plank walls on steel frames, single concrete and expanded metal lath on steel frames, concrete blocks, and light concrete curtain walls between reinforced concrete columns. Methods of determining these costs closely for any particular case are given in a later chapter, on Wall Details.

Solid walls of either stone or concrete collect condensation on the inside, and not only keep the interior damp but the wall and floor will become soiled and discolored, making them less desirable than brick or some form of hollow walls. Weatherboarded plank on steel framing has a low first cost, but has a high insurance rate and is a poor fire risk. An ideal factory wall is made by using reinforced concrete columns and lintels, with a thin concrete curtain wall between them, the whole being faced on the exterior and around the window jambs with four inches of bluff or yellow face brick secured to the concrete by projecting metal wall anchors. The wall has the merit of being rigid, the light steel angles in the concrete columns being sufficiently strong to temporarily support the trusses without any covering, and permit the frame to be erected rapidly and the joints easily made. It has the additional merit of presenting a finished appearance, while the cost is not excessive.

CHAPTER VI.

COST OF STEEL BUILDINGS.

Mill and other industrial steel buildings are so various in their forms and needs that it is difficult if not impossible to give rules for their weight and cost. The nearest costs that can be given are those estimated for a number of actual buildings of various kinds, and these may serve as a general guide in deciding upon the probable cost of proposed new ones. Estimated costs are better for comparison than actual ones, for external conditions can then be considered more nearly uniform.

The buildings described in this chapter are all original designs by the author, and are classified under the following headings:

Buildings with Cranes, and Brick Walls.
Buildings with Cranes, and Corrugated Iron Walls.
Buildings with Cranes, and Concrete and Expanded Metal Walls.
Buildings without Cranes, and Concrete and Expanded Metal Walls.
Buildings without Cranes, and Corrugated Iron Walls.
Steel Frame Factory Office Buildings or Dwellings.

Steel frames covered with corrugated iron or metal sheathing are specially suited for low priced buildings in tropical or semi-tropical countries, where artificial heating is unnecessary. In the following pages there are several buildings of this type shown. The cost of floors and foundations is not included in the prices given unless especially stated, for these can usually be made by local builders at a less expense. For this reason it is customary for foreign buyers or owners to ask for quotations on the steel superstructures only, not including either ground floors or foundations.

Buildings for export to foreign countries may cost more in some particulars than those for erection in the United States. The various parts must be made in weights, sizes and lengths which can be conveniently loaded into vessels. Trusses or other large pieces which could be shop-riveted for home erection may need to be shipped in separate parts, in order to be loaded into the ship hatches. Some additional expense may be incurred on export work in preparing explicit erection drawings and in marking the various shipping pieces so the building can be erected without difficulty. Occasionally the purchaser of a building for a foreign country will require complete drawings of his buildings, and these drawings may have to be made in metric system. This will add extra expense, as American shops and workmen are more accustomed to working in feet and inches than in meters. There is also the expense of crating small or loose pieces for export, and the cost of ocean freight, as well as loading and unloading the material from the vessel.

BUILDINGS WITH CRANES—BRICK WALLS.

The foundry building, 100 feet wide and 200 feet long, shown in Fig. 17, has brick walls without side columns, and the roof

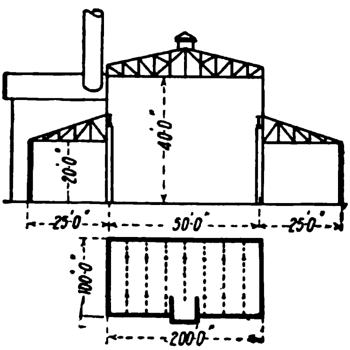


Fig. 17.

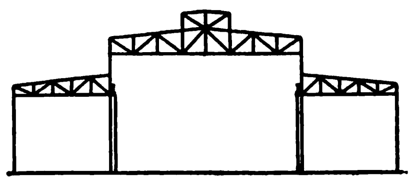


Fig. 18.

is covered with No. 22 galvanized corrugated iron, with moving sash in the side walls above the crane runway. The framing has 25-foot panels, and it is proportioned for a 20-ton traveling crane. The iron work and roofing erected complete without walls cost $12,640, which is equal to 63 cents per square foot of ground covered, and the entire building, including walls, but without floor or foundations, cost 83 cents per square foot of ground covered.

Fig. 18 is another foundry building, 80 feet wide and 100 feet long, with complete inside frame, proportioned for a 10-ton traveling crane. It has tar and gravel roof on 2-inch plank, with brick wall on one side and two ends. The other side has a brick base 5 feet in height with 8 feet of glass above it, finished with a 2-inch slab of concrete and expanded metal to the eave.

The total cost, including foundations, is $8,840—equal to $1.10 per square foot of ground covered.

Fig. 19 is a foundry building in Ohio, 100 feet wide and 120 feet long, with brick side and end walls without wall columns. It has a slate roof on small angle iron purlins spaced 10½ inches apart, without lining. The framing is proportioned for a 20-ton traveling crane and the steel work erected cost $7,200—equal to 60 cents per square foot of ground. If a corrugated iron roof had been used instead of slate, there would have been a total saving on the building of about $1,400—equal to 11 cents per square foot. The total cost with walls and slate roofing is $12,200, or slightly more than $1.00 per square foot of ground area.

Another foundry building for the same company, 100 feet wide and 216 feet long, of the same general design as the one illustrated above, cost $11,200 for the steel work erected—equal to 52 cents per square foot of ground. The total cost, including walls and slate roofing, was $19,000—equal to 88 cents per square foot. If a corrugated iron roof had been used instead of slate, there would have been a saving in the steel work of $2,500.

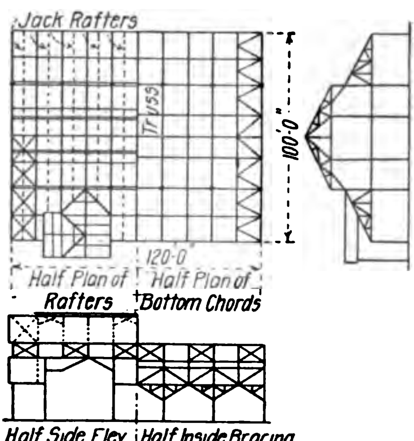
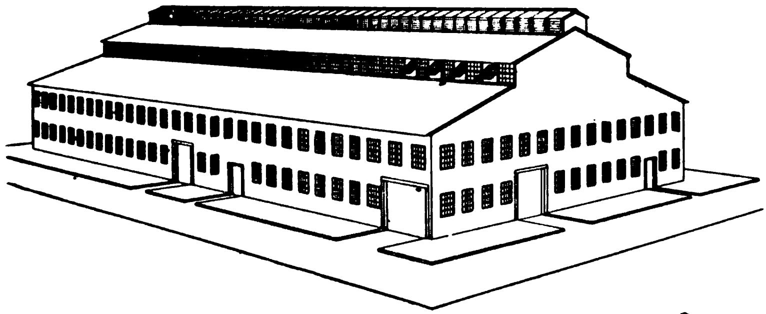


Fig. 19.

*Fig. 20 is a foundry building for Copenhagen, Denmark, 118 feet wide and 230 feet long. It has a galvanized corrugated iron roof with sides and end of brick. The crane system is proportioned for a 30-ton traveling crane. The roof of the monitor is covered with glass and on the monitor sides are louvres. There are steel columns in the side walls, and the main bents are 15 feet apart. The gallery has wood floor on steel joist. The structural work weighs 182 tons, and the cost of the steel and corrugated iron roof erected is $14,540—equal to 54 cents per square foot of ground area, while the entire cost of building complete is $22,000, or 80 cents per square foot.

BUILDINGS WITH CRANES—CORRUGATED IRON WALLS.

Fig. 21 is a foundry building, 80 feet wide and 203 feet long. The front end wall facing on the street is of brick, while the



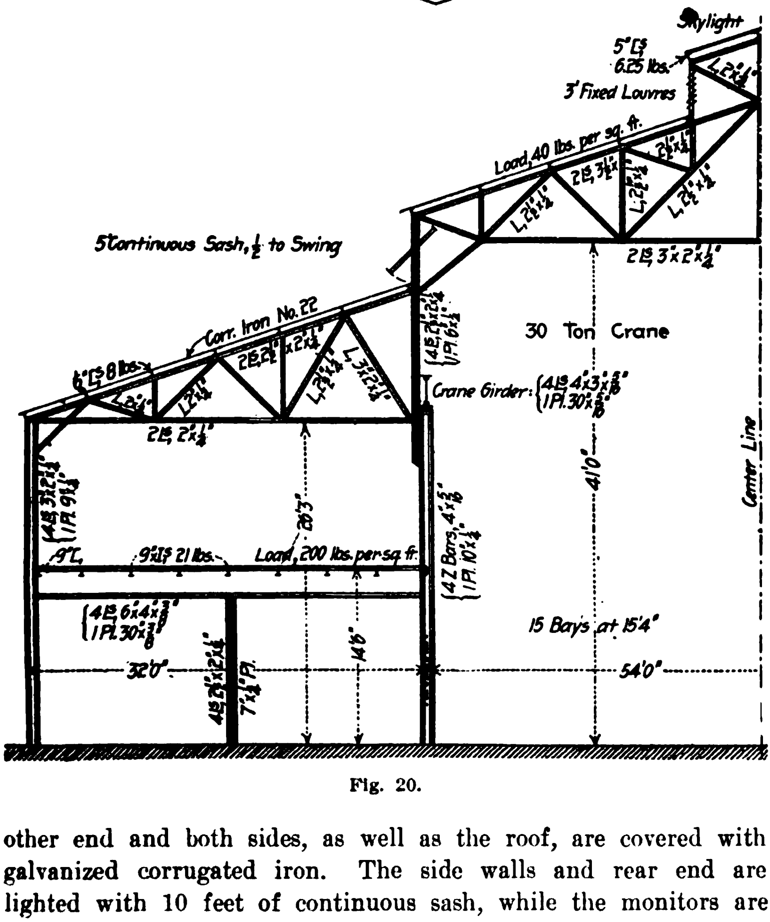


Fig. 20.

other end and both sides, as well as the roof, are covered with galvanized corrugated iron. The side walls and rear end are lighted with 10 feet of continuous sash, while the monitors are covered with glass and have ventilator shutters on the sides. Trolley beams beneath the trusses with capacities of two tons, deliver goods to two large doors at the street end. The cost of the build-

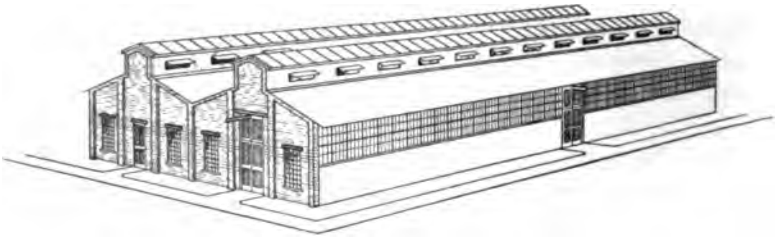
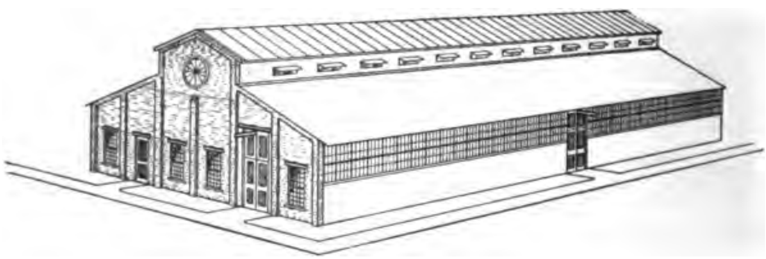


Fig. 21.



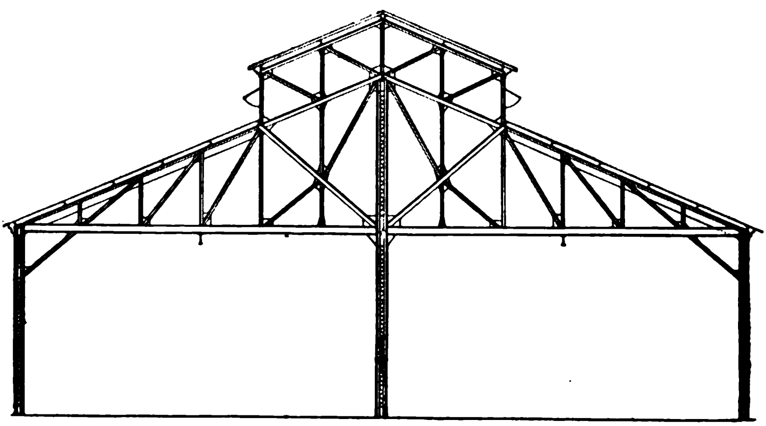


Fig. 22.

ing complete is $12,880—equal to 84 cents per square foot of ground covered. The structural steel weighs 100 tons. One-half of the building is divided into machine, pattern, core, and shipping rooms, and there is an office 40 feet square at the street end.

This is one of the most acceptable framing outlines, for the absence of interior gutters avoids any possibility of leakage and laterally the bents are well braced and rigid. The center line of columns also reduces the weight of truss framing. When greater height is needed for an erecting bay, two lines of interior columns can be used instead of one, in which case they may be located in line with the monitor sides.

Fig. 22 is an alternate design for the above building, with a single ridge, instead of two. The walls and roof covering are the same as in the previous design. It has five tons more steel framing in the roof, but there is less gable wall and a fewer number of monitor shutters, so the total cost is but little more than the two-gable design. The cost per square foot of ground covered is 85 cents with partitions and 75 cents without them. The corresponding costs per square foot of exterior building surface is 45 cents and 40½ cents, respectively.

Fig. 23 is a machine shop for the Southern States, 64 feet wide and 128 feet long, with 16-foot panels. The galleries have plank floors on wood joist. The roof, sides and ends of the building are covered with corrugated iron on steel girths. The center erecting bay is served by a 15-ton traveling crane. The cost of the steel framing erected is 73 cents per square foot of ground, and the total cost of frame and corrugated iron is 95 cents per square foot.

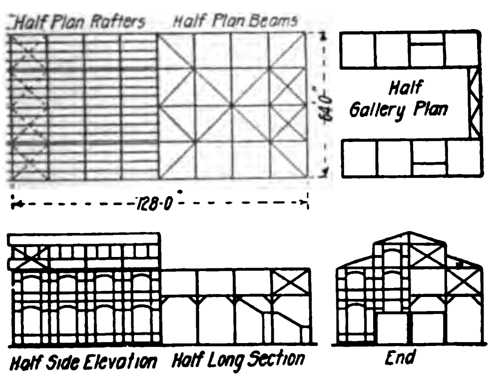


Fig. 23.

BUILDINGS WITH CRANES—REINFORCED CONCRETE WALLS.

Fig. 24 is a machine shop 100 feet wide and 310 feet long, with tar and gravel roof on a 3-inch slab of reinforced concrete, and walls made of a 2-inch slab of concrete and expanded metal on steel girths. It has provision for one 20-ton traveling crane, and another 5-ton at a lower level. The low roof trusses are 13 feet apart, while the higher ones over the erecting bay are 26 feet apart, and there are steel columns in the side walls. The cost of the steel work erected is $12,700—equal to 41 cents per square foot—while the whole cost of the building is $28,900—equal to 95 cents per square foot of ground covered.

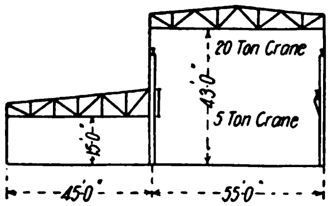


Fig. 24.

BUILDINGS WITHOUT CRANES—REINFORCED CONCRETE WALLS.

Fig. 25 shows a shop 45 feet wide and 200 feet long, having a 3-inch reinforced concrete roof covered with tar and gravel. The walls are made of a 2-inch slab of concrete and expanded metal, on light metal girths. The building contains 40 tons of structural steel, and the cost, erected complete, including steel, gravel roofing, doors, windows, walls and roof, is $5,570—equal to 82 cents per square foot of ground covered.

*Fig. 26 is a one-story warehouse, 50 feet wide and 200 feet long. The walls consist of a 2-inch slab of concrete and expanded metal laths over light steel girths. The building has a complete steel frame with side columns, weighing 30 tons. It is lighted entirely from a skylight on the roof, thus permitting goods to be piled up against the walls, without obstructing the light. It has a plank roof covered with tar and gravel. The cost complete is $7,500—equal to 75 cents per square foot of ground. If 8-inch brick curtain walls were used between the steel columns, instead of the concrete walls, the cost would then be $8,200, or 82 cents per square foot.

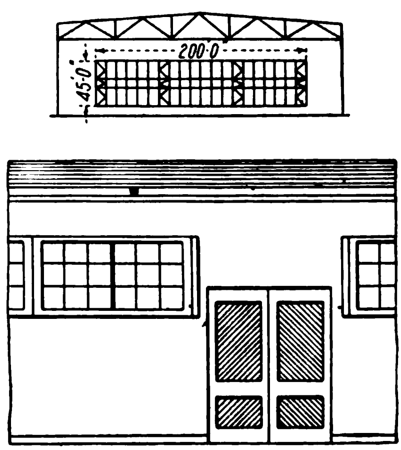
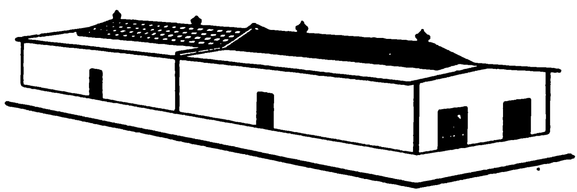


Fig. 25.

BUILDINGS WITHOUT CRANES—WALLS AND ROOF CORRUGATED IRON.

*Fig. 27 is a gold ore mill for Johannesburg, South Africa. It has a total width of 83 feet, the center 23 feet being occupied with ore bins, while 30 feet at each side is open. Its length is 110 feet. The building is covered on sides and roof with No. 22 galvanized corrugated iron. The ore pocket is lined on the sides and bottom with 5-inch plank, and it contains 2,600 tons of ore. The total weight of steel is 300 tons, which is equal to 7 pounds for



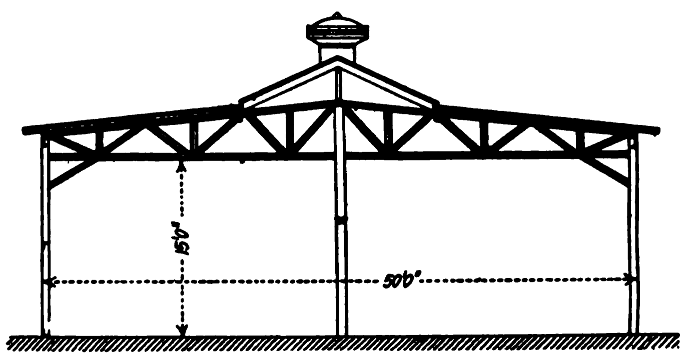


Fig. 26.

every cubic foot of bin. The total cost of the building is $37,000 —equal to $2.60 per square foot of ground area covered.

*Fig. 28 is a steel frame sugar warehouse for Porto Rico, to hold 20,000 bags of sugar, piled up equally on the two floors. The building is fireproof, with brick arch floors between steel beams. The sides, ends and roof are covered with corrugated iron. The weight of steel framing is 163 tons, and the cost, erected complete, is $17,000—equal to $2.60 per square foot of ground covered.

Fig. 29 shows a work shop, 52 feet wide and 230 feet long, for South Africa. It is covered on the roof and sides with No. 24 galvanized corrugated iron. There are five ridges running crosswise of the building, instead of lengthwise, in the usual way. The location was a very exposed one, and the framing was therefore proportioned for a wind load of 30 pounds per square foot. Trusses and columns are placed 13 feet apart and columns have shafting brackets 3 feet below the trusses. There were 400 separate shipping pieces, and the material on shipboard occupied 9,000 cubic

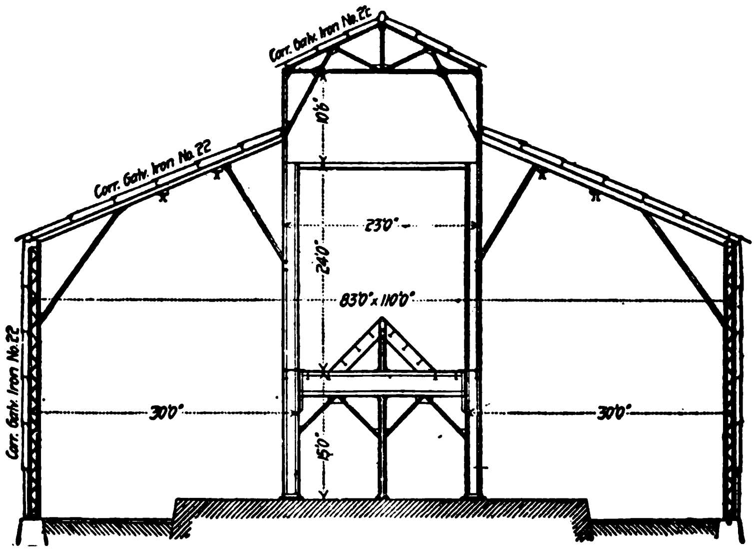


Fig. 27.

feet. The total shipping weight was 80 tons, and the total cost of the building, erected complete, was $8,200, which is equal to 60 cents per square foot of ground covered.

**Fig. 30 is a market building, 61 meters wide and 66 meters long, for South America. It covers a whole city square, having streets on four sides. The building is made entirely of steel, excepting counters, which were furnished by a local builder. It is divided into stalls of various sizes, from 10 feet for the smallest to 20 feet square for the largest. The counters are accessible by means of the swinging shutters that form sunshades when open, and at night are shut down and locked. Ventilation is secured by louvres in the monitors and a continuous line of wire netting underneath the eaves. The upper part of all partitions is made

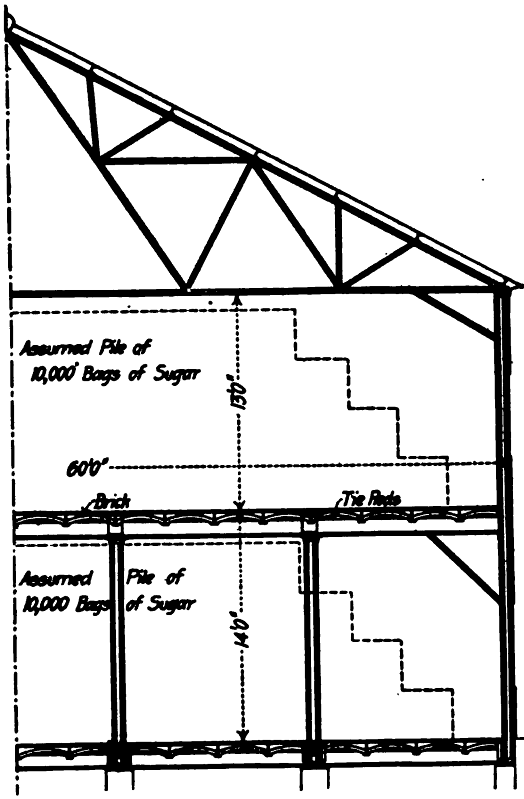


Fig. 28.

of wire, thus giving a free circulation of air throughout the building. The weight of steel frame is 96 tons, and the total shipping weight is 185 tons. The total cost above foundations is $18,000—equal to 53 cents per square foot of area covered.

**Fig. 31 is another market building, 50 meters square, somewhat similar to the above. It has streets on only two sides and is made of steel and glass, excepting the wood counters. On the outside are swing doors, which, when open, act as sunshades. The building is ventilated by fixed louvres below the upper eaves and also on the sides of the central tower. There is also around the building, above the doors, two feet of wire

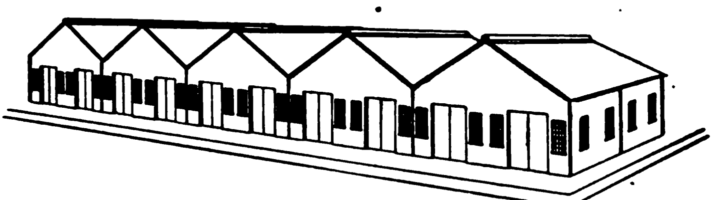


Fig. 29.

netting, which permits a free air circulation at all times through the market. Stalls are generally 10 feet square. The area covered by the market is 27,000 square feet. There were 76 tons of structural steel and 118 tons in the whole shipment. The cost of

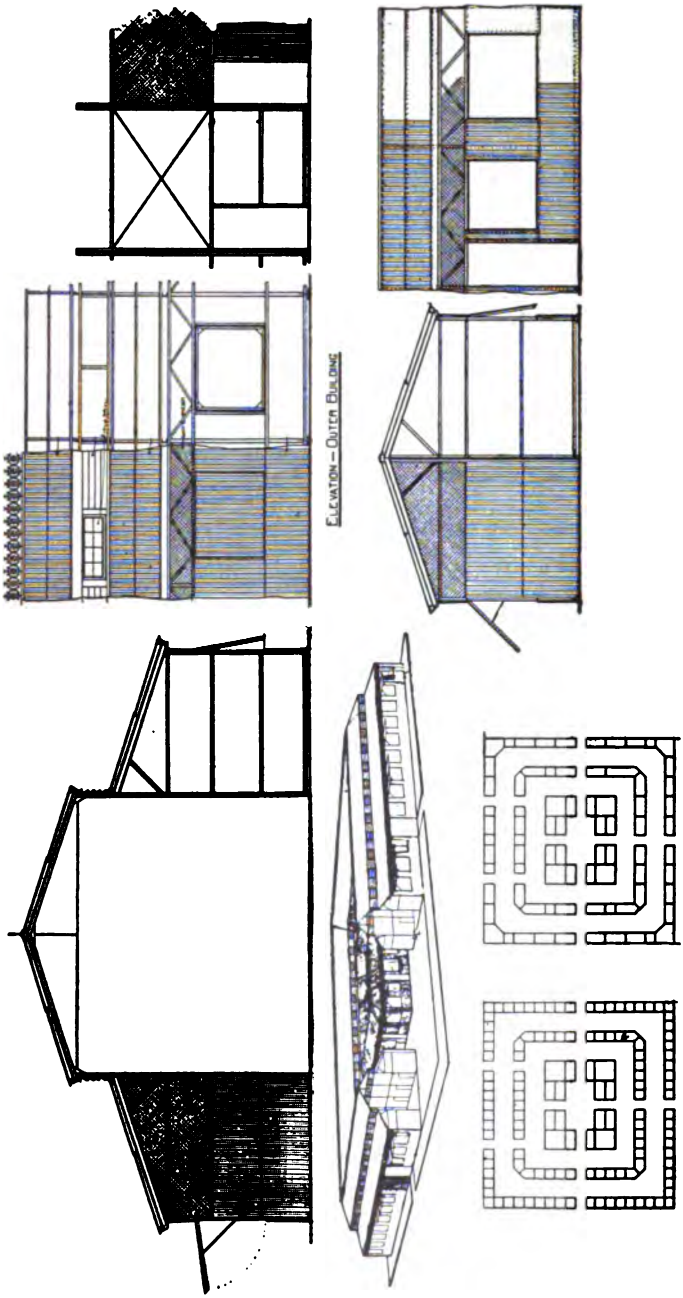
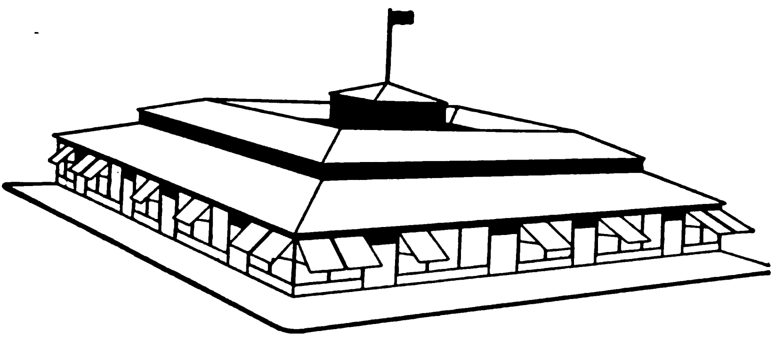


Fig. 30.

the building complete is $11,900, which is equal to 44 cents per square foot of area covered.

**Fig. 32 is a market hall for the City of Mexico. It is fire-proof, the roof being covered with galvanized corrugated iron, and the walls in expanded metal lath and concrete. The open arch construction for the sides and ends, together with swinging



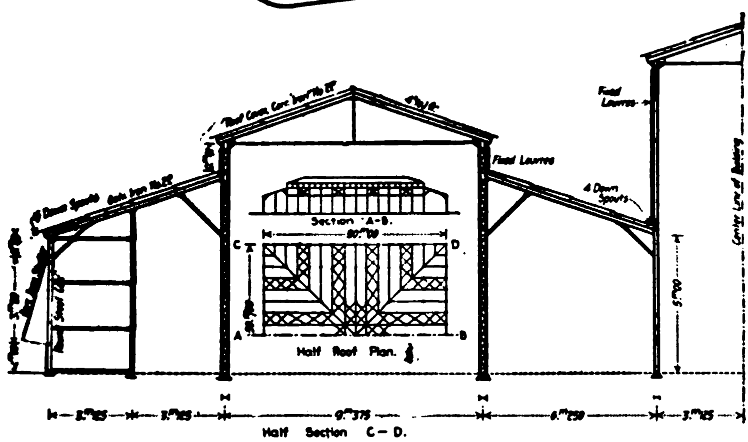


Fig. 31.

windows in the sides of the monitors and dome, give ample ventilation. The open arches are provided with rolling steel shutters to be closed at night or when desired. The extreme outside dimensions of the building are 98 feet by 230 feet, while the dome is 50 feet in diameter. It covers a ground area of 22,540 square feet, and the total weight is 102 tons. The total cost of the building complete above the floor and foundations is $22,000, or 95 cents per square foot of area covered.

**Fig. 33 is a market house in Moorish style, made to conform with the surrounding architecture. It is 26 feet wide and 481 feet long, with three towers as shown, each of which has two floors. On the second floor of the center tower is a tank to supply water to the building. A notable feature of this market is the line of raising shutters, supported, when open, on small round iron columns. These shutters form also a continuous sun-

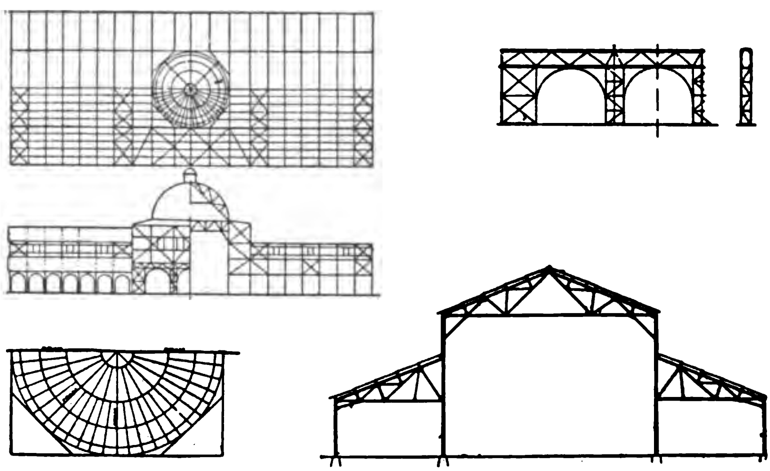


Fig. 32.

shade for the market and stalls. The building is ventilated by means of swinging windows over the doors, and the space in front of these windows is covered with ornamental iron grill, the windows remaining open over night, if desired. The roof is covered with galvanized corrugated iron, and the sides and columns are made of paneled cast iron. The filling of the sides above the doors is made of stamped sheet metal and portions of the tower are ornamented with blue tiles. It contains 78 tons of steel and its total cost above floor and foundations is $22,100, or $1.70 per square foot of area covered.

**Fig. 34 is a market building, 39 feet wide and 481 feet long, with complete steel frame, and covered on the roof and sides with corrugated iron. The building is divided longitudinally in panels 13 feet in length. The two end houses are two stories in height. The center portion is 26 feet wide between side walls, and on each

Fig. 33.

side the eaves overhang by 6½ feet, forming sunshades. At the center of the building is a 5,000-gallon water tank, to supply water to the market. In each panel there is a swing door 5 feet wide and 8 feet high, which is raised during the day and closed at night. Above these doors is 3 feet of continuous sash, and between the sash and eaves is a continuous line of wire mesh, 2 feet in width, for ventilation. Stalls on each side are 10 feet

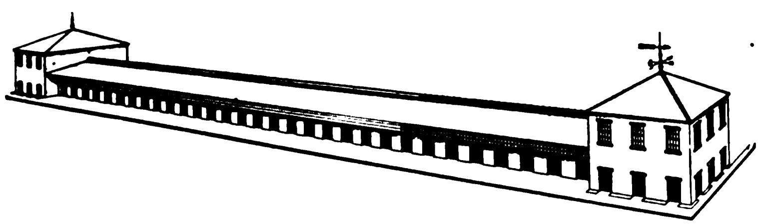


Fig. 34.

deep. The total cost of the building is $12,900—equal to 68 cents per square foot of floor.

**Fig. 35 is a market building, 34 meters wide and 76 meters long, covering an area of 25,500 square feet. The dome is 68 feet in diameter. It has a total shipping weight of 137 tons, and there are 550 separate shipping pieces. The space occupied on board the vessel is 13,000 cubic feet. The weight of steel is about 93 tons, and the total cost is $12,800, which is equal to 50 cents per square foot of area covered, not including either floor or foundations. The building is covered on both sides and roof with galvanized corrugated iron. The curved roof gives a pleasing appearance. There are no partitions.

Fig. 36 shows a steel frame market building for export, 55 feet wide and 150 feet long. It is in the form of a cross, with a central dome. It has steel frame and corrugated iron covering on walls and roof. The floor area is 8,630 square feet, and the total cost of the building complete, not including ocean freight, is $5,800—equal to 66 cents per square foot of ground covered.

Fig. 37 shows a building 80 feet wide by 180 feet long, for

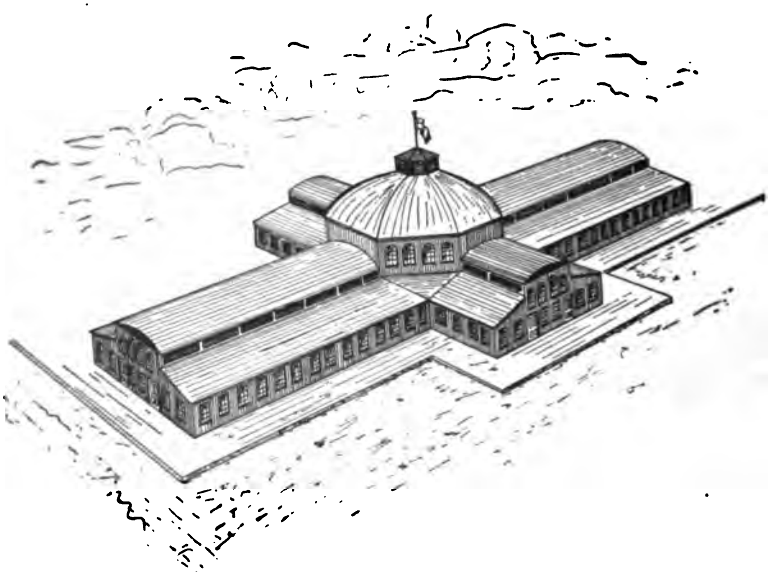


Fig. 35.

a roller skating rink. It contains 67 tons of steel, and the cost, erected complete, with corrugated iron roof and walls, including all windows, doors, glazing, etc., is $8,975, or 62 cents per square foot.

SHOP OFFICES OR DWELLINGS.

*Fig. 38 is a two-story, eight-room portable steel house, suitable for tropical countries. It has a wide veranda on all sides at each floor, and the upper story has a paneled sheet metal ceiling. Beneath the eaves are open spaces covered with galvanized wire mesh, leaving the space between ceiling and roof open for the free circulation of air. The arrangement prevents the upper story from becoming excessively hot from the sun. The house frame is bolted together and may be taken apart and erected elsewhere without injury. There are two floor designs, one with boards on wood joists and the other with corrugated metal flooring overlaid with

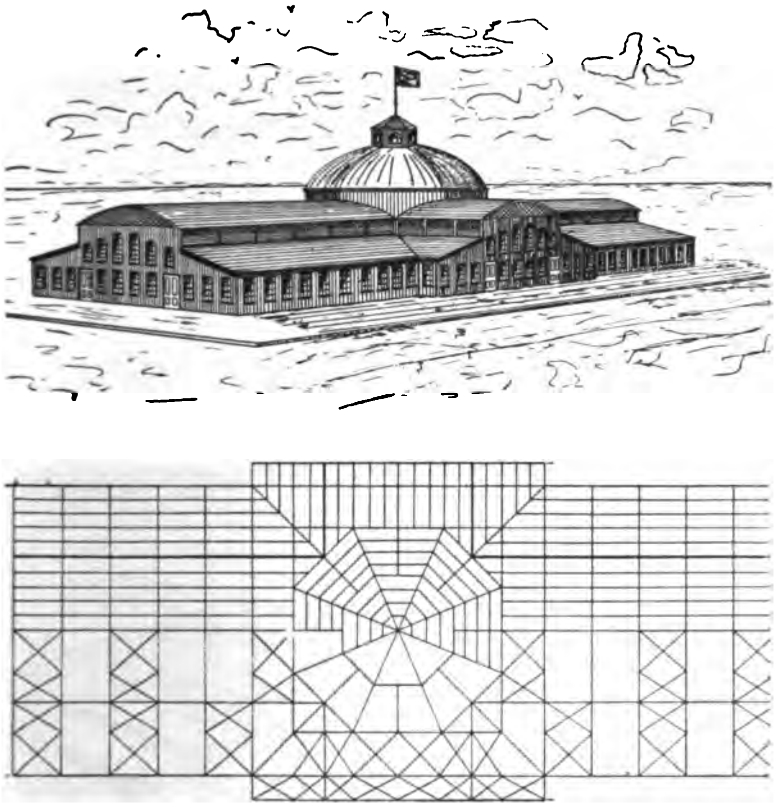


Fig. 36.

flat steel, and the space between filled with mud or sawdust. The total cost, erected complete, is $1,850, and the shipping weight is 24 tons.

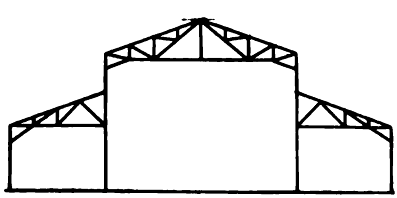


Fig. 37.

Fig. 39 is a one-story, six-room house or office, of similar construction to that above. It has a veranda and open space beneath the eave for ventilation. The cost, erected complete, is $1,450, and its total weight is 20 tons.

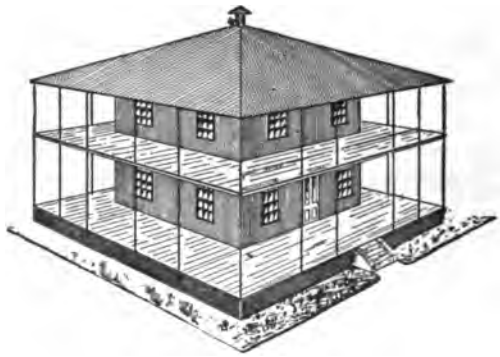


Fig. 38.

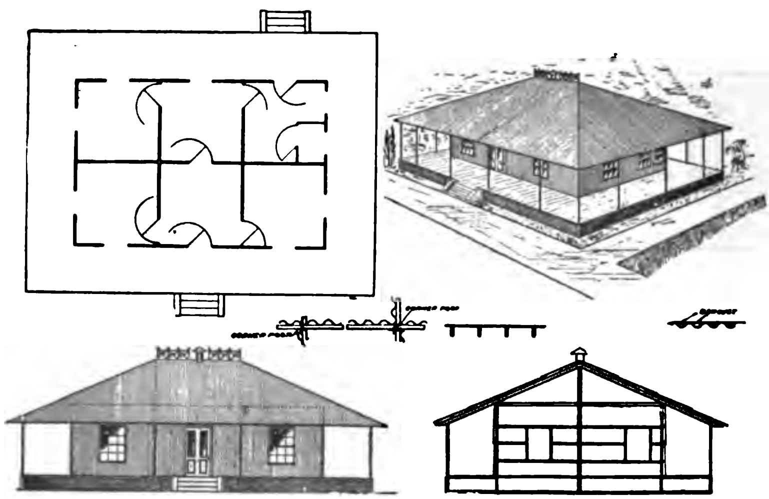


Fig. 39.

Fig. 40 shows a four-room, one-story house or office, with a wide veranda on two sides for sunshade. The total weight of the house is 23 tons, and its cost is $1,730. The floor is raised about 3 feet above the ground, and the whole is built on steel sills. The building requires no foundation other than a level lot or site. As the joists are all bolted, it can be taken apart and removed without injury.

Fig. 41 is a steel frame factory office building, 40 feet square, with walls and roof of concrete and expanded metal. Its total cost is $2,750, including floor and foundations. It is all in one room, and has plaster finish on the inside, with an open fireplace and chimney in the center.

Fig. 40.

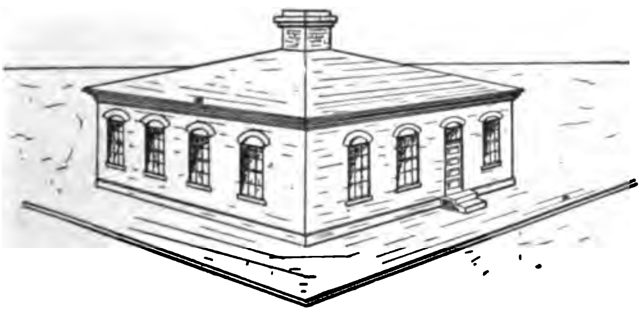


Fig. 41.

TABLE VIII.

SUMMARY OF BUILDING COSTS AS GIVEN IN CHAPTER VI.

Buildings with Cranes and Brick Walls.

No.	Size.	Total cost.	Cost per sq. ft. of ground covered.
1.	Foundry, without walls, 100x200 ft	$12,640	$0.63
2.	Foundry, with walls, 100x200 ft	.....	.83
2.	Foundry, complete, 80x100 ft	8,840	1.10
3.	Foundry, steel only, 100x120 ft	7,200	.60
3.	Foundry, complete, 100x120 ft	12,200	1.00
4.	Foundry, steel only, 100x216 ft	11,200	.52
4.	Foundry, complete, 100x216	19,000	.88
5.	Foundry, steel and metal, 118x230 ft	14,540	.54
5.	Foundry, complete, 118x230 ft	22,000	.96

Buildings with Cranes and Corrugated Iron Walls.

No.	Size.	Total cost.	Cost per sq. ft. of ground covered.
6.	Foundry, with partitions, 80x203 ft.	$12,880	$0.84
6.	Foundry, without partitions, 80x203 ft.	.....	.75
8.	Machine shop, steel only, 64x128 ft.	.....	.95
8.	Machine shop, complete, 64x128 ft.	.....	.73

Buildings with Cranes, Reinforced Concrete Walls.

No.	Size.	Total cost.	Cost per sq. ft. of ground covered.
9.	Machine shop, complete, 100x310 ft.	$28,900	$0.95
9.	Machine shop, steel only, 100x310 ft.	12,700	.41

Buildings with Cranes, Reinforced Concrete Walls.

No.	Size.	Total cost.	Cost per sq. ft. of ground covered.
10.	Shop, complete, 45x152 ft.	$ 5,570	$0.82
11.	Warehouse, complete, 50x200 ft.	7,500	.75
12.	Ore mill, complete, 83x110 ft.	37,000	2.60
13.	Sugar house, complete, 60x110 ft.	17,000	2.60
14.	Shop, complete, 52x230 ft.	8,200	.68
15.	Market, complete, 202x216 ft.	18,000	.53
16.	Market, complete, 164x164 ft.	11,900	.44
17.	Market, complete, 98x230 ft.	22,000	.95
18.	Market, complete, 39x481 ft.	21,000	1.70
19.	Market, complete, 39x481 ft.	12,900	.68
20.	Market, complete, 112x250 ft.	12,800	.50
21.	Market, complete, 55x151 ft.	5,800	.66
22.	Rink, complete, 80x180 ft.	8,975	.62

Factory Offices or Dwellings.

No.	Size.	Total cost.	Cost per sq. ft. of ground covered.
23.	Eight-room house	$1,850	....
24.	Six-room house	1,450	....
25.	Four-room house	1,730	....
26.	One-room house, 40x40 ft.	2,750	....

Roughly speaking, one-story steel mill buildings with cranes and solid walls, erected complete without ground floor or foundations, will cost from 80 cents to $1.10 per square foot of ground covered, while similar buildings with cranes and corrugated iron walls will cost from 70 cents to $1.00. One-story steel frame sheds or buildings without cranes, and covered with corrugated iron will cost erected complete from 50 to 70 cents per square foot of ground covered.

One-story office buildings or dwellings erected complete, including floor and foundations, cost from 80 cents to $1.00 per square foot of area covered, while similar two-story buildings cost from $1.20 to $1.50 per square foot.

In order to give a rough idea of the cost of steel buildings for export, the following prices are given for the material delivered at Atlantic seaboard. The steamship companies do their own loading, and the prices given are for material delivered at the wharf and not on board ship. The prices are for all material for complete steel buildings, including steel frame, corrugated iron, doors, windows, flashing, gutters and conductors, but do not include ground floors or foundations. They are in all cases for buildings covered with metal sheathing.

The material for machine shops, foundries, etc., cost from 40 to 50 cents per square foot of ground covered.

Sheds and other buildings proportioned only for ordinary roof and wind loads cost from 30 to 40 cents per square foot of ground covered.

A fairly close estimate may be made for sheds and other plain iron buildings without cranes, by figuring all the exposed surface of both walls and roof at 30 cents per square foot, and if the building contains a traveling crane, then add $1.00 per lineal foot of building for every ton capacity of the crane. This covers crane supports and girders only, and not the cost of crane itself. The cost of cranes may be compiled from the weight given in Tables I, II, III, IV, XXII and XXIII.

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* H. G. Tyrrell, in Engineering News, April 11, 1901.
** H. G. Tyrrell, in Architect's and Builder's Magazine, July, 1901.

CHAPTER VII.

COMPARATIVE COST OF WOOD, STEEL AND REINFORCED CONCRETE BUILDINGS.

To ascertain definitely the comparative cost of buildings in wood, steel, and reinforced concrete, an examination will be made of two typical buildings, and the cost estimated for framing them in the three different materials.

The first of these buildings is a bakery, 55 feet wide, 88 feet long, and contains seven stories and a basement. It differs from other factory buildings only by having specially heavy framing on portions of the floor to carry the brick bake ovens. These ovens are about 16 feet square and 10 feet high and there are two on each floor. This feature of the building would add about $3,000 to its cost, but this item is not included in the following comparative estimates. It has walls and windows on all four sides. The estimates given are for the structural parts of the building only, including walls, columns, floors, framing, roofing, windows, doors, excavation, foundations and stairs, but do not include plumbing, elevators, heating, partitions, electric wiring or lighting. Neither do they include any miscellaneous or ornamental iron work such as store front, walk lights, coal hole covers or chute, or sidewalk grating. The cost of the items not included are the same for all the estimates and are given below:

Oven framing	$3,000	Heating	2,400
Miscellaneous iron	1,100	Electric wiring	1,000
Plumbing	3,100		
Elevator	1,500	Total	$12,100

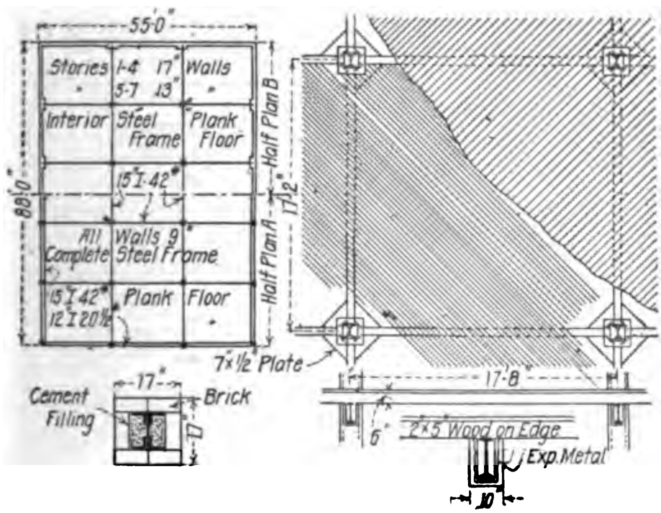
The floors, excepting under the bake ovens, are designed to carry a uniformly distributed load of 200 pounds per square foot, including both dead and live loads. The roof has a flat pitch and is designed to carry a uniform load of 100 pounds per square foot. The columns are designed for a total load of 150 pounds per square foot on the floors.

The thickness of the basement walls is 24 inches in all cases.

The various plans considered are as shown by Figs. 42 to 48, and are as follows:

Plan A. Complete interior and exterior steel frame, 9-inch curtain walls, plank floor on steel beams, all steel work fireproofed. Total cost $49,100, equal to $1.28 per square foot of floors, or 10.3 cents per cubic foot of buildings. (Fig. 42.)

Plan B. Interior steel frame, brick walls 17 and 13 inches thick, plank floor on steel beams, steel work fireproofed. Total cost $44,800, equal to $1.16 per square foot of floors, or 9.4 cents per cubic foot of the building. (Fig. 43.)



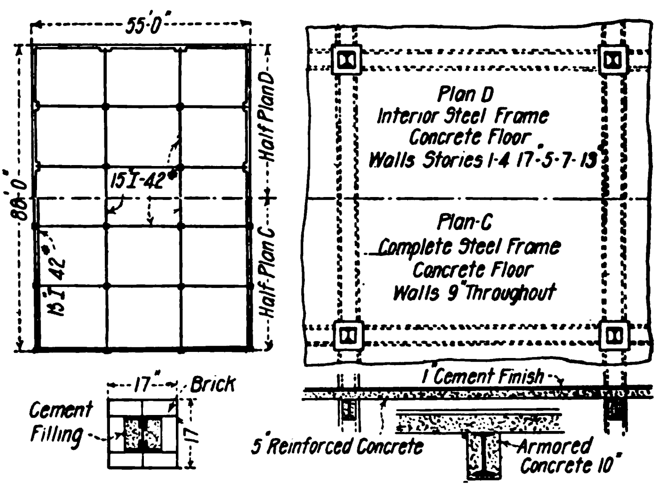
Figs. 42-43.

Plan C. Complete interior and exterior steel frame, 9-inch curtain walls, reinforced concrete floors, columns fireproofed. Total cost $52,000, equal to $1.34 per square foot of floor, or 10.8 cents per cubic foot of the building. (Fig. 44.)

Plan D. Interior steel frame, brick walls 17 and 13 inches thick, reinforced concrete floors, columns fireproofed. Total cost $47,700, equal to $1.24 per square foot of all the floors, or 9.8 cents per cubic foot of the building. (Fig. 45.)

Plan E. Entire building reinforced concrete. Total cost $44,000, equal to $1.15 per square foot of all the floors, or 9.1 cents per cubic foot of the entire building. (Fig. 46.)

Plan F. Part interior steel frame, not fireproofed, steel columns and two lines of steel beams in each floor, floors slow burning wood construction, brick walls, 17 to 13 inches thick. Total cost $40,600, equal to $1.07 per square foot of all the floors, or 8.4 cents per cubic foot. (Fig. 47.)



Figs. 44-45.

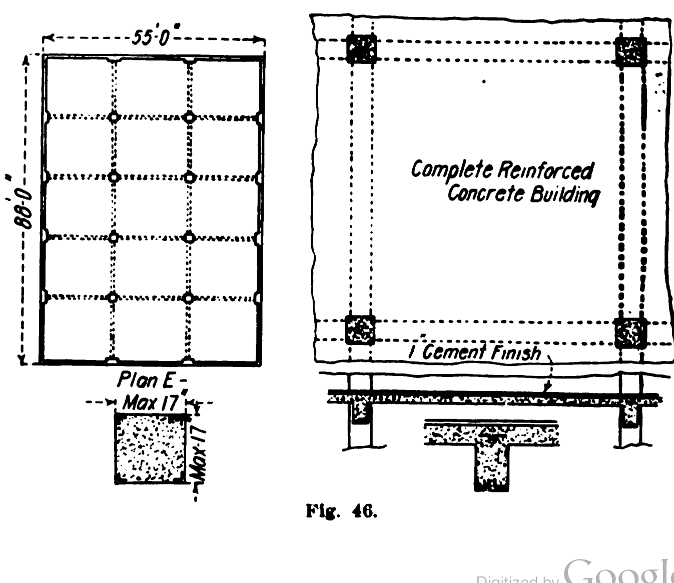
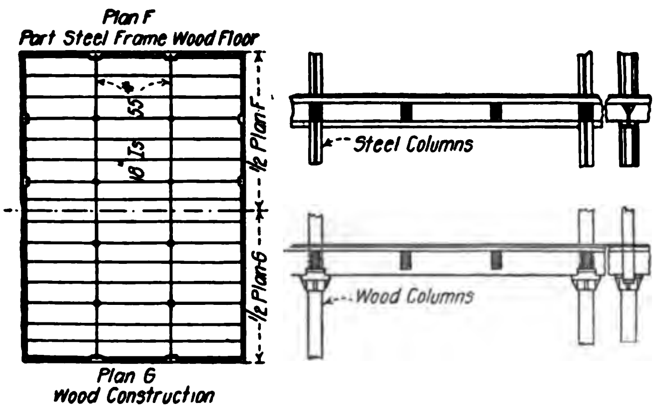


Fig. 46.

Plan G. Ordinary slow burning construction throughout, with wood columns and plank floor on wood beams spaced 5 to 6 feet apart. Total cost $37,000, equal to 96 cents per square foot of all the floors, or 7.7 cents per cubic foot of the entire building. These figures correspond closely with the usual cost of slow burning wood construction for 200 pound floor loads. (Fig. 48.)

In plans A and C, if alternate courses of wall girders are omitted, and the exterior curtain walls carried on the remainng girders, the total saving in the building would then be $1200, which is equal to 3 cents per square foot of floors, or 1/4 cent per



Figs. 47-48.

cubic foot of building. In case alternate wall girders are omitted, a channel only is then needed on the inside of the walls at these floors to carry the floor loads.

In the first five designs, plans A to E, the floors are 6 inches thick in all cases, but in plans F and G, where slow burning wood construction is used, a greater floor thickness is required.

The comparative cost of the floors alone in plans A, B, C and D, including the steel beams is as follows: Wood floors cost $7000, or 18 cents per square foot, while reinforced concrete floors cost $10,000, or 26 cents per square foot.

In computing the costs in all the above cases, the total area of the seven floors and basement is taken at 38,700 square feet, and the total cubical contents of the building 484,000 cubic feet. The height of building from cellar floor to roof is 100 feet. A summary of the above comparative estimates is as follows:

Plan.	*Total cost.*	*Cost per sq. ft. of floor surface.*	*Cost per cu. ft. (cents.)*
A	$49,100	$1.28	10.3
B	44,800	1.16	9.4
C	52,000	1.34	10.8
D	47,700	1.24	9.8
E	44,000	1.15	9.1
F	40,600	1.07	8.4
G	37,000	.96	7.7

Taking the cost of the building in wood mill construction, estimate G, as a basis, and calling its cost unity, the comparative costs of the other methods is as follows:

TABLE IX.

A.	Complete steel frame, curtain walls, plank floor	$1.30
B.	Interior steel frame, solid brick, plank floor	1.19
C.	Complete steel frame, curtain walls, reinforced concrete floors	1.37
D.	Interior steel frame, solid brick walls, reinforced concrete floors	1.26
E.	Entire reinforced concrete building	1.17
F.	Part interior steel frame, solid brick walls, wood mill floors	1.09
G.	Entire wood mill construction, slow burning, solid brick walls	1.00

The conclusion, therefore, from these estimates is that a building with complete steel frame, side curtain walls, and wood floors costs 30% more than wood mill construction, while the same building with only interior steel frame and solid side bearing walls, will cost 19% more than wood mill construction. If the first building mentioned above had a reinforced concrete floor, its cost would then be 37% more than mill construction, while the corresponding cost of the second one with reinforced concrete floor would be 26% more. An entire building of reinforced concrete costs 17% more than one in wood mill construction. If steel columns and two lines of longitudinal steel beams are used at floors and roof, with the balance of floor and roof of wood mill construction, the use of this partial steel frame increases the cost by 9%.

It appears, therefore, that reinforced concrete buildings cost 17% more than wood mill construction, and about the same as buildings with complete interior steel frames, solid walls, and wood floors.

The second building for which comparative estimates are made, is a six-story factory building, 60 feet wide, 100 feet long, containing six floors and a roof, as shown in *Fig. 49. The floors are designed to carry an imposed load of 100 pounds per square

* H. G. Tyrrell, Canadian Engineer, October, 1904.

foot. Windows are on all sides and the walls carry the ends of the floor beams. The walls in the basement are 24 inches thick, while in the first four stories, they are 17 inches. The remaining two stories have 13-inch walls. The estimates given are for the structural parts of the building only, including walls, columns, floors, roof, excavation, doors, windows and foundations, but do not include any stairs, partitions, elevators, plumbing, heating, wiring or lighting.

The framing of the slow burning design is as follows: Eight tiers of columns spaced 20 feet apart in both directions, carry the floors and roof. The columns from the roof down through four stories are of yellow pine. In the lowest of these stories, the size

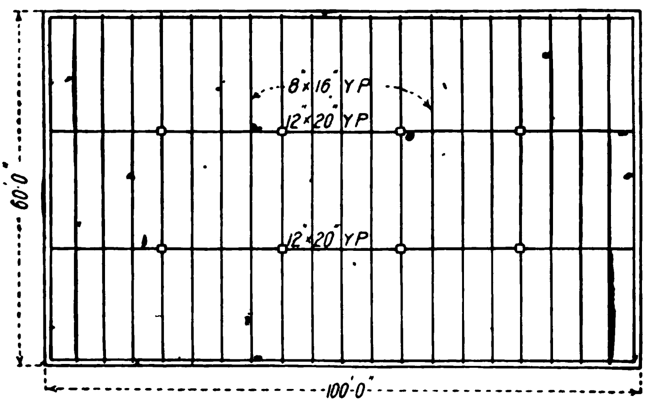


Fig. 49.

of column used is 14x14. Below this, where a greater size would be required than can be secured economically in wood, round cast columns are used, 11x1¼ inches in the first story and 12x1¼ inches in the basement. All the columns have cast iron bases, 3 feet square and 16 inches high. Lengthwise through the building, in the floors, run two lines of 12x20-inch yellow pine, which rest on brackets of cast iron column caps. The cross floor beams are 8x16-inch yellow pine, spaced 5 feet apart. At the columns, they rest on column caps, and at intermediate points, hang from the 12x20 header beams by means of wrought iron stirrups. The cross floor beams in the walls rest on cast iron wall plates, 9x20x¾ inches. The floor is made of ⅞-inch maple laid on 1¾-inch yellow pine. The roof is similar in construction and has a tar and gravel covering. The quantities of material in the building as outlined above are as follows:

Excavation, yds.	1,800
Cellar cement floor, sq. ft	6,000
Foundation concrete, cu. yds	150
Brick, cu. ft	39,000
Windows, 4 × 7 ft	238
Roofing, sq. ft	6,000
Yellow pine lumber, ft. B. M	116,000
Yellow pine flooring, ft. B. M	73,000
⅞ matched flooring, ft. B. M	46,000
Iron work, tons	46

The estimated cost of this design is $35,000, which is equivalent to 6.1 cents per cubic foot of the building, or 83 cents per square foot of the entire area of all the floors. The interior framing of floors and columns, including wall plates, column caps, bases and stirrup irons, costs 27 cents per square foot of floor area.

In the fireproof design, the arrangement of beams and columns is similar to that used for the slow burning design. Riveted steel columns are used from cellar to roof, and the floors are framed with steel beams. The flooring between the beams is reinforced concrete and the arrangement is therefore similar to plan D in the previous building. The quantities are as follows:

Excavation, cu. yds	1,800
Cellar floor, sq. ft	6,000
Foundation concrete, cu. yds	150
Brick, cu. ft	39,000
Windows, 4 × 7 ft	238
Roofing, sq. ft	6,000
Steel columns, tons	105
Steel beams and wall plates, tons	252
Concrete floors and roof, sq. ft	42,000

The cost of the building in this case is $57,000, which corresponds to 10.2 cents per cubic foot of the building or $1.36 per square foot of the entire floor area. Floors and columns cost 75 cents per square foot of floor area. Hence comparative estimates are as follows:

	Total cost.	*Cost per sq. ft. of floor area*	*Cost per cu. ft. of building (cents).*	*Cost per sq. ft. for floor and cols. only (cents).*
Fireproof steel construction	$57,000	$1.36	10.2	75
Wood mill construction	35,000	.83	6.2	27

Figs. 50 and 51 are views of a two-story steel frame workshop, with complete steel frame and walls of a 2-inch slab of concrete and expanded metal, on light steel purlins. It has a tar and gravel roof. The intermediate floor is wood mill construction with hard pine beams spaced 5 feet apart, overlaid with two layers of plank. The building contains 48 tons of structural steel and its cost erected complete is $10,100, equal to $1.35 per square foot of ground covered. If an 8-inch brick curtain wall were used instead of the concrete and expanded metal, the cost would then be $11,000, or $1.45 per square foot of ground.

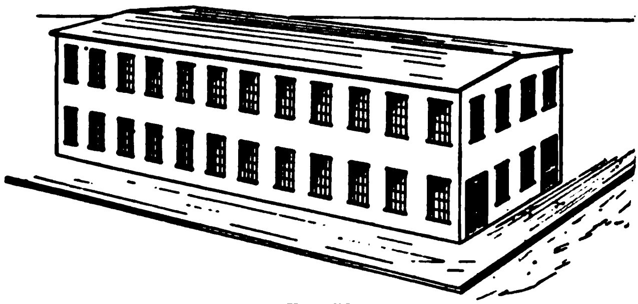


Fig. 50.

A two-story factory building, 40 feet wide and 100 feet long, with a complete steel frame, is similar to the last one described, except that the second story is free from inside columns. It has a 2-inch plank and gravel roof, with walls of concrete and expanded metal. The intermediate floor has two layers of plank on wood beams 5 feet apart. The total cost of the building complete above

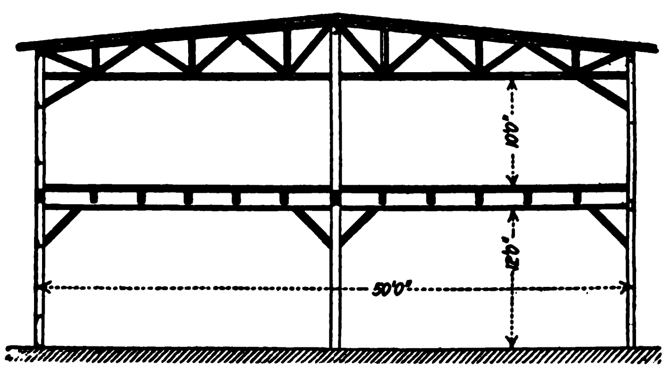


Fig. 51.

foundations is $5,400, equal to $1.35 per square foot of ground covered. It contains 26 tons of structural steel. The same building with 8-inch brick curtain walls instead of concrete and expanded metal, would cost $5,800, or $1.45 per square foot or area covered.

COST OF WOOD MILL CONSTRUCTION.

The cost of wood mill buildings of the slow burning type, with plank floor, wooden beams and columns and brick walls, for various widths and heights of one to five stories, has been given on the chart Fig. 12. For widths of 50 feet, these costs are about as follows:

TABLE X.

COST OF WOOD MILL CONSTRUCTION.

	Cost per sq. ft. of floor area.	*Cost per cu. ft. (cents).*
Mills, 3, 4 and 5 stories high, 50 feet wide..	$ .85 to $ .95	6.5 to 7.5
Mills, 2 stories high, 50 feet wide..........	.90 to 1.00	7.0 to 8.0
Mills, 1 story high, 50 feet wide...........	.95 to 1.05	7.5 to 8.5

These costs are for northern cities and do not include partitions, plumbing, heating or elevators. If these items are included, the cubic foot cost would then be increased to a maximum of about 11 cents. In country districts where labor is cheaper, the cost may be 15 to 20% less. In the South, where the price of labor and materials is from 30 to 50% less than in the North, the prices per square foot and cubic foot will be reduced accordingly. Under the most favorable conditions in the South, wood construction mills, not including the items above, can be built from 4½ to 5 cents per cubic foot. The cost of plumbing, heating, lighting and elevators, will not vary greatly between the North and South and these items will add from 20 to 25 cents per square foot of floor surface or from 1½ to 2 cents per cubic foot, to the cost of the building.

COST OF REINFORCED CONCRETE BUILDINGS.

Costs of reinforced concrete manufacturing buildings in heights of one to five stories, and widths of about 50 feet, are as given in the following:

TABLE XI.

COST OF REINFORCED CONCRETE BUILDINGS.

	Cost per sq. ft. of floor area.	*Cost per cu. ft. of building (cents).*
Buildings, 3, 4 and 5 stories, 50 ft. wide..	$1.00 to $1.10	7.5 to 8.5
Buildings, 2 stories, 50 ft. wide..........	1.05 to 1.15	8.0 to 9.0
Buildings, 1 story, 50 ft. wide...........	1.10 to 1.20	8.5 to 10.0

The prices given above are for cities in the northern states and do not include partitions, plumbing, heating, lighting or elevators. If these are included, the cubic foot price may be increased to 12

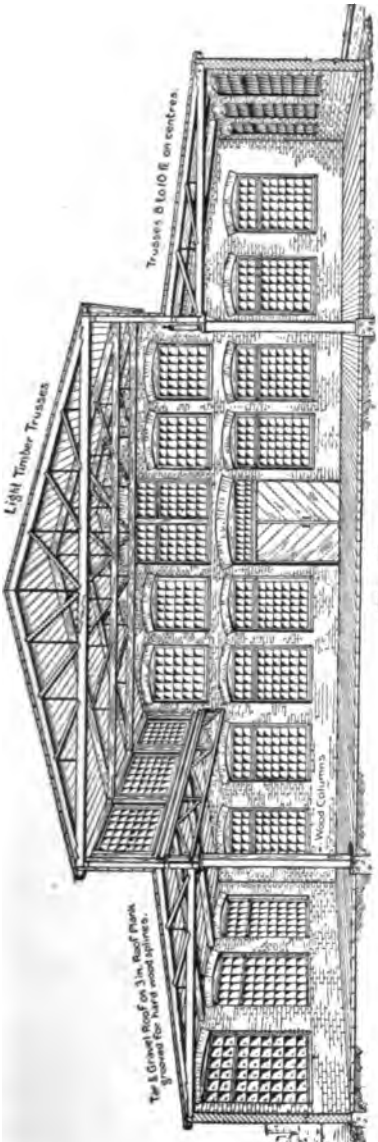

Light Timber Trusses
Trusses 8 to 10 ft. on centres.
Tar & Gravel Roof on 3 in. Roof Plank grooved for hard wood splines.
Wood Columns

Fig. 52.

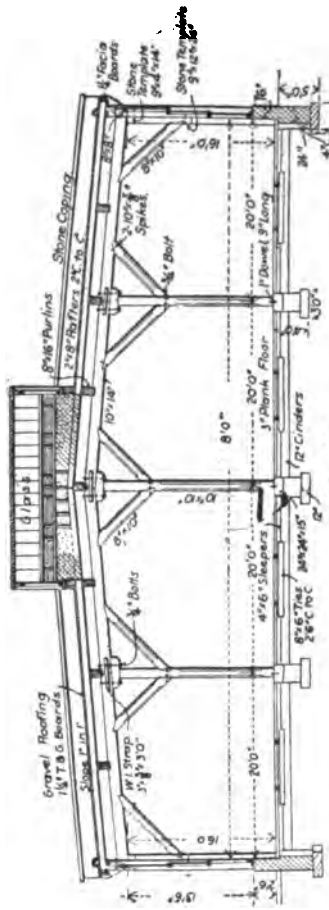

Stone Coping
8"x16" Purlins
3" Plank Floor
12" Cinders
4"x6" Sleepers
Gravel Roofing
Stone Template

Fig. 53.

cents. In country districts or in the South, where labor is cheap, the above costs may be from 10 to 15% less.

Reinforced concrete buildings will cost more than wood mill construction with brick walls, by 15 to 20% in the northern states and from 25 to 30% in the southern states, where wood is abundant and less expensive. If the wood mill construction has a double layer of diagonal flooring, the above differences in cost will be reduced by about 5%. The additional cost of plumbing, heating, lightning and elevators per square foot and cubic foot of building will be the same as for wood construction, which has already been given.

CHAPTER VIII.

ROOF COVERING AND DRAINAGE.

Any kind of roofing that will withstand the action of heat and cold, wind and rain, snow and ice, will be satisfactory. The chief essential is, however, that it be absolutely water tight.

FIREPROOF QUALITIES.

The building laws of many large cities specify the kinds of roofing that are accepted in the fire limits of their municipalities. In many cases, therefore, there is little or no choice to be made, as the laws require that all roofs within certain areas shall be covered with non-inflammable material. Where such laws do not exist, as in suburbs or rural districts, the fire risk must be carefully considered and comparative insurance rates secured for roofing of different qualities. Investigation of insurance charges may show that a net saving will result by a somewhat larger investment for a fireproof roof. If the interest on the extra expenditure required for a fire-proof roof is less than the corresponding insurance charges, there will evidently be a saving by the use of the expensive roof.

NON-CONDENSING ROOFS.

Condensation on the under side of roofs is caused by the warm air from the inside of the building coming in contact with the walls or roof that are chilled by the lower temperature from without. Condensation, therefore, occurs only in buildings where these different temperatures exist. Sheds or warehouses with open sides or storage buildings that have no artificial heating will not be subject to condensation.

On a certain large class of manufacturing buildings, it is absolutely necessary that the roofs be so designed that there will be no condensation or dripping. On other buildings, the matter of condensation need not be considered. In the former class may be placed all such works as machine shops, power houses, dynamo rooms, or other buildings containing valuable material and products that would be injured by water falling on them. Non-condensing roofs are required only on such buildings that must be heated in cold weather or where there is a difference in temperature between indoors and out.

Condensation may be avoided in buildings that need no artificial heating, by providing enough ventilation and air circulation so that the interior of the building will at all times maintain the same temperature as the air without.

This can be done by placing ventilators in the roof and air intakes at or near the floor, so that continuous air currents may pass into the building and out again through the roof.

Any form of roof is non-condensing that is built either double or with a ceiling beneath, in which there is an air space between the inner and outer surfaces. Wood and paper are poor conductors of heat and therefore roofs covered with plank, the joints of which are overlaid with several layers of building paper so the interior warm air cannot reach the outer sheathing, will be subject to little or no condensation. Roofs on which condensation is most likely to form, are those covered with sheet metal and slate or tile, laid directly on purlins, without lining. These forms of roof covering are desirable because they are not inflammable, and are frequently used on fireproof buildings. To prevent condensation without introducing any inflammable material, several patented linings have been used, one of which is shown in Fig. 54. It consists of a layer of strong galvanized poultry netting, tightly stretched over the iron purlins which are trussed or braced to resist bending from the tension in the netting; over this are laid two or three layers of asbestos paper and two layers of Neponset building paper, above which the roofing sheets are placed and secured to the purlins. The layers of paper are shingled one over the other, to shed any water from condensation or leakage. A weak point about this patent lining is, that the layers of paper are necessarily perforated by the bolts or wire hooks used for fastening the roof plates to the purlins, and some little leakage is liable to run through and drip from these bolts or wire hooks. A good rule is to have no metallic connection on the roof between the interior and exterior.

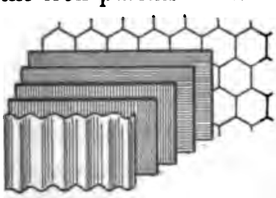


Fig. 54.

ROOF SLOPES.

The amount of slope that must be given to any roof will depend to some extent on the nature of the covering. Tin roofs with the joints all soldered tightly in both directions, with no chance whatever for the water to leak through, can be laid at any slope, either flat or steep, as desired. Tar and gravel roofs can be laid only on surfaces that are comparatively flat, where the asphalt or tar will not run off before it hardens, or even after completion, as the tar will soften in hot weather and tend to run if the inclination be too steep. Their slope should not exceed 1½ inch per foot and should preferably be less. Roof coverings consisting of sheets or plates shingled over each other, and depending only on their slope to shed the water, must have a sufficient inclination to prevent driving storms from blowing rain up under the joints and causing leakage. If, however, these roofing plates or sheets are laid in

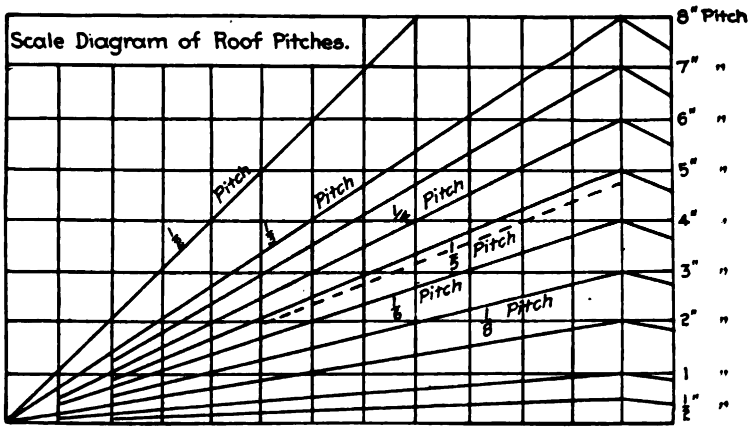


Fig. 55.

cement to make the joints impervious to water, it is then safe to lay them on a much flatter slope. Fig. 55 shows to scale, the various roof slopes or pitches from ½ inch per foot up to a slope of 45 degrees.

Roofs with steep pitch are more effective in quickly shedding rain or snow, but they have a greater area to cover and the covering costs proportionately more. Steep pitch roofs are generally heavier than flatter ones, because they carry a larger area of covering and because the truss framing is also somewhat heavier. The steep pitch has a larger area upon which the wind will blow, and it must be proportioned to resist those additional forces. Flat roofs are considered safer for fire protection than pitched roofs because firemen can walk upon them.

Table XII gives a list of common roof coverings with the least pitch on which they should be laid. Any kind of wood or metal shingle, slate or tile, when laid in the ordinary way, should have a pitch of not less than 6 inches per foot, but if any of these are laid with joints cemented, the pitch can then be as small as 3 or 4 inches per foot. The various kinds of prepared roofings, such as Ruberoid, Granite, Carey's, etc., and sheet tin or steel with soldered joints or standing seams can be laid on roofs with as flat a pitch as 1 inch per foot, while tar and gravel roofs are suitable for slopes varying from ½ inch to 1 inch per foot.

TABLE XII.

MINIMUM ROOF PITCHES FOR DIFFERENT COVERINGS.

Wood shingles on plank	Rise ¼ of span
Slate, large	Rise ⅕ of span
Slate, ordinary	Rise ¼ of span
Slate, in cement	Rise 1/6 of span
Steel roll roofing	Rise 1/12 of span
Ruberoid	Rise 1/12 of span
Asbestos	Rise 1/12 of span
Asphalt	Rise 1/12 of span
Corrugated iron in cement	Rise ⅛ of span
Corrugated iron without cement	Rise ¼ of span
Composition	Rise 1/12 of span
Tar and gravel	Flat.
Tin and terne plate	Flat.
Tile	Rise 7/12 of span

COMPARATIVE MERITS.

In reference to duration, slate or clay tile roofs will outlast all the other forms, and if desired, may be removed and used elsewhere, while gravel roofs or some of the best kinds of prepared roofing will be next in durability and will last from ten to twenty years. Any common form of sheet metal roofing will soon be destroyed by rust unless it is frequently painted, and will not generally last longer than from three to five years.

In comparing the cost of roofings, it appears that some of the various prepared roofings are the cheapest. Other kinds, in order of cost are wood shingles, tar and gravel, corrugated iron, standing seams, sheet steel, metal shingles, slate, tin, corrugated asbestos board and tile.

Iron or steel are unsuitable for roofing buildings where destructive fumes or gases accumulate, as the thin metal is quickly destroyed by corrosion, and leaks develop. It is better on such buildings, if sheet metal is preferred, to have it lead coated, as on a boiler shop for the Standard Oil Company, designed by the writer, where the roof and sides were covered with a heavy grade of lead coated corrugated iron.

Metal roofs have the advantage of being lightning proof and, as the roof surface is smooth, they are more easily kept clean by the wind and the rain. If it is desired to collect rain water from the roofs, water will be purer when taken from a clean metal roof than if drained from one of tar and gravel. Metal has the disadvantage of transmitting heat and cold, and metal roofed buildings are harder to heat in winter and in summer are uncomfortably warm. The objection to plank roofing from the standpoint of fire risk has probably been overestimated, for heavy plank supported on purlins 4 to 8 feet apart, will at the worst, burn very slowly, and will not collapse as soon as light steel framing, which warps and bends quickly under heat. Several disastrous fires have been traced directly to this cause.

Slate has the disadvantage of cracking quickly under heat, should fire sparks get in between the joints and ignite the boards below. It appears, therefore, that the selection of a roof covering will depend upon the necessity for its being fireproof or not, the desired amount of durability, the first cost, pitch of the roof, and the amount of money the owners are willing to spend, either for the sake of appearance or permanence.

Red slate or some of the many kinds of clay tile, especially red or green, add greatly to the appearance of roofs, though at extra cost, but this additional cost may easily be warranted on such buildings as pumping stations or power houses, located as they often are, in public places and open for the inspection of visitors.

ROOF DRAINAGE.

The primary object of a sloping roof is to shed the rain and snow. Snow slides from its own weight on surfaces inclined at an angle of about 45 degrees to the horizontal.

In considering the subject of drainage, roofs may be divided generally into two classes, (1) those which shed the snow and water entirely to the exterior of the building and (2) those which drain all or part of the roof to interior gutters. The first class is illustrated in Figs. 62, 64, 66, 67, 68, 74, etc., while the second is shown by Figs. 63, 69, 70, 71, 88, 89, 98, etc.

Draining into outside gutters has the advantage that no shoveling of snow is required and there are no interior gutters to collect dirt which may cause water to overflow and leak into the buildings.

The objection to exterior or side gutters for drainage is that snow on the roof which is easily melted by heat of the building from within, will again freeze when it reaches the external gutter at the eave, and the freezing will cause the gutters and down spouts to burst and leak.

One benefit to be derived from the use of inside gutters, is that they permit down spouts to be placed within the building in a temperature where they will not freeze and burst. The gutters being over the building which is heated, are less liable to freeze and can be more easily thawed out should freezing occur, than

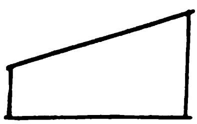


Fig. 56.

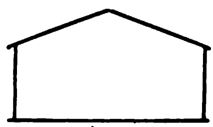


Fig. 57.

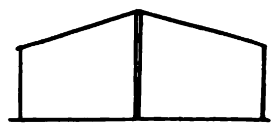


Fig. 58.

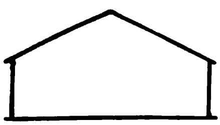


Fig. 59.

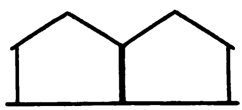


Fig. 60.

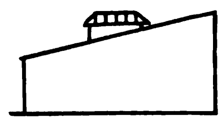


Fig. 61.

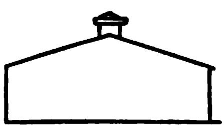


Fig. 62.

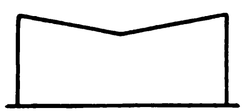


Fig. 63.

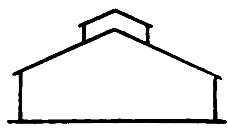
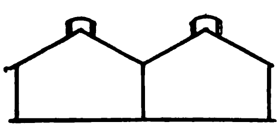


Fig. 64.



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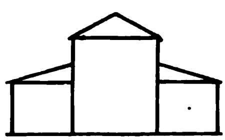


Fig. 66.

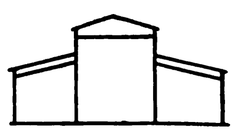


Fig. 67.

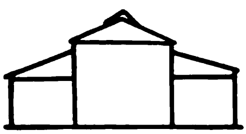


Fig. 68.

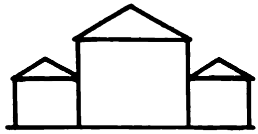


Fig. 69.

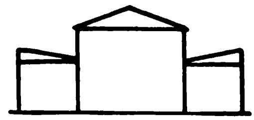
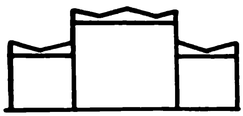


Fig. 70.



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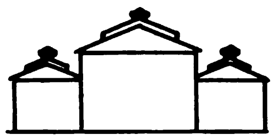


Fig. 72.

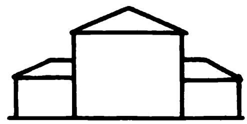
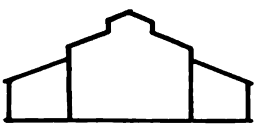


Fig. 73.



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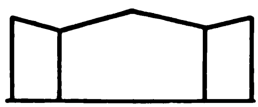

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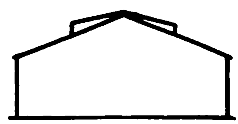

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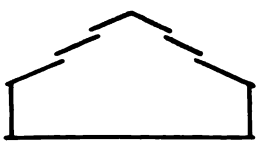

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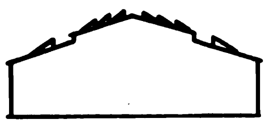

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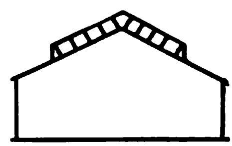

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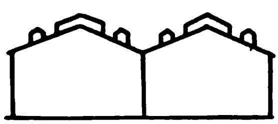

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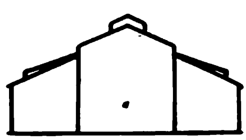

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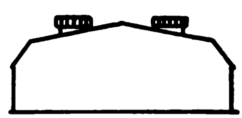

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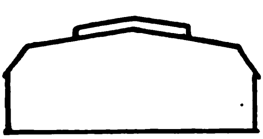

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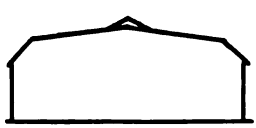

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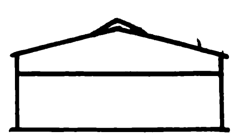

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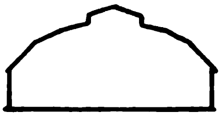
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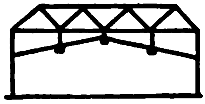
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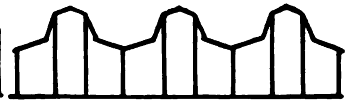
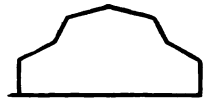


Fig. 88.


Fig. 89.


Fig. 90.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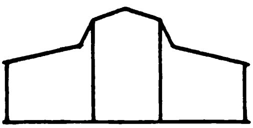
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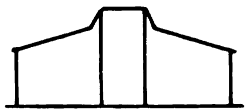
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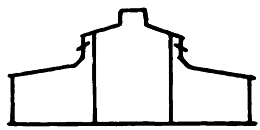
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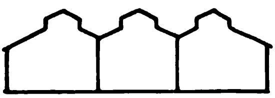
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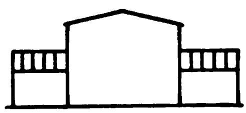
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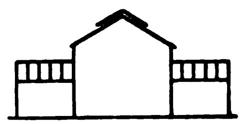
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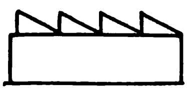
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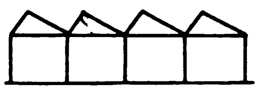
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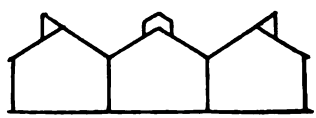


Fig. 100.

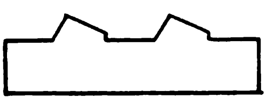


Fig. 101.

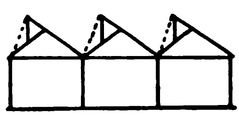
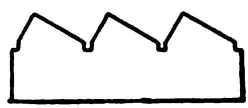


Fig. 102.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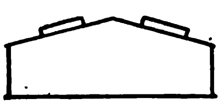
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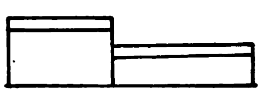
Fig. 105.

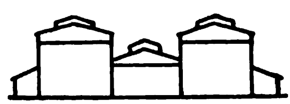
Fig. 106.

when placed at the eave. To prevent freezing of interior gutters, it is customary to suspend a line of small steam pipes directly beneath the gutter, which will not only prevent trouble from freezing, but will also serve as a part of the general heating system. While snow will accumulate in the interior gutters in the winter season, severe storms are not very frequent, and even when they do come, there is little liability for snow to accumulate in large quantities on roofs which are exposed to wind. Unless the snow is heavy, it is more likely to be blown off than to remain. In any case, the roof will be sufficiently strong to safely carry a snow load, and the expense of occasional shoveling is not great.

A shop with a saw tooth roof, built in 1889 for the Straight Line Engine Works at Syracuse, New York, required snow shoveling from the roof only once in seventeen years.

The chief objection to inside gutters is their extra expense and the care that must be taken to keep them clean. If a leak occurs in an interior gutter, it must be immediately repaired to prevent water running into the building, whereas numerous leaks may occur on external gutters without causing any damage, and individual leaks will not necessitate immediate attention. The usual custom is to ignore separate leaks on eave gutters and renew or repair them only when the leaks become so numerous as to make repairs positively necessary. Saw tooth gutters that were formerly built as shown in Figs. 313 and 317, are now being made from 2 to 4 feet in width or even more, in order that there may be less chance for ice forming and bursting them. The greatest danger from leakage results when ice in the gutter begins to melt. The water is then drawn up the roof slopes under the ice and snow, and if there are any openings in the roof up to the surface of the ice, the water is sure to leak through. The latter form is illustrated in Figs. 101 and 103. Interior gutters should be very carefully designed and strongly built. Various details of both interior and exterior gutters are given in Part IV, Chapter XXVIII.

GUTTER PITCHES.

Ordinary eave gutters should if possible, have a pitch of about 1 inch in 10 feet and never less than 1 inch in 15 feet. Interior gutters, such as those between saw tooth trusses, should have a greater pitch, or about ½ inch per lineal foot. These gutters will drain to interior downspouts at the columns and their steeper inclination will help to keep them clean and free from silt or dirt.

Unless on narrow buildings, there should be no effort made to drain the gutters to the sides of the building. It is better to have them drained to downspouts placed either inside, or against the interior columns, and spaced from 40 to 50 feet apart. The gutters can then be given a greater slope than if carried a longer distance to the side walls.

CHAPTER IX.

LIGHTING AND VENTILATING.

The importance of proper lighting for manufacturing buildings is evident. The amount of light must be ample but it must not be bright or glaring to cause shadows or tire the eyes of the workmen. Buildings having the entire wall surface composed of glass are apt to be so bright that the work will be less effective than in a more subdued light. The effect of direct rays of the sun on large areas of glass, even though they are protected with shades, tends to unevenly light the interior of the building and may produce high lights where they are not needed and shadows where there should be the best light. It is also difficult and expensive to heat these buildings in winter, and in summer they are excessively warm because of the heat radiation from the glass.

The subject of Lighting will be considered under two headings, (1) General Lighting and (2) Specific Lighting. It is evident that a good degree of general light should exist throughout the working space of any manufacturing building, and that each machine or particular location where work is done, should be well lighted in order to secure the highest class of workmanship.

All manufacturing or industrial buildings will not necessarily require either the same amount of light or light from the same directions. Warehouses in which goods are piled around the walls will often require very little or no light from the sides, and perhaps none from the roof. Many warehouses are in use only when the receiving and loading doors are open, and such openings themselves may admit enough light. If, however, more is needed than will enter through the open doors, it is probable that light from the roof will be better than from wall windows which might be obstructed with boxes or other piles of goods. In warehouses, if wall windows are desired, it is usually better to place them high above the floor and make them only large enough to prevent the warehouse interior from being dark.

General lighting will be secured in one of the following ways:

(1) Side wall lighting,
(2) Roof lighting through flat skylight in the plane of roof,

(3) Roof lighting through longitudinal monitors,
(4) Roof lighting through transverse monitors,
(5) Roof lighting through box skylights,
(6) Roof lighting through saw tooth roof windows.

Lighting from side windows is effective for distances not exceeding 20 to 25 feet and for this reason, buildings in several stories or those depending entirely on side lighting, cannot usually be made of a greater width than 40 to 50 feet. Buildings that must be wider than 50 feet must therefore receive additional light from the roof.

WALL LIGHTING.

Windows in factory walls have been made in a great variety of ways, depending chiefly on two factors, the first of which is the need of the particular building or the kind of products made therein, and the second factor is the personal preference of the designer or owner. There are buildings existing with side windows made

(1) Narrow and high,
(2) Low and broad,
(3) With small window areas near together,
(4) With large window areas far apart,
(5) With continuous sash over entire wall,
(6) With small and high windows above the floor, etc., etc.

In many of these buildings, other conditions are quite similar and products the same, so there is little reason for the great diversity in lighting systems.

The quality of glass also differs without apparent reason. In some places ordinary window glass is used, protected inside with shades, while in other places the shades are omitted and the glass painted white. In other buildings may be seen windows glazed with ground or ribbed glass or with prisms, though the cost of prism glass is generally so great as to make its use unwarranted in ordinary factory buildings.

The general use of plain glass for side windows is unsatisfactory on account of the need of either inside or outside shades. Under the most favorable circumstances, the duration of shades in factory buildings is short, and they are frequently the source of disputes or discord among the workmen. Light that is agreeable to one man, may be disagreeable to another, and it is hard to adjust shades to suit all. On this account, ribbed glass has been adopted entirely in some new factory buildings, for all side window openings, but the result has been unsatisfactory because the occupants of the building are then unable to get a view of the outdoors or to rest the eyes by changing the length of vision. It is well known that the eyes quickly grow weary from continuous observation of objects at the same distance, whether near or far away, and there is no better means of resting them than by changing the view to distant hills, sky or foliage, even though these changes be for a few moments only. It is therefore unwise to use ribbed or obscure glass for all side windows of a factory building, but it is still advantageous to use ribbed glass in the upper half, as the ribbing tends to distribute and more evenly disseminate the light over the floor. The rough glass costs about the same as plain and avoids the use of shades. The experience in some factories where ribbed glass only was used for windows, was that the workmen not only were unable to do effective work, but refused to continue where no opportunity was given for seeing further than the building walls.

It has been found that the amount of light inside of a building is doubled when the walls and framing are painted white, and hence it has become common practice to paint a dark colored dado of brown or green about 5 feet in height on the walls and columns, and to either paint white or whitewash the balance of the interior.

TOTAL REQUIRED LIGHTING AREA.

There is a great variation in the amount of window and skylight area provided by different designers for manufacturing buildings, so great indeed that it would seem impossible to establish any acceptable rule to cover the subject. The required area of glass in walls and roofs depends on several conditions, some of which are, (1) the kind of glass used, (2) the prevailing atmospheric conditions, whether clear or smoky, (3) the use to which the building will be put, (4) proximity to other buildings, and (5) the angle which the glass makes with the vertical. A shop where fine detail work is carried on will need more light and a greater area of glass than a forge shop or rolling mill, and if color work is done in connection with detail, a still greater degree of light will be needed. A common rule for lighting is to make the glass area in walls and roof equal to 10% of the entire exterior surface for mill buildings, and 20% for machine shops. The Pennsylvania Steel Company's new buildings have windows and skylights in the proportion of one square foot for every 82 cubic feet in the buildings, or for every $2\frac{1}{2}$ square feet of floor surface. A shop for the American Car and

Foundry Company at Detroit has 27% of its entire exterior surface composed of glass, while the new Engineering building at the Brooklyn Navy Yard has glass equal to 60% of its exterior.

WALL LIGHTING.

A good general rule for the amount of wall window surface, is to make such area not less than 20% of the entire wall. Some designers make this area as large as 50% of the wall surface, while another rule is to make the window area equal to the square root of the cubic contents of the shop.

Other rules are to make the windows not less than 10% of the floor area or not less than one square foot of window for every 100 cubic feet of shop contents. An English architect says that the breadth of a window should be one-eighth of the sum of shop width and height, and the height of the window twice its breadth. The new plant of the American Bridge Company at Ambridge has side window areas varying from 20 to 30% of the wall, while the new Canadian Pacific Railway shops at Montreal have side windows equal to 50% of the entire walls.

REQUIRED SKYLIGHT AREA.

Mill buildings over 80 feet in width should receive at least half the light from the roof and the area of roof lights should be about one-half the entire roof surface. The new General Electric Company's machine shop at Schenectady, New York, shown in outline in Fig. 73 has skylights equal to 40% of the roof. The skylight area on the St. Louis train shed is equal to 25% of the roof, while a machine shop for the Chicago City Railway Company has wire glass skylights covering 35% of the whole roof.

ROOF LIGHTING.

Figs. 66 to 74, inclusive, show types of roof having two rows of interior columns, with sash or windows in the side walls above the side or leanto roofs. The amount of window area in these sides may be increased or diminished as desired by varying the height of the center bay. It is evident that for the same height beneath the trusses, Fig. 69 may have a greater window area on the side than is possible in such a design as Fig. 66, but it is also evident that the framing shown in Fig. 66 will be stiffer laterally than 69. Figs. 70 and 72 are somewhat similar to 69, inasmuch as the side roofs in each case slope inward and permit a greater height of glass adjoining the central columns. There are, however, other questions beside that of light which are important factors in the selection of a general roof outline and these will be considered in later pages.

FLAT SKYLIGHTS.

There are two principal objections to the use of skylights in the plane of the roof, namely, that in winter seasons, when the roof is covered with snow, light is liable to be obscured; and they are apt to leak. To overcome these objections, the skylight at the ridge may be given a steeper pitch than the balance of the roof, as shown in Figs. 68, 84, 85 and 90. The increased pitch of skylight will tend to more quickly shed the water, and when the slope is as great as 45 degrees, snow will slide off by gravity. A plant of this description built in seven transverse bays, each bay 50 feet in width, has been constructed for the Deutsche Niles-Werkzeugmaschinen-Fabrik, Berlin, and is shown in Fig. 107. The design is somewhat different from current American practice but has some very commendable features. If it is desired to use north light to avoid direct sunlight and resulting shadows, these ridge skylights may be glazed on the north slope only, the south side being covered with ordinary roofing.

LONGITUDINAL MONITORS.

To be of any value for lighting purposes, longitudinal monitors must have sufficient width to permit the direct light to reach all parts of the floor. Roof monitors are frequently made quite narrow, not over 4 to 6 feet in width, to secure better ventilation. Windows in the side of such monitors are of little use for lighting, because light shines across the monitor and very little reaches the floor. A narrow monitor is preferable for ventilation, as smoke and impure air, rising to the highest part of the roof, are then drawn out through the open sides. Monitors for lighting should have a width of about one-quarter of the roof span, as shown in Fig. 81. Light entering at the monitor windows will then be unobstructed. With this width, foul air and gases will collect in the upper part of the roof and, if the building is one where smoke and gas is developed to any great extent, it may be necessary to use a second narrow monitor for ventilation. The sides of this smaller monitor may be provided with sheet metal shutters instead of windows, as the amount of light from the sides will be small. Since the cost of movable sash is no greater than the corresponding cost of shutters, the sash

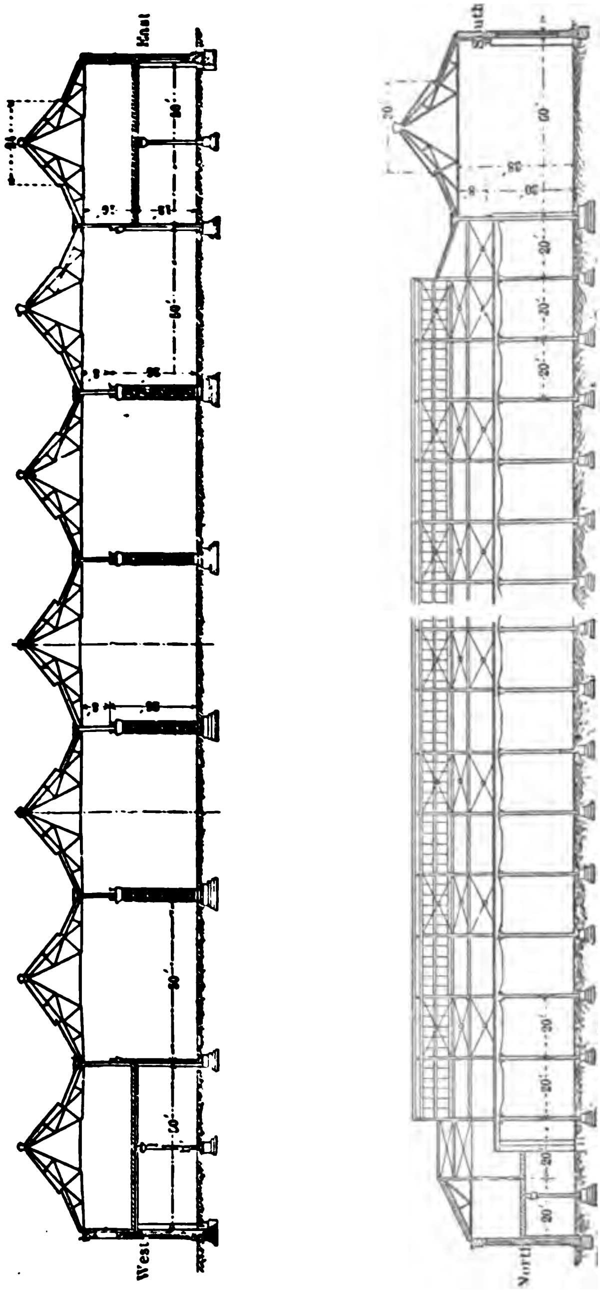

Fig. 107.

are sometimes preferred, as they will at any rate light the upper part of the roof, even if no light from them reaches the floor. Improved forms of monitor construction are shown in Figs. 88, 91, 92, 93 and 94. In all of these forms, the glass is inclined at an angle of about 45 degrees or less with the vertical, so snow will not lodge thereon, while a larger amount of light is admitted than when windows stand vertical. Figs. 91, 92 and 93 have no ventilator monitor and occasional movable windows are required to secure circulation of air. Figs. 88 and 94 have provision for ventilation above the sloping glass and are probably the most approved and acceptable forms for shop buildings which are lighted through continuous monitors. A power house built in the form of Fig. 94 for the Pullman Car Company at Pullman, Illinois, has the side walls above the sloping skylights set out a distance of several feet from the two interior rows of columns, and gives ample clearance, not only for the traveling crane, but also for swinging a sash or an interior footwalk for the purpose of inspecting or cleaning the monitor windows.

CROSS MONITORS.

There are a number of mill buildings lighted through the roof by means of occasional transverse monitors extending either part way or entirely across the roof. Fig. 79 shows an outline sketch of a roof recently built by the Jones and Laughlin Company. Trusses are spaced about 20 feet apart and the transverse monitors shown are of one full panel length and occur at every third panel. The entire ends of these transverse monitors are filled with glass, and the designers of the building report that the arrangement is preferable to one continuous monitor down the center of the building. Fig. 83 shows a somewhat similar roof, built for the Pencoyd Iron Works.

Assuming the trusses to be 20 feet apart, with a full transverse monitor over every third panel, the cost of this type of construction would be about equal to the cost of a longitudinal one, when the length of the transverse monitor is equal to three panels or 60 feet. If the transverse monitors have a less length than three panels, the cost will then be less than the corresponding cost of longitudinal ones.

BOX SKYLIGHTS.

Figs. 78, 80 and 82 show forms of roofs through which light is admitted to the floor by means of numerous small box skylights.

These skylights may serve also as ventilators, either by having movable tops, or sides of sufficient height for swinging ventilators, sash, or louvres. Numerous skylights have the advantage of distributing light uniformly over the floor but they are apt to leak and require continual care. The best skylight of all is the one which, after completion, requires no attention or cost for maintenance.

NORTHERN LIGHT ROOFS.

The type of roof shown by Figs. 98 and 99 has long been a favorite for use in southern latitudes where little or no snow falls and where the glare of the sun is generally bright. For a long time, it was not used to any great extent in northern climates, because snow gathers on the roof and not only obstructs the windows but produces abnormal roof loads. The alternate melting and freezing of the snow from heated air within the building in contact with the gutters and roof, causes ice to form in the gutters which frequently bursts them and makes them leak. This objection of snow and ice does not occur in southern climates and the type is therefore particularly suitable for these locations.

A room lighted entirely from the north without either sunlight glare or shadows is unquestionably the most satisfactory. To appreciate the difference in lighting, it is only necessary to examine and compare two shops, one with side windows, and the other with northern roof light only. In the latter shop, while every part of the building and machinery is perfectly lighted, there is no glare and never any shadows. The principal objection to a more general use of northern light roofs is their excessive cost, but as more and a better grade of work can be done under the better lighting, the extra expenditure is frequently warranted. It is evident from inspection that roofs in the form of Figs. 98 and 99 have a greater cost than roofs of the ordinary types, for the saw tooth roof, especially that shown in Fig. 98 with vertical teeth, has a greater roof area. The whole glass area is, in fact, additional over the area of a plain pitch roof similar to Fig. 59. The angle which the sash makes with the vertical must be small enough so the noonday sun at midsummer will not strike directly on the glass. The magnitude of this angle will evidently depend upon the latitude, but in the United States it may be made from 25 to 30 degrees, or somewhat greater if a projecting cornice is placed above the glass, to serve not only as a finish for the ridge, but also to shade the windows from the noonday sun.

To exclude direct sunlight, the glass must face directly or very nearly north, and the saw teeth may be placed either transversely or longitudinally on the building.

It was formerly the custom to ventilate saw tooth roofs either with circular metal or steamboat ventilators on the ridge, or by making all or part of the side windows in the saw teeth movable. As the former method was insufficient, the windows were frequently made movable, and as it was difficult to make inclined movable windows weatherproof, some of the more recent saw tooth roofs have the windows vertical, as show in Fig. 98. This precaution is not so necessary for roofs with stationary windows, because the joints can then be flashed or battened.

Saw tooth windows should have a height of about one-fourth the truss span. They should be double glazed in northern latitudes or wherever the difference between inner and outer temperatures is considerable, and in any case there must be condensation gutters beneath the sash. The forms shown in 96 and 97 have the advantage that ventilation is secured through movable sash or shutters in the upper walls of the center bay, and the saw tooth sash in the side bays may be fixed. The improvement removes the danger of leakage, which has always been the chief objection to saw tooth construction.

Fig. 97 shows the general outline of a locomotive shop for the Atchison, Topeka, and Santa Fe R. R. Co. at Topeka, Kansas. A form of saw tooth has been proposed as shown by full lines in Fig. 102, but the form has no special merit, as that shown by dotted lines could be built at a less cost and would at the same time give a greater amount of light. The most recent and approved type of saw tooth roof is shown in Figs. 101 and 103, where wide gutters are used to prevent leaks. Ice forming in narrow gutters is apt to burst them. Fig. 101 is an outline of the new Carnegie Steel Company's storehouse at Waverly, New Jersey, while Fig. 103 is a roof at the American Bridge Company's plant at Ambridge, Pennsylvania. An objection to using wide gutters on saw tooth roofs is, that beneath the gutter, there will be a less degree of light, and for this reason the gutter width should not exceed 2 to 4 feet.

North light may be secured by using plain skylights on one side only of ordinary pitch roofs, or may be admitted as in Figs. 88, 89, 90, 91 and 92, by placing sash on the north side of monitors, but the amount of roof light would be insufficient for ordinary shops.

It is well wherever possible, in designing roofs, to make provision for some form of narrow foot walks near the monitor sash of skylights, for the purpose of repairing and cleaning them. There are but few features about a manufacturing building which show negligence or indifference to appearances more than numerous broken windows, and certainly no system of skylights can be effective even though designed and built with the greatest care, if the glass is allowed to become covered with smoke and dirt. Beating rain storms will partially cleanse the exterior but skylights should be accessible on the interior for frequent cleaning.

VENTILATING.

The subject of ventilating must be considered when deciding upon the general roof outline. There are many unfortunate examples of manufacturing buildings, which have been insufficiently planned and hurriedly erected, where the resulting building has proved inadequate to its purposes. Men cannot work at their best or produce work of the best quality when they are in a foul atmosphere. Many badly ventilated buildings were originally made for some purpose in which but little ventilation was needed, but are now put to use as manufacturing buildings, and gas and smoke accumulate to such an extent that effective work is impossible. Too often, short-sighted management refrains from adding the necessary ventilation facilities, knowing that the cost of heating in the winter seasons will be increased thereby. There are plenty of proofs of increased production in mills and factories built on modern principles, with provision and thought for the comfort and welfare of the workmen. The ventilation of manufacturing buildings is so important that it is now being scientifically treated by companies, who give their entire attention to heating and ventilating.

Forced ventilation in connection with the heating system gives the best results, and many modern shops are now using it. As artificial ventilation will not affect to any great extent the form of the roof, further than providing space for ventilation ducts, it is not necessary to discuss this part of the subject in connection with the general design. In many buildings, such as forge shops where smoke, fumes or gases occur, artificial ventilation may be necessary. In any case, the amount of ventilation required will depend upon the use to which the building is put and the number of workmen that it will accommodate. Certain kinds of manufacturing causing but little smoke or gas, may require no more ventilation than is easily secured by an occasional open window, while other buildings will need continuous lines of open ventilators in the roof with intake openings near the floor. Too much ventilation is plainly wasteful, for the cost of heating is then excessive and the results are no better than where there is less ventilation and a correspondingly less amount of heat.

Good ventilation is as essential as sanitation, and both subjects are receiving their deserved attention in modern manufacturing buildings. The need of ventilation is not quite so evident as sanitation, for men will still continue to work in impure air, who would not tolerate old unsanitary conditions, but lack of proper ventilation produces a stupifying influence on workmen, and lessens their productiveness. Each occupant of a mill or factory should have hourly not less than 200 to 300 cubic feet of fresh air, and if gas, fumes or smoke collect, not less than 400 to 600 cubic feet, with an additional 40 cubic feet per hour for every burning gas jet. Some states require that schools and public buildings shall have 1,800 cubic feet of fresh air per hour for each person. Air inlets and outlets should both be under control, for too much circulation in cold weather may be unnecessary, while it will add to the cost of heating. If too much warm air is admitted, and too little foul air discharged, the effect will be to produce drowsiness on the workmen, with a corresponding loss in production. The best results are obtained when a large volume of air is admitted at a small velocity, keeping all the air in motion at a slow speed, for there will then be no drafts. When air is admitted through small openings at high velocity, drafts are formed which may result in colds and sickness. Heating by rapid air currents at high temperatures, lacks uniformity, as that part of the shop adjoining the air inlets will be too warm, while other parts will be too cold.

The following table gives the approximate ventilation area required in the roofs of manufacturing buildings of different kinds per 100 square feet of floor area for side wall heights of 20 to 50 feet. The areas are net, and if louvres are used these areas must be increased by about 60% to compensate for the obstruction caused by the louvre slats.

REQUIRED VENTILATION AREA.

Height, in feet, above ground	20	30	40	50	
Machine shops—square feet	7/8	3/4	5/8	1/2	Round ventilators
Mills—square feet	7	6	5	4	Louvre ventilators
Forge shops—square feet	9	8	7	6	Louvres—or open

ROOF VENTILATION.

The following are the common methods of securing roof ventilation in ordinary manufacturing buildings:

(1) Continuous longitudinal or transverse monitors, with louvre shutters,
(2) Saw tooth roof construction with movable windows,
(3) Ventilator openings in roofs as shown in Fig. 77,
(4) Individual circular metal ventilators.
(5) Box skylights with open sides or movable tops.

Continuous longitudinal monitors as shown in Figs. 64, 81, 94 and 95, with movable sash or shutters on the sides, ventilate best when they are narrow, for then all the foul warm air rising to the roof, is drawn out at the crown and none is allowed to remain. If the principal monitor is intended for lighting the working floor, a second narrow one may be added at the ridge as shown in Fig. 81.

Transverse monitors shown in Figs. 79 and 83, are also serviceable for ventilation when the sash on the sides are movable. These monitors are built primarily for the purpose of lighting a building interior and the sides would therefore be covered only with sash and not with louvres or shutters. Various monitor windows, shutters and louvres, together with apparatus for opening and closing the windows and shutters, are illustrated in detail in Part IV. Trunnion windows give a larger opening or ventilation area than those which slide horizontally or vertically past each other, for in the latter case, only half the window area is available for ventilation.

SAW TOOTH VENTILATION.

The old type of saw tooth roof with the entire roof area built on the same system, was difficult to ventilate, without making the windows movable, which is objectionable on account of being difficult to weather proof. For this reason, some recent ones have been made with movable windows standing in a vertical plane and therefore less liable to leakage than when inclined in the old way, at an angle of about 25 degrees to the vertical. In cases where the windows have been made stationary, ventilation is secured by means of ordinary metal or steamboat ventilators on the ridge as shown in Figs. 516 and 518. The effect is rarely satisfactory, however, for the air does not move at a sufficient rate to keep the atmosphere fresh and agreeable. Therefore, in some of the most recent saw tooth roofs, the side bays only are built for northern light, while the center bay is made much higher, with provision for ventilation either on the sides or at the ridge, as shown in Figs. 96 and 97. This arrangement makes almost perfect ventilation and at the same time allows the northern light windows on the sides to be stationary and water tight. It is best not to make saw tooth shops too low, with a minimum height of 12 to 14 feet beneath the trusses. Low roofs have the advantage that the skylight glass is near the work benches, with consequently better light, and there is less expense for winter heating, but in summer the heat radiation from the roof is oppressive and unless forced circulation is used, the ventilation may be insufficient.

OPEN ROOF VENTILATION.

A plan that is quite effective for ventilating very smoky buildings where little or no artificial heating is needed, such as rolling mills, furnace buildings, etc., where there is always excess heat even in the winter season, is shown in Fig. 77. Two or more lines of purlins on each side of the roof are built with upper and lower roof supports, and continuous open spaces are thereby left, varying in height from 4 to 18 inches. The upper roof projects far enough over the lower one to shed any ordinary rain or snow, and where large volumes of gas, fumes or smoke arise, these continuous openings are effective in clearing the atmosphere.

INDIVIDUAL METAL VENTILATORS.

Ventilators of this kind are shown in Figs. 62 and 72, and in detail in Part IV, Chapter XXIX. They are suitable only when a small amount of ventilation is needed. Numerous patent forms are on the market known by various names, such as Globe, Star, etc., but they are easily made in almost any sheet metal shop without the need of paying patent royalties. An objection to the use of these ventilators is that the warm air from the interior of the building coming in contact with the metal at a very much lower temperature in the winter season, will cause condensation that is liable to be damaging to the contents of the building, unless condensation gutters are used. The steamboat ventilator shown in Fig. 516 is made with double sides to prevent this. Circular metal ventilators should preferably have dampers to be opened or closed at will. The following table gives the area of circular ventilators for diameters from 12 to 48 inches:

AREA OF CIRCULAR VENTILATORS.

Diameter in ins.	12	18	24	36	38	42	48
Area in sq. ft.	.8	1.8	3.1	4.9	7.1	9.6	12.6

BOX SKYLIGHT VENTILATORS.

These are more or less effective when the curbs or sides of the boxes are provided with movable sash or shutters or covered with louvres. On account of their being separated, they require individual attention and are not as convenient as monitor windows which can be opened in groups with a single chain or hand wheel.

SPECIAL VENTILATORS.

Certain buildings require special ventilation. It is common practice to ventilate engine houses by lowering a funnel or smoke jack over the engine stacks.

Many modern blacksmith shops are ventilated by placing inverted hoods or funnels above the forges and drawing all smoke and fumes away to a ventilation stack by suction which not only draws the smoke but also keeps the air in circulation in the building (Fig. 108). In Germany a method has recently been used for ventilating by a central tower.

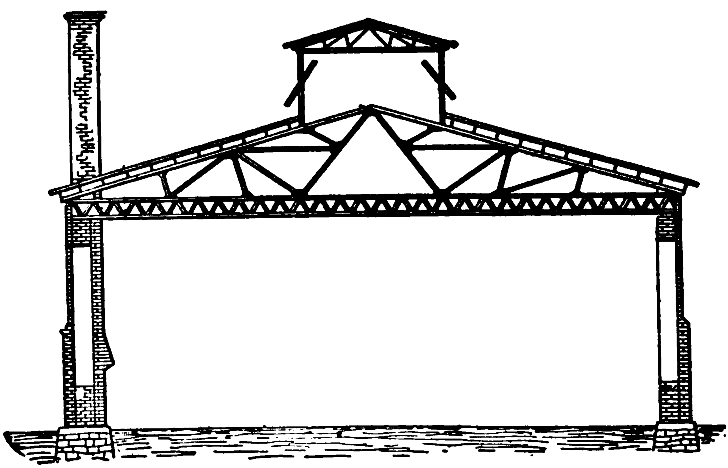

Fig. 108.

WALL VENTILATION.

Shops which require no artificial heating can be effectually ventilated by building the lower 10 feet of wall in the form of continuous doors or movable panels. The latter are the cheaper, but are troublesome to remove and replace, as they are bolted to the frame work.

When a plant is enclosed with a fence or wall and watchmen are on guard both day and night, it may be unnecessary to close the buildings at night when the workmen are absent, and the movable panels would then be as effective as the more expensive doors. They may be made as large as can be conveniently handled, 6 or 8 feet in width and about 10 feet in height, and in the springtime, when weather conditions will permit, may be unbolted and removed to a convenient place for storage, there to remain until again required on the approach of cool weather in the autumn. Panels may be made of cither wood or sheet metal, as preferred.

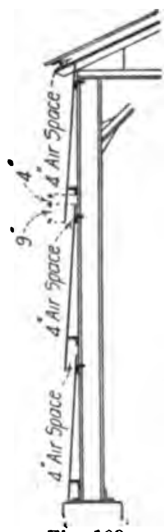

Fig. 109.

Ventilation is greatly facilitated by placing a line of shutters in the wall at or near the floor, which, when opened, will cause a current of air to circulate upward through the building, carrying the foul air and smoke out through the roof ventilators. These may be made as part of the movable panels as above described, so that in winter, when the weather will not permit the opening of the entire side, some or all of these small ventilating panels may be used as desired. When the sides are made of doors instead of movable panels (Fig. 16), the cost will be more because of the necessity of suspending or hinging them. It is generally impracticable to hinge large doors on account of their weight, for sooner or later the weight will cause them to droop and their movement to be impaired. A vertical sliding door, counterweighted at both sides, is satisfactory for continuous side-openings, if there are large window panels in the door to permit the light to enter from the side wall windows. Some form of folding door such as is shown in Part IV, Chapter XXXVI, is suitable for continuous side openings. These may be made in wood or metal, as preferred. Certain buildings may be left open at the sides during all seasons of the year. In this class are such buildings as storage sheds, furnace houses or others which are used both day and night and have at all seasons excessive heat.

A method of wall ventilation used by the writer in designing a wool treating warehouse is shown in Fig. 109. The walls are 20 feet in height and are covered with sheathing in three lengths and at the joints where the layers of sheathing overlap each other the purlins are framed to permit 4-inch air spaces around the entire length of sides and ends, interrupted only by the windows. Beneath the overhanging eaves there is another continuous 4-inch air space. On the roof at the ridge is a monitor ventilator with 3 feet of continuous metal louvres on either side, so that at all times there is free circulation of air through the building.

PART II

LOADS

CHAPTER X.

STATIC ROOF LOADS.

Mills, factories and other industrial buildings differ so greatly in their purpose and use that it is difficult to establish any rules or formulæ for the weight of material in them. Each building must be considered separately, and after its requirements are known and its general outline selected, the approximate amount of material and the corresponding weight may then be determined. The amount of material will depend upon the use and character of the building, whether temporary or permanent, fireproof or otherwise, the loads that it must carry, the nature of the roof covering and the presence or absence of cranes or other handling appliances.

The loads to which these buildings are subject are as follows:

Dead Loads.	*Live Loads.*
(a) Roof Framing and Covering.	(d) Snow.
(b) Walls.	(e) Wind.
(c) Floors.	(f) Cranes.
	(g) Pipes, Shafting, etc.

In the following pages, these various loads are considered separately in detail, and tables of weights are given. It is advisable to make liberal provision for future increased loads, as experience shows that buildings are frequently subjected to much harder usage than anticipated. There must also be liberal additions to the stresses from cranes or other moving loads to provide for impact and vibration which tend to jar and rack the building. This impact addition must be made in designing both the frames and the foundations.

The maximum loads of every nature must be positively known in order to produce a safe and satisfactory design.

ROOF FRAMING.

Before undertaking a design in detail, the engineer should have a general knowledge of the approximate loads. When a choice has been made as to whether the building shall be temporary or permanent, fireproof or otherwise, the weight of roof framing will depend chiefly upon the nature of the roof covering and the presence of cranes or trolleys beneath the trusses. The capacity of cranes, and the kind of roof covering, should be determined when considering the general requirements.

Table XIII gives the weight per square foot of roof surface for various kinds of roofing, to which must be added the weight of sheathing, if any, and from 2 to 4 pounds per square foot for purlins, depending upon the distance between trusses. The least weight of purlins results from close truss spacing, and this weight increases with the distance between trusses. The usual allowance for combined snow and wind loads is 20 to 30 pounds per square foot, depending on the latitude. To these must be added the weight of pipes, shafting or trolleys on the bottom chords and the weight of trusses. The truss weight can be approximated by use of the eight original charts shown in Figs. 110 to 117, which give the total weight and also the weight per square foot of area covered, for trusses of four different types.

Fig. 110* gives the actual weight of steel roof trusses in pounds, for spans varying from 20 to 80 feet in length, and total roof loads of 40 pounds per horizontal square foot. The rafters have a rise of 6 inches per foot, known as one-quarter pitch. The curves show the weight of trusses for spacings of 10 to 20 feet apart, designed with compression and tension units of 12,000 and 15,000 pounds per square inch, respectively.

Fig. 111* shows the corresponding weight of the above roof trusses in pounds per square foot of area covered.

Fig. 112 gives the total weight of steel roof trusses in pounds, for spans varying from 30 to 80 feet, with the same rafter slope and unit stresses as used in Fig. 110. These trusses differ, however, from those previously described by having a lighter capacity of only 30 pounds per horizontal square foot and are suitable for tropical countries where no snow falls.

Fig. 113 gives the weight of steel in pounds per horizontal square foot for the trusses referred to in Fig. 112. The curves show weights for truss spacing varying from 10 to 18 feet. If

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* H. G. Tyrrell, in Engineering News, June 21, 1900.

weights are required for other spacings, they may be found approximately by drawing corresponding curves on the weight charts.

Fig. 114 gives the total weight of steel roof trusses for loads of 40 pounds per horizontal square foot and for roof slopes of 4 inches per foot. These weights are for spans varying from 20 to 60 feet in length, and truss spacings of 8 to 16 feet apart.

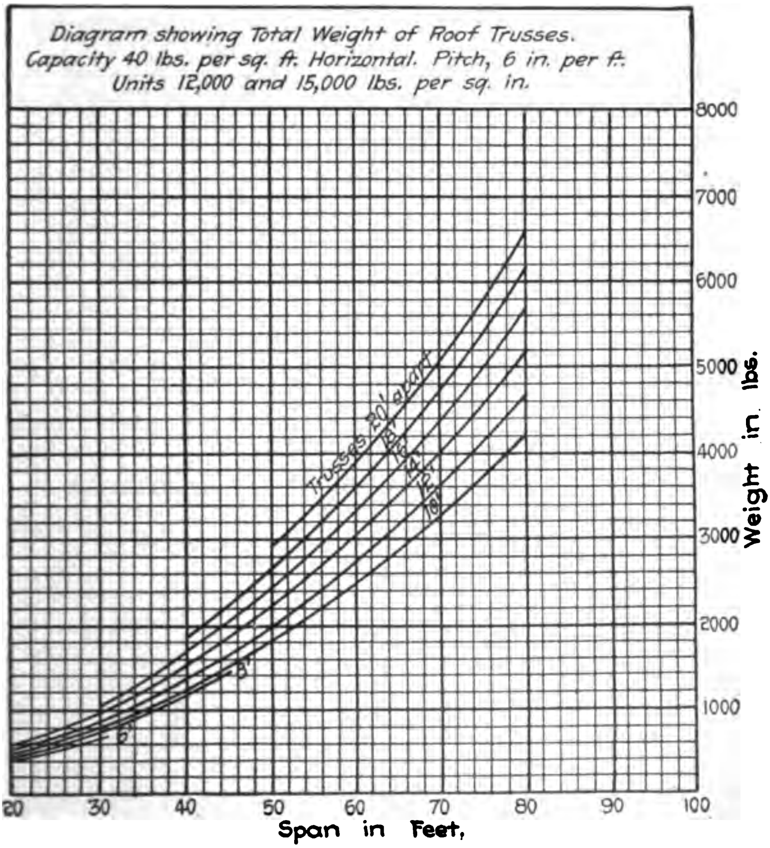


Fig. 110.

Fig. 115 shows the corresponding weight in pounds per horizontal square foot for the trusses referred to in Fig. 114.

Fig. 116 is chart showing the total weight in pounds for steel roof trusses with a capacity of 45 pounds per square foot, and a rafter slope of one-half inch rise per foot. These trusses are suitable for roofs with plank and gravel covering on longitudinal pur-

Formulæ by C. E. Fowler are:

For heavy trusses....................... $W = .06\,S + .6$
For light trusses....................... $W = .04\,S + .4$

Formula by Professor N. C. Ricker:

$$W = \frac{S}{25} + \frac{S^2}{6000}$$

In all the foregoing formulæ—

W is the weight of steel per square foot of area covered;
S, the span in feet, and
D, the distance in feet—center to center of trusses.

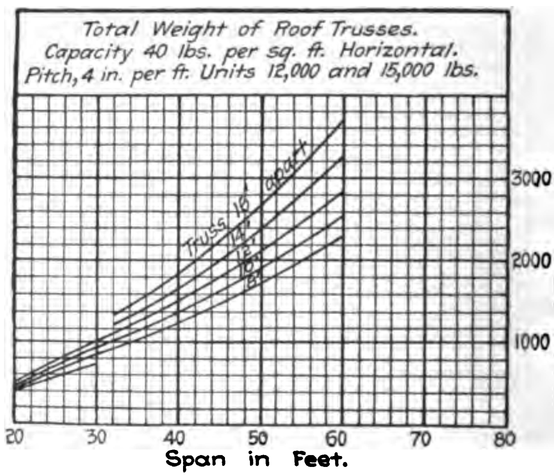


Fig. 114.

Fig. 118 is a chart showing comparative results of some of these formulæ, including another by Professor DuBois, compared with actual truss weights. From the chart, the approximate weight of steel roof trusses in spans up to 130 feet may easily be found by inspection.

These charts are for definite total roof loads in each case, but they may also be used for loading of a lesser or greater amount by observing the following directions. The weight of trusses depends upon the total load per lineal foot of truss carried. Trusses supporting a 40-pound roof load, spaced 20 feet apart, sustain the same load as those carrying a 50-pound load and spaced only 16 feet apart. Therefore, if it is desired to determine the weight of roof trusses for any other roof loading, such as 60 pounds per lins. As purlins are used, no provision is made in the top chords for resisting bending stresses.

Fig. 117 gives the weight of steel per horizontal square foot for the roof trusses referred to in Fig. 116.

An original formula by the author, giving the weight in pounds per horizontal square foot for the trusses referred to in Fig. 110, is as follows:

$$W = \frac{S}{20} + \frac{12}{D}$$

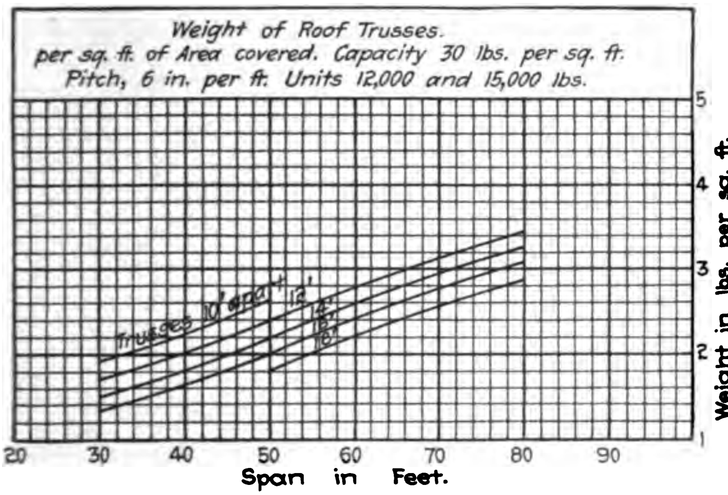


Fig. 113.

Corresponding formulæ for the weight of roof trusses given by other engineers are as follows:

Professor Merriman's formulæ for trusses in spans up to 180 feet and distances apart up to 40 feet are:

For steel trusses..................$W = \frac{3}{4}\ (1 + .1S)$
For wood trusses.................$W = \frac{1}{2}\ (1 + .1S)$

Trautwine's formula is as follows:

$$\text{Total weight of Fink roof trusses in pounds} = \frac{\text{Square of span in feet}}{3.1}$$

Professor Johnson's formula is:

$$W = \frac{S}{25} + 4$$

square foot spaced 12 feet apart, it is only necesary to find the total load per lineal foot carried by the truss, which in this case is 12 times 60, or 720 pounds; and then dividing this amount by 40, the corresponding spacing of 18 feet is found for the 40-pound trusses. The weight of 60-pound trusses spaced 12 feet apart is therefore the same as the weight of 40-pound trusses spaced 18 feet apart. These weights may be read directly from the charts, and they are therefore applicable not only for trusses to sustain the loads given but also for roof loads of other amounts as well.

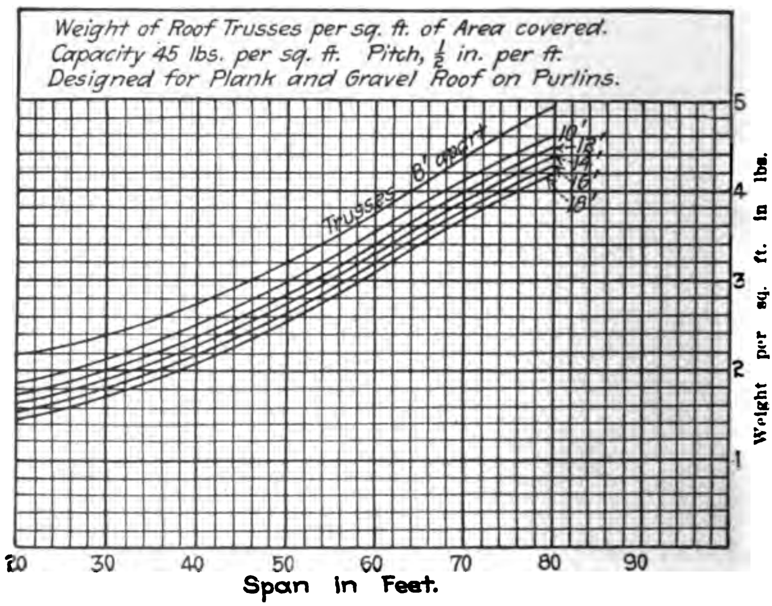


Fig. 117.

Figs. 111, 113, 115 and 117, for the weights of steel roof trusses in pounds per square foot of area covered, are only for the total roof loads given. It is evident that if the total load per square foot supported by the roof is increased, the corresponding weight of framing per square foot of area covered will also be increased. Figs. 111, 113, 115 and 117 are therefore applicable only for roof loads as given on each chart. For loads of a greater or less amount, the weights per square foot will vary nearly in direct proportion, but not exactly, for it is not always possible to realize the required areas in all the members, especially in the smaller ones. For example, if it is required to find the weight of steel per square foot of area covered, in roof trusses to carry a total roof load 50 per cent greater than given on the chart, or 60 pounds per square foot, the increased weight of metal would be about 45 per cent, or somewhat less than the proportion of increased load.

Comparing two trusses, if one carries twice as much load as the other, the first will not be quite twice as heavy as the lighter one. Fig. *119 is an original chart from which the weight of steel trusses of ordinary slopes may be determined for spans of any

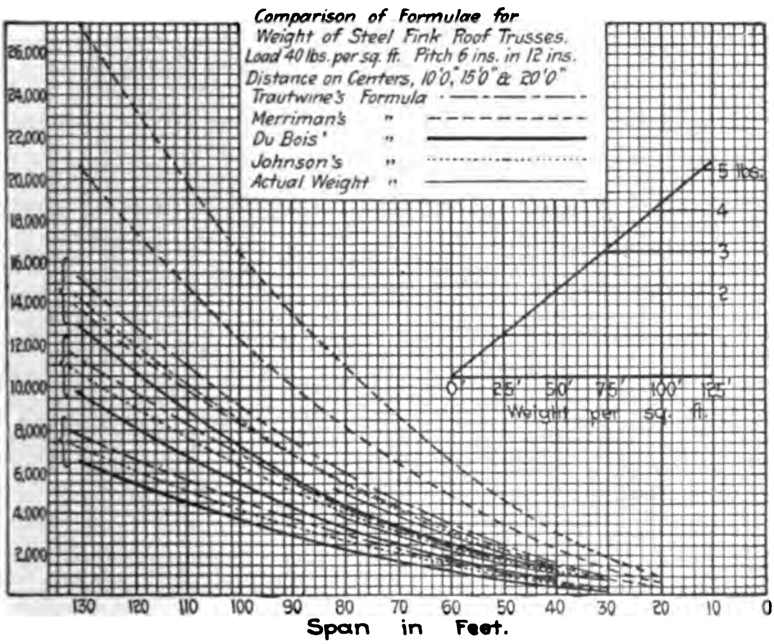


Fig. 118.

length and loads of any amount, as well as for varying unit stresses. It is general in its form, and is suitable for all spans and loads. The diagrams are drawn from a large number of actual cases and are therefore correct.

Loads per lineal foot include both dead and live loads. For concentrated loads, the equivalent uniform load may be used, remembering that a concentrated load at the center of a span produces bending moments that are twice as great as when the same load is distributed uniformly over the entire length.

To illustrate the use of this chart, suppose that it is required to find the weight of a steel roof truss of 80-foot span, to carry a total load of 2,000 pounds per lineal foot, with an allowable tensile unit stress of 15,000 pounds per square inch. The weight of steel per lineal foot of truss is as follows:

$$W = \frac{\text{Span in feet} \times \text{total load per lineal foot}}{F}$$

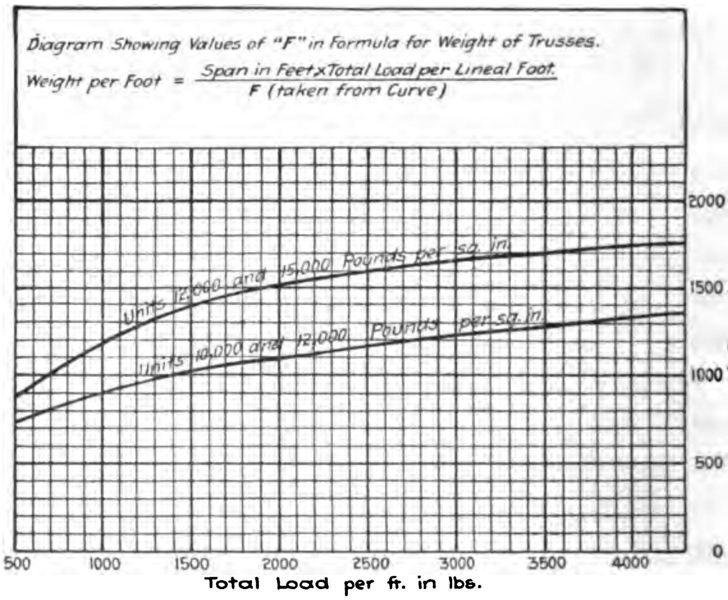


Fig. 119.

Inserting the length of span and total load per lineal foot in the numerator, and the value of F, taken from the chart, in the denominator, the equation then becomes—

$$W = \frac{80 \times 2000}{1500} = 107 \text{ pounds per lineal foot.}$$

The total weight of truss is, therefore,

$$80 \times 107 = 8560 \text{ pounds.}$$

A corresponding original chart for the weight of plate girders is given in Fig. 120.* To illustrate the use of the girder chart, the weight of a girder of the same span as the truss above, and for the

* H. G. Tyrrell, Street Railway Review, July 15, 1901; London Engineering, July 25, 1902.

same load, will be determined. The equation is of the same general form as used for finding the weight of trusses, the only difference being in the value of the denominator factors F, which are now taken from the girder chart (Fig. 120). Inserting the proper value of F from this chart, the formula becomes—

$$W = \frac{80 \times 2000}{700} = 227 \text{ pounds per lin. ft.}$$

The total weight of girder is therefore $80 \times 227 = 18{,}160$ pounds, or somewhat more than twice the corresponding weight of a truss for the same span and load.

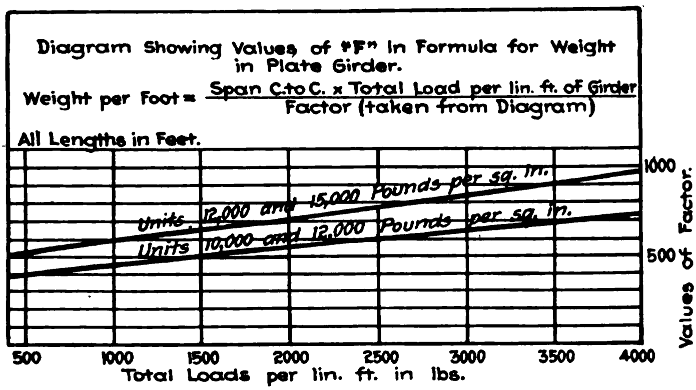


Fig. 120.

Snow and wind loads are discussed on a later page, but it may be stated here that in the northern states, roofs should not be proportioned for a less total load than 40 pounds per horizontal square foot. In tropical countries, where snow does not fall, a corresponding total load of 30 to 35 pounds per square foot is permissible.

Where office and drafting rooms of shops or mills are ceiled, the weight of lath and plaster ceiling must be added to the other weights. This will be about 10 pounds per square foot, not including joists, for which extra provision must be made.

TABLE XIII.

WEIGHT OF ROOF COVERING, WITHOUT SHEATHING IN POUNDS PER SQUARE FOOT OF ROOF SURFACE.

	Lbs. per sq. ft.
Three-ply prepared roofing, ruberoid	1.0
Standing seam steel	1.0
Tin on felt	1.0
Corrugated iron, painted or galvanized, No. 27	.9
Corrugated iron, painted or galvanized, No. 26	1.0
Corrugated iron, painted or galvanized, No. 24	1.3

Corrugated iron, painted or galvanized, No. 22	1.6
Corrugated iron, painted or galvanized, No. 20	1.9
Corrugated iron, painted or galvanized, No. 18	2.6
Corrugated iron, painted or galvanized, No. 16	3.3
Copper roofing in Sheets	1.5
Copper roofing in tiles	1.75
Shingles, common	2.5
Shingles, 18 in	3.0
Felt and gravel roofing, four-ply	5.5
Felt and gravel roofing, five-ply	6.0
Slate, ⅛ in. thick	5.0
Slate, 3/16 in. thick, 6x12 ins	7.25
Slate, 3/16 in. thick, 12x24 ins	8.25
Slate, ¼ in. thick	9.6
Tiles, Roman, in one part	8.0
Tiles, Roman, in two parts	12.0
Tiles, Spanish, in one part	8.0
Tiles, Spanish, in two parts	19.0
Tiles, Ludowici	8.0
Extra, if tiles are laid in mortar	10.0
Skylight with ¼ in. glass	4.5
Skylight with 5/16 in. glass	5.0
Skylight with ⅜ in. glass	6.0
Wood sheathing, white pine or spruce	3.0
Wood sheathing, southern pine	4.0
Wood sheathing, chestnut or maple	4.0
Wood sheathing, ash or oak	5.0
Wood rafters and purlins	7.0
Reinforced concrete slabs, per inch thickness	13.0

TABLE XIV.

The total loads per square foot of roof surface for different kinds of roofing, including framing, is as follows:

Roof Covering.	*Lbs. per sq. ft.*
Corrugated iron, unboarded	8 to 10
Corrugated iron, on boards	10 to 12
Slate on laths	12 to 15
Slate on 1¼ in. boards	15 to 18
Tar and gravel	10 to 12
Shingles on laths	8 to 10
Tile on plank	20 to 30
Tile laid in mortar	25 to 35
Sheet metal on boards	7 to 9
3 in. reinforced concrete	40 to 45

CHAPTER XI.

FLOOR LOADS.

Building laws of various cities, for the purpose of regulating the strength of floors, specify the minimum safe loads for which they shall be proportioned (Table XV). These laws, however, apply more to buildings which are subject to regular classification than to mills and factories. The loads in such buildings must be determined separately, and the floors proportioned in each case to sustain them. For such buildings as foundries, the charging platforms may be subjected to 1,000 pounds per square foot or more, while floors for light manufacturing may have no greater than 200 to 300 pounds per square foot. The necessity is therefore evident, for investigating the requirements of each case by itself and proportioning the framing accordingly.

The following weight tables are given for the purpose of estimating these imposed loads. Table XVI gives the weight per cubic foot of various kinds of building materials, and also the weight of manufactured materials and merchandise. By the use of these tables the approximate amount of imposed loads can be estimated. To these must be added the weight of the floors, which can be computed after the general type has been determined.

Green timber weighs from 20 to 50 per cent more than the weights given in the table, which are for dry woods.

If partitions occur, the weight of these must also be added to the total loads. Ordinary stud partitions, plastered on both sides, weigh about 20 pounds per square foot.

TABLE XV.

MINIMUM SAFE IMPOSED LOADS ON FLOORS, ACCORDING TO BUILDING LAWS OF VARIOUS CITIES.

	Minimum live loads on floors in pounds per square foot.					
Kind of building.	*New York.*	*Chicago.*	*Philadelphia.*	*Boston.*	*St. Louis.*	*Buffalo.*
Dwellings	60	70	...	50	70	40
Apartments, hotels	60	50	70	50	70	70
Office buildings, 1st floor	150	100	100	100	150	70
Office buildings, upper floor	75	100	100	100	70	...
Stables or carriage houses	75	40-100	...	...	...	...
Public assembly halls	90	100	120	150	120	100
Light man'f'g and storage	120	100	120	...	...	120
Storehouse for heavy materials; warehouses or factories	150	...	150	250	...	...

TABLE XVI.

WEIGHT OF BUILDING MATERIAL.

Seasoned woods—	*Weight per cu. ft.*
Ash	38
Cherry	43
Chestnut	41
Cypress	64
Elm	35
Hemlock	25
Hickory	53
Mahogany, Spanish	53
Mahogany, Honduras	35
Maple	49
Oak, live	59
Oak, white	52
Pine, white	25
Pine, yellow, northern	34
Pine, yellow, southern	45
Poplar	29
Spruce	25
Sycamore	37
Walnut, black	38
Brick and stone—	
Brick, best pressed	150
Brick, common, hard	125
Brick, soft, inferior	100
Cement, Rosendale	56
Cement, Louisville	50
Cement, English Portland	90
Granite, solid	170
Granite, broken	96
Limestone, solid	168
Limestone, broken	100
Quartz	165
Sandstone	150
Shales, red and black	165
Slate	175
Gravel and sand	90 to 130
Masonry—	
Brickwork, pressed brick	140
Brickwork, ordinary	112
Stone concrete	140
Cinder concrete	95
Granite or limestone, dressed	165
Granite or limestone, rubble	154
Granite or limestone, dry	138
Sandstone, dressed	144

WEIGHT OF MERCHANDISE.

	Lbs. per cu. ft.
Alcohol	50 to 57
Aluminum	162
Asphaltum	88
Alum	33
Brass	510
Bronze	520
Boxwood	60
Bleaching Powder	31
Calcite	170
Chalk	156
Charcoal	15 to 30
Coal, anthracite	81 to 106

Coal, anthracite, piled loose	47 to 58
Coal, bituminous	78 to 88
Coal, bituminous, piled loose	44 to 54
Coke	23 to 32
Copper	540
Cork	16
Cotton goods	11 to 33
Carpet	12
Corn	31
Corn Meal	37
Cutch	45
Caustic Soda	88
Crockery	40
Cheese	30
Clay, potters	100 to 140
Clay, in lumps	65
Earth, common loam, dry	72 to 80
Earth, soft flowing	100 to 110
Flour	40
Glass	160
Glassware in boxes	60
Gypsum	142
Gypsum, in lumps	82
Gypsum, ground, loose	56
Gutta percha	61
Hay, baled	24
Iron	450
Ice	57
India rubber	58
Indigo	43
Oats	27
Oils	54 to 57
Lead	710
Lard Oil	34
Lime	50
Leather in bales	16 to 23
Petroleum	55
Pitch	72
Plaster	53
Paper, strawboard newspaper	33 to 44
Paper, calendered book	50 to 70
Paper, writing and wrapping	70 to 90
Rosin	69
Rope	42
Rags in bales	15 to 36
Salt	50 to 70
Snow, fresh fallen and light	5 to 12
Snow, packed and heavy	15 to 50
Steel	490
Sulphur	125
Sugar	42
Starch	23
Soda Ash	62
Silk	8 to 32
Sumac	39
Tallow	58
Tar	62
Tin	459
Tobacco	28
Wool in bales	15 to 22
Woolen goods	13 to 22
Wheat	39 to 44
Water	62

CHAPTER XII.

SNOW AND WIND LOADS.

Table XVII and the chart in Fig. 121 show the amount of snow loads that will occur in different latitudes of North America for roofs of various pitches.

Light snow will weigh from 5 to 10 pounds per cubic foot, while heavy snow that is packed may weigh 40 to 50 pounds. While snow in Manitoba, Minnesota, Quebec and Maine frequently

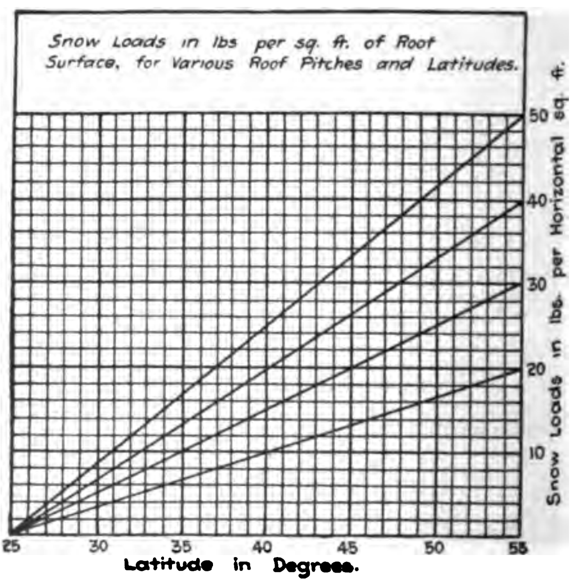


Fig. 121.

falls to a depth of 4 to 6 feet, or even more, it does not lie to this depth on exposed surfaces such as roofs, and a maximum snow load of 42 pounds per horizontal square foot is therefore safe for 50 degrees north latitude. In addition to roofs being in exposed positions, they frequently have considerable slope, so that the snow will slide from its own weight. Snow will not remain on roof slopes exceeding 45 degrees, or half pitch, and there will consequently be no snow load.

Even on comparatively flat roofs, there are certain locations so exposed to wind that the probability of large snow loads is comparatively small. Therefore, in making allowance for snow, judgment must be used. Snow conditions in the mountain states and high altitudes are different from those at lower levels, and these conditions may also be affected by the amount of precipitation, which is less in the arid states than near the sea coast.

The general rule for the northern part of the United States is to provide for snow loads to the extent of from 10 to 20 pounds per square foot, on pitches of 1/4 or 1/5. For the latitude of Chicago or New York, 20 pounds will ordinarily be ample. The snow loads given in the table and chart above are per square foot of exposed roof surface, but it will be noted that the weight itself acts vertically.

In designing the Sayer shops, which are covered with a 3-inch reinforced concrete slab, the ordinary pitch roofs were proportioned for a total load of 75 pounds per square foot, while the saw tooth roof was figured for a total load of 85 pounds to provide for the extra snow.

TABLE XVII.

SNOW LOADS IN LBS. PER SQ. FT. OF ROOF SURFACE FOR VARIOUS PITCHES AND LATITUDES.

	Latitude.	*⅓ Pitch.*	*¼ Pitch.*	*⅕ Pitch.*	*1/6 Pitch or less.*
New Orleans	30	4	5	7	8
Memphis	35	7	10	13	16
Cincinnati	40	10	15	20	24
St. Paul	45	13	20	26	33
Winnipeg	50	17	25	33	42

TABLE XVIII.

WIND VELOCITIES AND CORRESPONDING PRESSURES.

	—Velocity— Miles Per Hr.	*—Pressure— Lbs. Per Sq. Ft.*
Just perceptible......................	2	.02
Gentle breeze	5	.12
Pleasant	10	.50
Brisk gale	20	1.90
High wind	30	4.40
Very high wind......................	40	7.80
Storm	50	12.30
Violent storm	60	17.70
Hurricane	80	31.40
Violent hurricane	100	49.00

TABLE XIX.

WIND COEFFICIENTS FOR VARYING ROOF PITCHES AND WIND PRESSURES.

Angle of Roof.	5°	10°	20°	30°	40°	50°	60°	70°	80°	90°
N = F ×	.125	.24	.45	.66	.83	.95	1.00	1.02	1.01	1.0
V = F ×	.122	.24	.42	.57	.64	.61	.50	.35	.17	.0
H = F ×	.01	.04	.15	.33	.53	.73	.85	.96	.99	1.0

In the above—

A = angle of roof surface with horizontal.
F = force of wind in pounds per square foot.
N = pressure normal to roof surface.
V = pressure perpendicular to direction of wind.
H = Pressure parallel to direction of wind.

For wind pressure of 30 pounds per square foot against a vertical surface, normal wind pressures on roofs of varying slopes may be obtained by use of the coefficients given in Table XIX. These normal wind pressures are given in Table XX.

TABLE XX.

NORMAL WIND PRESSURE ON ROOFS OF VARIOUS SLOPES FOR A HORIZONTAL WIND PRESSURE OF 30 LBS. PER SQ. FT. AGAINST A VERTICAL SURFACE.

Angle.	*Pressure Lbs. Per Sq. Ft.*
5°	3.9
10°	7.2
15°	10.5
18°-26′ (1/6 pitch)	13.
20°	13.7
21°-48′ (1/5 pitch)	15.
25°	16.9
26°-34′ (1/4 pitch)	18.
30°	19.9
33°-41′ (1/3 pitch)	22.
35°	22.6
40°	25.1
45° (1/2 pitch)	27.1
50°	28.6
55°	29.7
60°	30.

Table XX from Mill Building Construction, by H. G. Tyrrell.

WIND LOADS.

The result of wind action on buildings can only be approximated. Experiments to ascertain the force of wind for various velocities show that the greatest wind pressures during violent hurricanes amount to 40 to 50 pounds per square foot. It is impracticable to proportion ordinary buildings to resist the pressures of tornadoes or hurricanes, for if the building were not destroyed by the wind, it probably would be from flying wreckage and materials. It is sufficient, excepting, perhaps, in very exposed positions, such as unsheltered points on stormy coasts, to proportion buildings to resist a wind pressure of 30 pounds per square foot of vertical surface.

Table XVIII gives the wind pressures on vertical surfaces, for velocities varying from two to one hundred miles per hour. A pressure of 30 pounds per square foot corresponds with a wind velocity of 80 miles per hour.

Table XIX gives wind coefficients for roof pitches varying from 5 to 90 degrees with the horizontal.

Table XXI gives combined snow and wind loads for roofs of different pitches in northern latitudes. Roofs should never be proportioned for a less combined snow and wind load than 25 pounds per square foot of roof surface. Wind is more severe when acting on surfaces in exposed positions high above ground than on lower buildings. It is, therefore, good practice to proportion building frames that are 60 feet in height or more for a horizontal pressure of 30 pounds per vertical square foot, or 20 pounds per square foot for heights of 25 feet or less. Between these limits of 25 and 60 feet, wind pressures should be assumed from 20 to 30 pounds, depending on the height. In all cases the action of wind is considered normal to the plane of the roof or surface.

The overturning effect on a building as a whole need be considered only for high, narrow buildings, but the increased stress in the leeward columns must be considered. No side girths should have provision for a less pressure than 20 pounds per square foot of wall.

TABLE XXI.

ALLOWANCE FOR WIND AND SNOW, COMBINED, IN LBS., PER SQ. FT. OF ROOF SURFACE.

	Pitch of Roof.					
Location.	60°	45°	⅓	¼	⅕	⅙
Northwest States	30	30	25	30	37	45
New England States	30	30	25	25	35	40
Rocky Mountain States	30	30	25	25	27	35
Central States	30	30	25	25	22	30
Southern Pacific States	30	30	25	25	22	20

CHAPTER XIII.

CRANE AND MISCELLANEOUS LOADS.

The load on each of the two end wheels of small shop traveling cranes is approximately equal to the capacity of the crane when the fully loaded trolley is at that end. The load at the other end will then be proportionately less. Tables XXII and XXIII give in detail loads on crane girders from traveling cranes, Table XXIII being for hand cranes, while Table XXII is for electric traveling cranes.

The necessary capacity of cranes having been decided to properly serve the shop needs, the framing for the crane system can be proportioned by use of the load tables given. No feature of a modern shop is of greater importance than its appliances for handling and moving materials, for upon these much of the shop efficiency depends. In many cases and especially for light loads, pneumatic or electric hoists with their rapid operation, are the most convenient.

Jib cranes are too various in arrangement and design to admit of any satisfactory tabulation. The principal stresses in the framework will occur in the bottom chord bracing and the knee braces joining the trusses to columns. Traveling jib cranes, which are now very generally used, will also cause heavy stresses in the framework and must be carefully provided for, as there is no class of stress to which manufacturing buildings are subjected, so severe on the building as is the action of traveling cranes. The action of cranes is constant and continuous, while high winds or snow loads may seldom occur.

The loads on trolley beams suspended from the trusses will cause stresses, the amount of which will depend directly upon the weight lifted and the weight of trolley and hoisting block.

All crane loads referred to and tabulated include the weight of the materials lifted and the dead weight of the crane, with trolley and machinery, but they do not include the weight of the supporting crane system, such as crane girders or columns. In proportioning crane girders, their dead weight and the weight of track rail must be added to the weights tabulated.

TABLE XXII.

*MAXIMUM LOAD IN LBS. ON EACH OF TWO END WHEELS, ELECTRIC TRAVELING CRANES.

Capacity in Tons.	Span in Ft. —30— Load.	D.	—40— Load.	D.	—50— Load.	D.	—60— Load.	D.	—70— Load.	D.	—80— Load.	D.
3½.....	9300	8	10200	9	11300	10	12600	10	14300	12	16000	13
5	11600	10	12800	10	14100	10	15500	11	17100	12	18900	13
7½.....	14900	11	16200	11	17600	10	19100	10	20800	12	22700	13
10	18500	11	19800	11	21200	11	22700	11	24500	12	26800	13
15	25000	12	26500	12	28100	12	29800	12	31800	12	34300	13
20	31000	12	32700	12	34600	12	37000	12	39700	12	42800	13
25	37000		39300	12	41800	12	44500	13	47500	12	50800	13
30	43000		46200	13	48800	13	51700	13	55000	13	58800	13
40	57000		60100	14	63400	14	67000	13	71000	13	75600	13
50	70000		74000	13	77600	13	82000		86600		90000	

TABLE XXIII.

*MAXIMUM LOAD IN LBS. ON EACH OF TWO END WHEELS, HAND TRAVELING CRANES.

Capacity in Tons.	Span of Crane in Ft. —20— Load.	D.	—30— Load.	D.	—40— Load.	D.	—50— Load.	D.	—60— Load.	D.	—70— Load.	D.
2.......	2900	4	3100	4	3500	5						
4.......	5000	4	5400	4	5800	5	6400	5				
6.......	7500	6	8000	6	8600	7	9200	7	10000	8	10700	8
8.......	10000	6	10500	6	11100	7	11800	7	12600	8	13400	8
10.......	12400	6	13000	7	13600	7	14300	8	15300	8	16100	9
12.......	15000	6	15600	7	16300	7	17100	8	18100	8	19100	9
16.......	20000	7	20700	7	21400	8	22300	8	23400	9	24600	9
20.......	25100	7	26000	7	27000	8	28000	8	29300	9	30700	9
25.......	31100	7	32300	7	33500	8	34800	8	36200	9	38000	9

Dimension D is the distance apart in feet of two end crane wheels.

Addition must be made to crane loads to provide for the effect of impact, and this should be from 25 to 50 per cent, depending upon the severity of the crane service. It is the practice of some designers to neglect the impact addition and to use lower unit stresses for the crane system than for the other parts of the building; but a more scientific method of design is to consider and include all loads, and use tension units approaching one-half the elastic limit.

In the Tables XXII and XXIII above, the dimension D is the distance in feet between the two wheels at either end of the crane. It will be noted that the loads given are the loads on each wheel. It may sometimes be desirable to make two or more roof trusses at either end, sufficiently strong to permit the crane bridge to be lifted from its track by pulleys attached to the trusses. This provision would avoid the need of temporary staging, and the extra expense might be warranted.

* From Mill Building Construction, by H. G. Tyrrell.

MISCELLANEOUS LOADS.

There are numerous other loads which do not permit of any systematic arrangement or tabulation, but which may exist. It is sometimes convenient to provide trolleys running directly on the bottom truss chords, or provision may be desired for attaching pulley blocks, for raising light weights, to the bottom chords at any point. Steam pipes, heating ducts and shafting often add much to the load, and occasionally a plank walk is placed in the trusses for the purpose of reaching the ventilator windows, for making inspection and repairs, or oiling the shafting. Other items which may increase the roof loads are circular metal ventilators, skylights, sash operating machinery, shutters, etc., provision for all of which should be liberal. Columns in exposed positions may be subject to jars or blows from passing vehicles or materials, and their strength must be increased accordingly. Other loads, such as the pull from belts and the general effect of vibration from rapidly moving machinery, should also have ample provision. It is the practice of some designers to make a general addition to the loads of from 5 to 10 pounds per square foot over the entire truss area, to cover the effect of vibration.

It is convenient in shops with electric power to place motors above the floor and thereby save useful floor space. If they are set on platforms between the roof trusses, provision must be made for this extra load. It should be noted, however, that all the above loads may not always occur at the same time, and provision need not be made for them all combined.

SUMMARY OF LOADS.

The weight of framing in ordinary mill roofs varies generally from 4 to 7 pounds per square foot of ground area. Adding to this the weight of roof covering, gives the combined weight of framing and covering, according to Table XIV, page 106.

These weights are for roofs with spans up to about 75 feet. For spans of 100 feet, add 3 pounds per square foot to the above and proportionally between. If roofs are ceiled and plastered, add 10 pounds per square foot for the lath and plaster only, and additional weight for the ceiling joist.

For combined snow and wind in northern latitudes of the United States, add from 25 to 35 pounds per square foot of roof surface as given in detail in Table XXI.

No roof, even where snow does not fall, should be proportioned for a less load than 30 pounds per square foot, and no purlins for less than 25 pounds per square foot.

The weight of steel framing on sides of buildings consisting of steel columns and girths covered with corrugated iron, is from 4 to 6 pounds per square foot of exposed surface, for the framing only.

An approximate rule for the extra weight of steel in the supporting systems of traveling cranes is that for every 5 tons' capacity of crane there will be about 100 pounds of extra steel per lineal foot of building in the two side girder and crane columns.

PART III

FRAMING

CHAPTER XIV.

STEEL FRAMING.

All the general features of a building, with its size, shape and dimensions, must be determined as described in Part I, before starting the framing plans. The arrangement and location of machinery, inside height and clearance, kind and capacity of cranes, kind of building material, size and weight of contents, with the methods of lighting, heating, ventilating and draining, must all be considered, preliminary to laying out the framing plans or computing the sizes. The number of columns and the clear space between them, the roof pitch, amount and kind of skylights, number and width of monitors, must all be fixed before undertaking the work outlined in this chapter. The building must be rigid, large enough for its equipment and occupants, and suited to the work to be done therein. Before detail plans are made, the preliminary considerations should be reviewed, and the general arrangement verified, so expensive alterations will not result.

The framing should be studied out on small sheets of paper, preferably not larger than cap size, 8½ by 13 inches, single lines being used to indicate members (Fig. 32). From these small sketches, ¼-inch scale details may be made, and a show drawing prepared.

The design for each building should be developed according to its special requirements, and for the roof framing should begin with the kind of covering and the method of supporting it. The spacing of rafters or purlins will depend on the supporting strength of the plank or slab, and the relative arrangement of parts must be proportioned to each other. Pieces must be included in the design only when they have a definite purpose, and not merely to copy other designs or to follow usual methods.

BUILDING FRAMES.

The frames of mill and manufacturing buildings are a combination of trusses, monitors, rafters, purlins, columns and girders, properly braced together, to form a shelter and enclosure, and support for cranes and machinery. Framing may consist of single-span roofs resting on side walls or columns in the walls, or may have one or more lines of interior columns to support the roof and crane tracks, with or without intermediate floors or galleries. The outline of the building, and all its general features, will be selected according to the principles explained in Part I.

Figs. 122 to 161 show a variety of building frames, the first thirteen having a single line of interior columns, while the remaining ones have two lines. Figs. 130 to 133 have monitor frames over the center line of columns, with clear open space beneath them. Fig 134 is a simple flat pitch roof with beams and columns knee braced together, a double pitch being given to the center part by blocking the purlins up to the proper slope. Fig. 138 is another simple roof supported on two lines of inside columns, the rafter bases of the central part being tied together with rods. Figs. 147 and 148 have lean-to trusses with steep rafter pitches under the skylights near the walls, the pitch decreasing towards the center, leaving a greater side window area without unnecessarily increasing the height of the building. Fig. 151 receives roof light entirely through skylights, and is the form used for the Coventry Ordnance Works, which are 200 feet wide and 980 feet long. Figs. 152 to 155 all have inside gutters and drainage, and lack the stiffness of frames with single pitch lean-to trusses. Figs. 156 to 161 are building frames with curved trusses, suitable for exhibition halls, markets or armories. They have a much better and lighter appearance than heavy trusses with horizontal chords, but are not generally suitable for shops, which need horizontal supports for shafting, trolleys and hoisting appliances.

TRUSSES.

Curved sheets of corrugated iron without regular truss frames, may be used for spans up to 30 feet. The sheets are riveted together at the ends and framed into an arch, the ends of which thrust against side angles tied together with rods. Large 5-inch corrugations have a greater compression strength than smaller ones, and are therefore preferable, and the arch may be braced with occasional struts. Curved forms are also largely used, especially in

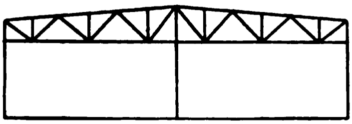


Fig. 122.

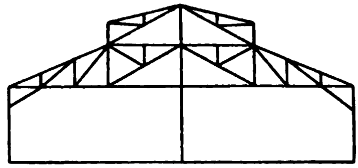


Fig. 123.

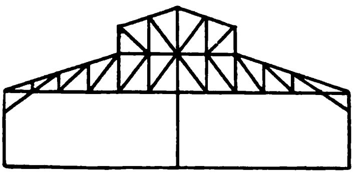


Fig. 124.

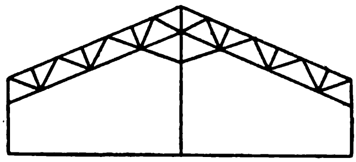


Fig. 125.

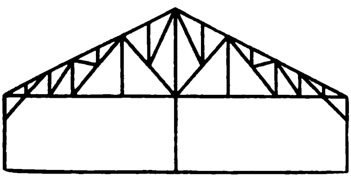


Fig. 126.

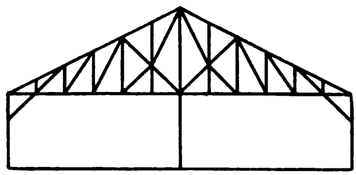


Fig. 127.

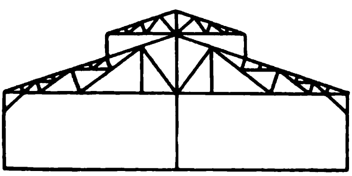


Fig. 128.

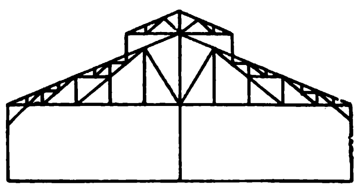


Fig. 129.

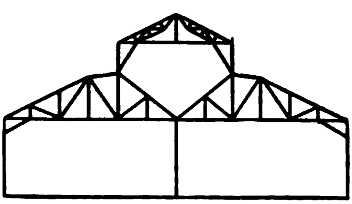


Fig. 130.

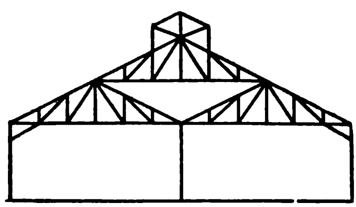


Fig. 131.

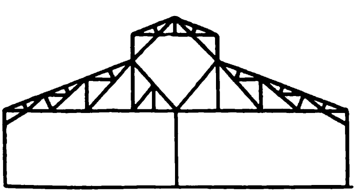


Fig. 132.

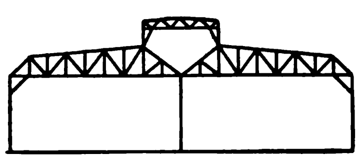


Fig. 133.

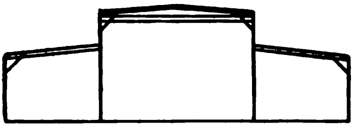


Fig. 134.

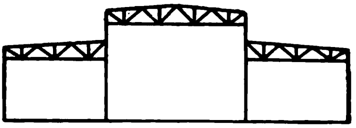


Fig. 135.

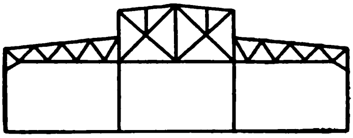


Fig. 136.

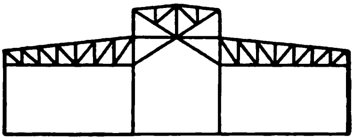
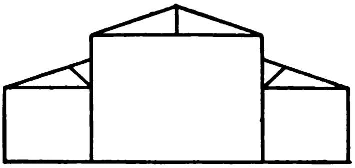


Fig. 137.



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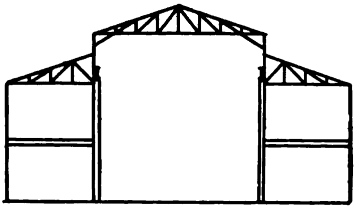

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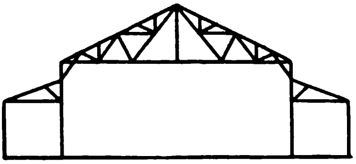

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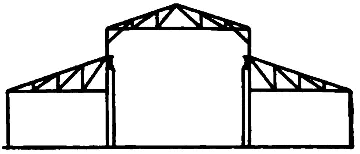

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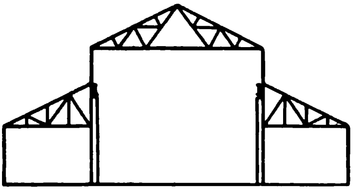

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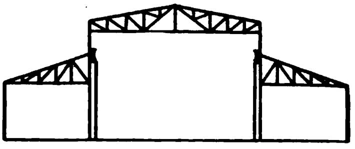

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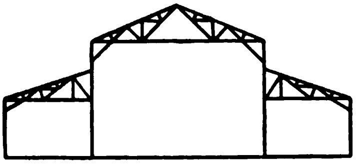

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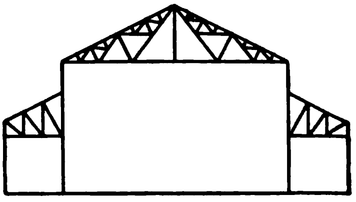

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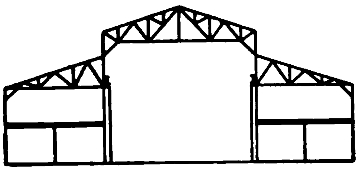

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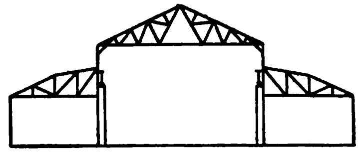

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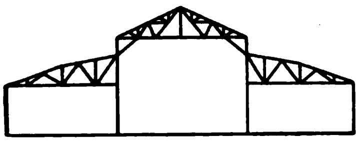

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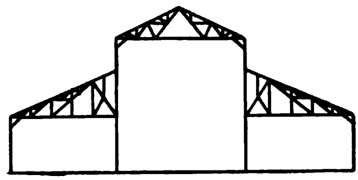

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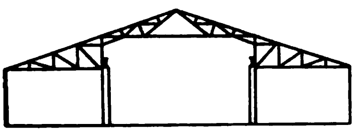

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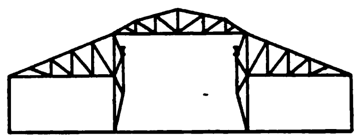

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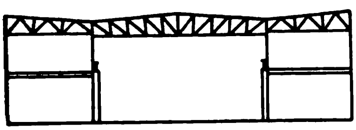

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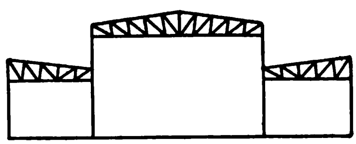

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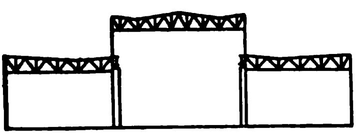

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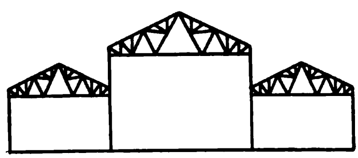

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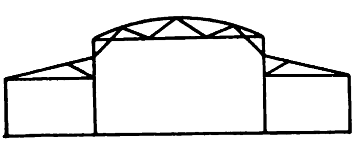

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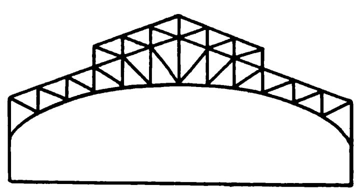

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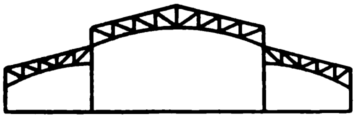
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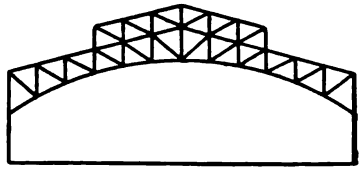
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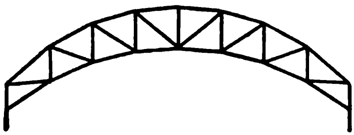
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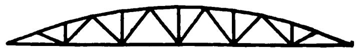
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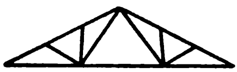
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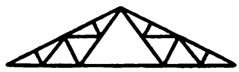
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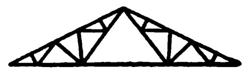
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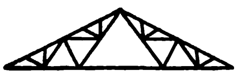
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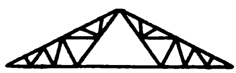
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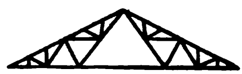
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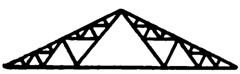
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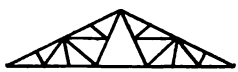
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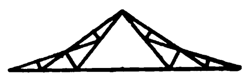
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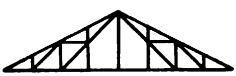
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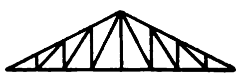
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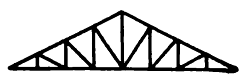
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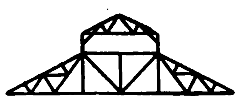
Fig. 174.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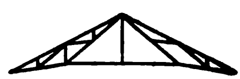
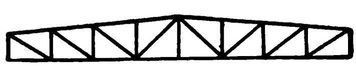


Fig. 176.


Fig. 177.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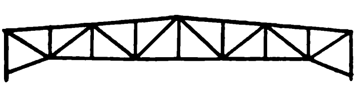


Fig. 179.


Fig. 180.

Fig. 181.

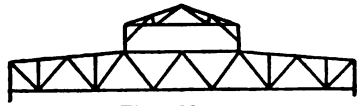


Fig. 182.

Fig. 183.

Fig. 184.

Europe, for monitors and ventilators, and are believed to present a better appearance.

Standard types of steel roof trusses and building frames are shown in Figs. 122 to 184. Figs. 162 to 171 are Fink trusses suitable for spans as indicated, the last one having vertical rafter braces. Fink trusses are more commonly used than any other kind, and are economical because the struts are short, and the longer web members are in tension. Figs. 172 and 173 are forms of English roof trusses with vertical members, which in Fig. 172 are in compression and in Fig. 173 in tension. By comparing Figs. 171, 172, and 173, the economy of the Fink truss will be seen, for the longest compression members in the English truss are avoided. Figs. 163 and 171 are similar, except that the latter has struts in a vertical position, instead of normal to the rafter. Vertical truss members are often necessary, as, for example, in hip trusses, for the attachment of intermediate trusses and rafters. They are also preferable for small roof pitches, as the truss members can be arranged with more effective angles of intersection. Trusses with small rafter pitch are most conveniently framed with vertical and diagonal members (Figs. 124 and 178), rather than with rafter braces normal to the upper chords (Fig. 174). When trusses are not proportioned for concentrated loads at any point of the bottom chord, vertical braces are then needed only for supporting the top chord (Fig. 182), and the additional pieces of Fig. 179, with the corresponding connection plates and details, are saved.

Side or lean-to trusses with a slope in one direction only are illustrated in the various building frames. It is economy of column sections to apply the load from side truss as low down on the column as possible. The form of Fig. 142 is, therefore, preferable to 141, and is the one generally used.

All parts of roof trusses, including members in tension, should be made stiff, for flat bars are liable to be bent in shipping, and when once bent are rarely, if ever, straightened. The center line of members should meet at panel points when stresses are large, even though the connection plates must be increased (Fig. 185), but when stresses are small it is better to arrange the truss members at the panel points to produce the smallest plate and the fewest number of rivets (Fig. 186). A common truss connection shown in Fig. 187 is faulty in having secondary or eccentric stress due to the center line of web members meeting outside the chord, but it makes a neater detail and is satisfactory for light members. Of

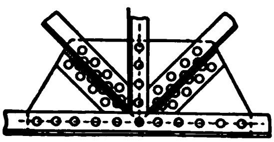


Fig. 185.

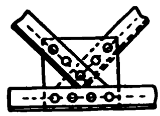


Fig. 186.

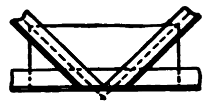


Fig. 187.

the three details for truss connections to columns (Figs. 188, 189, 190), the eccentric stress in the first one is avoided in the latter two, which are, therefore, preferable for heavy members.

Fire curtains in the roof at intervals of one or two hundred feet, are recommended by insurance companies, to prevent fire from spreading under the roof, and these consist of thin solid web plates instead of separate members in occasional trusses.

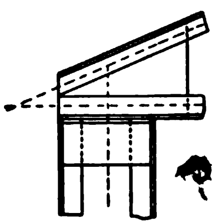


Fig. 188.

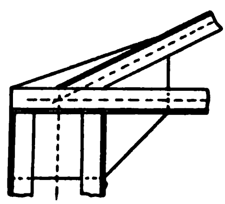


Fig. 189.

Trusses must be stiff enough to permit handling without injury, and small ones completely riveted in the shop should have bent cover plates at the peak. Without such a cover, small trusses loaded on a wagon for delivery, would bend at the center (Fig. 191).

Single-truss systems, or those composed of a series of united triangles, are preferable to trusses with double systems of web members crossing at the center, for in the latter case the amount of stress borne by each system is indeterminate.

The number and length of rafter panels depend on the method of loading the trusses. When purlins are used, the rafter braces should preferably come under the purlin, and rafters with combined direct compression and cross bending require more trussing than those for compression only. The length of truss panels depends also on the depth of truss. Shallow trusses should have shorter panels than deeper ones, to make the diagonal braces lie more nearly at an angle of 45 degrees with the horizontal. Trusses which have a small end depth may have shorter web panels towards the end than near the center. In the design of trusses, as well as other parts, the essential requirements must first be met, and the design developed according to those requirements. To arbitrarily select a

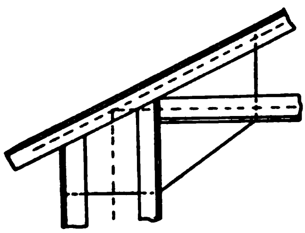


Fig. 190.

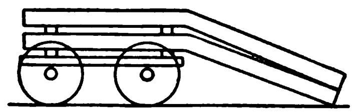


Fig. 191.

system of framing without studying the needs of the case is almost sure to result in waste.

The rafters, bottom chords and main struts should be made symmetrical, as of double angles, but single angles may be used for minor braces. The proper form of truss is often fixed by external requirements. The width of monitor may make Fig. 175 preferable to Fig. 169, and a flat ceiling will require a straight bottom chord.

Figs. 192 and 193 show the right and wrong way of outlining a

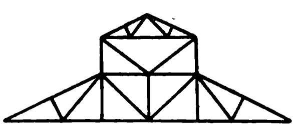


Fig. 192.

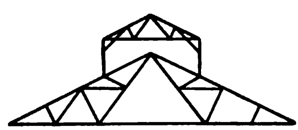


Fig. 193.

steep pitch roof with monitor, while Figs. 194 and 195 show right and wrong ways of outlining trusses with a flat rafter pitch. In the latter case, it is economical to use the shortest web members in compression and the longer or diagonal ones in tension.

When a floor or other heavy load is suspended from the trusses (Fig. 197), the principal details will be at the eaves, peak and the two suspension points.

The end connection plates on long, shallow trusses may be so large as to make a solid web preferable in the end panel, but these plates may be lightened by cutting holes in them. When holes are located as shown in Fig. 196, web stress is possible in one diagonal direction only.

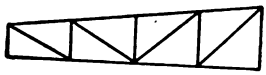


Fig. 194.

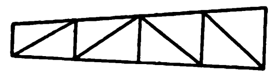


Fig. 195.

TRUSS CONNECTIONS.

The choice between pins or rivets for roof connections depends largely upon the relative cost of manufacture and erection. Bolts or rivets are generally cheaper than pins for all ordinary spans and conditions, but pins may be preferable for long spans and difficult erection, as illustrated by several large train shed roofs.

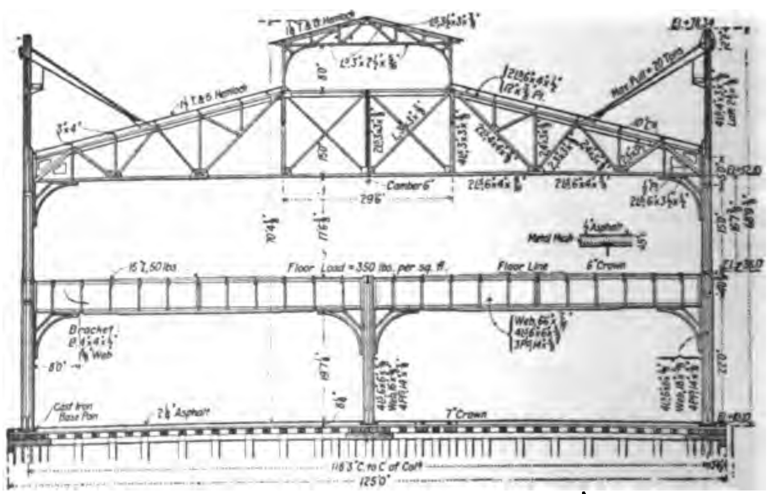


Fig. 196.

TRUSS DEPTH.

The economical depth of truss is usually from one-fifth to one-seventh of the span, but special conditions may require a less depth, and the weight is not seriously affected by a small variation. Deeper trusses have lighter chords but longer web members, while shallow trusses have heavier chords and shorter web members, and these two variations tend to balance each other. Extra depth for flat pitch trusses may be secured as shown in Figs. 20, 179 or 198.

RAFTERS.

The most convenient form of rafter for riveted trusses is made of two angles placed back to back with connection plates between them at the joints (Fig. 199). The angles should be riveted together at intervals of 2 to 4 feet, so that the strength of each angle

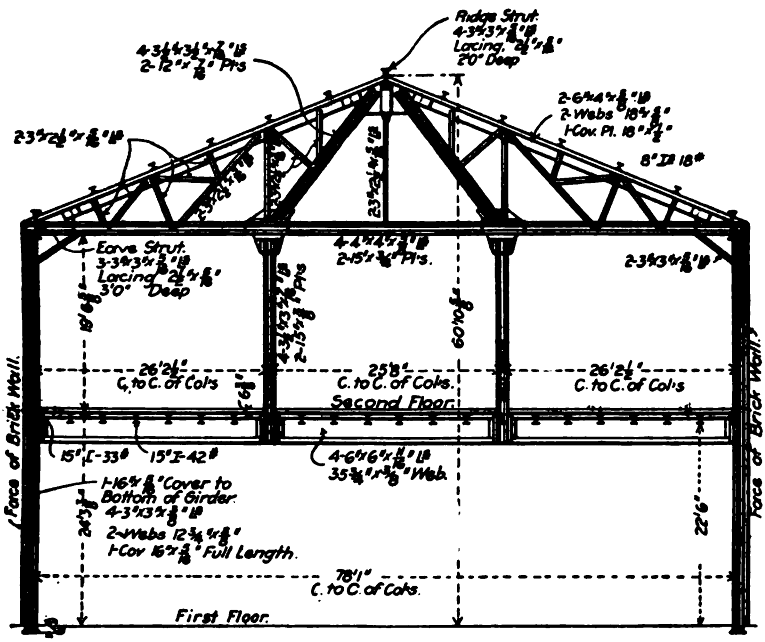


Fig. 197

in compression will be at least equal to the strength of the two combined for its greatest unsupported length. If the rafter is subjected to bending from directly applied loads, a continuous plate between the angles is then economical (Figs. 197, 219), or larger angles and shorter panels may be used instead; or, when bending stress is excessive, the rafter may be made of four angles and a web plate (Fig. 198). The kind of roof covering, thickness of plank or slab, and spacing of purlins, must be fixed before the rafter can be designed. If it carries directly a part of the roof load, as when plank is fastened to nailing pieces on the rafter, it must then be proportioned for bending. The rafter bracing in Fink trusses should, wherever possible, be at the load points.

BOTTOM CHORDS.

The bottom chords of roof trusses for all ordinary cases are most conveniently made like the rafters, of two angles placed back to back, but if weight must be borne at any point, a continuous plate should be inserted between the angles, or two channels used. A stiff chord may also be made of four angles laced together (Fig. 108). It is often necessary to have the chord strong and stiff enough so that a hoisting block can be attached to it at any point, or a trolley operated on the lower flange. This or other requirements may necessitate a horizontal member. The appearance of

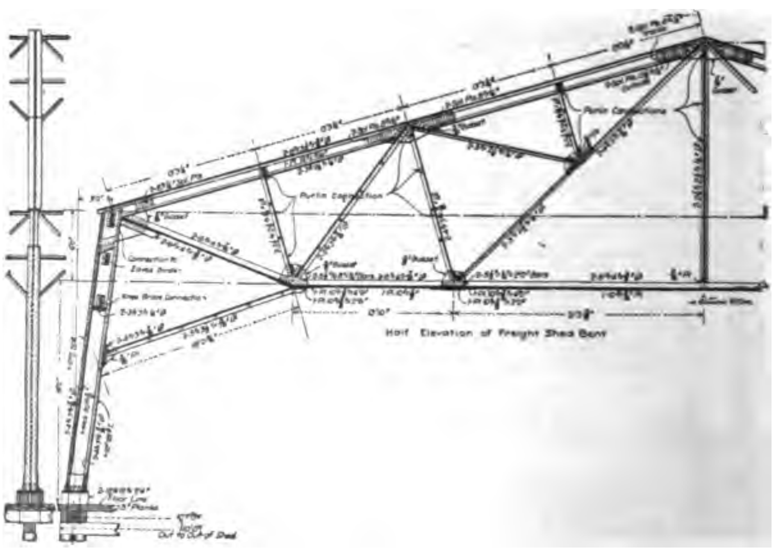


Fig. 198.

a truss is, however, improved by a slight camber not exceeding one to two feet, but a greater rise is wasteful of section and may necessitate bending the bracing plates.

When the vertical mast of a jib crane is supported at the top by struts between the trusses, the lower chords must be proportioned as compression members for the bracing system, in addition to resisting the combined tension from crane stress and roof loads.

When trusses are spaced not more than 8 to 10 feet apart, the lower chords form a convenient support for shafting, although many shops are now placing shafting in a basement or tunnels beneath the floor.

TRUSS SPACING.

The weight of purlins is a minimum when trusses are placed close together, but since the weight of trusses is proportional to the load upon them, the least total weight of truss and purlin combined would result from close truss spacing. This is true only when the small sections required for light trusses can be realized, which is usually impossible. Comparative estimates show that the most economical truss spacing is one-fourth to one-eighth the span, or 10 to 15 feet for spans up to 50 feet, and 15 to 20 feet for spans of 50 to 100 feet. Above 100 feet, the economical truss spacing is proportionately increased. When plank is laid directly on the rafters, truss spacing should not exceed 8 feet for 2-inch plank and 10 feet for 3-inch plank. For economy of framing, the spacing should be large enough to stress the smallest members up to their safe working load.

Fig. 199.

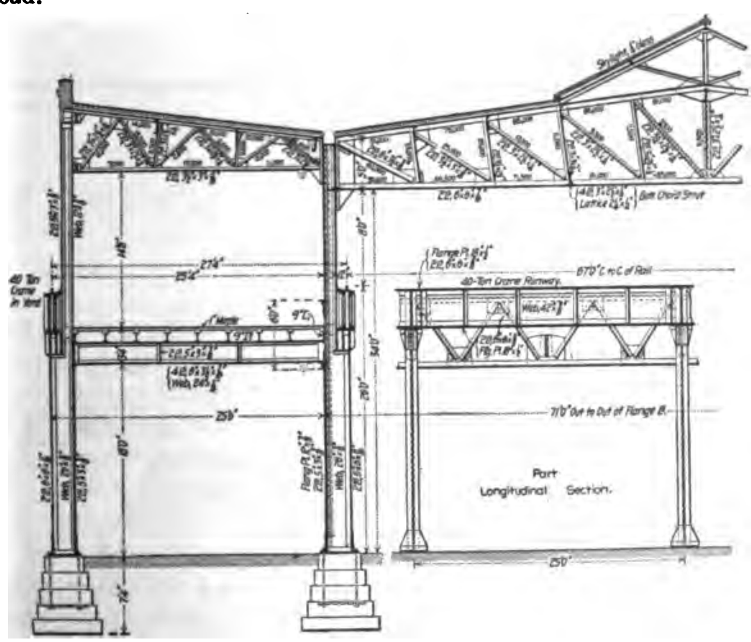


Fig. 200.

WEIGHT OF TRUSSES.

Curves* giving the weight of trusses for spans and loads of any amount are shown in Fig. 119. The total weight of steel is

$$W = \frac{L S^2}{C}$$

when W = total weight of truss in pounds,

L = the total truss load per lin. ft. of span,
S = span in feet, and
C = a constant varying from 1,000 to 1,700, generally taken at 1,200.

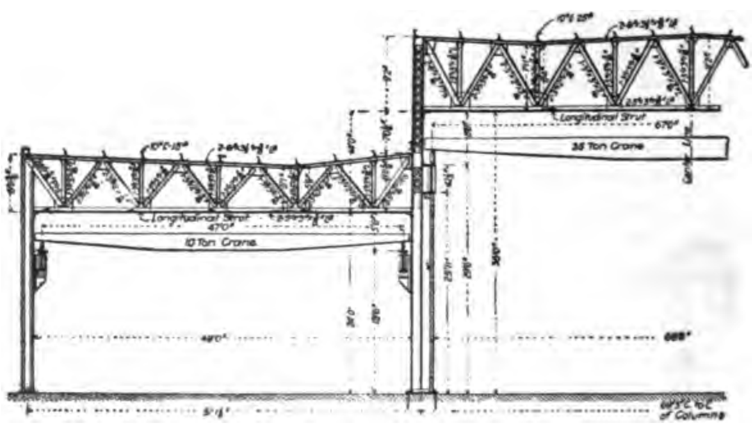


Fig. 201.

The truss weight is therefore more affected by the length of span than by any other factor.

MONITOR FRAMES.

Some forms of monitor frames are shown in Figs. 202 to 210, and they are further illustrated in connection with roof trusses and building frames. Only enough members are needed to support the covering and hold the frame in position without distortion. Fig. 202 is the kind generally used for narrow monitors not over 8 or 10 feet wide, while Fig. 203 is suitable for monitor with sloping glass sides, to better throw the light to the floor. The monitor rafter of Fig. 207 has a greater roof slope than the truss on which it stands, and is used when the monitor roof has a skylight covering. The two-story monitor (Fig. 208) has side windows on the lower

* H. G. Tyrrell in London Engineering, July 25, 1902.

rise and ventilator shutters on the upper one. Fig. 209 is suitable for ventilating only with shutters or louvres on the side.

Monitors are often made as shown in Figs. 175 or 206, when a clear space is needed for coal conveyors, or for men in cleaning windows or skylights.

Electric light stations often admit wires to the building through the monitors, and wire supports with insulation are then needed on the sides. One or more panels of the regular monitor can be used for this purpose if required.

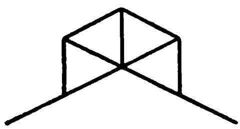


Fig. 202.

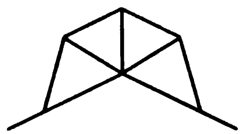


Fig. 203.

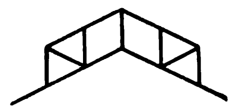


Fig. 204.

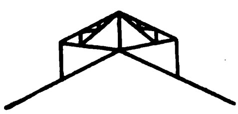


Fig. 205.

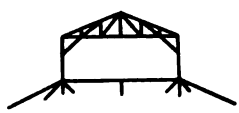


Fig. 206.

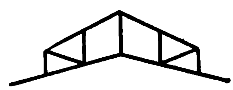


Fig. 207.

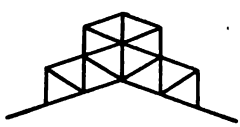


Fig. 208.

Fig. 209.

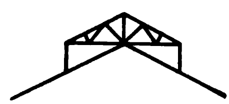


Fig. 210.

GIRTHS AND PURLINS.

Wall girths and roof purlins are both used to support the covering, and their details and connections are similar, but roof purlins must be capable of sustaining the greatest load. It is economical, for single roofing slabs or sheets, to span the opening between at least three purlins, for the covering then has the added strength of continuity. The proper purlin spacing for corrugated iron and slate is given in Part IV, and the spacing for other material must be proportioned to its strength or thickness. Two-inch plank must be supported at intervals of 8 feet, and 3-inch plank at not more than 10 feet. A line of purlins should be placed under the end of the corrugated iron at the eave, to prevent its being bent or injured, but the projection need not exceed 12 to 15 inches. When a better appearance is desired, a molded sheet metal cornice may be added (Fig. 461).

Steel purlins are made of simple shapes, either with or without trussing. Angles, channels, beams and zee bars are commonly used, the first being most easily cut, and usually the cheapest. Simple angles, untrussed, can be used for spans up to 15 feet, and trussed angles or other shapes up to 20 feet. Angle purlins on roofs should be placed as shown in the upper view of Fig. 211, rather than as in the lower, for in the first position they have a greater vertical resistance to bending. It is economical to use simple shapes such as beams or channels, even with a slightly greater weight, than to incur the extra shop expense of trussing. Angles are trussed with light bent rods and struts (Fig. 213), or with other light angles with riveted joints, bent rods being the cheaper. Purlins should have a line of ½-inch rods in the center of each panel, to prevent their sagging vertically in the wall, or down the plane of roof, when panel lengths exceed 15 feet.

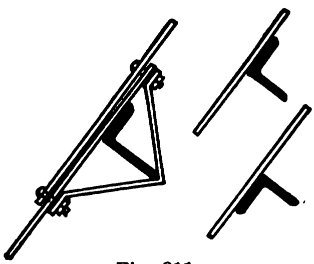


Fig. 211.

Simple shapes are preferable to trussed purlins, not only for their less shop cost, but also for their better appearance, as

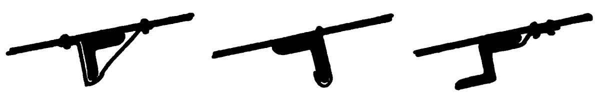


Fig. 212.

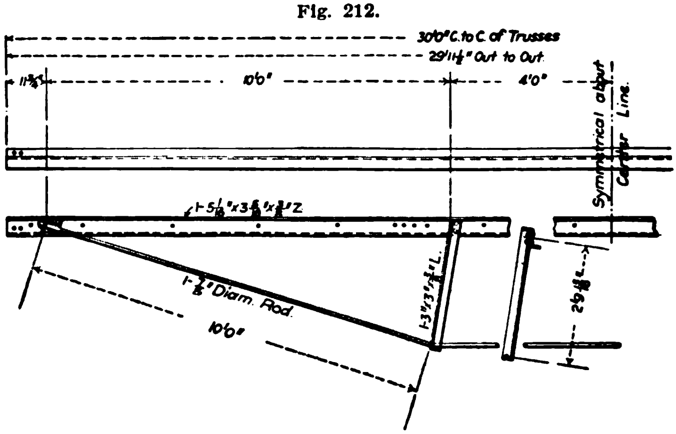


Fig. 213.

too much trussing and bracing obstruct the roof light and produce complexity.

Angles, channels and zee bars are bolted to the rafters through angle clips (Fig. 214), but beams must be fastened directly through the flanges. Clips and purlins are fastened with bolts instead of rivets, for the joints have little stress, and bolted joints are cheapest. Purlins are fastened to brick gable walls, either by bolting to an angle anchored in brickwork (Fig. 215), or with rod anchors hooked through the purlins and driven into the brick joints (Fig. 216). Openings around stacks or skylights should be framed with pieces standing out an inch or two for clearance, with diagonal corner pieces if necessary. They may be surrounded with a bent angle and the whole made watertight with a flashing hood (Fig. 483). When the roof is fastened with nails, wood spiking pieces must be bolted to the top or sides of purlins, and these are always needed for translucent fabric skylight, unless wood purlins are preferred.

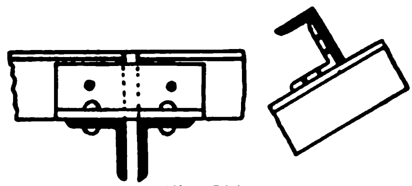


Fig. 214.

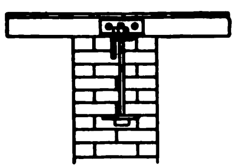


Fig. 215.

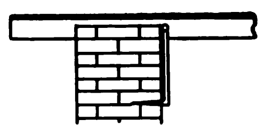


Fig. 216.

The application of steel wall girths is shown in the market building design (Fig. 30), and the proper spacing is given in Table XLVII.

JACK RAFTERS.

Jack rafters are not very generally used on mill buildings, excepting to support slate purlins, for trusses are not often placed more than 20 feet apart. In panel lengths exceeding 20 feet, it is economical to use a few lines of heavy purlins, supporting one or two intermediate rafters, which carry the small purlins on which the roofing rests. This construction is generally used on large buildings such as train sheds or exhibition halls, for wider truss spacing. For non-fireproof buildings, wood rafters may be placed 16 to 24 inches apart.

CRANE SUPPORTS.

Building frames for shops with heavy cranes might more fittingly be called covered crane ways than shop buildings, for most of the framing material is in the crane supports. Modern locomotive shops have traveling cranes of 120 tons' capacity or greater (Fig. 217), strong enough to lift an entire engine and transfer

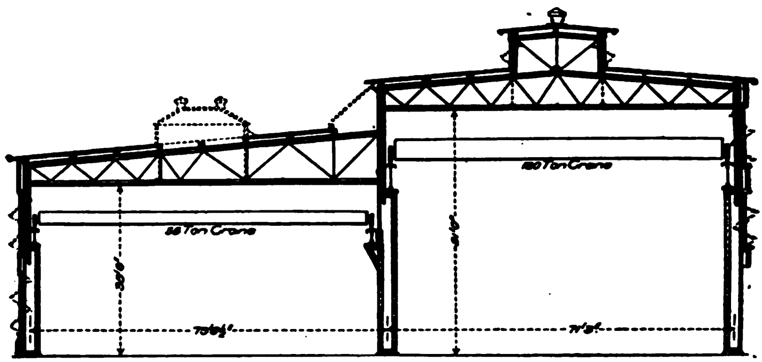


Fig. 217.

it to another place. It was formerly the practice to design manufacturing plants with very limited crane capacity, but more recent shops have large cranes for occasional use and smaller ones for lighter loads and regular service. Carefully arranged crane framing is important because the cranes will have frequent or constant use, while wind or snow loads may seldom or never be realized.

Shop lifting and handling appliances are made in great variety, including tramrails, hoists and trolleys, traveling bridge cranes, stationary and traveling jib cranes, etc.

Trolleys run either on the bottom flange of beams, as in the shops (Figs. 21 and 23), or on the bottom chords or tie beams of trusses, and the hoists attached to them are operated by compressed air, electricity or hand chains.

Traveling bridge cranes are supported on girders between adjoining lines of columns, and are often made of different capacities, in two or more tiers, one above the other. The large cranes would, of course, lift the smaller loads, but as they are heavy and slower to operate, it is a saving of time to install smaller cranes for ordinary light service (Fig. 218). The crane girders and supporting columns should be rigidly connected to the roof trusses, for if standing alone or merely fastened to the walls, a slight variation between the centers of crane rails may occur, causing the crane to bind or run untrue. It is good practice to fasten rails to their bearings in such

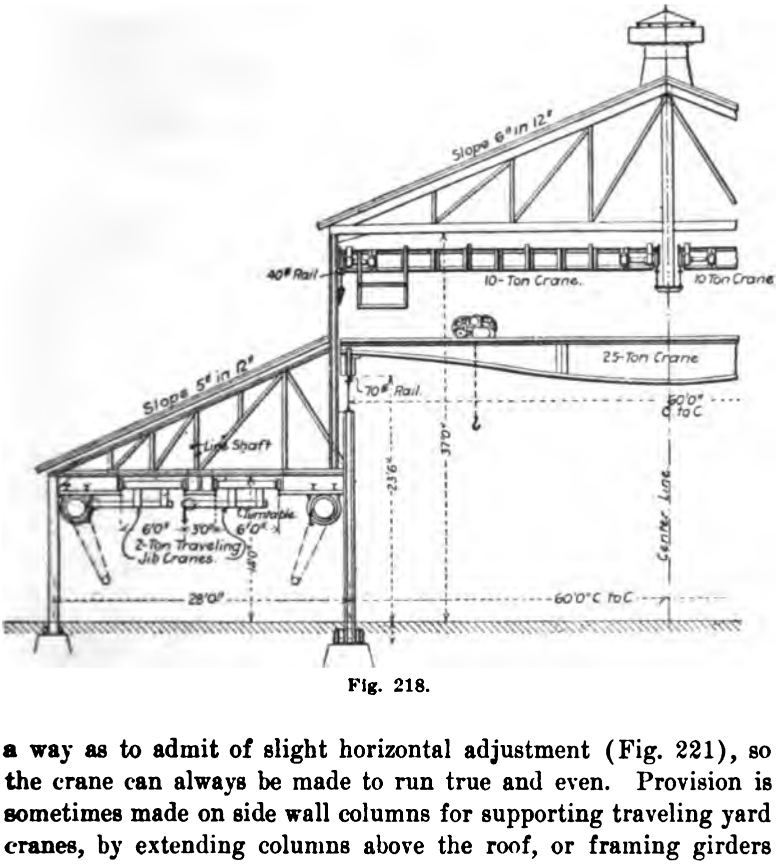


Fig. 218.

a way as to admit of slight horizontal adjustment (Fig. 221), so the crane can always be made to run true and even. Provision is sometimes made on side wall columns for supporting traveling yard cranes, by extending columns above the roof, or framing girders into them (Fig. 222). Fig. 219 shows a system of framing for traveling bridge cranes over the center aisle of an iron works shop, with two sets of cranes, one above the other. The lower crane spans the entire center floor space between the columns, while the upper ones are only half as long, and are supported at the center of the span on suspension brackets from the trusses.

Tables with outside dimensions and required clearances for electric traveling cranes are given in Chapter III.

Traveling jib cranes (Fig. 223) supported from the walls or inside line of columns are convenient and much used in modern

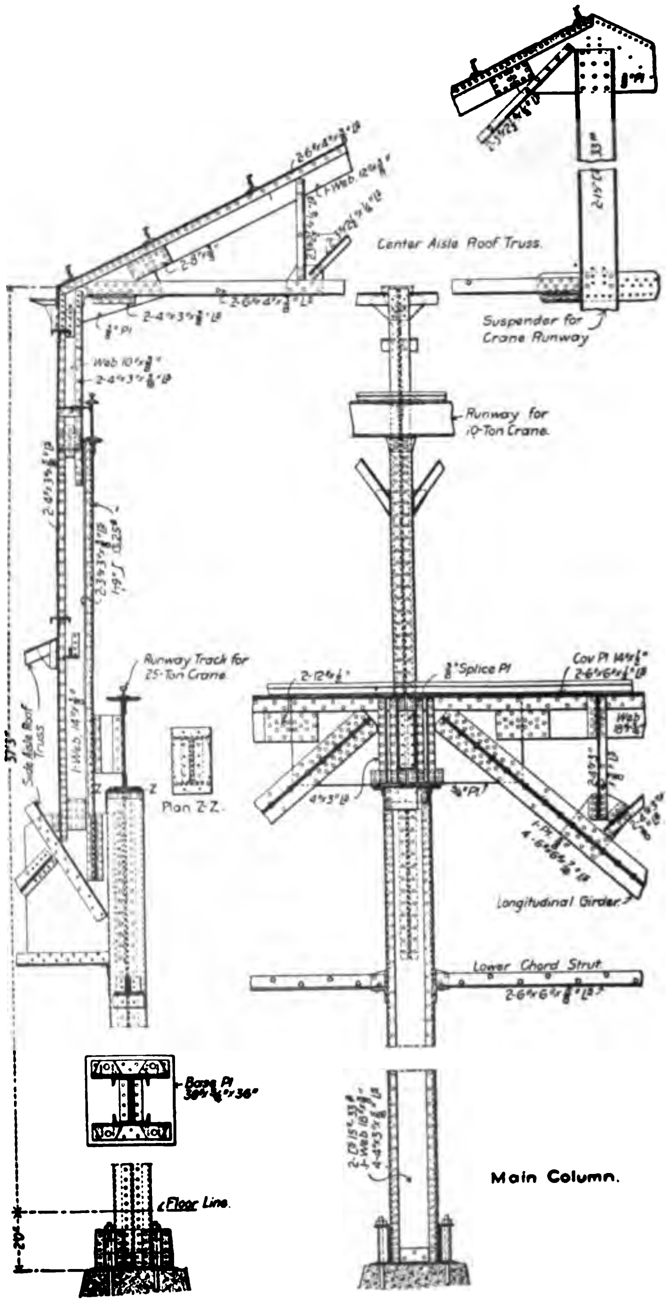

Center Aisle Roof Truss.
Suspender for Crane Runway
Runway for 10-Ton Crane.
Runway Track for 25-Ton Crane
Plan Z-Z.
Side Aisle Roof Truss
Splice Pl
Longitudinal Girder.
Lower Chord Strut
Base Pl
Floor Line.
Main Column.

Fig. 219.

shops. They are light, can be easily and quickly handled, and are used in single lines (Fig. 224) or in double tiers, one above another (Fig. 225). The framing to support some makes of traveling jib cranes is shown in Figs. 226, 227 and 228.

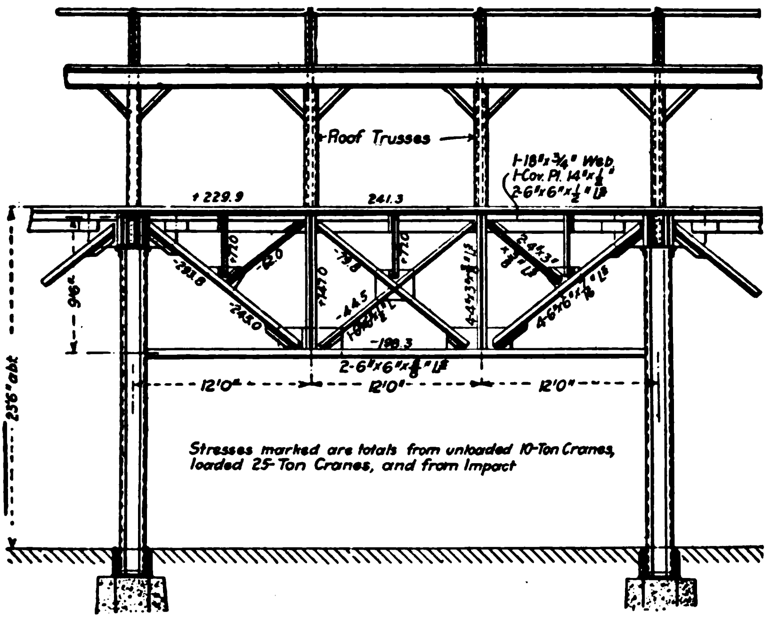


Fig. 220.

The older form of stationary jib crane, standing on the ground, has the upper end of the mast supported by a system of framing connected to the truss chords. These cranes produce heavy stresses in the bottom chord bracing, which must be properly transferred to the walls or columns, and thence to the foundations.

Crane girders may have either a single or a double web, the latter (Figs. 200, 229) with its wide cover plate producing a stiffer frame. Side longitudinal trusses to support intermediate roof trusses, should be either disconnected entirely from the crane system or fastened with slotted joints, so movements of the traveling cranes, and deflections or vibrations of the crane beams, will not be transmitted to the side wall or roof system, and break the window glass or skylight.

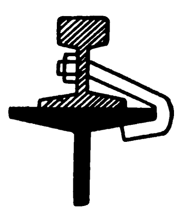


Fig. 221.

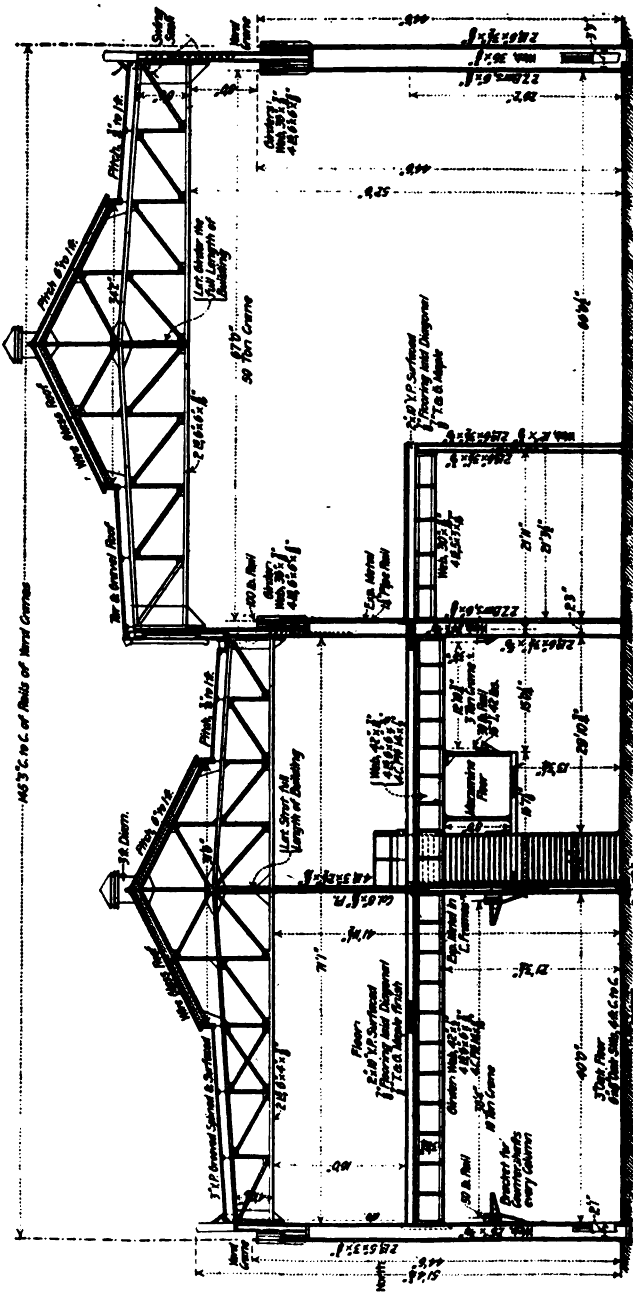


Fig. 222.

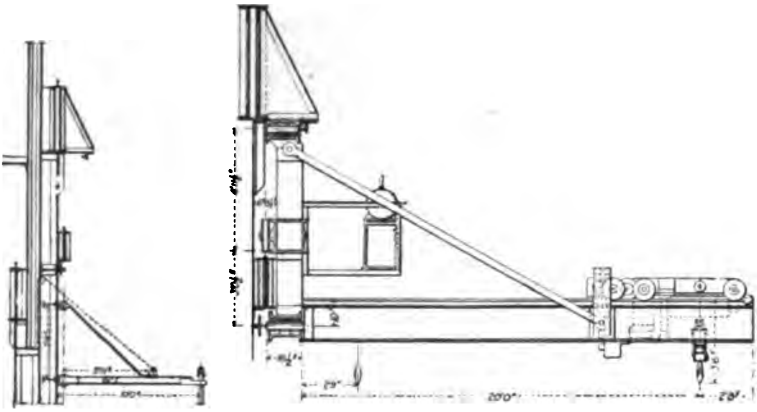


Fig. 223.

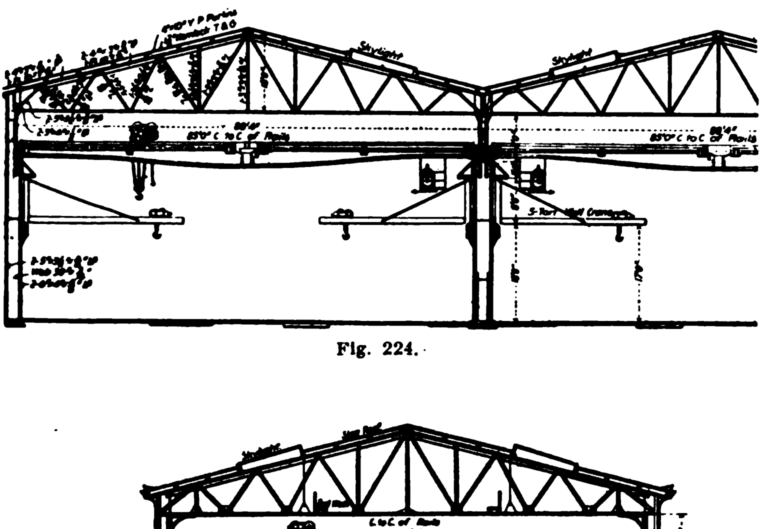


Fig. 224.

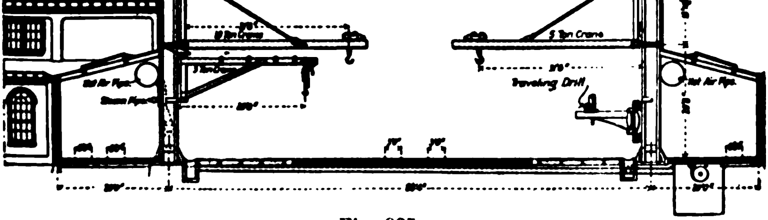


Fig. 225.

COLUMNS.

The weight of steel in trusses and girders is affected more by the number and frequency of columns than by any other factor. Framing with wide column spacing has a greater weight and cost, than similar framing with columns closer together. In many lines of manufacturing, the presence of columns is a disadvantage, for they interfere with handling the large material and products, but in shops for the manufacture of small goods, columns may be of benefit for supporting shafting or dividing the floor into separate parts.

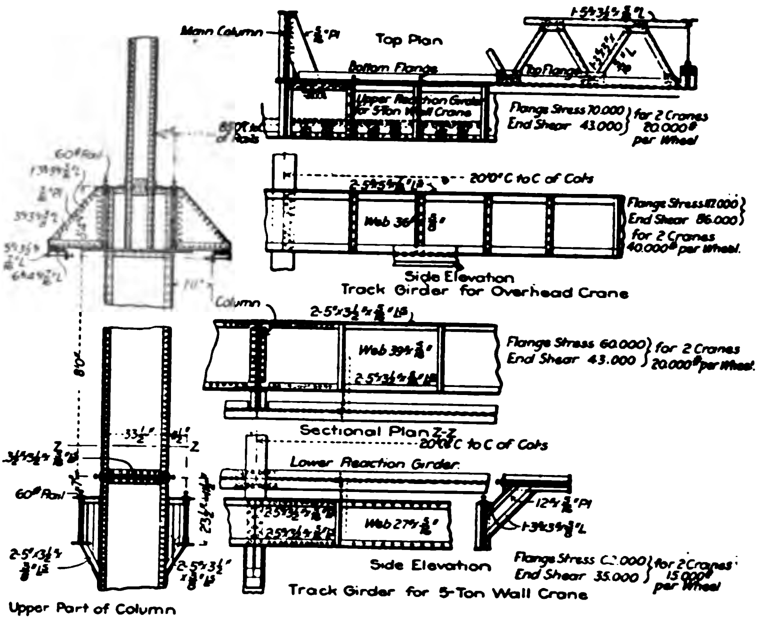


Fig. 226.

In order to have few inside columns, part of the regular roof trusses are sometimes carried on longitudinal trusses, which serve also as effective column bracing. Fig. 229 has regular transverse trusses 20 feet apart, with alternate ones on lattice girders, making a clear space of 40 feet between the principal inside columns, while Fig. 220 has trusses 12 feet apart, with every third one supported directly on columns 36 feet apart.

The trusses and other parts should be so arranged that loads are delivered to the columns as low down as possible, for long loaded columns require greater section than shorter ones. Diagonal compression members in connecting trusses (Fig. 142) are therefore often preferable to tension members (Fig. 141), for while the truss members are increased, the extra expense is more than offset by the saving in and greater security of the columns, which may be subject to jars or impact.

Fig. 230 shows a variety of common column forms, the ones most used being a, b and c. Closed sections should not be used, for connections to them are not easily made, and their inside condition cannot be inspected. Rolled H shapes (Fig. 230d) with wide flanges, which have long been used in Europe, are now made in America, and are well suited for shop columns, saving much riveting; but they are sold at a higher price per pound than plate and angles, and this tends to offset the saving in shop work. A column which is quite economical, though inconvenient for connections, consists of round wrought steel pipe filled with concrete, the 12-inch size being strong enough to support 100 tons or more. Round cast iron columns are frequently used for supporting gallery or upper floors, but on account of its brittle nature, cast iron is not recommended for structural use.

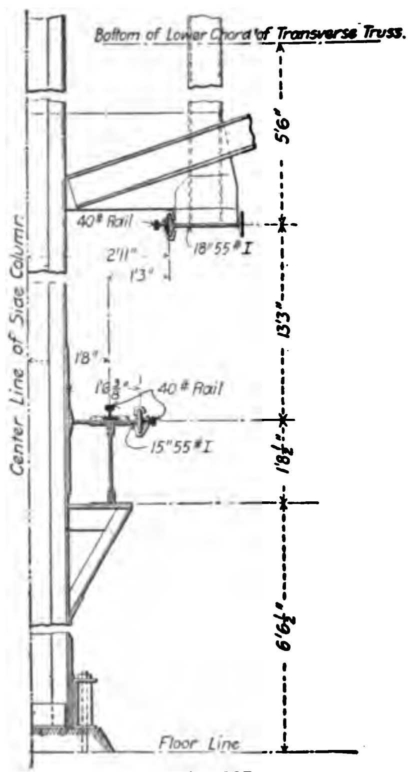
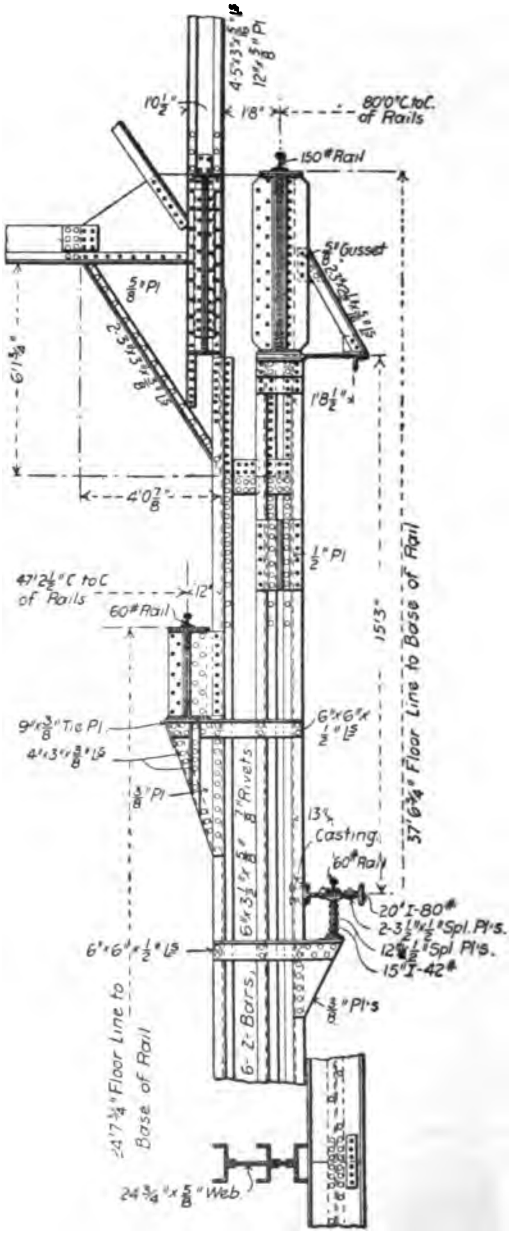


Fig. 227.

Open sections made of plates and angles are convenient for building into walls, as their width can be made to suit any size of brick, and they are easily enclosed. When the columns extend through the wall without being enclosed with pilasters, web lattice is unsuitable, as the space between the angle bars of the column leaves an opening through the wall, and a solid web plate should be used instead. Enclosed wall columns may have provision for expansion by leaving



80'0" C to C of Rails
150# Rail
1'8"
10½"
5/8" Gusset
5/8" Pl
6'1⅜"
4'0⅞"
1'8½"
½" Pl
47'2½" C to C of Rails
12"
60# Rail
15'3"
37'6¾" Floor Line to Base of Rail
9"x⅜" Tie Pl
4"x3"x⅜" Ls
6"x6"x ½" Ls
⅜" Pl
⅞" Rivets
13¾
Casting
60# Rail
20" I-80#
15" I-42#
6"x6"x½" Ls
⅜" Pl's
6- Z- Bars,
24'7¾" Floor Line to Base of Rail
24¾"x⅝" Web

Fig. 228.

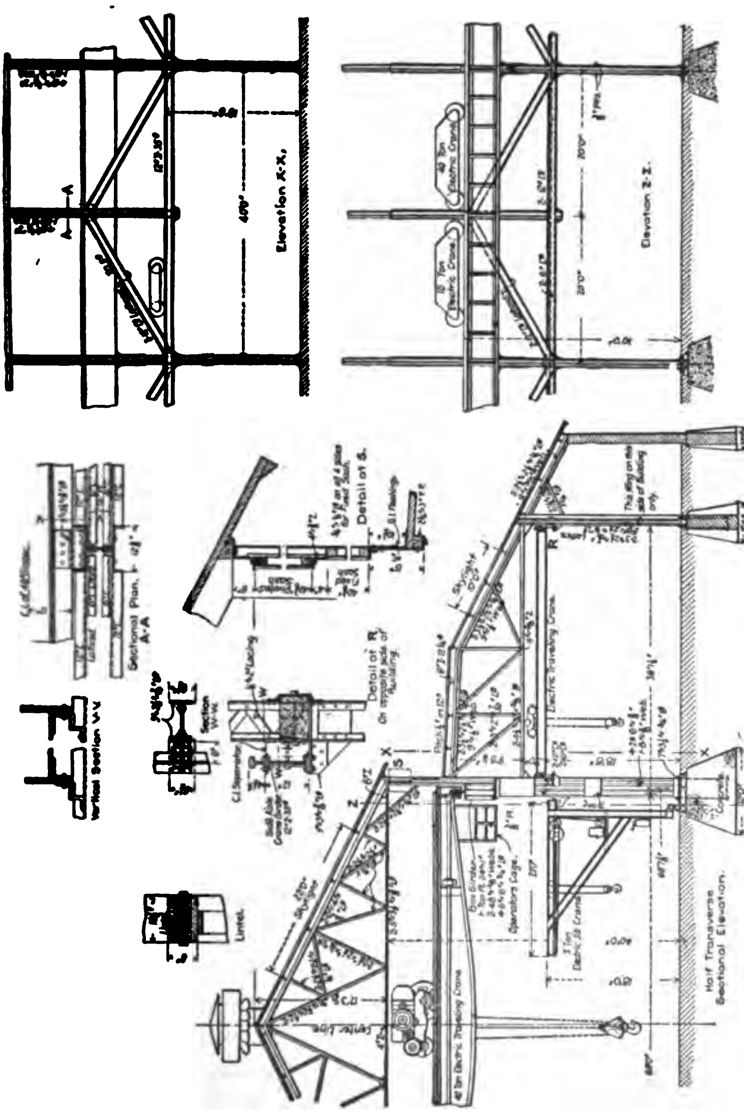

Elevation X-X.
Elevation Z-Z.
40 Ton Electric Crane
10 Ton Electric Crane
Sectional Plan, A-A
Vertical Section V-V
Section W-W
Lintel.
Detail at S.
Detail at R. On opposite side of building.
Electric Traveling Crane
Operators Cage.
Center Line
Half Transverse Sectional Elevation.

Fig. 229.

clearance between the brick and steel (Fig. 231), the brick casing being a complete enclosure without touching any part of the column. Wall columns having excessive bending stress from knee braces should, when necessary, be reinforced on the inner or greatest compression flange with extra section, as shown in Fig 232.

Pier shed columns are sometimes sloped (Fig. 198) or extended above the roof (Fig. 196) to support lattice girders or framing, which are useful in unloading goods from vessels.

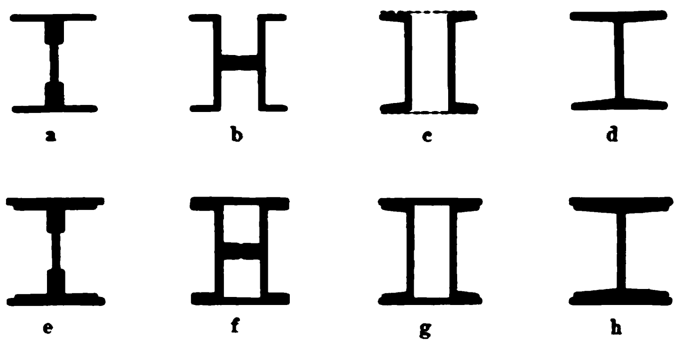


Fig. 230.

When provision is made for extending the building, the principal end columns should be similar to the regular ones, for they can then be used for the extension, without strengthening or replacing them, and much expensive alteration will be avoided. Regular roof trusses should also be used, and the end enclosed with a temporary frame of columns and girths covered with board, or corrugated iron

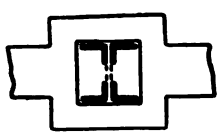


Fig. 231.

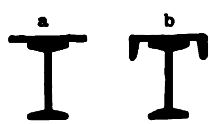


Fig. 232.

sheathing. End columns should have a full symmetrical section up to the level of the bottom chords, above which the outer two angles only may be extended to the roof, forming a convenient support for the gable purlins. The end of buildings without provision for extension should have columns 10 to 15 feet apart, supporting a gable rafter instead of an end truss, with a stiff member at the bottom chord level to act as chord for the horizontal bracing system. This construction is much cheaper than using end trusses, but is not convenient for extending the building. End crane girder columns must be made of proper strength to carry the crane loads, and must also have end girth connections.

It is sometimes convenient to frame the end of a building so the traveling shop crane with its load can be run out into the loading yard (Fig. 621). An arrangement of this kind was used by the author, in 1898, in the design and construction of a structural shop

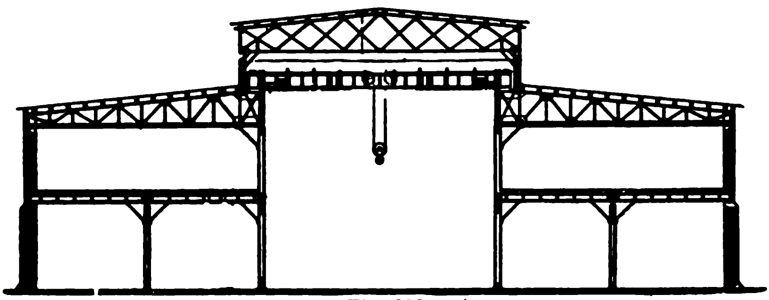


Fig. 233.

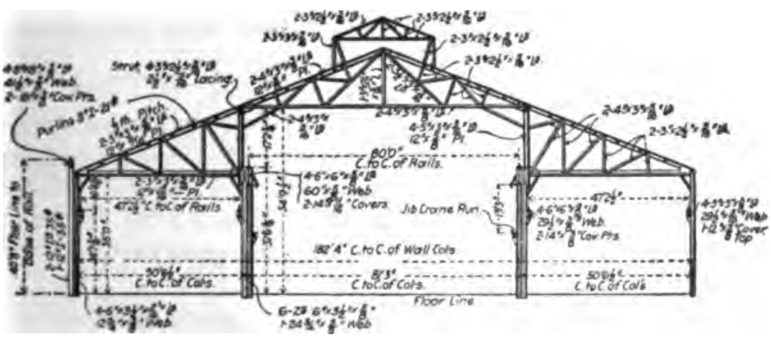


Fig. 234.

in the East, and was found satisfactory. The end is enclosed with rolling steel shutters, held in place by hinged posts, which are swung up out of the way when the end is opened for the crane. The end may be partly enclosed with brick, as shown, with only the center panel fully open, or each of the three panels may have rolling shutters to the floor. A car barn with the end similarly enclosed with rolling shutters is shown in Fig. 622.

Crane columns must have proper seats to support the crane girder. Brackets are suitable only for light cranes, as they produce eccentric column loads, which are a frequent cause of excessive vibration in improperly designed buildings, resulting continually in broken skylights and windows. A properly designed column for supporting crane girders will be as outlined in Fig. 235a, and not like b or c, as both the latter have eccentric loading. Columns supporting two tiers of crane girders, one above the other, may have girders for the lighter crane, supported as illustrated in Fig. 219, but crane columns must in all cases be fastened to the roof trusses or otherwise tied together at the top, to prevent the crane track from getting out of line. If bracket or eccentric connection is necessary for either the roof or crane loads, it should be used for the smaller of the two, which is frequently the roof load on the clear story column. This construction is illustrated in Figs. 228 and 218. Struts should connect the upper end of clear story wall and wall columns at the eave.

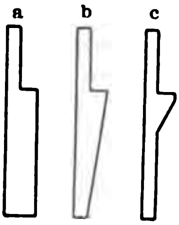


Fig. 235.

Traveling jib cranes necessitate quite elaborate framing on the columns to carry the lines of rails for their support (Figs. 226, 227, 228), and longitudinal trusses require additional framing. In detailing columns, the connections should first be designed, and minor details such as lattice or batten plates located afterwards.

The large flaring bases of interior columns (Figs. 219, 220) should be depressed below the floor to avoid obstruction and should preferably be coated heavily with asphalt paint. They should have only the fewest possible number of rivets in the base to avoid the expense of countersinking. An original table for the weight of cast iron column bases similar to Fig. 238 is as follows:*

TABLE XXIV.*

WEIGHT OF CAST IRON COLUMN BASES.

22×22 ins.	600 lbs.	32×32 ins.	1,340 lbs.
24×24 ins.	750 lbs.	34×34 ins.	1,450 lbs.
26×26 ins.	880 lbs.	36×36 ins.	1,600 lbs.
28×28 ins.	1,020 lbs.	38×38 ins.	1,720 lbs.
30×30 ins.	1,180 lbs.	40×40 ins.	1,850 lbs.

A circular column form is sometimes preferable to open steel work, in which case the interior columns may be enclosed for a height of 5 feet above the floor with concrete, held in place with a light sheet metal form. The sheet metal, if allowed to remain, makes a smooth resisting surface, and may be preserved by painting.

* H. G. Tyrrell, in Architects' and Builders' Magazine, Jan. 1903.

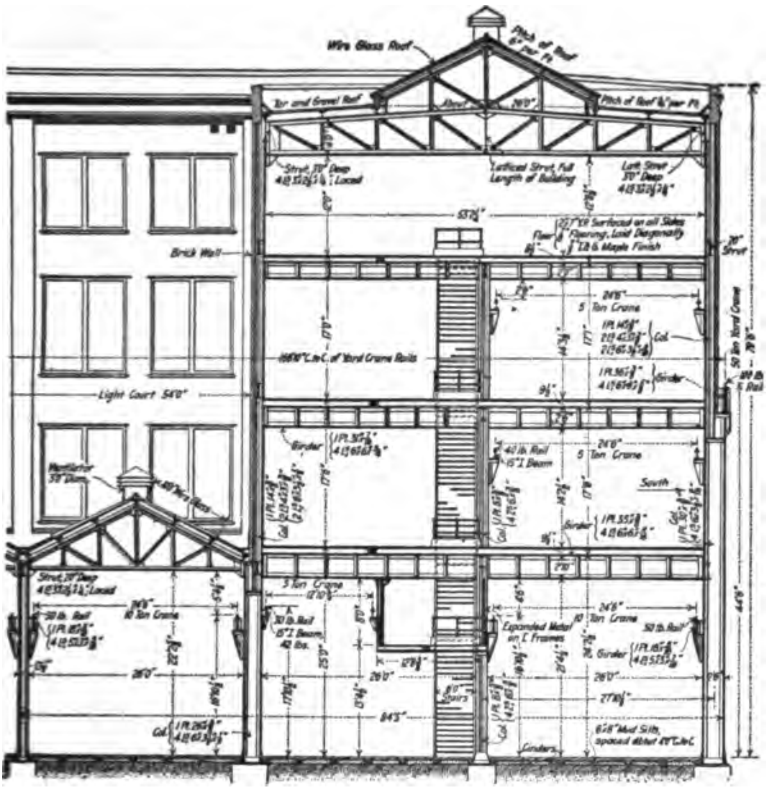


Fig. 236.

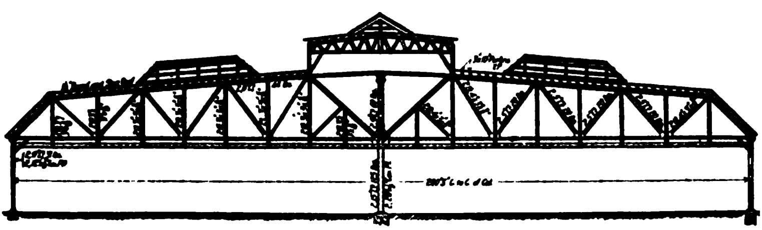


Fig. 237.

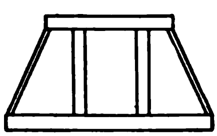


Fig. 238.

Buildings may occasionally be more convenient when made without any interior columns, as in the armory and drill hall (Figs. 239 to 241).

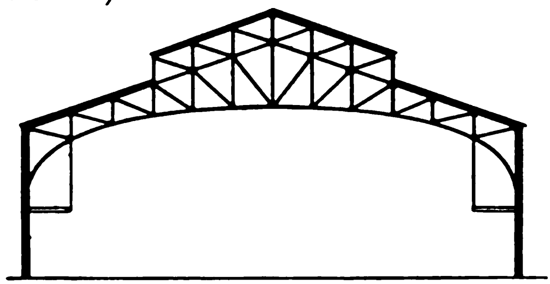


Fig. 239.

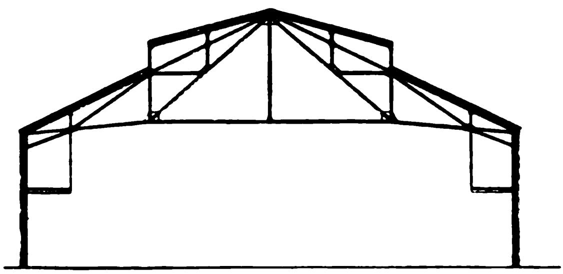


Fig. 240.

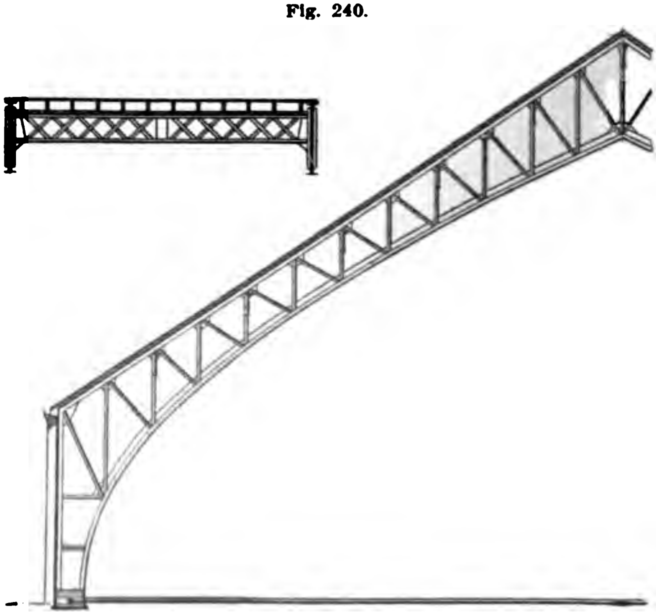


Fig. 241.

See Architects' & Builders' Magazine, October, 1901.

FLOOR FRAMING.

Steel floor framing may have steel for all or only part of the supports. The cross floor girder at the panels may span the clear space between main columns (Fig. 222) or may have one or more additional columns under it (Fig. 20), which will greatly lessen the combined cost of girder and columns. Heavy floor girders are shown in the pier shed (Fig. 196). Floor joist between the girders may be of either steel or wood, and may rest on top of the girder or frame into the web (Fig. 410), the latter being preferable, as it leaves greater head room below. Joists are generally placed from 4 to 10 feet apart, the distance depending on the kind and thickness of flooring. They should rest on angle seats on the girder web (Fig. 410), and steel beams are fastened with standard connection angles such as are given in any mill hand book. Plank flooring on steel joist requires nailing strips bolted or hooked to the upper flange, to receive the nails. Cupola floors carrying heavy loads must be strongly framed and supported with numerous columns, and are frequently covered with steel or cast iron floor plates. Gallery floors may be provided with occasional loading platforms projecting over the main erecting floor, from which material can be lifted by the center traveling crane. A machine shop designed by the author has a bridge at one end connecting the two side galleries (Fig. 23) and two or three lines of gas pipe fastened to the columns with intermediate pipe posts 8 to 10 feet apart for gallery railing.

BRACING.

The durability of a mill building depends on the efficiency of its bracing. Columns, girders, trusses or other main parts are rarely broken under their loads, but building frames have been racked to pieces by continuous vibration from cranes and machinery. Stationary and traveling cranes, shafting, belts, eccentric column loading, and many other causes, tend to keep the frame of a mill building in constant motion, and unless this is prevented by thorough bracing, it will soon require expensive repairs. When the frame becomes loosened, traveling cranes bind on their track, production is delayed, and the cost of operation is increased. Broken windows and skylights are a common result of insufficient bracing, and even when replaced they are repeatedly broken again. Lack of bracing affects operating expenses, for 10 to 30 per cent more power is needed to run line shafting and machinery in a building that vibrates than in a stationary one. It also causes undue wear on machines and interferes with fine tool work.

The general outline of a building is important in securing rigidity. A form like Fig. 142 is more secure transversely than one like Fig. 155, and a hipped roof is nearly always stiffer than a continuous pitch. Angles braced together to resist compression are preferable to rods, though the latter have their legitimate use. When rods are used, they should have adjustment either by means of nuts and bevel washers or with clevises or turnbuckles. Standard rod details are shown in Figs. 242 and 243, and light bracing struts in Figs. 244, 245 and 246.

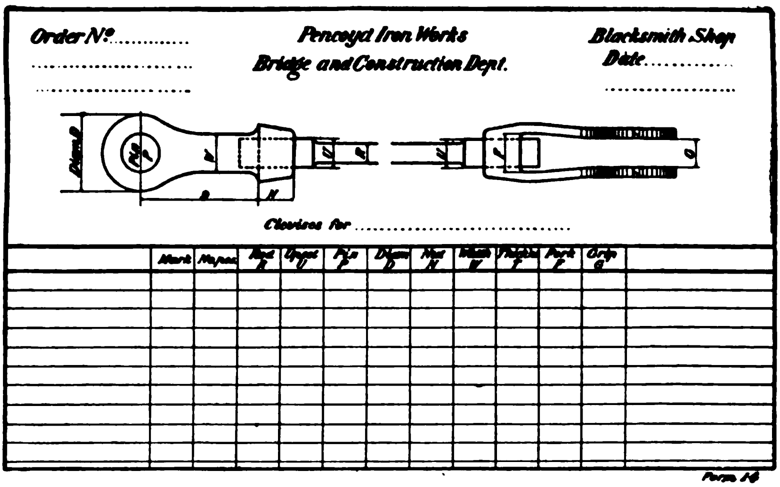


Fig. 242.

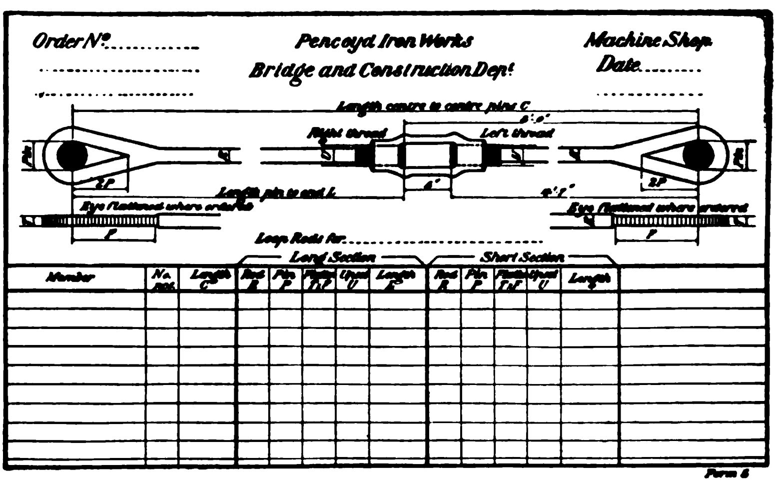


Fig. 243.

Bracing must be placed wherever needed, the most important being that on the rafter and bottom chord, and between columns in the walls; but other bracing may be used in the monitor, and vertically between the trusses. Rafters are the chief compression mem-

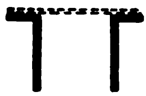


Fig. 244.

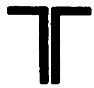


Fig. 245.

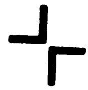


Fig. 246.

bers of roof trusses, and cross bracing must be placed in occasional panels, corresponding with the bracing in the bottom chord, and other rafters are tied to the braced panel with the purlins and roofing. Rafter bracing is more needed during erection than afterwards, for when applied and fastened, the roofing itself is the most effective kind of bracing, especially when it consists of plank or

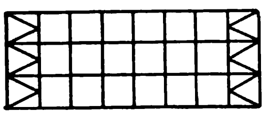


Fig. 247.

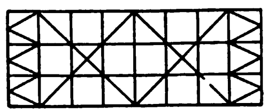


Fig. 248.

concrete. Car sheds or buildings without machinery are sufficiently rigid with occasional panels of the bottom chord braced, and two or three lines of longitudinal spacing angles between the chords (Fig. 247), but buildings with cranes require complete diagonal bracing systems (Fig. 248). The longitudinal spacing struts of Fig. 247

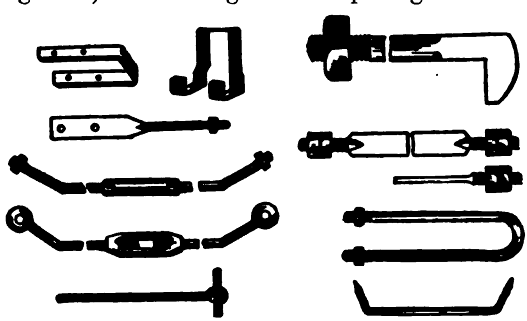


Fig. 249.

may be omitted in car barns which have lines of trolley boards fastened to the trusses. Bottom chord bracing, to resist the action of stationary and traveling jib cranes, must be carefully proportioned to its maximum stresses, and these stresses must be as carefully computed as those in any other truss system. It is generally impracticable to transfer all the crane and wind loads to the foundations at the ends of the buildings, and knee braces from trusses to columns are therefore introduced. Wall bracing must be placed in panels corresponding with those in the rafter and bottom chord, and longitudinal trusses (Fig. 220) make effective bracing between interior columns. Stiff bracing is nearly always more effective than rods and is therefore preferable. Care should be taken to have the parts properly arranged, that chords and web members of any truss system will act together, and the joints should be well riveted.

Knee braces from trusses to columns must join the trusses at braced panel points, which are capable of transmitting stress directly to the truss frame. These braces should be as deep as head room or clearance will permit, and they must be capable of resisting both tension and compression. Clearance for traveling cranes frequently limits the space available for corner bracing, and when space above

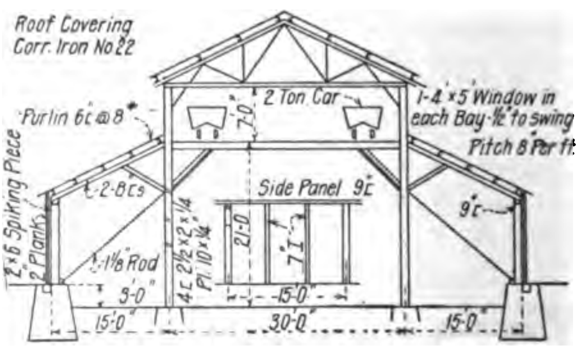


Fig. 250.

the center part of the crane is not required for machinery or trolleys, it may be preferable to give the truss enough end depth so the end bottom panels, which act as knee braces, will be in line or nearly in line with the bottom chord (Fig. 179). Knee braces may also be placed between crane girders and columns, or wherever their presence adds stiffness to the building.

After the framing has been arranged and designed, it is well to review the methods of bracing and see where this feature of the building can be improved. Places may be found where additional bracing is needed, and other places where it is ineffective or unnecessary. Special framing may also be needed for tanks, stairs or elevators, and for shop offices, toilet or tool room partitions. Fig.

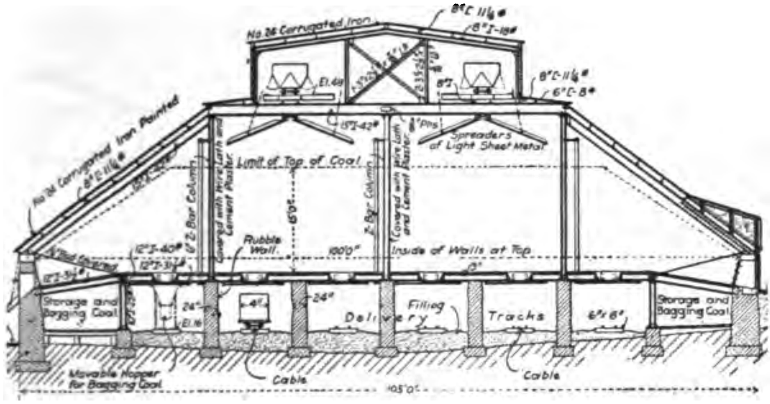


Fig. 251.

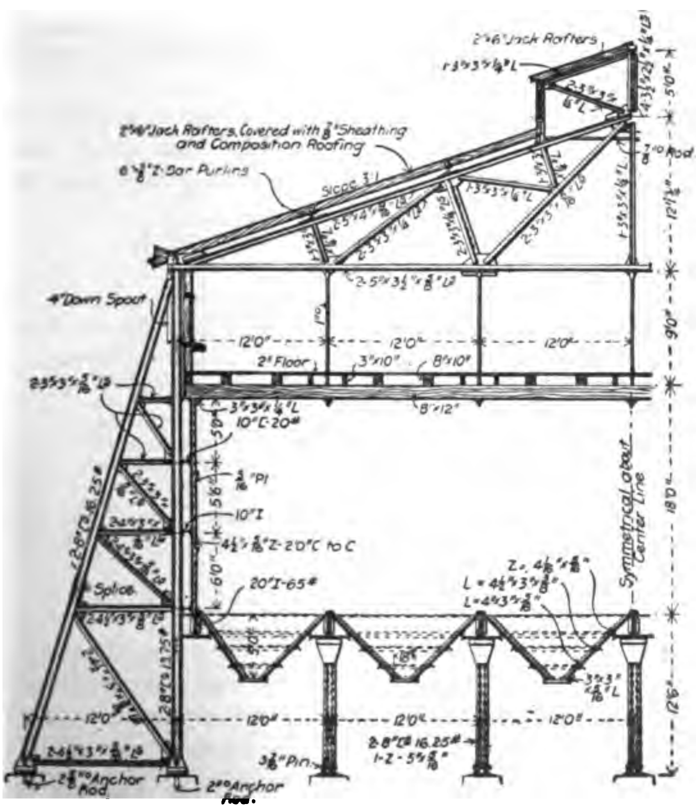


Fig. 252.

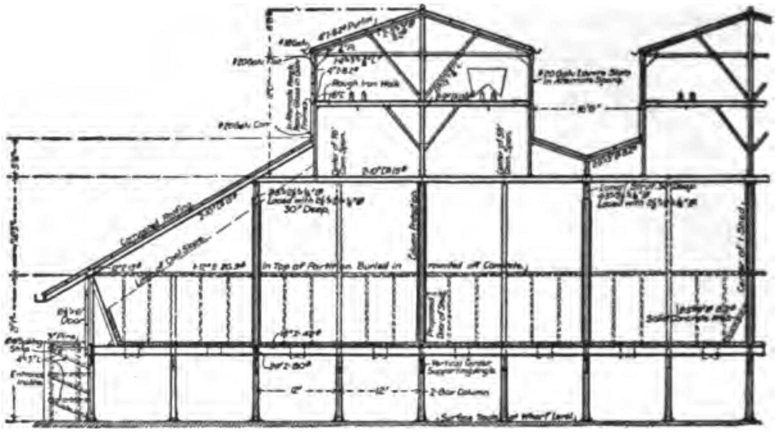


Fig. 253.

249 shows details of anchors, bolts, straps, stirrups, expansion bolts, etc.

Large riveted sections must have field splices so arranged that no section will have dimensions exceeding those which can be accepted by the railroads or other transportation lines over which they are carried.

TABLE XXV.

MAXIMUM SHIPPING DIMENSIONS ACCEPTED FOR TRANSPORTATION BY THE RAILROADS OF THE UNITED STATES.

Height above rail top of	*Maximum width of*
12 ft. 4 ins.	10 ft. 0 ins.
12 ft. 8 ins.	9 ft. 9 ins.
13 ft. 0 ins.	9 ft. 0 ins.
13 ft. 4 ins.	8 ft. 8 ins.
13 ft. 8 ins.	8 ft. 4 ins.
14 ft. 0 ins.	7 ft. 2 ins.

NOTE.—A height of 4 ft. 6 ins. should be allowed for car above rails. The width for loading is usually 8 ft., but if greater, it should be specially noted before making.

COAL STORAGE SHEDS.

Fig. 250 shows a design by the author for a coal storage shed, 60 feet wide and 473 feet long. The side foundation walls stand 3 feet above the ground, and the main side columns, which are 15 feet apart, act also as beams to resist the side pressure of the coal, and are tied from the base to the building frame. Intermediate steel studs 5 feet apart support the plank sheathing.

Other coal shed designs are shown in Figs. 251 to 254, the last being designed by Mr. F. M. Bowman. Designs for boiler house coal bins are illustrated in Fig. 255.

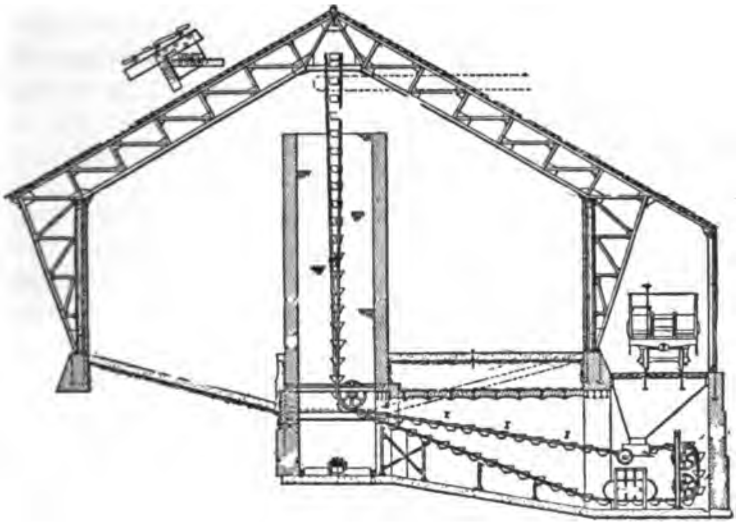


Fig. 254.

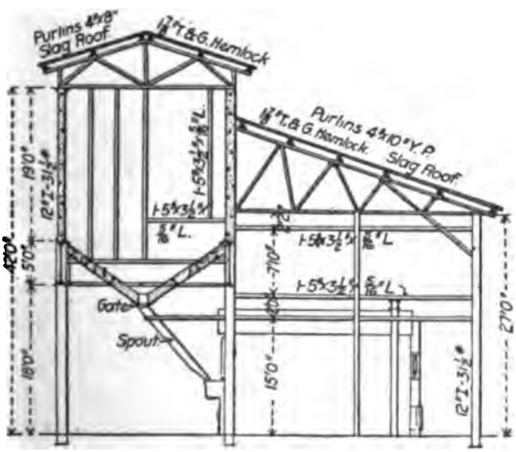


Fig. 255.

CHAPTER XV.

WOOD FRAMING.

Timber is still much used, especially in the South and West, for framing mill and factory buildings, although in the North and East its increased cost is causing it to be replaced with steel and concrete. It is well known that properly designed timber frames will collapse less quickly in a fire than unprotected steel, which warps and bends easily under heat and allows the roof to fall.

In order to be reasonably safe against fire, timber frames must be designed according to a few well established principles, which are as follows:

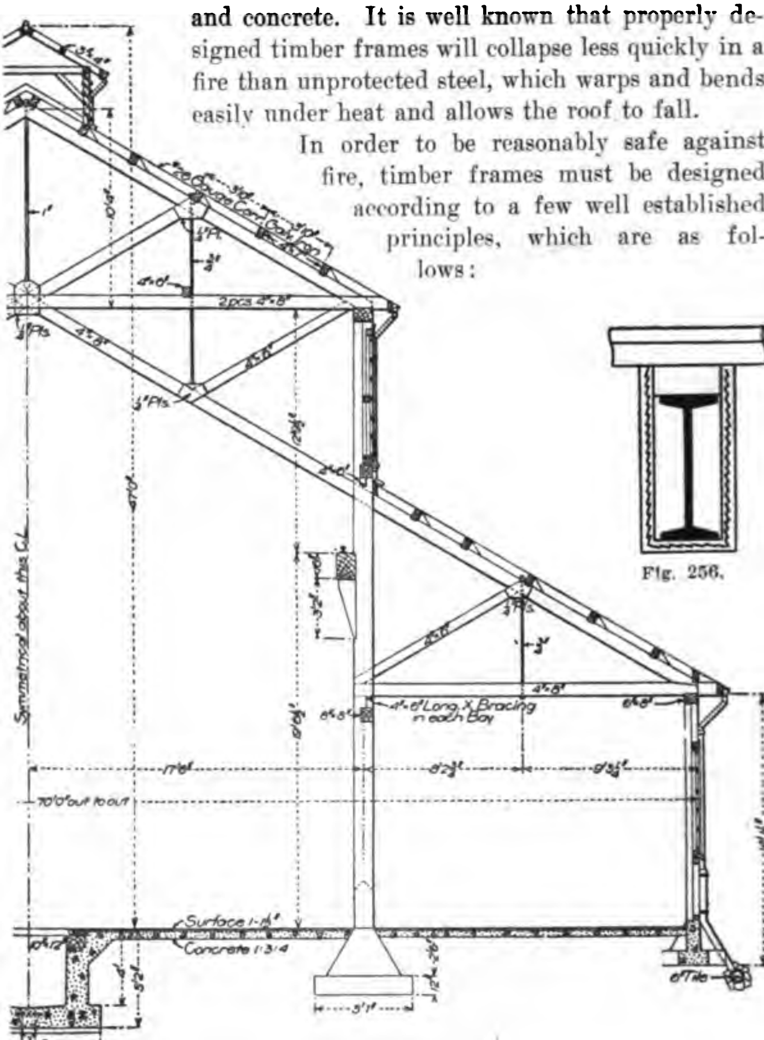


Fig. 256.

Fig. 257.

(1) Framing must have the least number of corners and the smallest possible amount of exposed surface.

(2) Floor beams must be made in large sizes, 5 to 10 feet apart, the wider spacing preferred, and must be covered with at least two layers of matched or splined flooring plank, with two or three thicknesses of asbestos paper between them. They must be proportioned for weight, deflection and vibration, and when steel beams are used with wood nailing pieces on their upper flange, the steel must be surrounded with wire lath and plaster. (Fig. 256).

(3) There must be the fewest possible number of floor openings, or preferably none, through which fire may pass, but when they are necessary, as at elevator openings, must be covered with automatic closing doors.

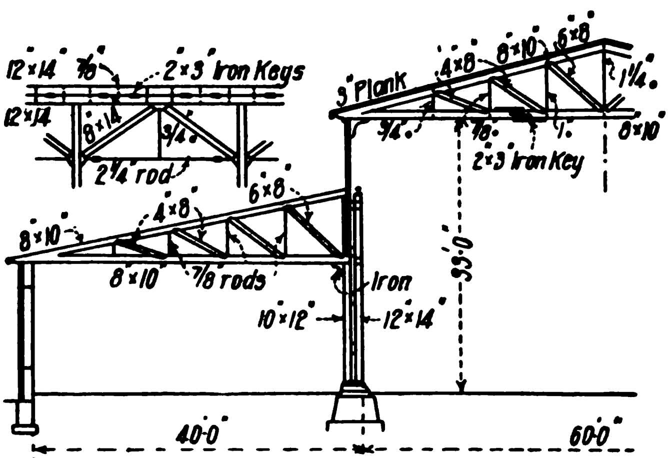


Fig. 258.

(4) Stairways must be placed in separate towers with fireproof walls, and landings one inch below the regular floor level with door openings covered with automatic self-closing tin-clad or other fireproof doors.

(5) There must be no concealed or enclosed spaces in the walls or floors through which fire can travel, the object being to leave all wood surface exposed so water can be turned upon it in case of fire.

(6) Ceilings are permitted only where heat endangers the woodwork, as over boilers, and they must then be placed directly against the wood surface and around the beams with the least possible air space between the metal lath and the wood.

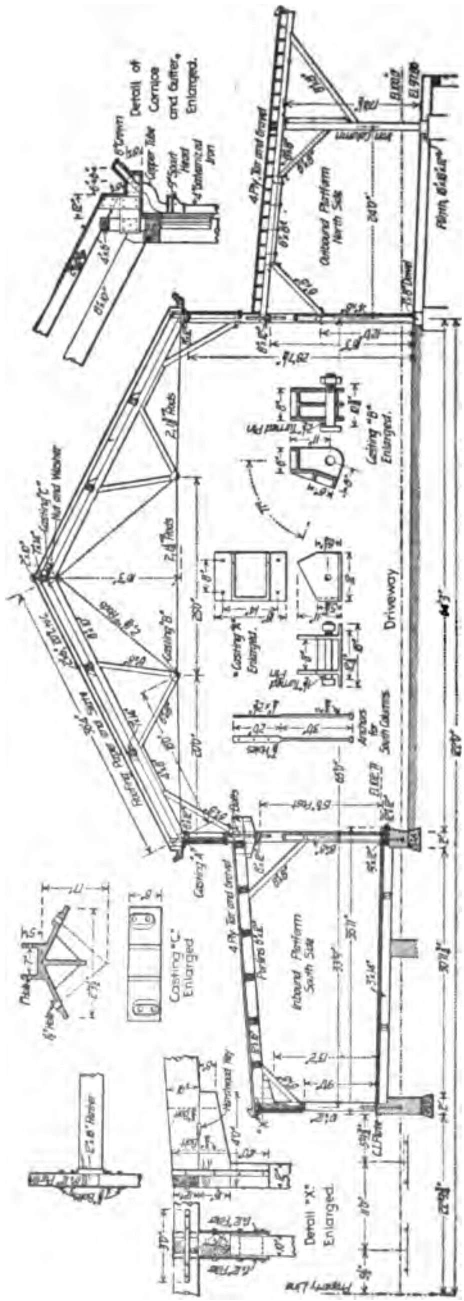

Detail of Cornice and Gutter, Enlarged.
Outbound Platform North Side
Inbound Platform South Side
Driveway
Casting "A" Enlarged.
Casting "B" Enlarged.
Casting "C" Enlarged
Anchors for South Columns
Detail "X" Enlarged.
Property Line

Fig. 259.

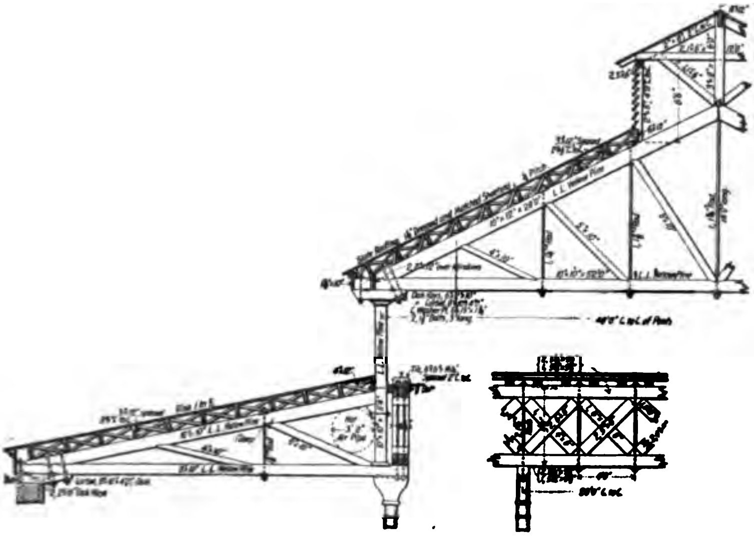


Fig. 260.

(7) Wood furring on walls is not permitted.

(8) Wood must be well seasoned before painting, and for two or three years should be coated with nothing more impervious than whitewash or kalsomine. Oil paint or varnish is not permitted.

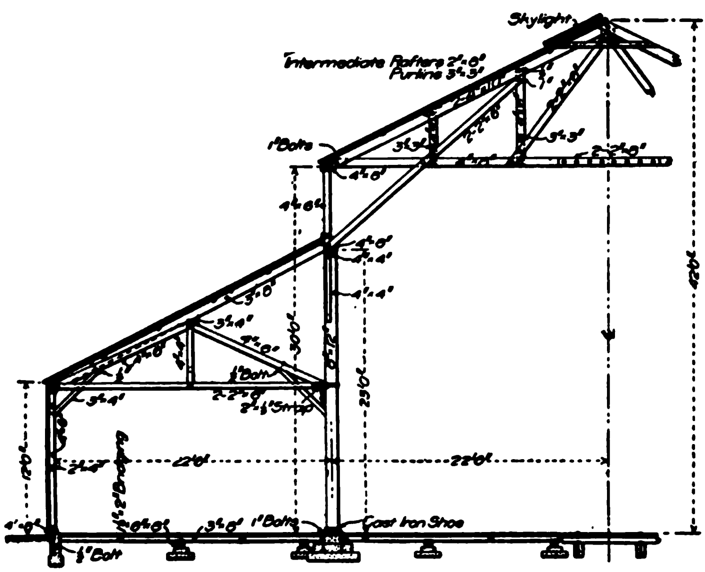


Fig. 261.

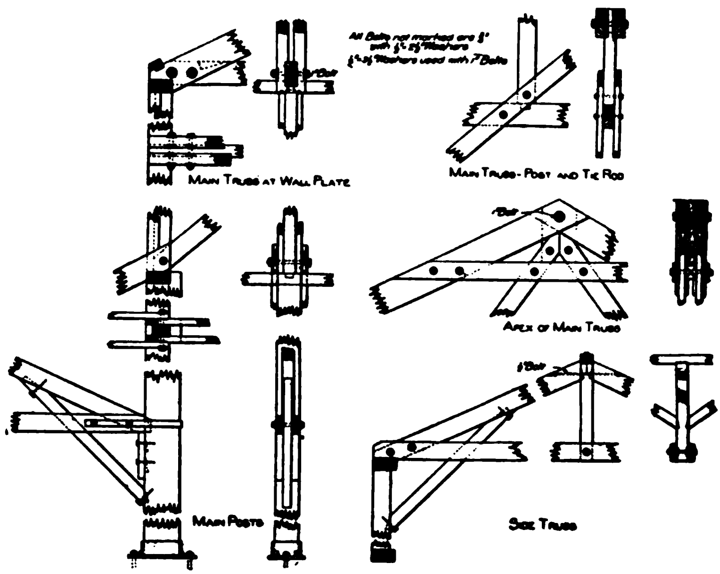


Fig. 262.

(9) Partitions must be made of brick, tile, concrete, asbestos or sheet metal. Wood partitions are not allowed.

(10) Windows exposed to fire from adjoining buildings must be protected with fire shutters or have wire glass, the latter being preferred. Lintels must be of reinforced concrete or brick arch rather than timber.

(11) Timber columns are preferred to exposed cast iron or steel, and may be loaded to 600 pounds per square inch. They may be placed at 20 to 25 feet apart.

(12) All floors must have occasional scuppers through the wall at floor level to discharge the water in case of fire. (Fig. 266).

(13) There must be a complete and well organized system of fire protection.

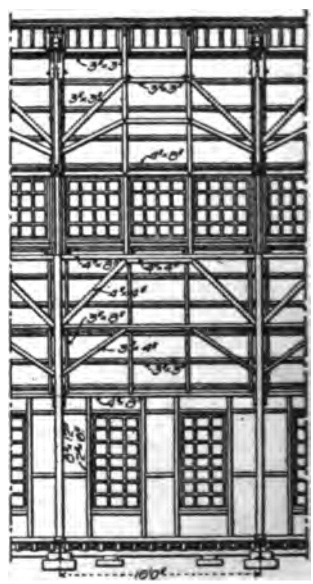


Fig. 263.

Wood roof covering may be made as described and illustrated in Chapter XX. Trusses are made all or partly of wood, combina-

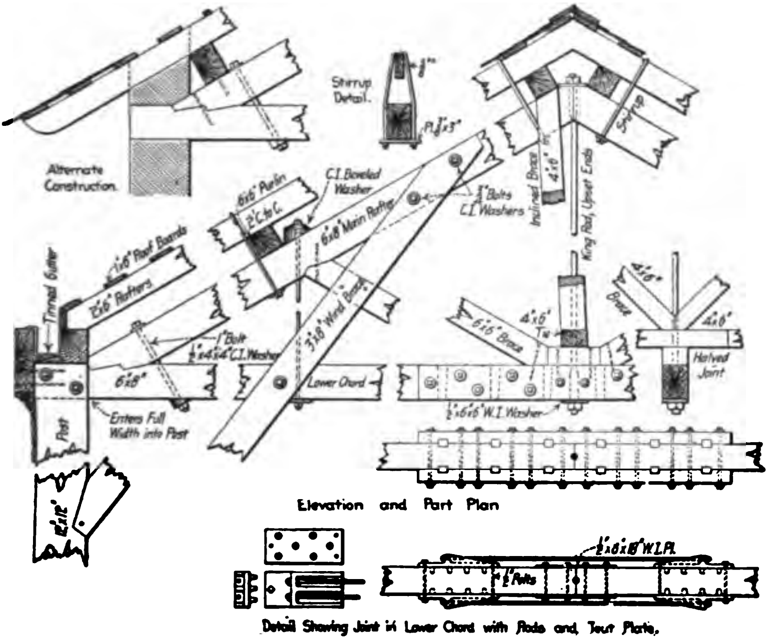


Fig. 264.

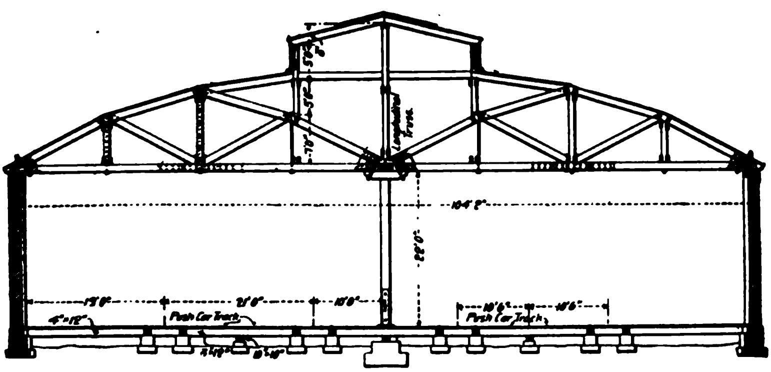


Fig. 265.

tion trusses having timber rafters and struts with rods for tension members. The panel lengths should be such as to give web members an inclination of 30 to 60 degrees to the horizontal. Wood trusses weigh about the same as steel ones of the same strength, and their weight is not affected greatly by a variation in roof slope from one-third to one-fifth the span. Cambering the bottom chord adds rapidly to the weight and cost. Timber lengths and sizes must frequently be used, which can be quickly procured from local yards, and a large wood framed building, designed by the writer, and built complete, in forty days, had trusses and columns made of 2-inch planks bolted together in the required thickness.

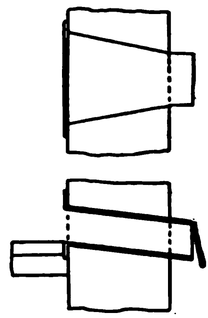


Fig. 266.

Observing the principles of simplicity and duplication will greatly cheapen construction. The general arrangement of the timber framing with the spacing of trusses and columns, should be about the same as outlined for steel. The necessary thickness of plank for various spans and loads is given in Table XLI.

Floor beams in the walls should bear on cast iron wall boxes or plates (Fig. 273), with upper corners of the beams cut to a bevel as shown. In case of fire, if the beams burn through and the floor falls, it will not carry the wall in with it. When wood beams are large, they may be made in two pieces. (Fig. 273a) doweled together, with a small ventilated air space at the center to prevent dry rot. Other details of wood floors are as described in Chapters XX and XXI.

Columns are usually of hard pine, bored with a 1½-inch auger hole through the center, with ½-inch ventilation hole at the top and bottom. Square columns are 25% stronger than round ones of the same thickness, and their corners should be rounded to a ¾-inch radius. Protection against fire must be secured by automatic sprinkling systems on the ceilings, and standpipes in the stair towers with hose attachment to each story. Water must be taken from two separate sources. In addition to these, fire pails and hand extinguishers should be freely placed about, and the occupants drilled in their use.

The cost of wood construction is given in Chapter VII.

Figs. 256-272 illustrate typical and recent details of timber framing for factory buildings.

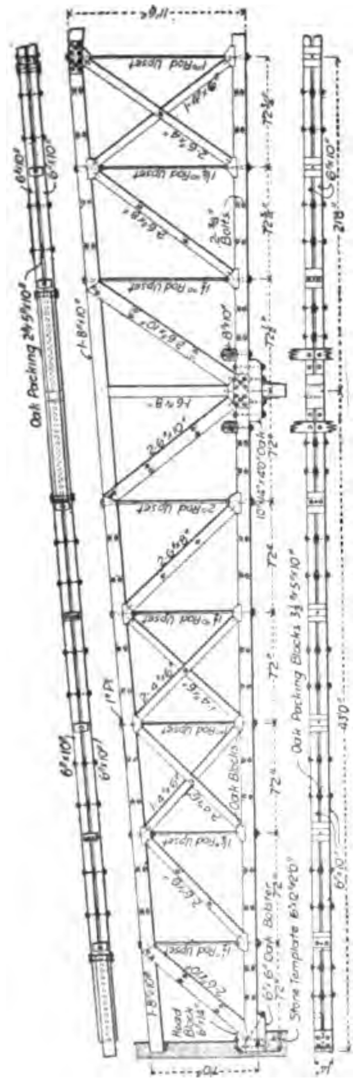


Fig. 267.

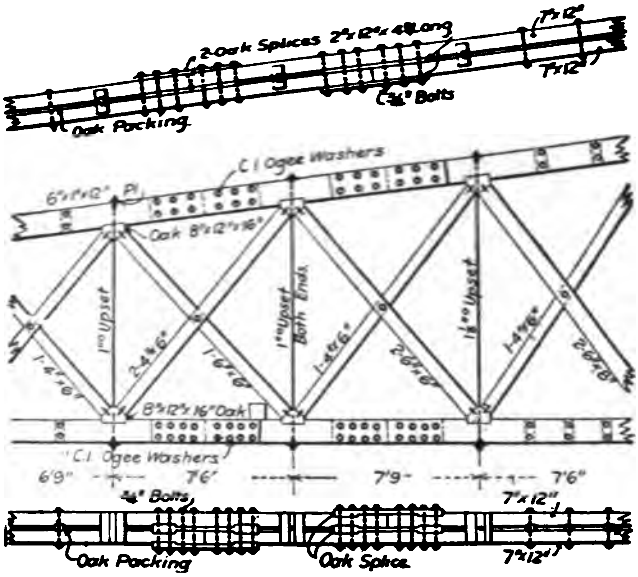


Fig. 268.

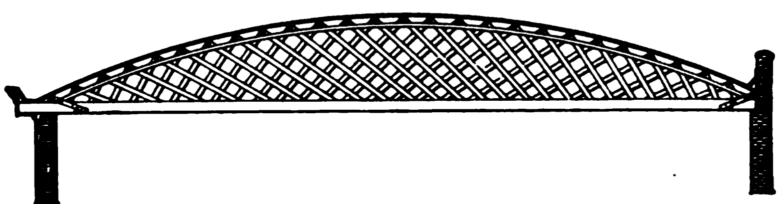


Fig. 269.

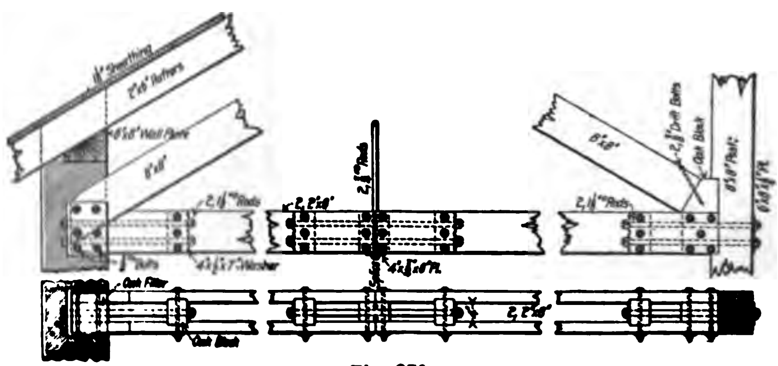


Fig. 270.

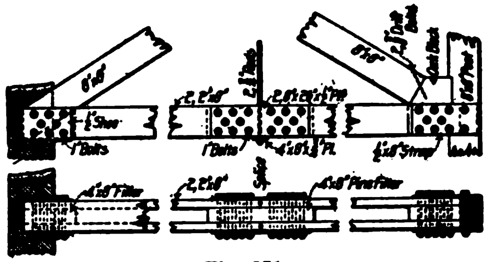
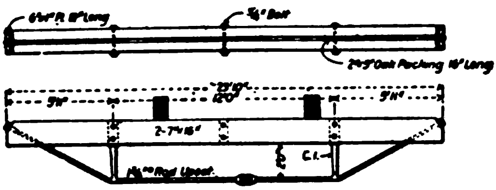
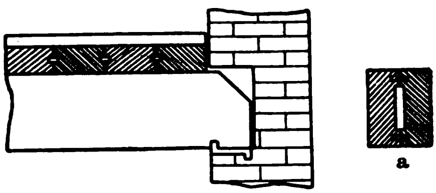


Fig. 271.



Purlins for Car Machine Shop

Fig. 272.



a

Fig. 273.

CHAPTER XVI.

CONCRETE FRAMING.

Several comprehensive books on concrete building construction have been written and only its application to mill buildings is given here. The material is well suited for manufacturing buildings, as it is fireproof, durable, free from vibrations, and the concrete materials can be quickly and easily procured. Money spent in building may be paid to local people instead of to others at a distance, as for structural steel. Delays in waiting for structural steel are avoided, and a building can generally be more quickly erected in reinforced concrete. Insurance charges on concrete buildings are small, usually not exceeding 15 cents per $100. Reinforced concrete buildings are cheaper than steel and cost only a little more than wood, the relative costs being given in Part I. Wood construction is generally limited to six stories, but concrete can be carried to a greater height. In case of fire, water does not leak through the floor and injure goods in the lower stories, which may occur with wood floors.

ADHESION AND BOND.

Rich cement concrete in which iron or steel is imbedded has an adhesion thereto of 500 to 600 pounds per square inch of exposed surface. Adhesion of concrete to metal occurs only when the metal is thoroughly imbedded and the concrete has opportunity to surround and grip the bars, but not when simply lying in contact with the metal.

It has been proven by numerous experiments that concrete adheres as securely to smooth rods as it does to rough ones. Frequent and continued shocks and vibrations tend to destroy the union between the two materials, and experiments show that continuous watersoaking from six to twelve months reduces the adhesion by about 50%. Poor workmanship in placing and ramming the concrete is also probable, and it is, therefore, desirable to use rough or twisted reinforcing rods, so the bar will have a mechanical grip on the concrete in addition to its adhesion.

When this roughening of the bar is secured without reducing its cross section, the whole area is then available in tension, and no strength is lost. Roughening the bars can therefore do no harm, and it may be the source of extra strength.

METAL REINFORCEMENT.

There is no sufficient reason from a scientific standpoint, for the use of high tension bars or rods for concrete reinforcement. After years of investigation and experiment, brittle metal was discarded for structural use, and the only reason for a return to high tension bars now, is a commercial one and not scientific. It is well known that in rerolling bars to produce surface roughening, the tensile strength of the metal is increased. Instead of admitting the inferiority of the bars, interested parties have endeavored to explain that this increase in tensile strength and corresponding decrease in ductility is a benefit. Medium steel with an elastic limit of 32,000 pounds per square inch, and soft steel with a corresponding elastic limit of 28,000 pounds per square inch, are proper grades of metal for all ordinary concrete reinforcement. These may safely be stressed up to half their elastic limit under working loads.

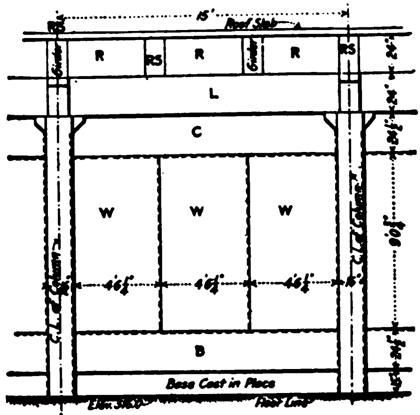
MONOLITHIC OR SEPARATELY MOLDED MEMBERS.

The present tendency in concrete construction appears to be towards the use of separately molded members. The objection to the method is the difficulty of handling and erecting the heavy blocks, but this is overcome by the use of a derrick car. The separately molded members (Figs. 274, 275 and 276) contain slightly more reinforcing steel, and have the extra cost of erection, but nearly all the expense of forms and carpenter labor is avoided. The shop floor may first be laid and used as a molding platform for the members, or a separate one adjoining the shop may be laid especially for the purpose.

One set of forms will serve to cast 100 pieces or more, or previously made concrete members properly placed can be used instead. Pieces are jointed with neat cement, and where bolting is needed, as when girders rest on columns, pipes are cast into the concrete in the right positions. Four-inch slabs cast in this manner, cost as follows:

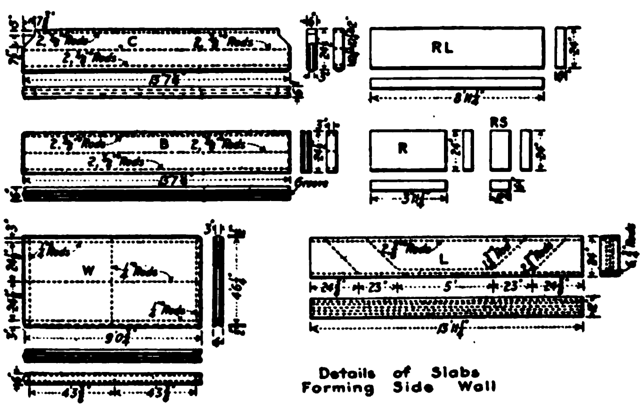
TABLE XXVI.

Steel	$2.36 per 100 sq. ft. or	30 % of total cost
Concrete material	2.55 per 100 sq. ft. or	32 % of total cost
Carpenter labor	.59 per 100 sq. ft. or	7½% of total cost
Labor, mixing and placing......	.56 per 100 sq. ft. or	7 % of total cost
Erection	1.86 per 100 sq. ft. or	23½% of total cost
	$7.91	100 %



Elevation of Side Wall

Fig. 274.



Details of Slabs Forming Side Wall

Fig. 275.

TYPE OF CONSTRUCTION.

A very convenient type of construction for shops and mills, is one where columns, sills, lintels, foundations, floors and beams, are made of reinforced concrete, and trusses and heavy girders of steel,

Fig. 277. Trusses are sometimes made in reinforced concrete, but they are clumsy and the form work is expensive. Heavy girders such as those carrying cranes which are subject to shock, are more reliable and smaller in steel. Wall panels between the columns may be filled with brick or concrete, or a combination of the two

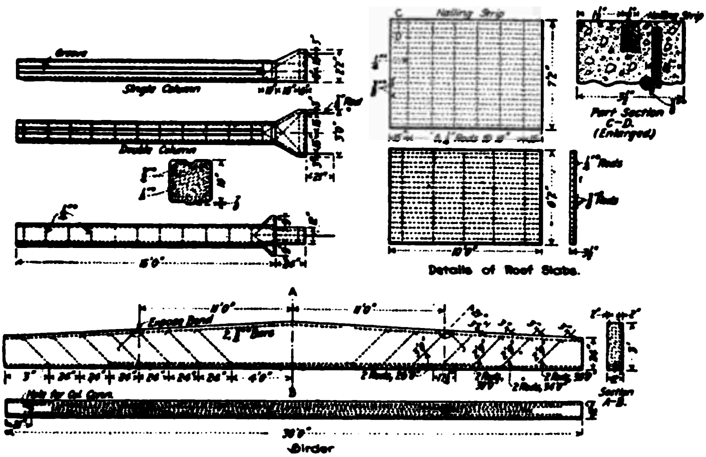


Fig. 276.

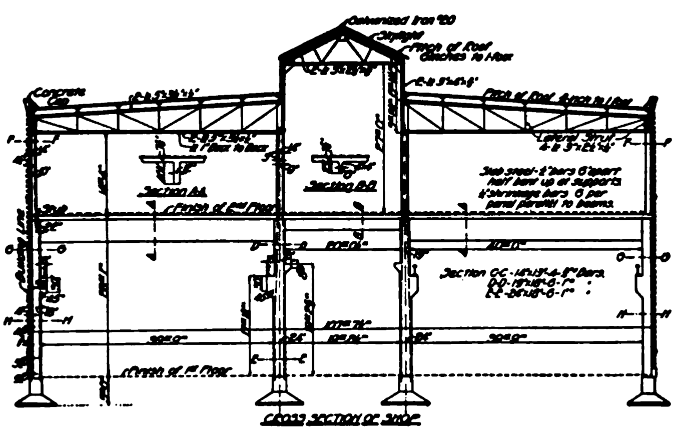


Fig. 277*.

materials. The concrete columns are reinforced with light angles strong enough to support the other framing without roof covering, during erection. Floor beams or light girders are also reinforced with structural shapes (Fig. 278), heavy enough to support a temporary floor and to brace the columns before the concrete is placed. The steel frame can be completely jointed before placing

*Atlas Portland Cement Co.

any concrete, thus insuring connections. A very pleasing exterior is produced by facing the wall surface with 4 inches of buff or yellow brick, anchored to the concrete, or a finish of Portland cement and white sand and quartz. Large buildings of this type can be erected at the rate of about 100,000 cubic feet of building contents per week.

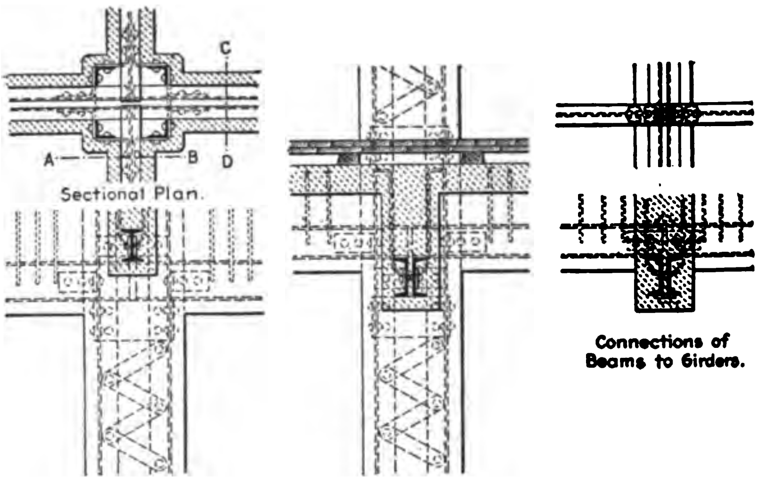


Fig. 278.

FLOORS AND ROOFS.

Floors and roofs may be made of the same general type of construction with the beams in the roof farther apart. Slabs are reinforced with expanded metal, wire mesh or rods, and the thickness of slab and area of reinforcing steel is found from the author's formulæ:

$$D = \sqrt{\frac{M}{1,000}}$$

$$A = \frac{D}{12}$$

Where D is the depth of slag in inches
M, the bending moment in inch pounds per foot width of slab, and
A, the area of steel in square inches per foot width.

When the arrangement of beams will permit, it is economical to use slab reinforcement in two directions at right angles to each other.

The cost per square foot of reinforced concrete slabs 6 inches thick is as follows:

Concrete costs	12 cents per sq. ft.
Steel	5 cents per sq. ft.
Centers	8 cents per sq. ft.
Total	25 cents per sq. ft

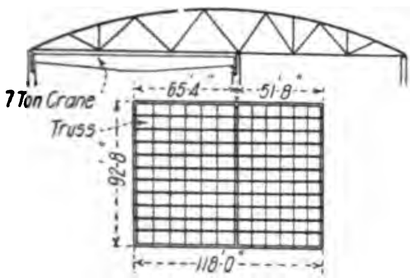


Fig. 279.

Flat slab floors without beams in either direction require about 40 per cent more steel than floors with beams and thin slabs, but this extra cost is partly offset by the low cost of centers.

An unusual form of shop roof is shown in Fig. 279, the roof slab being made in the form of an arch, 4 inches thick at the crown and 10 inches at the haunches. The arch thrusts against skewbacks at the sides, which are tied together at intervals with rods. The usual concrete slab roof construction on steel trusses is illustrated in Fig. 280.

Concrete and steel cost	45 cents per lin. ft.
Forms	25 cents per lin. ft.
Total	70 cents per lin. ft.

Concrete girders, 12 × 20 inches, cost:

Concrete and steel	60 cents per lin. ft.
Forms	35 cents per lin. ft.
Total	95

Girders, 15 × 22 inches, with light structural reinforcing, 18 feet long and 16 feet apart, to carry an imposed load of 125 pounds per square foot, are shown in Fig. 281. The steel framework erected in place costs $65 to $70 per ton. Separately molded floor beams in I forms (Fig. 282) are used and have the merit of lighter weight than solid ones.

COLUMNS.

The practice in designing columns is to use plain concrete columns with four to eight reinforcing rods (Fig 283), for sizes up to 16 or 18 inches square, the concrete being loaded to 500 pounds per square inch, neglecting the strength of the metal in compression. If this form would require a size exceeding about 18 inches square, a hooped or wound column may then be used instead (Figs. 284 and 285) with the part inside the winding loaded to 1,000 pounds per square inch, at the same time considering the bearing value of 'the steel in compression. Figure 285

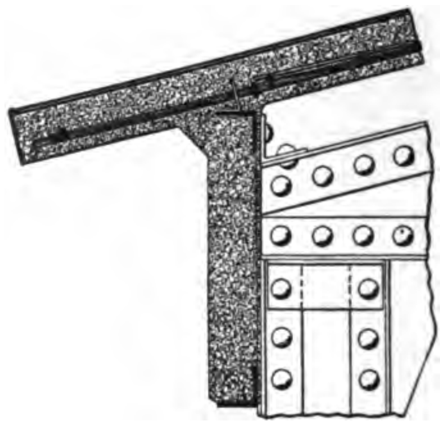


Fig. 280.

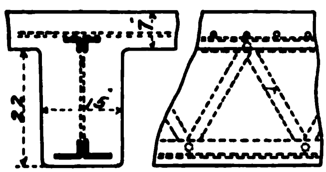


Fig. 281.

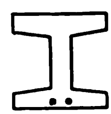


Fig. 282.

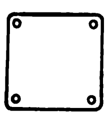


Fig. 283.

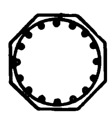


Fig. 284.

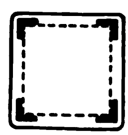


Fig. 285.

with laced or battened angles, is cheaper than 284 with circular winding.

The cost per vertical foot of a column 18x18 (Fig. 284), is as follows:

Concrete, 18 × 18 in	.55 cents per vertical ft.
Steel	.75 cents per vertical ft.
Forms	.50 cents per vertical ft.
Total	$1.80 per vertical ft.

An approximate cubic foot cost for reinforced concrete columns and girders is as follows:

Concrete costs	.25 cents per cu. ft.
Steel	.15 cents per cu. ft.
Forms and form labor	.25 cents per cu. ft.
Total	.65 cents per cu. ft.

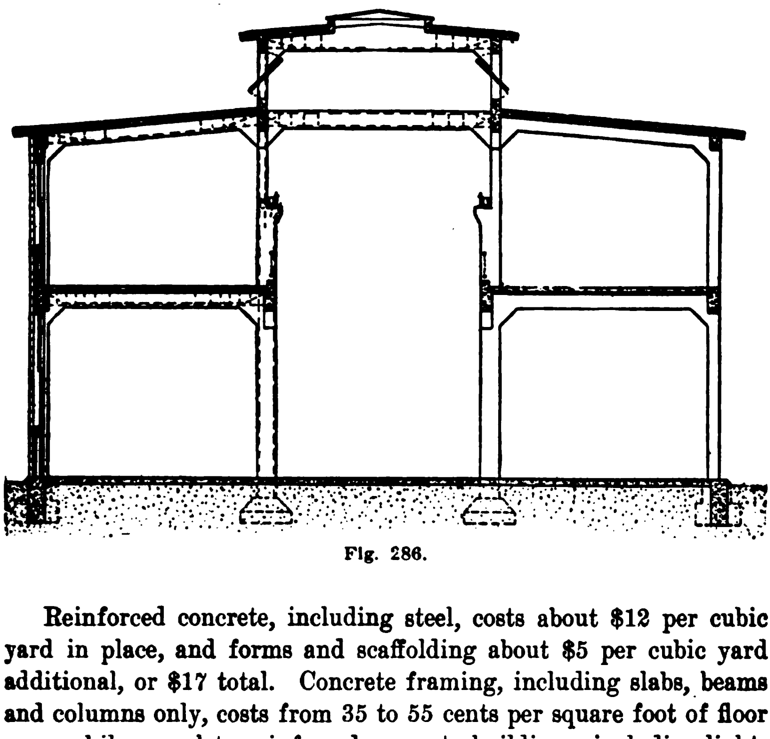


Fig. 286.

Reinforced concrete, including steel, costs about $12 per cubic yard in place, and forms and scaffolding about $5 per cubic yard additional, or $17 total. Concrete framing, including slabs, beams and columns only, costs from 35 to 55 cents per square foot of floor area, while complete reinforced concrete buildings, including lighting, heating, plumbing, and stairs or elevators, but without plastering or partitions, cost from 6 to 12 cents per cubic foot of contents.

Figs. 286, 287 and 288 show three views of a model reinforced concrete mill building, 60 feet wide, 125 feet long and 40 feet clear height at the center, erected in New Jersey in 1908. It has a complete frame of reinforced concrete, the exterior being enclosed

Fig. 287.

Fig. 288.

with molded concrete blocks. It was designed by Mr. A. N. Hazen, Engineer for the Expanded Metal Engineering Company of New York, and costs complete less than 6 cents per cubic foot. Fig. 289 illustrates the method of erecting the roof.

Fig. 277 is a section of a machine shop erected in Ohio, 107 feet wide and 256 feet long, with columns 16 feet apart longitudinally. The walls, floors and columns are of reinforced concrete, with steel roof trusses and crane girders. Columns have concrete brackets, supporting girders for a ten-ton traveling crane.

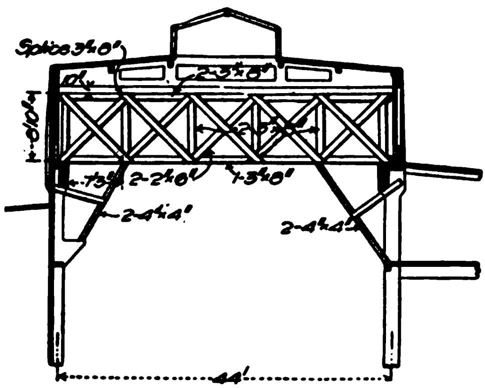


Fig. 289.

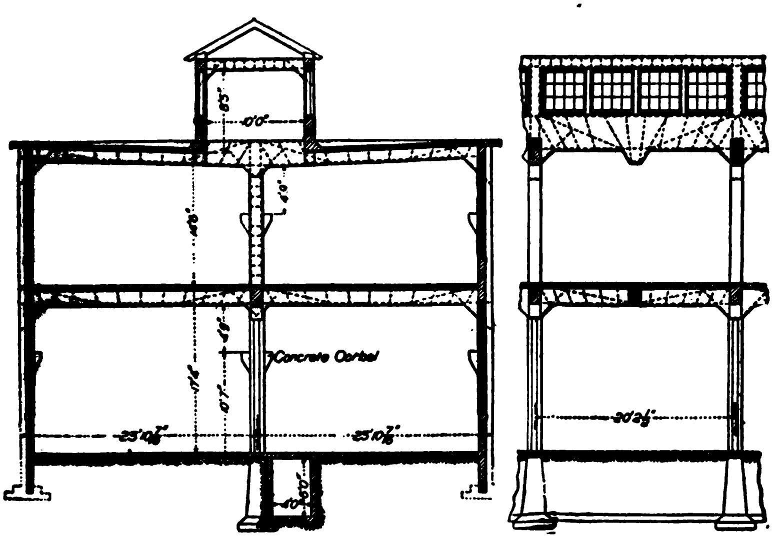


Fig. 290.

The floor is proportioned to sustain 225 pounds per square foot, and the slabs are 8 inches thick, supported on thin and deep concrete beams, 16 feet apart. Until the center traveling crane is installed, a temporary wood floor is used in the middle bay. The

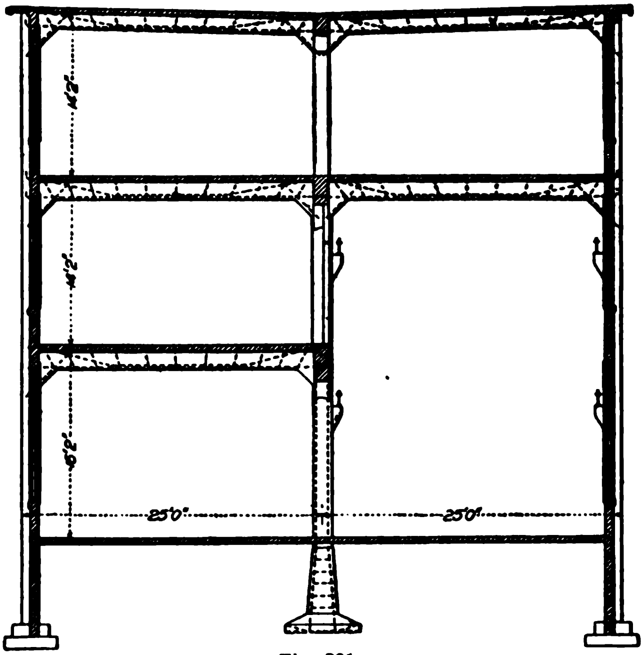


Fig. 291.

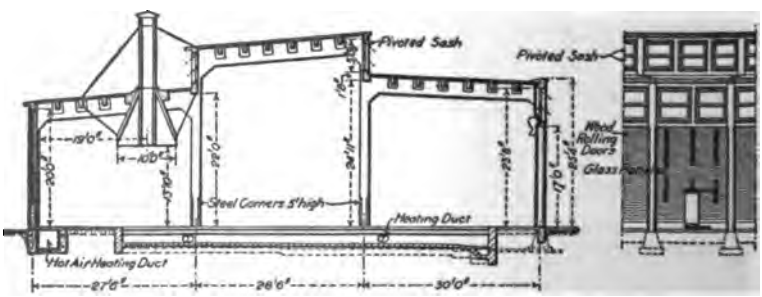


Fig. 292.

work of constructing and completing the building occupied less than two months' time.

Figs. 290 and 291 show concrete framing details for shop buildings with traveling cranes, while Fig. 292 is an engine house with separate molded members, at Waterbury, Conn.

CHAPTER XVII.

NORTHERN LIGHT ROOF FRAMING, IN WOOD, STEEL AND CONCRETE.

Northern light roofs were introduced into the United States about the year 1870, but were not very generally adopted excepting for cotton mills until twenty years later, when their use was extended to other lines of manufacture.

Their chief advantage is that clear north light from the sky can be received without admitting direct sunshine or using window shades, and work benches can be arranged crossways of the floor, as well as longitudinally against the walls. Abundant light free from shadows is necessary to produce the greatest quantity and the best quality of work. It is easy in case of fire for employees to escape through the windows of one-story shops, and on a single floor, goods can be more easily transferred from one place to another. Single story, square buildings have less than half the wall surface of long narrow buildings 40 or 50 feet wide of the same floor area.

The objection to northern light roofs is their greater cost and liability to leak at the gutters, especially in cold or freezing weather. The worst leaks occur when water collects under ice and snow in the gutter, and is forced or drawn up over the flashing, or when gutters freeze up solid and burst. Like other low buildings, they are harder to ventilate than higher ones, and the exterior temperature is transmitted through, and radiated from the under side of roof, producing draughts and physical injury to the occupants. Another objection is that condensation from the roof windows may drip and cause injury. The area and cost of northern light roofs exceeds that of ordinary double pitch roofs without skylight by 40 to 60%, which is about the extra area and cost of the sloping windows. In northern latitudes, snow may occasionally need removing from the roof, for it may drift into the valleys and obstruct light, but records show that this condition is not frequent. The unsymmetrical form of these roofs is not pleasing, but this may be partially remedied by extending the gable walls high enough to conceal them.

Northern light roofs are suitable chiefly for wide one-story buildings, but their extra expense is unwarranted on high buildings less than about 100 feet in width, where abundant light can be had from the side wall windows. Multi-story buildings have a less cost per square foot of floor area than single story shops, and when loads and other conditions will permit, should generally be used with the greatest available area of wall windows, before resorting to the more expensive type of single story saw tooth roofs.

ROOF OUTLINES.

Glass should face directly or nearly north, and to receive the clearest light, should be inclined to the vertical as steep as possible without admitting sunshine in the longest days of summer. An angle of 25 or 30 degrees to the vertical is usually satisfactory, though the slope varies with the latitude, being 6 degrees nearer the vertical in the southern states than in the north. Windows are often placed vertical for convenience in framing, weighting the sash and making them water tight, but vertical windows admit less light and make a greater roof area to cover. The south roof slope should be great enough to shed water, and to comply with the required pitch for the chosen roof covering as given in Table XII, but it should not be so steep as to prevent light from reaching the floor or make the cost of windows excessive. Gutters should be one or two feet wide to prevent clogging and bursting, but if wider, shadows or poorer light under them will result. Ridges are generally horizontal, but in some cases (Fig. 323) both ridge and gutter are sloped to the sides.

When a roof has a series of saw tooth sections, it is convenient to stop the sloping part or monitor a few feet from either side, leaving a flat walk, to permit access to the valleys without climbing over the ridges.

Some outlines of northern light roofs are shown in Figs. 96 to 105, the semi-sawtooth of 101 having the disadvantage of forming dark places or shadows under the flat part or gutters.

WINDOW AREA.

The general rule for area of roof light is to cover 25 to 50% of the roof with glass, the amount depending on the degree of detail work to be performed in the building. The shop will usually be sufficiently lighted when the height of windows is one-third to one-fourth of the saw tooth span. If the under side of the south slope is painted white, lighting will be improved by reflecting it to the floor. A design shown in Fig. 294 has skylight on the south slope in addition to the north light windows.

GUTTERS AND CONDUCTORS.

An objection to northern light roofs is the danger of leakage from the gutters. If less than 1 or 2 feet in width, gutters are liable to be clogged with snow and ice, and if wider than 3 or 4

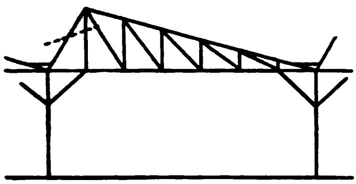


Fig. 293.

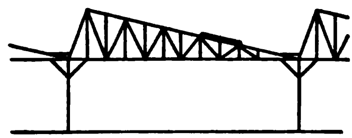


Fig. 294.

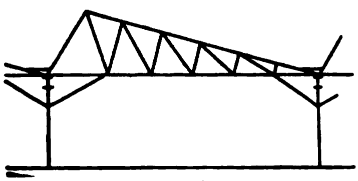


Fig. 295.

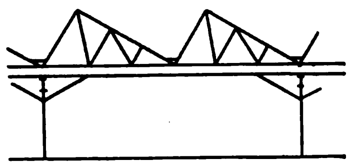


Fig. 296.

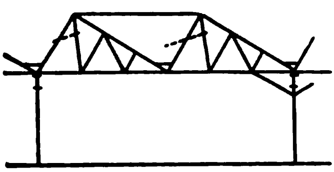


Fig. 297.

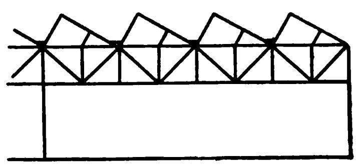


Fig. 298.

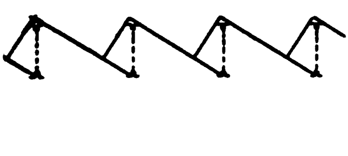


Fig. 299.

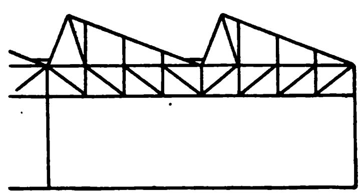


Fig. 300.

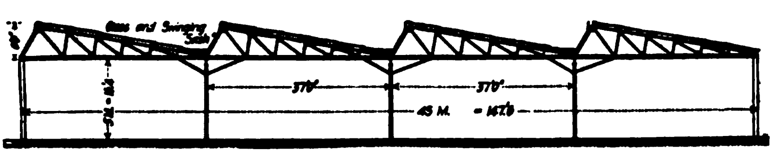


Fig. 301.

feet, the uniformity of interior lighting is affected. Minimum and maximum gutter widths should therefore be 1 to 4 feet. To prevent injuring or breaking gutters when cleaning them or removing snow, some designers have laid a board walk in them with open slats, but it is not recommended, for the walk tends to collect and hold snow and dirt. Freezing can be partly or entirely avoided by running lines of steam pipes beneath the gutter in the shop, which serve also as part of the general heating system. Some shops place one-third of the heating pipes there. Change of temperature causes metal gutters to contract and expand, resulting in cracks and leaks. To prevent these cracks, cast iron gutters were

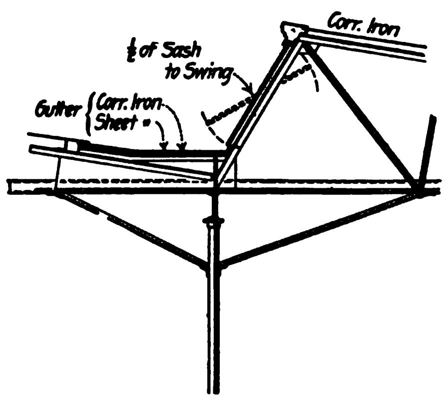


Fig. 302.

formerly used, but they are heavy and expensive, and the modern and better way is to use wider ones, covered with flashing or the regular roofing.

Gutters should pitch ¼ or ½ inch per foot to interior downspouts rather than to exterior ones, for when placed outside the building, conductor pipes freeze up in cold weather. Down spouts should be placed 40 to 50 feet apart at the columns, and should connect to drains leading to a reservoir for plant use, or to the sewer. A 3-inch pipe will drain 1,000 square feet of roof, and the pipe should be protected at the top by a wire screen or basket (Fig. 311).

COLUMN SPACING.

The cost of roof framing depends largely on the column spacing. If long spans and open floor space is needed, the cost of framing will be increased. For many kinds of manufacture, columns are convenient rather than otherwise, and will result in much saving in the roof trusses. Pipe columns, either plain or filled with concrete, are much used for the light roof loads in saw tooth buildings, and are quite economical, though inconvenient for connections.

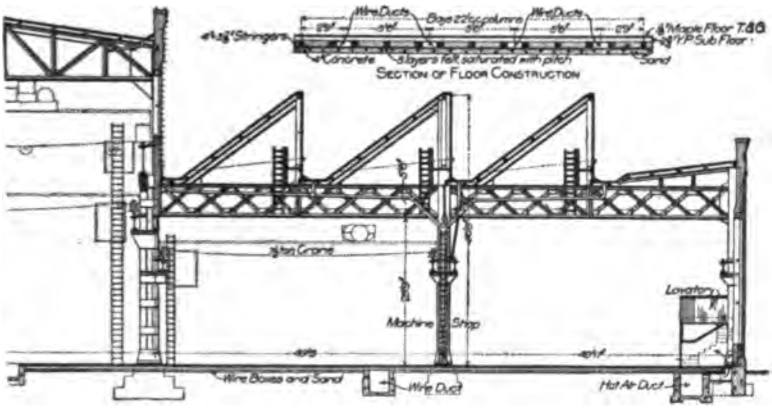


Fig. 303.

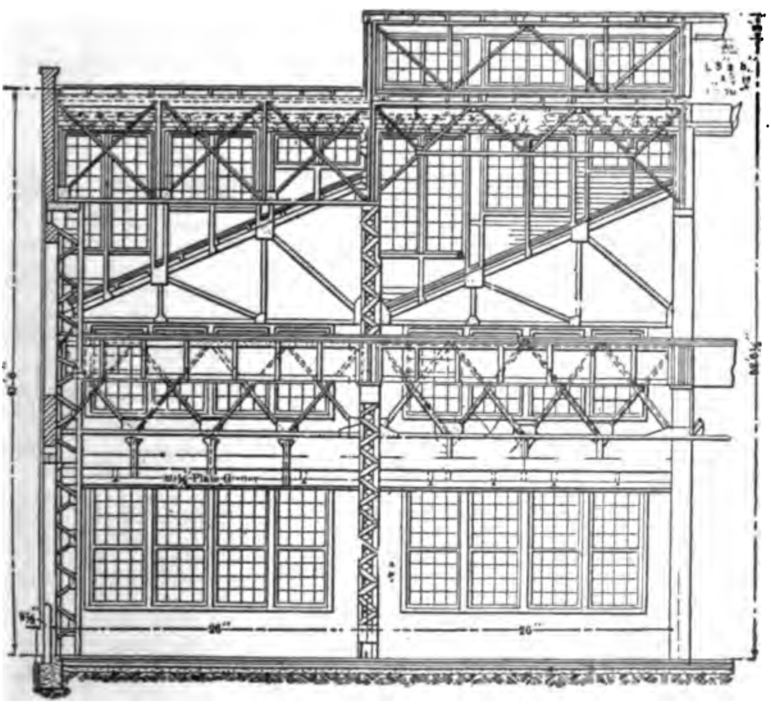


Fig. 304.

FRAMING.

The kind of framing for northern light roofs depends upon the permissible number of columns, the length of spans, amount of window area and the roof outline as determined, by preliminary investigation. Glass should face the north, but ridges may lie either transversely or longitudinally of the building. The different kinds of northern light roof framing may be classified under three headings as follows:

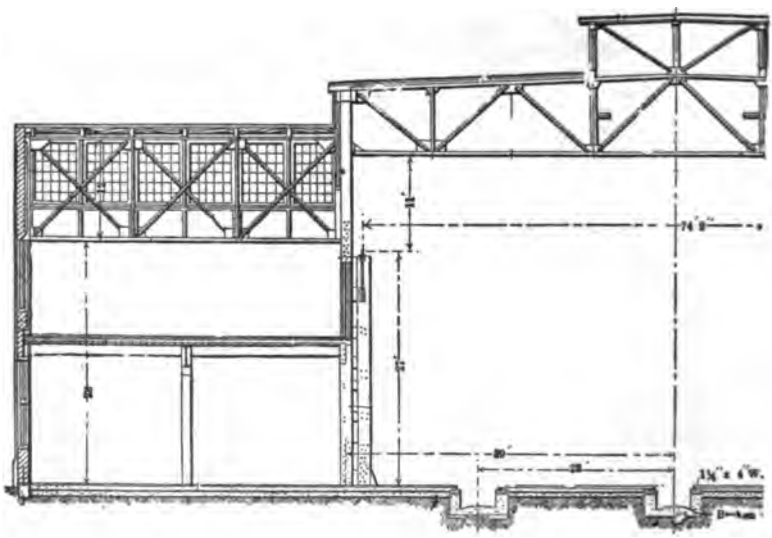


Fig. 305.

(a) Trusses on columns with rafters in the slope of roof,
(b) Rafters supported on longitudinal beams (Fig. 296) or trusses (Fig. 298).
(c) Rafters supported on transverse beams or trusses (Fig. 299).

Class (a) are suitable for spans not exceeding 60 feet, and preferably not over 40 feet, but (b) and (c) can be used for much greater lengths. Class (c) has the disadvantage that the truss framing lies across the windows, and casts shadows on the floor. Wherever possible, framing should be arranged to avoid these shadows, and in some trusses, rods are used instead of riveted members for bottom chords, but stiff chords are more convenient for shafting. Framing across the windows is more objectionable than parallel with the trusses, but in either direction below the window level, shadows, and light obstruction may result. Saw tooth roofs should have a clear height beneath the trusses, of 12 feet and

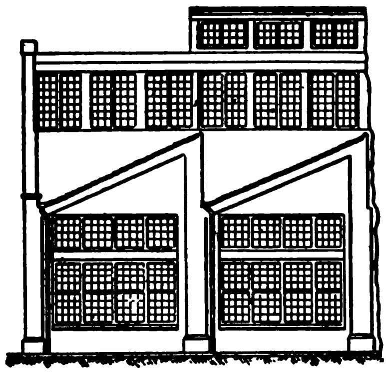


Fig. 306.

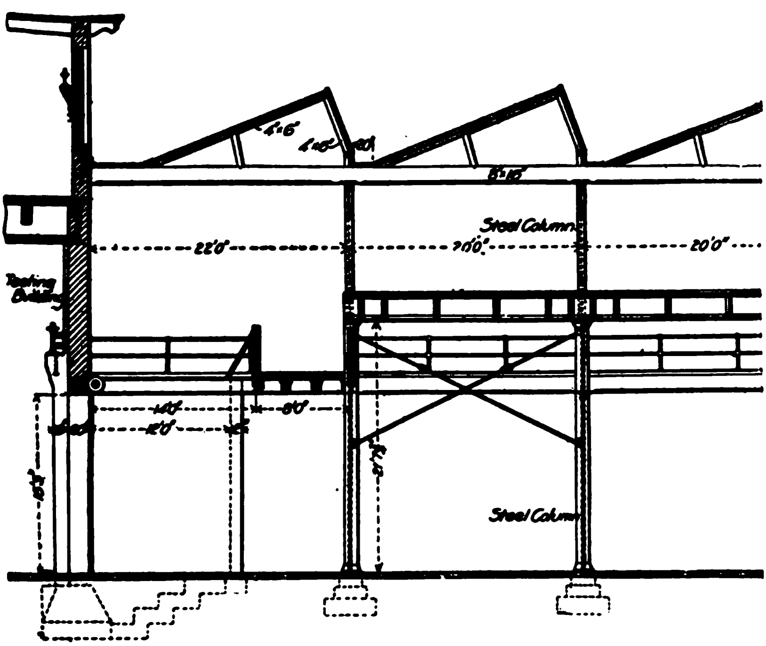


Fig. 307.

preferably more. Low rooms are easier to heat, and the windows are down nearer to the work, but ventilation is poor and heat excessive in summertime. When the small tools of machine and erecting shops are placed all at one side of the erecting floor the need of crossing back and forth under the cranes is avoided and time is saved.

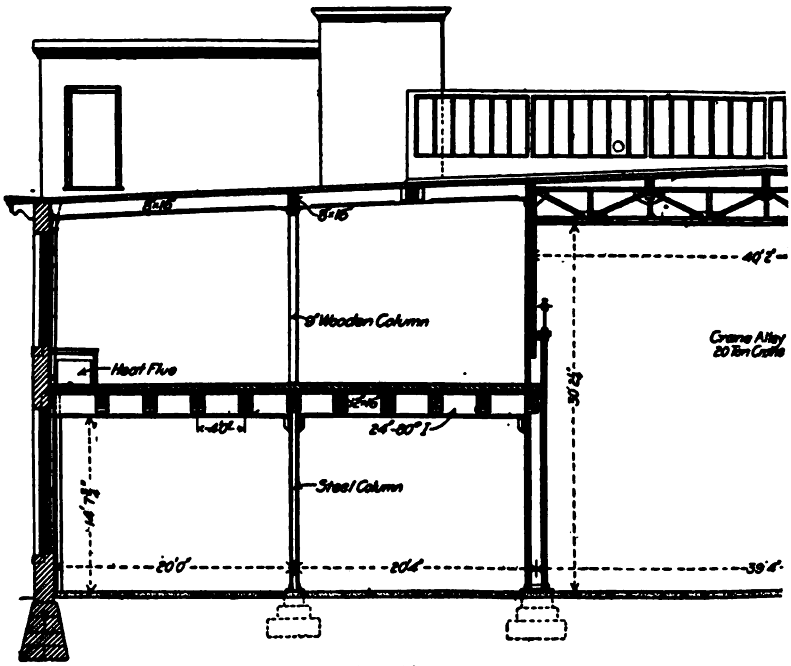


Fig. 308.

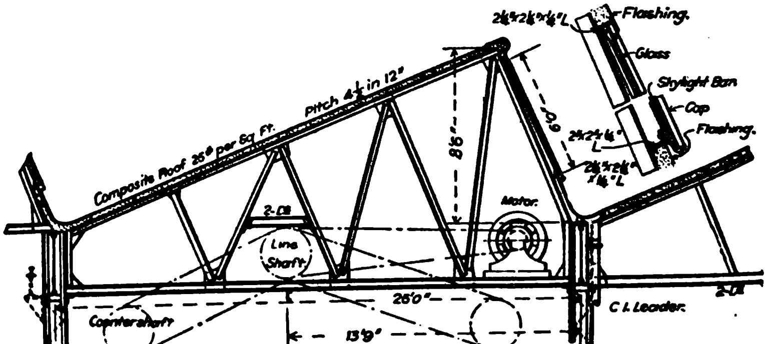


Fig. 309.

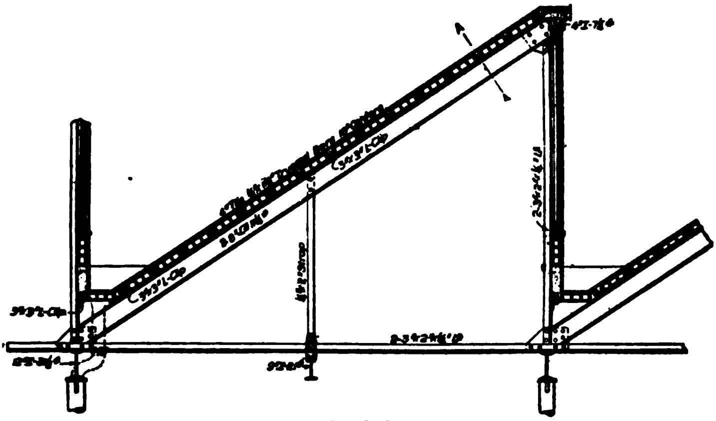


Fig. 310.

A saw tooth roof of novel design, erected for a large plant in Belgium, is shown in Fig. 313. Trusses are three-hinged, and alternate ones rest on braced piers. They have spans of 53 feet and a crown angle of 90 degrees.

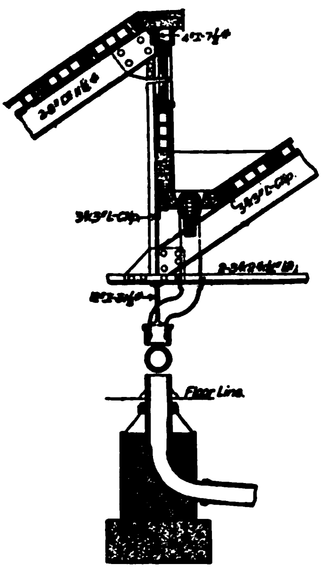


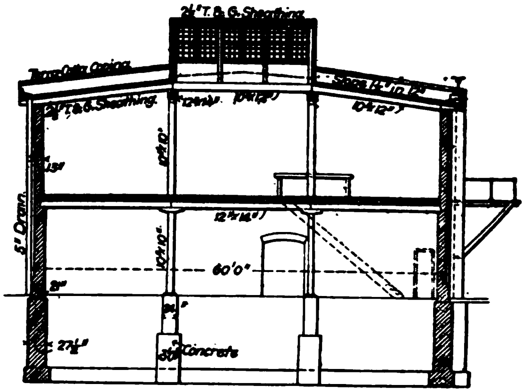
Fig. 311.

A design made in 1898 by the author with a clear span of 58 feet and trusses 12 feet 6 inches apart, is shown in Fig. 299. It has the advantage of no inside columns, but has lattice trusses crossing the windows. A similar design for a saw tooth roof on the side bays of a locomotive shop with windows vertical, is illustrated in Figs. 304 and 305.

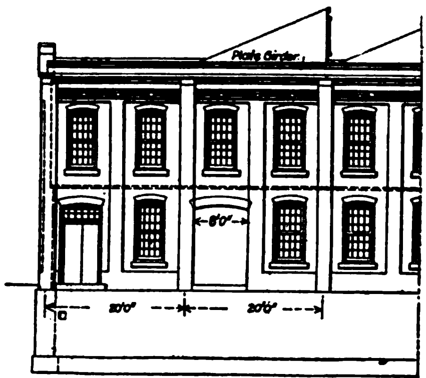
The saw tooth lighting of Fig. 323 consists of transverse north light monitors over alternate bays, supported on lattice trusses 150 feet between columns. The arrangement affects only the monitor frames but not the trusses, which are of usual construction.

CONDENSATION.

Condensation forms when the inner and outer atmospheres are at different temperatures. To prevent condensation, there should



Cross-Section



Part Front Elevation.

Fig. 312.

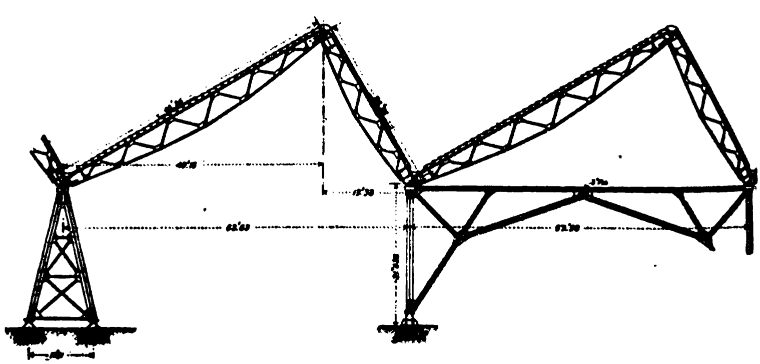


Fig. 313.

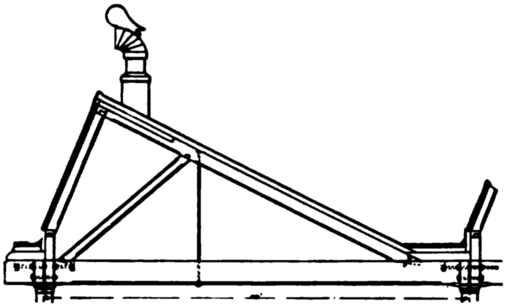


Fig. 314.

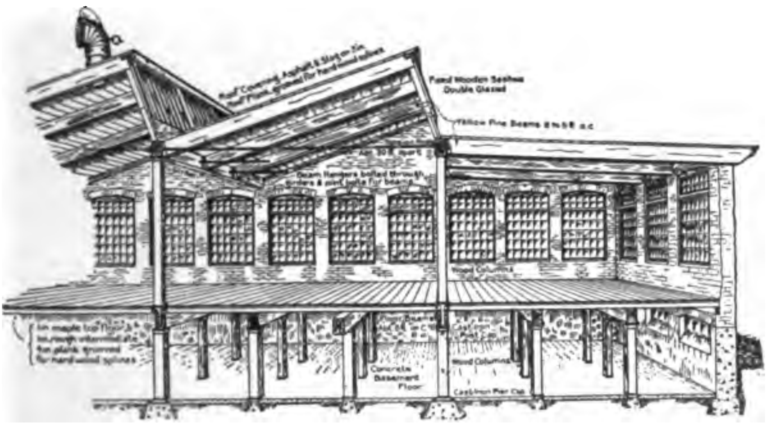


Fig. 315.

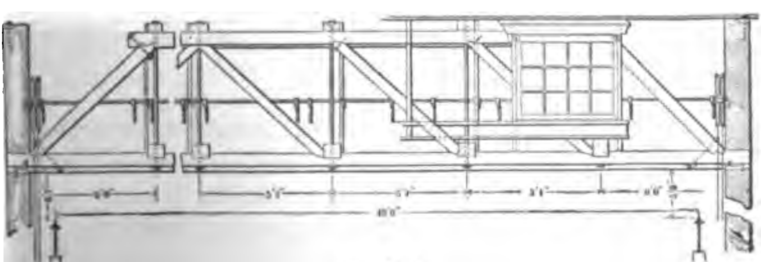


Fig. 316.

be no heat conducting connection between the inside and outside air. In cold climates, windows should be double glazed, and metal ventilators should have double walls with air space between (Fig. 516). Skylight and window bars are sometimes made with ventilation holes (Fig. 543), which assist in maintaining a uniform temperature on both sides of the bar. Wood framing is less liable

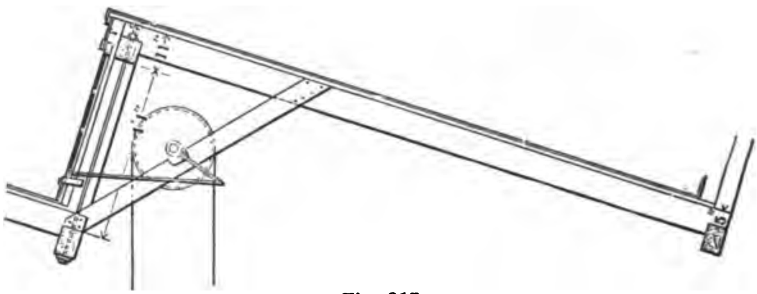


Fig. 317.

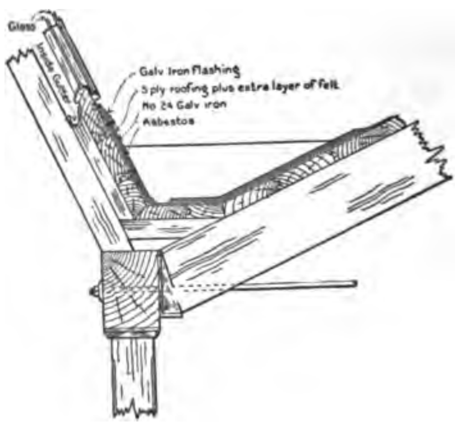


Fig. 318.

to collect condensation than steel or concrete, and is therefore sometimes preferred.

VENTILATION.

The most effective ventilation is that secured from a fan and blower heating system, with ducts overhead or beneath the floor. In warm weather the heating system is changed to a cooling one, by passing cold water through the pipes over which the air is blown.

Separate metal ventilators with double walls and weather vane caps may be placed on the south slope near the ridge. They should have dampers in the shaft for closing the draft when it is not desired (Fig. 516).

Ventilation may also be secured by swinging all or part of the windows, though movable windows are not desirable, as water is

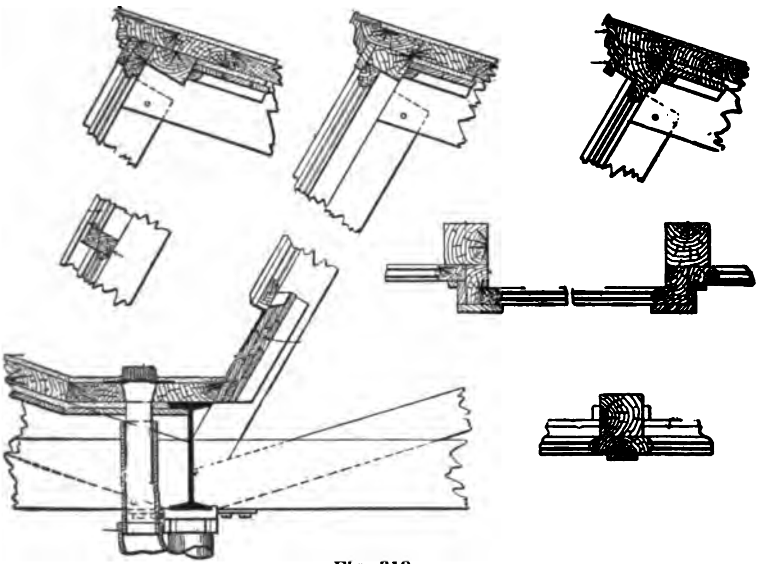


Fig. 319.

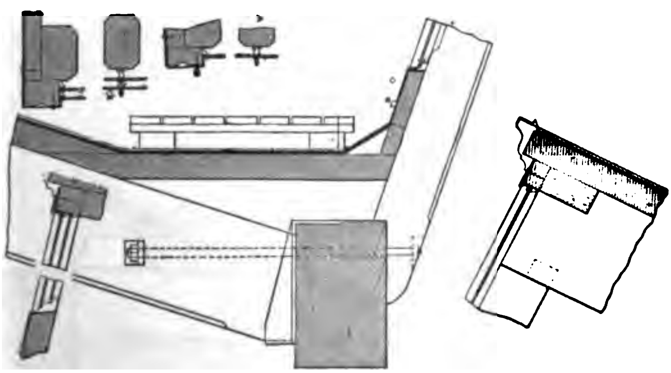


Fig. 320.

liable to leak through during driving storms. Opening the upper half of alternate panels will give ample ventilation, and top hinges are preferable to trunnions, as joints are then more easily flashed. End gables may have fixed or movable louvres or swinging windows.

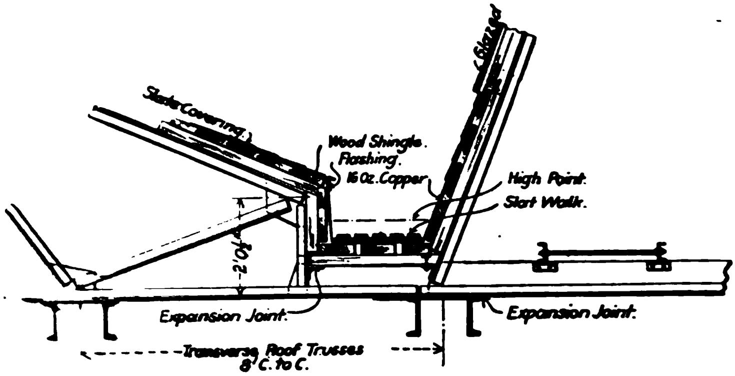


Fig. 321.

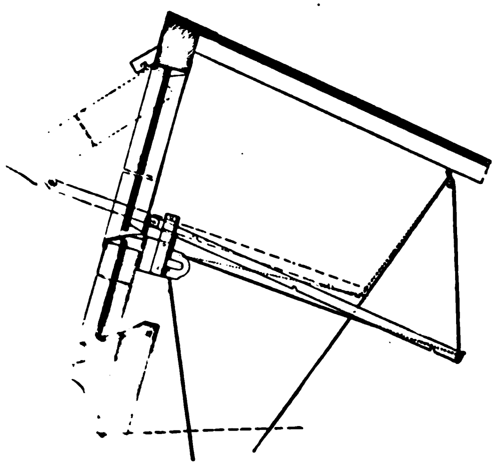
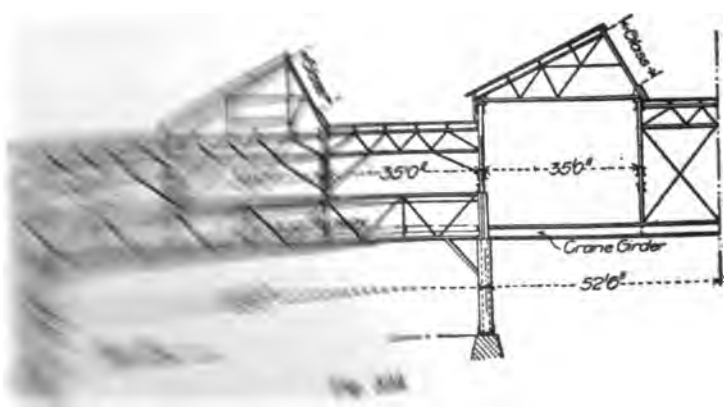


Fig. 322.



WINDOWS.

Windows should have clear white, rather than green glass, and in cold climates should be double glazed, the inner pane being factory ribbed, with the smooth side exposed to view. In all cases with either single or double glazing, windows must have condensation gutters (Figs. 309, 318 and 319) to prevent dripping. Wood sash are cheaper than metal ones, though the latter

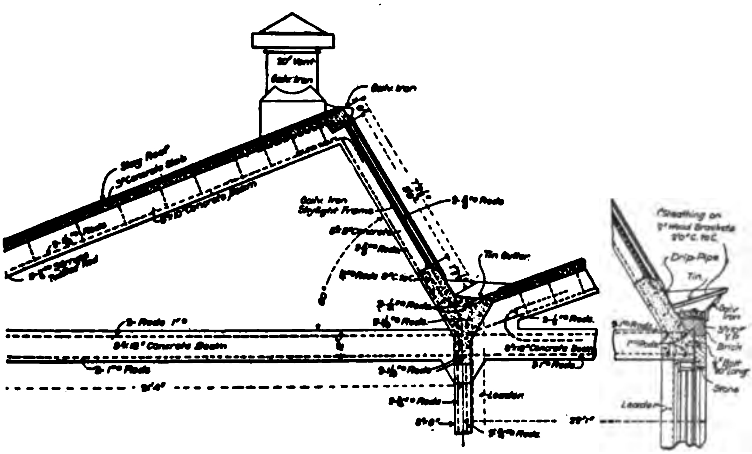


Fig. 324.

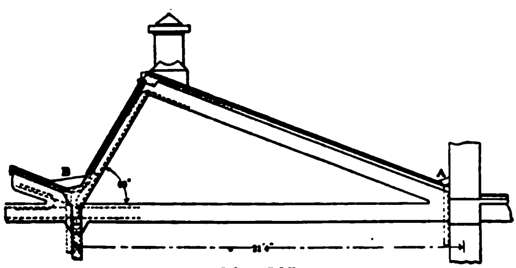


Fig. 325.

are fireproof, and sloping sash should have muntins similar to greenhouse or skylight bars, with condensation gutters.

Movable sash must be carefully designed and flashed, to prevent leakage during severe storms which usually blow from the northeast or northwest. Appliances for opening these windows are shown in Figs. 316, 317 and 322. No arrangement of windows will make effective lighting unless the glass is frequently cleaned.

COST.

The cost per square* foot of floor area for a large saw tooth shop, covering 60,000 square feet of ground is as follows:

Steel work	33.7 cents per sq. ft. of floor area
Six-inch concrete floor	11.5 cents per sq. ft. of floor area
Foundation and brickwork	10.3 cents per sq. ft. of floor area
Lumber	14.0 cents per sq. ft. of floor area
Painting	1.1 cents per sq. ft. of floor area
Roof covering	1.1 cents per sq. ft. of floor area
Sewers	2.0 cents per sq. ft. of floor area
Miscellaneous	6.3 cents per sq. ft. of floor area
Total	80.0 cents per sq. ft. of floor area

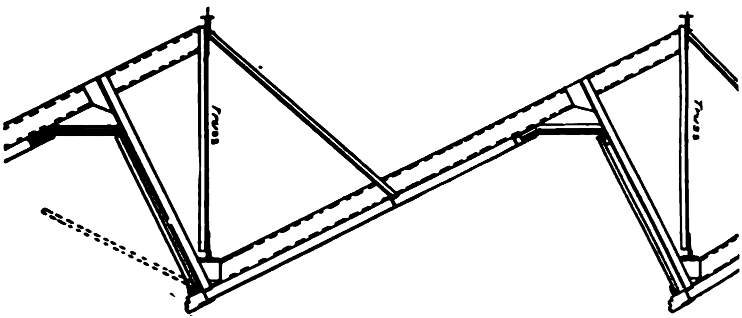


Fig. 326.

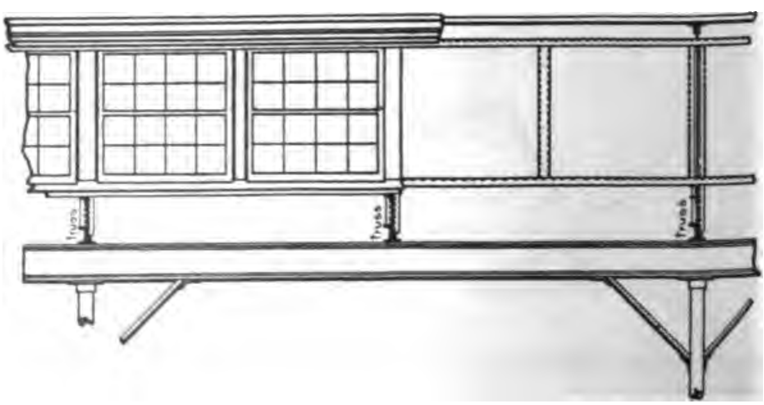


Fig. 327.

PART IV

DETAILS OF CONSTRUCTION

CHAPTER XVIII.

FOUNDATIONS AND ANCHORAGES.

The subject of foundations is very extensive and will be referred to only briefly, for building the foundations of manufacturing plants will generally not be difficult. Unless in special cases, sites will be selected on which buildings can be erected economically, and where foundations will be comparatively simple. There are cases, however, where other considerations outweigh economy of construction, as that of the American Bridge Company's plant at Ambridge, and the Lackawanna Steel Company's plant at Buffalo. The location at Ambridge, beside the river, was low and required much filling and deep foundations, while at Buffalo the plant was built over a swamp, the top of which was excavated 3 feet and the buildings supported on piles capped with timber and concrete. Some of the extensive manufacturing buildings at Sault Ste. Marie, Ontario, are also built over swampy ground adjoining the source of power, and the new Steel Corporation's buildings at Gary, Indiana, on the shore of Lake Michigan, are built on sand, below lake level, requiring a solid slab of concrete 5 feet thick under the entire area of some of the buildings.

LOADS.

The amount and character of loads must be known before proportioning the foundations. To know the loads definitely, the parts of the building above ground, including walls, roofs and floors, must be designed. Brick work weighs 120 pounds and concrete 140 pounds per cubic foot, while the weight of floors will depend upon their design. The live loads on floors, including the weight of machinery and material must be separated from the dead load, for the effect of impact from live loads must be considered. Live loads must be increased 50 to 100% for impact, depending upon the extent of vibration from the machinery. Floors for light machinery will have a capacity for sustaining imposed loads of 100 to 200 pounds per square foot, and those for heavy machinery, 200 to 400 pounds per square foot, while cupola or foundry floors where iron or lead is piled, may be proportioned for 500 to 1,000 pounds per square foot. The side footings and foundations on tall narrow buildings have important vertical loads from the overturning effect of wind on the building, which may be considered as dead load, because it will not ordinarily occur in conjunction with maximum floor loads.

BEARING POWER OF SOILS.

TABLE XXVII.

SAFE BEARING PRESSURE ON SOIL.

Hard rock on native bed	250 tons per sq. ft.
Ledge rock	36 tons per sq. ft.
Hard pan	8 tons per sq. ft.
Gravel	5 tons per sq. ft.
Clean sand	4 tons per sq. ft.
Dry clay	3 tons per sq. ft.
Wet clay	2 tons per sq. ft.
Loam	1 ton per sq. ft.

The sustaining power of soils may be increased by draining the subsoil with tile drains or layers of sand and gravel, or by compressing and hardening it. Greater supporting power is secured by distributing the bearing over greater areas, with spread footings of timber, steel or concrete, or by driving piles.

Gravel and sand are the best foundations, for they are firm and well drained; sand will sustain great loads if held from spreading sideways. Rock is too hard and non-resisting and not often found at the surface on manufacturing sites, while loam is too soft and unreliable. Foundations on clay are greatly improved by filling the foundation pits and trenches with a thick layer of gravel and sand rammed in solid between the trench side walls. The size of most building foundations is proportioned to load the ground not more than 1 to 2 tons per square foot. Where there is any doubt about the safe bearing power of the soil, soundings should be made and a small known area tested by piling weights upon it. An easy way of sounding is to drive lengths of pipe into the ground with a water jet inside the pipe to force out the core, a method which was successfully used by the author for sounding to great depth in the harbor at San Pedro, California.

AREA ON SOIL.

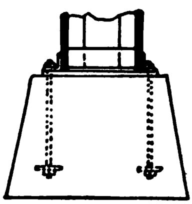
Foundations are proportioned not to resist settling, but to settle uniformly over the whole building area. If some parts of building stand on rock and other parts on yielding soil, cracks in the wall are sure to result, for the part on solid rock will have no settlement, while other parts will sink a little. For this reason partial rock foundations for manufacturing buildings should be avoided. All foundation beds should have as nearly as possible the same load per square foot. It is just as injurious to have some parts of the foundation too large as it is to have them too small. If side walls are used, care must be taken that the wall base will not cover too great an area and make a less pressure per square foot on the soil under the wall than under interior columns. To better secure even pressure on the soil, the weight of side walls is sometimes transferred by beams or arches to individual piers under the columns at the panel points.

SIDE WALL FOUNDATIONS.

A continuous foundation under side walls is economical when the columns of piers are fairly close together, but for longer panels, separate piers are preferable, with a light base between them if necessary, to support the curtain wall.

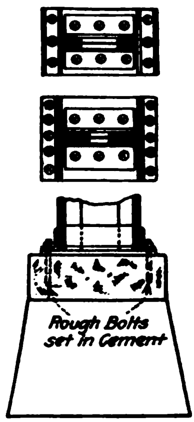
PIERS.

Hard brick or concrete is well suited for building isolated piers, producing generally a better bond than can be secured with stone; but if stone is used, it must be laid flat on its original bed and built solid through the pier, rather than by making the exterior of dressed stone with a rubble center. Concrete piers are most economical when laid in courses 12 to 18 inches thick, with stepped or offset edges similar to stone piers (Fig. 343), for a few regular size form boxes can then be used for several piers. Another common form box, though not as economical as the one just described, is made in the shape of a truncated cone with straight sloping sides (Fig. 341), and whether the sides are sloped or offset, the angle of slope should not be less than 60 degrees to the horizontal, for if greater, the offsets are liable to crack and not distribute the pressure evenly on the base. Pier caps should be large enough to allow at least 6 inches from the bolt holes to the edges of the stone, without producing a pressure on the pier below the cap greater than 200 pounds per square inch on brick and 250 pounds per square inch on concrete. Unless for very small piers, dressed caps of natural or artificial stone are preferable, the thickness of which should be from one-third to one-fifth their greatest length (Fig. 342). All piers and foundations should extend at least 6 inches below the frost line, and not less than



Set Bolt Anchorage.

Fig. 341.



Rough Bolt Anchorage.

Fig. 342.

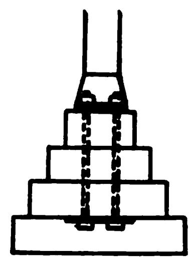


Fig. 343.

3 feet below the natural ground surface, and generally for shops without much floor filling, will be from 4 to 5 feet in height.

Piers with spread footings are economical and much used, and are made with a grillage of steel beams, old rails, reinforced concrete or heavy timber. The pressure on the soil under these piers is distributed by the bending resistance of the lower courses. Reinforced concrete spread footings are more used and cheaper than those made with heavy steel, and more durable than timber, though in many cases, particularly for light foundations, spread footings made with double courses of timber laid crosswise to each other, are more economical and quite as satisfactory. When timber is used, however, it must be placed below water where it will be always submerged, or must be always dry and should then be coated with lime or tar as a preservative. The dimensions of spread footings in steel and reinforced concrete can be obtained from any steel or concrete handbook, or can very easily be computed.

MACHINERY FOUNDATIONS.

Machinery foundations are often quite different from piers supporting static loads, for the former must resist the action of continuous vibration without injury, and heavy anchor bolts are generally needed to fasten the machines securely to the base and prevent lifting or lateral movement. Solid masonry, even though of great size, under a heavy steam hammer would soon be shattered, for it offers no spring or elasticity. Piers all or partially of timber are the best for this purpose, and machines of any kind are found to run more smoothly on timber than on stone (Figs. 344 and 345).

PILES.

Piles are needed under piers and foundations when the soil is too soft to sustain a less load than one or two tons per square foot. Building sites are often chosen adjoining deep water and well located for shipping, but which are not economical in foundations. The cost of shipping is continuous and often more important than the first cost of the plant, and sites are sometimes chosen convenient for shipping but requiring extra expense on the foundations.

Wooden piles can be driven $2\frac{1}{2}$ to 3 feet apart, and will generally safely sustain loads of 10 to 20 tons each. The most approved formula for the safe load on piles is:

$$\text{Safe load in tons} = \frac{D\,H}{1000\,(1+P)}$$

Where D is the drop of hammer in feet,
H the weight of hammer in pounds, and
P the penetration of the pile in inches under the last blow.

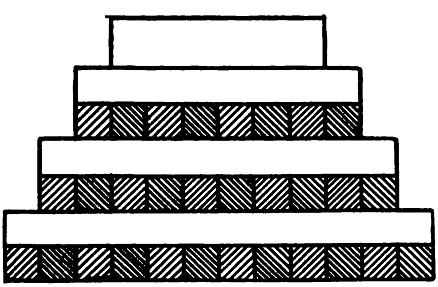


Fig. 344.

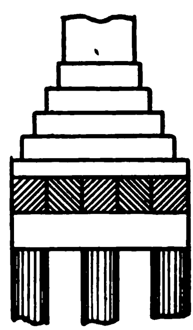


Fig. 345.

Piles should be capped with heavy timber or concrete, and when concrete is used it should cover and surround the pile heads for a depth of 6 to 12 inches. When timber is always below water, it is permanently preserved, and this condition is preferable to having it alternately wet and dry, for timber then rots rapidly.

Piles are frequently pointed to facilitate driving, and they are sometimes provided with cast iron points, though this adds expense and is often of little benefit. When there is a tendency to split under the hammer, the piles should have wrought iron rings fitted tightly over their heads, which can be removed after the piles are driven. A final penetration of one inch under the last blow of a 2,000-pound hammer is generally satisfactory and small enough to insure permanence.

Several kinds of concrete piles are now largely used, and are more permanent and durable than wood, though at a higher cost. The new union depot at Winnipeg, Manitoba, for the Canadian Northern Railway and the Grand Trunk Pacific Railway, contracted for at the author's estimate of about a million dollars, stands on a foundation of concrete piles costing $1.25 per lineal foot in place. Further particulars of concrete piles can be found in treatises on concrete or foundations.

ANCHORS.

Table XXVIII gives in a general way the recommended sizes of anchor bolts for several kinds of columns. It is intended as a general guide and does not apply to special cases with shear or tension on the anchors. No bolts are used less than ⅝ inch diameter, and the united area of the bolts is about ⅛ the area of the column. As they are of small diameter, no economy results from upsetting, which process should be used only on anchor bolts of the following lengths and sizes:

¾, ⅞ and 1 in. diam. bolts over 5 ft. long, use ⅛ in. smaller and upset.
1¼, 1⅜ and 1½ in. diam. bolts over 5 ft. long, use ¼ in. smaller and upset.
1⅝, 1¾ and 1⅞ in. diam. bolts over 4 ft. long, use ¼ in. smaller and upset.
2 , 2⅛ and 2¼ in. diam. bolts over 4 ft. long, use ⅜ in. smaller and upset.

Set bolts, or those which are built solid with the masonry, should be used for all towers, trestles and posts carrying jib cranes, and crane girders or posts subject to shocks or heavy moving loads. They should be used also in the columns of buildings with corrugated iron sides, or for high and narrow buildings, where the wind stresses may nearly or entirely balance the dead loads.

TABLE XXVIII.

SET ANCHOR BOLTS FOR POSTS OF VARIOUS SECTIONS.

Zee Bar Columns.

Section.	*2 Bolts.*	*4 Bolts.*	*Area of Anchor Pl. sq. ins.*
6×¼, Z cols	1⅛	¾	110
6×⅜, Z cols	1⅜	1	100
8×¼, Z cols	1¼	⅞	150
8×⅜, Z cols	1⅝	1⅝	236
10×⁵⁄₁₆, Z cols	1⅜	1	180
10×⁷⁄₁₆, Z cols	1¾	1¼	300

Channel Columns.

Section.	*2 Bolts.*	*4 Bolts.*	*Area of Anchor Pl. sq. ins.*
2 6-in. channels	¾	⅝	75
2 7-in. channels	⅞	⅝	75
2 8-in. channels	⅞	⅝	75
2 9-in. channels	1⅛	¾	110
2 10-in. channels	1⅛	¾	110
2 12-in. channels	1¼	⅞	150

Four Angle Columns.

Section.	*2 Bolts.*	*4 Bolts.*	*Area of Anchor Pl. sq. ins.*
4 angles, 2×2×³⁄₁₆	¾	⅝	75
4 angles, 2×2×¼	¾	⅝	75
4 angles, 2½×2×³⁄₁₆	¾	⅝	75
4 angles, 2½×2×¼	¾	⅝	75
4 angles, 3×2×¼	¾	⅝	75
4 angles, 3×2×⅜	⅞	⅝	75
4 angles, 3½×2½×¼	⅞	⅝	75
4 angles, 3½×2½×⅜	1⅛	¾	110
4 angles, 4×3×⁵⁄₁₆	1⅛	¾	110
4 angles, 4×3×⅜	1⅛	¾	110

Four Angle and Plate Columns.

Section.	*2 Bolts.*	*4 Bolts.*	*Area of Anchor Pl. sq. ins.*
4 angles, 2½×2×¼ 1 plate, 7×¼	⅞	⅝	75
4 angles, 2½×2×¼ 1 plate, 8×¼	⅞	⅝	75
4 angles, 2½×2×¼ 1 plate, 10×¼	⅞	⅝	75
4 angles, 3×2×¼ 1 plate, 8×¼	⅞	⅝	75
4 angles, 3×2×¼ 1 plate, 10×¼	1⅛	¾	110
4 angles, 3×2×¼ 1 plate, 12×¼	1⅛	¾	110
4 angles, 3½×2×¼ 1 plate, 8×¼	⅞	⅝	75
4 angles, 3½×2×¼ 1 plate, 10×¼	1⅛	¾	110
4 angles, 3½×2×¼ 1 plate, 12×¼	1⅛	¾	110
4 angles, 3½×2×¼ 1 plate, 14×¼	1⅛	¾	110

Anchor plates should generally be set about $\frac{4}{5}$ of the height of pier below the top and should have a thickness not less than $\frac{1}{4}$ of the bolt diameter, plus $\frac{1}{8}$ inch. The area of the anchor plate should be about eight times the value of the anchor bolts in tons. Bent anchor bolts in U form with nuts on the upper stems, require no anchor plates.

Rough or foxtail bolts set 6 inches in the cap and fastened with cement, should be used for all other anchorages.

The framework of a large structural shop in the East, when the erection was only partially completed, was struck by a violent wind storm before the bracing was in place, and successive bays of framing, including trusses and columns, were blown over in one direction, but the columns had been so firmly anchored by set bolts to the piers, that their bases remained fastened in their original horizontal positions, while the columns bent or broke 4 or 5 feet above the bottom, showing the effectiveness of set anchors in producing square action for columns. The practice of the author in proportioning building columns is to consider them as square ended or fixed at the base, if they are firmly anchored or if they have load enough upon them to hold them down, but smaller columns and particularly those with only plug anchors, frequently have a tendency to pin action.

Anchor bolts are located with wood templets supported on stakes above the piers, the position of the holes being carefully located on the templet with a transit and level. The bolts are suspended through holes in the templet, and are built into the piers. Holes for plug anchors are drilled after the columns have been set, and they are fastened to the masonry with melted lead or sulphur.

CHAPTER XIX.

WALL DETAILS.

Walls are for the purpose of carrying loads, and forming an enclosure to retain heat; and solid walls are made either of a uniform thickness, or with thin curtain walls and piers at the panel points to sustain the loads. Framed walls have wood or steel columns and sheet metal or plank covering. The common types are stone, brick, combined brick and concrete, concrete blocks, reinforced concrete, sheet metal and plank.

THICKNESS OF WALLS.

Sufficient wall thickness must be provided under loads to produce no greater pressure than 125 pounds per square inch on brick, 200 pounds on concrete, and 250 pounds per square inch on stone, and concentrated loads must be distributed over the wall with stone or iron bearing blocks.

If solid masonry piers would be excessively large or take more space than is available, steel columns may be inserted in the piers, with only enough covering around them to serve as fireproofing. The method of using steel columns to carry all the loads is wasteful, because the compression value of the material around the column is not considered. A more economical method is that used for reinforced concrete columns, in which light steel is inserted large enough to support the dead load, and when completed, the whole area of both steel and concrete are available in compression. Broad and shallow pilasters are preferable to narrow and deeper ones, as they have a stronger appearance.

STONE WALLS.

Stone walls are not as much used for factory buildings as formerly, excepting in districts where stone is accessible and cheap, and other material higher in price. A notable set of large new buildings with walls entirely of stone are those for the Associated Industries at Sault Ste. Marie, Ontario. The stone is a spotted pink granite, quarried on the site or in the immediate vicinity, and presents an unusually attractive appearance. Stone walls 12 to 18 inches thick, cost 50 to 70 cents per square foot.

BRICK WALLS.

Solid brick walls without columns are rigid and free from the vibrations common in mill buildings with framed walls. Brick walls with piers and thin curtains between, are less rigid but much used. The required thickness of walls, according to the building laws of several cities, is given in Chapter V. Brick walls absorb water and are free from condensation inside, but if moisture must be excluded, paving bricks may be used on the exterior and enameled brick on the interior, as in the new shops of the American Arithmometer Company.

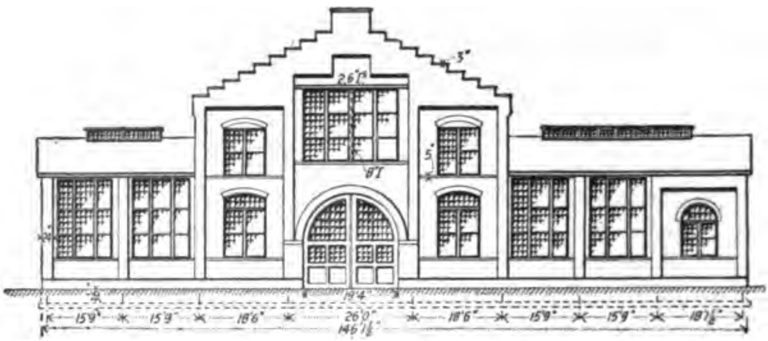


Fig. 346.

SIZE AND COST OF BRICK.

The standard size adopted by several brick manufacturers is for common brick, $2\frac{1}{4} \times 4 \times 8\frac{1}{4}$, and for face brick $2\frac{1}{4} \times 4\frac{1}{8} \times 8\frac{3}{8}$ inches, and in the walls, including mortar joints, they usually lay $22\frac{1}{2}$ bricks per cubic foot, or $7\frac{1}{2}$ per square foot of wall surface for each 4 inches in thickness. One thousand new bricks piled close occupy 58 cubic feet, while the same number of old cleaned bricks measures 70 cubic feet.

Hard bricks when struck together emit a clear ring, and good ordinary brick should absorb not over 10% of their weight of water, and the best not over 5%, while soft bricks will take up 25 to 35% of their weight.

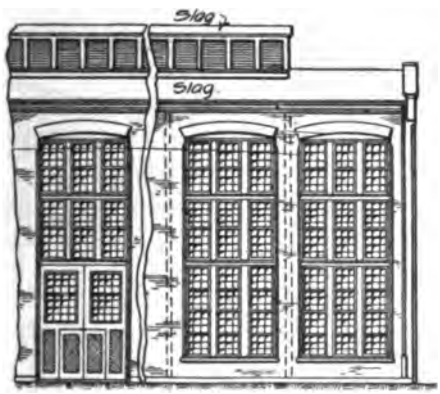
	Per M.
Common brick costs	\$ 6 to \$10
Paving brick costs	14 to 16
Glazed brick costs	20 to 25
Face brick costs	25 to 30
Moulded brick costs	40 to 50
Enameled brick costs	70 to 80

MORTAR.

Lime weighs 66 pounds per bushel, 53 pounds per cubic foot, and 230 pounds per barrel, and costs 40 cents per bushel. (1909.)

Portland cement weighs from 90 to 100 pounds per cubic foot, and a barrel weighs 375 pounds and costs about $1.35 at Chicago, while Rosendale or natural cement weighs 50 to 60 pounds per cubic foot and a barrel weighs 300 pounds and costs 80 cents to $1.00.

Seashore sand is not suitable for making mortar, for the salt which it contains forms efflorescence on the brickwork, and good sand ordinarily costs from 75 cents to $1.25 per cubic yard.



SIDE ELEVATION.

Fig. 347.

One barrel of unslacked lime will make 2¼ barrels of stiff lime mortar paste, or 6¾ barrels of mortar of one to three proportion.

The amount of mortar required to lay 1,000 bricks is as follows:

Lime mortar, 2½ bus. of lime and ⅝ cu. yd. of sand.
Lime and cement mortar, 2 bus. of lime, 1 bbl. cement, ⅝ cu. yd. of sand.
Cement mortar (1-3), 1½ bbls. cement and ⅝ cu. yd. of sand.

In making mortar the lime and cement should be thoroughly mixed before water is added, and the mortar must be made only in small quantities as needed.

COST OF BRICKWORK.

The cost of brickwork depends largely upon the rate at which the bricks are laid. A man and helper can lay 1,300 common brick per day of 8 hours on ordinary straight walls, or 1,000 to 1,200 on walls that are more broken, while in the same time one man with half the time of one helper will lay only 400 to 600 face bricks. Enameled brick around piers and openings are laid at the rate of 100 to 300 per man per day, depending on facilities and conditions.

One helper is required for each bricklayer on solid walls, and one helper for every two men laying 9-inch walls with pressed brick face. Ordinary hods contain 18 bricks.

A table of wages paid to bricklayers and laborers in different parts of North America is given in Chapter XLI. The cost of laying common brick varies considerably but is generally about

Fig. 348.

$6.00 per M, and face brick $10.00 per M. Itemized costs of common and face brick in walls are as follows:

Cost of common brick per M laid at the rate of 1,000 brick per man per day—

	Per M.		*Per M.*
Brick costs	$ 7.00	Hauling	$ 1.00
Sand, ¾ yard	.75	Hoisting	.50
Cement, 1½ bbls. at $1.35	2.00	Mason, 8 hours	5.00
		Helper, 8 hours	2.50
Material	$ 9.75		
		Total	$18.75

Cost of face brick per M, laid at the rate of 500 per man per day—

	Per M.		*Per M.*
Brick costs	$25.00	Hauling	$ 1.00
Sand, ¾ yard	.75	Hoisting	.50
Cement, 1½ yards at $1.25	2.00	Mason, 16 hours	10.00
		Helper, 8 hours	2.50
Material	$27.75		
		Total	$41.75

The cost of 12-inch common brick walls at $20.00 per M for brick in place is as follows:

Twenty-two and one-half bricks at 2 cents each is 45 cents per square foot, while the average cost per square foot for an 8-inch brick curtain wall with enclosed steel columns is:

	Per sq. ft. (cents.)
Steel, 4 lbs., at 4 cents	16
Brick, 15 lbs., at 2 cents	30
Total cost per sq. ft	46

COMBINATION BRICK AND CONCRETE WALLS.

A type of wall construction for mills and factories which has more merit than almost any other, has the columns, foundations, sills and lintel beams made of reinforced concrete, with a light filling wall between. The reinforced concrete columns (Fig. 349) have angle irons heavy enough to support the trusses during erection and have side grooves to receive the filling wall, which may be either brick or concrete, brick being the cheaper. The construction permits the use of steel roof trusses and girders, which can be fitted to the column angles before the concrete has been placed, insuring good connections. Buildings of this kind are erected rapidly, for the whole framing can be placed without waiting to complete the wall.

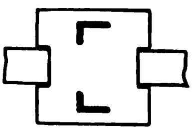


Fig. 349.

A very neat and artistic effect is obtained by covering the wall, both piers and curtain panels, with 4 inches of buff or yellow face brick. The average cost per square foot for such a wall without the brick covering and columns 20 feet apart is as follows:

	Per lin. ft. of col.
Column concrete, 2 cu. ft., at 25 cents	$0.50
Column steel, 10 pounds, at 4 cents	.40
Column forms	.50
Total cost per lin. ft. of col	$1.40

OR

	Per sq. ft. of wall.
Cost of col. and pilaster	$0.07
8-inch brick curtain wall, 15 bricks, at 2 cents	.30
Total average cost per square foot of wall	$0.37

REINFORCED CONCRETE WALLS.

A light strong reinforced concrete wall (Fig. 350) is made by placing a light double angle iron frame in the panels between the columns, heavy enough to support the windows and braced at the corners with thin plates. After the frame is erected, concrete is run in between plank forms, and the steel frame is afterwards painted red or black in contrast to the concrete. This kind of wall costs more than some others, owing to the presence of the permanent angle iron frame and the need of forms; but when brick is expensive and sand and gravel convenient, it may be economical. It can be erected in units, and single panels can be removed more easily than monolithic walls.

The objection to solid concrete walls is that condensation forms on the inside in cold weather and discolors the wall and

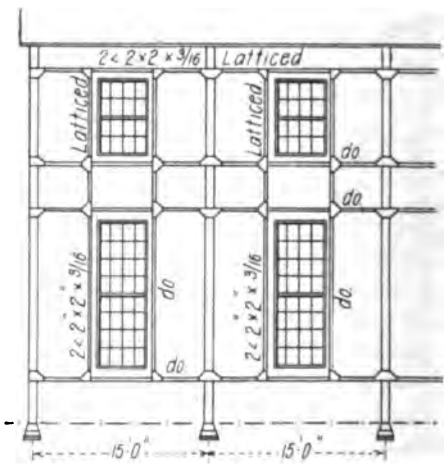


Fig. 350.

adjoining floor. An average square foot cost of an 8-inch concrete wall as described above is:

	Per sq. ft. (cents.)
Steel frame, 4 lbs., at 4 cents per lb.	16
Concrete, 8 ins.	20
Forms, 2 sides	10
Total	46

Walls of concrete and expanded metal are used in several buildings designed by the author, illustrated in Figs. 24, 25, 26, 51 and 52. The framing consists of ¾-inch channels placed vertically 12 to 16 inches apart, and fastened to longitudinal steel girths attached to the columns. The light channels are covered with expanded metal, which supports a 2-inch concrete wall.

These walls require the use of forms on both sides for placing the concrete and the cost per square foot of 2-inch concrete and expanded metal wall is as follows:

	Per sq. ft. (cents.)
2 in. concrete, at 2½ cents per sq. ft.	5
Expanded metal	2
Forms, 2 sides	10
Steel, 4 lbs., at 4 cents	16
Total cost per sq. ft.	33

The shop office (Fig. 41) and the market building (Fig. 32) designed by the author have double concrete walls with air space between them. The outer 2-inch slab is first formed as described above, and the inner lining of light channels and expanded metal is then applied over the girths and plastered. As the outer and inner girths are fastened to the column faces, the width of air space between the double wall is equal to the column thickness. The method is appropriate in very cold or very hot climates where non-conducting walls are desired. The cost of double walls is not quite twice the cost of single ones because less forms are needed. These walls are occasionally plastered with two or three coats, the first coat consisting of 1 part of cement, 2 of lime, and 3 of sand, and later coats having 1 part of cement and 2 of sand. The inside is sometimes coated with gypsum plaster instead of cement mortar.

Concrete walls are also made by erecting separately molded slabs 3 or 4 inches thick, and 4 or 5 feet square and hooking them with countersunk bolts to the wall girths (Fig. 351). These slabs are reinforced with wire fabric or expanded metal, and are molded one upon another with sheets of oiled paper between them, to prevent the blocks from adhering while the concrete is green. The government coal storage pockets at Bradford, Rhode Island, have corrugated iron walls lined with concrete slabs as described above. The duplicate buildings are 725 feet long and 87½ feet wide, hold 40,000 tons of coal, and contain more than 4,000 of these concrete slabs.

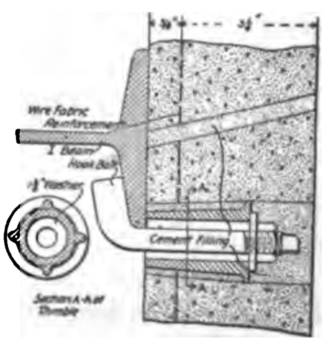
Molded concrete slabs may also be made with a frame of 2x¼-inch flat bars on edge, connected with ¼-inch round rods 4 inches apart, passing through punched holes in frame. The metal reinforcing is completed by weaving No. 14 wire under and over the rods, 6 inches apart, and the frame is then filled with stone concrete mixed in 1-2-4 proportion. The edges are offset to fit together and fasten over the framework, and grooves which are afterwards filled with cement, are left in the slabs for anchor bands.

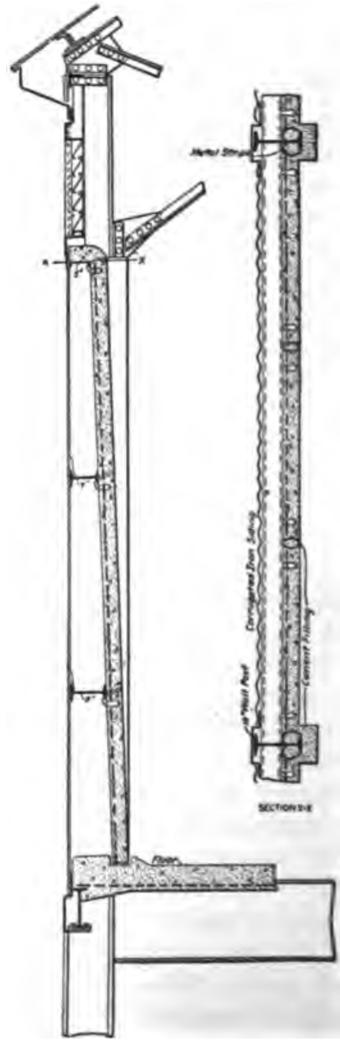
The finished slab is 2 inches thick, and is suitable for sizes up to 4 × 15 feet. They can be used both for walls and roofs, and lower side only and is patented by The Aiken Cement House Company.

Concrete walls are also made by molding complete wall sections in a horizontal position on the ground, and then hoisting them into place. The method has the advantage of requiring forms on the lower side only and is used by The Aiken Cement House Company of Chicago.

CONCRETE BLOCK WALLS.

Concrete block walls are made of either single or double blocks, the former going through the wall, while the latter are facings only, anchored in with one or more ribs. They are less expensive than brick or stone and form not only a lighter wall than either, but one which is a non-conductor of heat and cold because of the hollow center.





Concrete Block

Fig. 351.

Condensation on the inner face, which is liable on walls of solid stone or concrete, is almost or entirely absent on a wall of hollow blocks. Some concrete blocks have double lines of

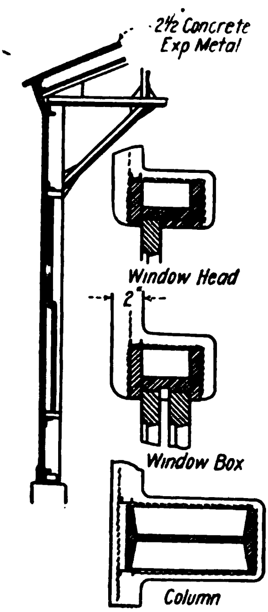


Fig. 352.

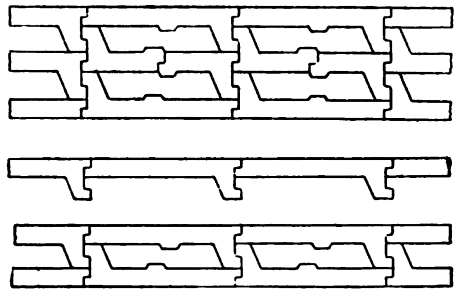


Fig. 353.

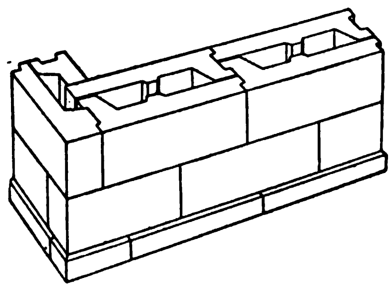


Fig. 354.

cores alternating with each other, and cross ribs never extend through the wall to conduct heat or cold and cause condensation. The hollow wall is cheaper than a solid one because it contains less material, and it is also lighter, requiring a less expensive foundation to sustain it. Blocks are made in much larger sizes than brick, and the cost of laying them is proportionately less. The hollow spaces in the walls are convenient for pipes and there is no delay in waiting for stone or brick, as the concrete blocks can be made at the site by the men who erect the building. The cost of the best concrete block machine does not exceed $100. Cinder concrete is serviceable for interior partitions, but it is too porous to use in blocks for outer walls. Another saving from the use of hollow concrete blocks in preference to brick or stone, is that furring and lathing on the inside is unnecessary, as they contain an interior air space, and plaster can be applied directly to the blocks.

Blocks are usually made from a mixture of 1 part of cement with 6 or 8 parts of sand and gravel or crushed stone not exceeding $\frac{1}{2}$ inch in diameter, and faced with $\frac{1}{4}$ to $\frac{1}{2}$ inch of fine material, which gives a better appearance and a more impervious surface. Different kinds of blocks are made in the same molds by using different cores. After being molded, the blocks require about a week to thoroughly harden, and during this time they should be occasionally sprinkled. They can be made at the rate of 300 square feet per man per day, and single blocks such as those in Figs. 353, 354 and 355, cost 10 cents per square foot, or 25 cents per cubic foot in the wall. Walls like Fig. 354, 10 inches thick, cost 20 cents per square foot, which is less than half the cost of brick walls with pressed brick face.

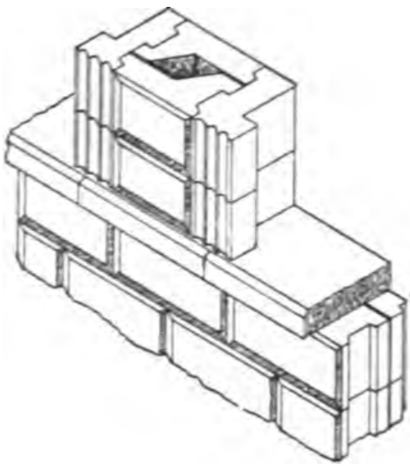


Fig. 355.

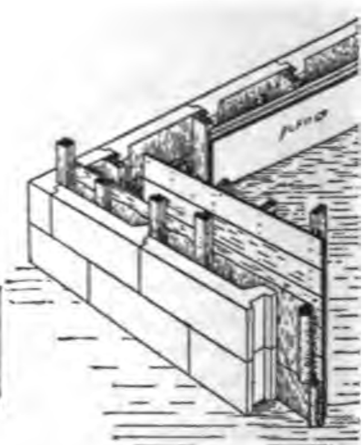


Fig. 356.

Hollow monolithic walls are made by placing concrete between wooden forms similar to the methods used for solid walls, excepting that concrete is placed around movable wooden cores 3 to 4 feet long, with concrete cross ribs between them to unite the inner and outer faces.

SHEET METAL WALLS.

Corrugated iron is one of the most common and cheapest walls for mill buildings, and its use is described in Chapter XXV. It is suitable only where interior heating is unnecessary, and usually has short duration owing to the formation of rust, but it is easily renewed. It is fastened to wood or steel purlins, supported on the columns, and when well braced this type of wall is suitable for buildings with heavy cranes. Bracing should preferably be stiff, and capable of resisting both tension and compression, but if rods are used, they must have turnbuckles or other adjustments for tightening them. Corrugated iron walls lined with concrete are shown on page 210. These walls are also made double thickness, thickness, using 2½-inch corrugations on the outside and 1¼-inch on the inside, but the inside corrugated iron must be nailed to wood strips or purlins, for the rear side of inner sheets are not accessible for clinching nails. Fig. 21 is a foundry designed by the writer, with side and rear walls of corrugated iron and continuous sash.

WOOD WALLS.

Wood shop walls are made either fixed or as a series of movable panels or doors, permitting all or half of the sides to be opened when desired.

Permanent wood walls are generally made of plank standing vertically, spiked to horizontal purlins, with joints between planks covered with ½-inch battens, or of matched sheathing without battens (Fig. 357). If instead of battening the joints the wall is covered with corrugated iron or metal siding, the plank should then be horizontal, and fastened to columns and intermediate studs. Plank walls shown in Fig. 368 are weather-proofed with slate. Wood walls made of movable panels are most convenient when arranged to roll horizontally past each other, leaving one-half of the side area open (Fig. 16). The whole wall space may be opened by using continuous counterweighted, sliding, rolling or folding doors, at an increased cost.

The detail cost of a weather-boarded plank wall is as follows:

	Per sq. ft. *Cents.*
Steel framework, 4 lbs., at 4 cents	16
2-in. plank, at 3 cents	6
Sheathing paper	½
Weather boarding	6
Paint, 2 coats	2
Total cost per sq. ft.	30½

WALL ANCHORAGES.

Fig. 369* is a common truss and wall connection with two ⅞-inch bolts passing through the bottom truss angles, fastened to a projecting steel plate built into the masonry. Bolts are easily inserted and the anchorage is usually satisfactory, permitting a slight variation in the distance between walls, without affecting the connection.

* Mill Building Construction, H. G. Tyrrell, 1900.

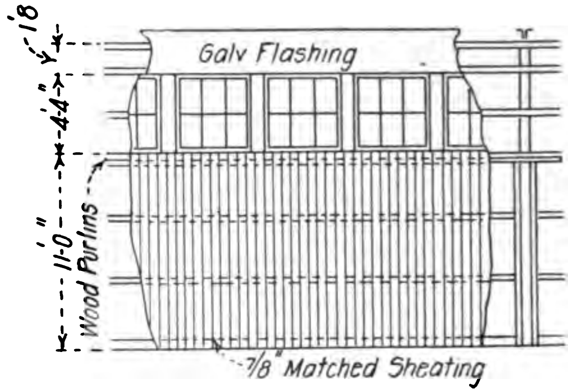


Fig. 357.

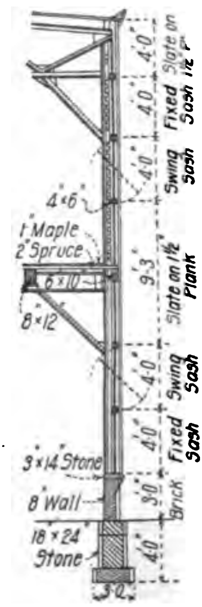


Fig. 358.

Anchors like Fig. 370* are more secure but require greater care in setting the wall bolts, and must have slotted anchor holes in the shoe plates. Bolts and anchor plates are built into the walls, and the trusses placed afterwards. The trusses in Fig. 371 rest on stone seats, and after they are placed, holes are drilled in the stones, and plug bolts set with lead or sulphur. In Fig. 372 the trusses are built into the wall and held by angle clips at the end.

Fig. 373 is a method of attaching a new steel truss to the inside of an old wall without cutting it. Bolt holes are drilled through the wall to match those in the outside washer plate, the area of which in square inches must be equal to eight times the tension on the bolts in tons. The bearing value in tons for bolts of different sizes in walls of various thicknesses, and the required area of washer plates for each bolt is given in the following table:

TABLE XXIX.*

Diameter in ins.	*8-in. Wall.*	*12-in. Wall.*	*16-in. Wall.*	*20-in. Wall.*	*Area of pl. sq. ins.*
⅝	.5	.7	..	..	18
¾	.6	.9	1.0	..	26
⅞	.7	1.05	1.4	..	36
1	.8	1.2	1.6	1.77	46

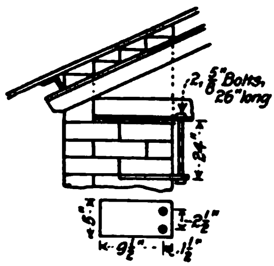


Fig. 369.

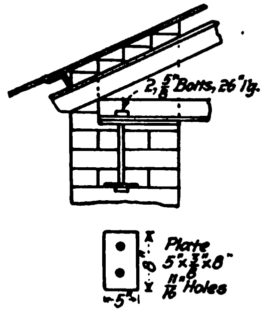


Fig. 370.

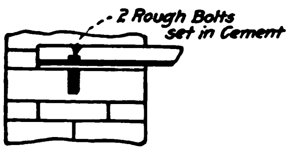


Fig. 371.

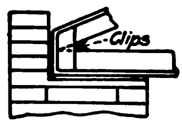


Fig. 372.

The trusses must be carefully set, using filler plates if necessary, between the truss and wall. When bolts cannot be passed through the wall, trusses are then fastened with expansion bolts, the bearing value of which, for different lengths and sizes, are as follows:

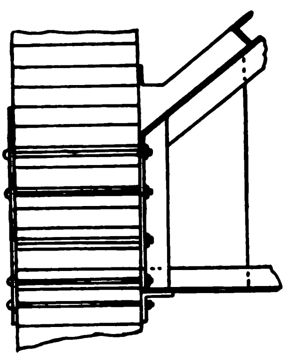


Fig. 373.

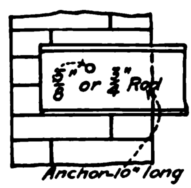


Fig. 374.

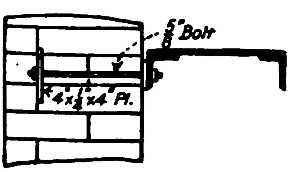


Fig. 375.

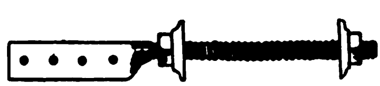
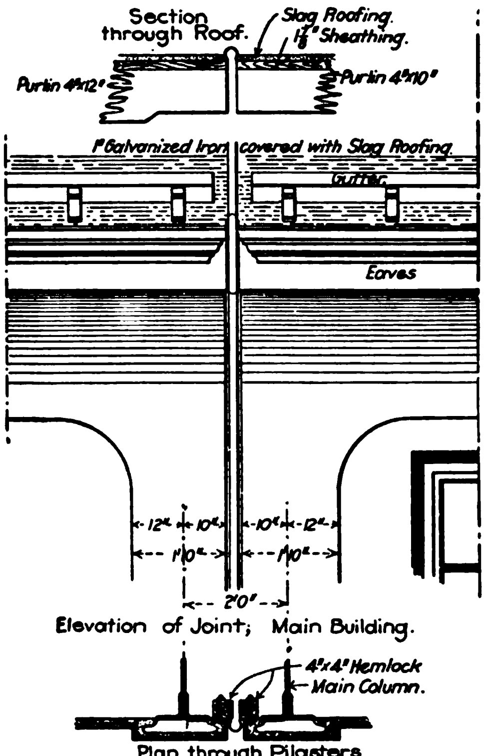


Fig. 376.

TABLE XXX.*

Diameter in ins.	4 ins. long.	6 ins. long.	8 ins. long.	10 ins. long.	12 ins. long.
⅝	.24	.36	.46	.52	..
¾	.28	.42	.56	.70	.84
⅞	..	.47	.65	.81	.99
1	..	.57	.75	.93	1.12



Expansion Joint in Main Shop Walls and Roof.

Fig. 377.

Fig. 374 is the anchorage for a beam in brickwork, the length of anchor being 6 inches greater than the width of beam flange.

Fig. 375 shows a lattice strut anchored to the wall with bolts 3 or 4 feet apart. When walls are already built, bolts must extend through the wall with washer plates, or the strut may be fastened with expansion bolts. The ends of angle struts are fastened into brickwork, as shown in Fig. 376. A round rod forged out flat at one end, is threaded and fitted with double nuts and cast washers, the flattened part being punched for connection to the angle strut. Two holes and a $\frac{7}{8}$-inch rod are required for a 2-inch angle strut, three holes and a 1-inch rod for $2\frac{1}{2}$-inch angles, and four holes with a $1\frac{1}{4}$-inch rod for 3 angle struts. The length between washers must be made to suit the wall thickness.

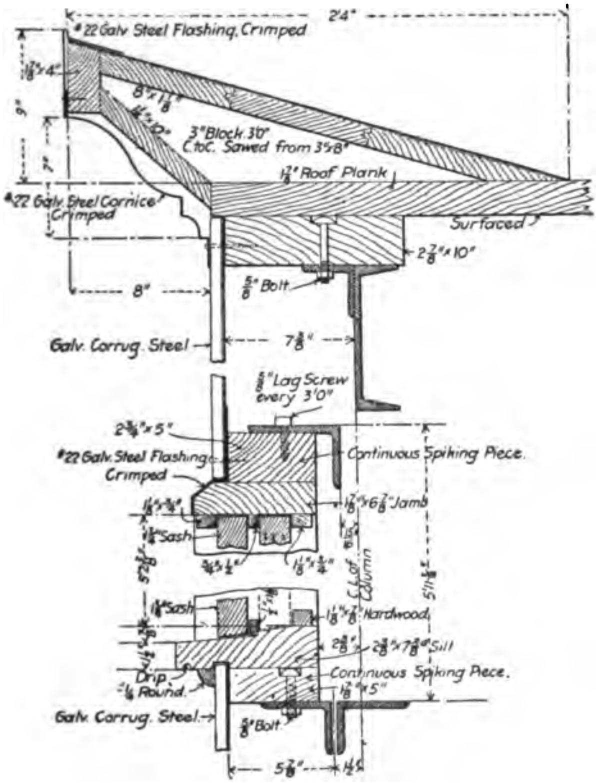


Fig. 378.

CHAPTER XX.

GROUND FLOORS.

Shop floors are of two general kinds: (1) Ground Floors, or those which rest upon the soil, (2) Upper Floors, supported on a frame of beams and columns, the construction of these two kinds being quite different. The purpose of the building and its contents will determine the most suitable kind of floor in each individual case. Some shops containing only very heavy machinery, require special foundations for each machine, but other shops for light work are more convenient when built with a solid floor on which machines can be placed anywhere without special foundations.

Ground floors may be made of natural compacted earth or clay, cement or tar concrete, brick, asphalt, plank, or wood blocks. Permanent or solid floors should be built like a street pavement, with a finished wearing surface bedded on substantial foundations, and should have a grade of about 1 or 2 inches per 100 feet for drainage. Certain other buildings, such as car shops, roundhouses, etc., in which water is freely used for washing, should have a greater floor slope to drain them quickly, for men cannot do effective work when standing in water. The ground floors of steel frame buildings which are usually made and erected by structural companies, can be laid more cheaply by the owner or a local builder, and ground floors should therefore not be included with a structural contract.

KIND OF FLOORS.

Experience has proven that different types of floors are best suited for different kinds of manufacturing buildings. Clay or earth are the best suited for forge shops or foundries where the presence of hot metal makes wood flooring prohibitive. A floor made by laying vitrified brick on plank foundation, water-proofed on the underside and imbedded in sand, is largely used and is satisfactory for foundries.

Machine shops or other buildings where men stand continuously, should have floors with a wearing surface of wood or asphalt, for cement, stone or brick are too cold and unresisting and tire the workmen. Asphalt is more comfortable to walk upon than wood, but is not as well suited for machine shops, because oil softens asphalt, and wood floors are therefore best, wherever oil is liable to drip. Floors of machine shops should be smooth and clean, so dust will not rise and settle on the machinery; earth or macadam are therefore unsuitable. They should be firm enough to support small machines anywhere, and are sometimes made to carry even heavy machines at any place without special foundations. These floors receive hard usage, not only from the direct weight placed upon them, but also from having castings dragged along the floor by the cranes, and they must be strong enough to stand the service.

The railroad companies have experimented with many kinds of floors in roundhouses, and have accepted brick pavement as the best. Cement or granolithic surfaces are found to break and crumble from the action of heavy hydraulic jacks and the weight of trucks and driving wheels. Timber, cedar block and cinder floors have all been found inadequate for the same reasons, and while brick paving is often damaged, it can easily be repaired by taking up part of the floor and replacing it without disturbing the rest.

CEMENT CONCRETE FLOORS.

Concrete floors with cement mortar surface are laid like basement floors on a foundation of broken stone, cinders or gravel. The sand, gravel and stone should be clean and free from foreign matter such as clay or loam, and the method of mixing and placing the concrete should be similar to that used in other kinds of concrete construction. A convenient method of determining the proportions of material to use, is to fill a barrel with sand and find the amount of water that can be poured in without overflowing; the water represents the quantity of cement that must be used with a barrel of sand. If gravel and broken stone are used, another barrel should be filled with gravel, and water poured in as before, to determine the amount of mortar, or cement and sand needed for a barrel of gravel. Another barrel may be filled with broken stone, and the amount of water that it will hold represents the quantity of cement, sand and gravel to be added to the stone. In order to have the sand, gravel and stone thoroughly covered with cement, the proportion of finer material should be slightly greater than indicated by the above tests, exceeding the water volumes by about 10%. A barrel of cement contains four bags measuring 3.8 cubic feet and weighs 380 pounds. The thickness of foundation depends on the nature of the soil and on the load the floor must sustain. Where ground is compact and firm, a single 4 or 5-inch layer of concrete may be enough, but softer soils may need a thicker floor made of several layers of broken stone, gravel, or sand under the concrete. Soft or spongy places should be dug out and refilled with solid material. Figure 379 is a section of a concrete floor having a 6-inch broken stone foundation overlaid with 8 inches of concrete and covered with a 4-inch thickness of spruce, under yellow pine or maple. The soil should be excavated to a depth of 18 inches and the surface well rammed before placing the broken stone. A wearing surface containing asphalt in combination with cement mortar is more elastic than solid cement finish, and is sometimes preferred. Another floor shown in Fig. 380 has several layers, the thickness of which depends upon local requirements. On a well rammed subsoil, is laid 8 to 12 inches of broken stone, which is covered with 4 to 6 inches of smaller crushed stone, each layer being thoroughly rammed before placing the next one. Concrete is then spread 2 to 4 inches thick and covered with ½ inch to 1 inch cement mortar surface. The top dressing is made by mixing one part of cement with one to one and one-half parts of sand, while a good proportion for concrete is one part of cement mixed with two of sand and five of gravel and broken stone. The concrete below the upper dressing must be carefully rolled and leveled before applying the wearing surface, and the dressing should be placed before the concrete has had time to harden, so it will adhere to its foundation. If the concrete stands long enough to become thoroughly hard on the top, the mortar surface is liable to crack and crumble. The surfacing must be laid in blocks 4 to 5 feet square, with joints between them, so if cracks should develop from change of temperature or contraction of the material, they will follow the joints and prevent irregular breaks from disfiguring it. The surfacing must be protected for one or two days, to give the cement time to harden before being thrown open to travel. A floor of this kind was laid in the machine shop at the Brooklyn Navy Yard, the top

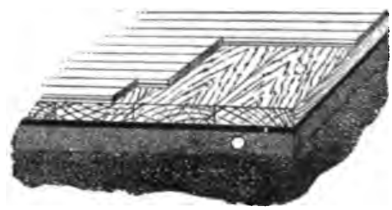


Fig. 379.

dressing being colored brownish red for better appearance.

A method of fastening light machines to the floor is shown in Fig. 381. Troughs made of sheet metal, with angle iron edge,

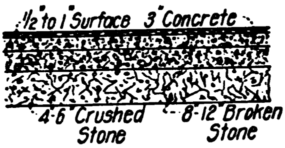


Fig. 380.

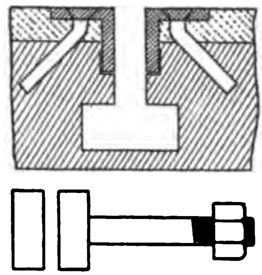


Fig. 381.

are built into the cement, and flat-head bolts are inserted into the grooves and turned sideways.

The cost of concrete floors varies with the richness of concrete and its thickness, and may be found for any particular case from the following unit prices:

Portland cement, per bbl., costs from	\$1.50 to \$2.00
Sand and gravel, per cu. yd., costs from	1.00 to 1.50
Crushed limestone, per cu. yd., costs from	1.50 to 1.75
Concrete in place, per cu. ft., costs from	.20 to .25

A 6-inch layer of concrete costs from 10 to 12 cents per square foot, and for each additional inch of concrete is added 2 cents per square foot, or 18 cents per square yard. One inch cement mortar surfacing costs 6 cents per square foot.

A light cement floor composed of ½-inch mortar surface on a 2-inch layer of concrete is reported to have cost 66 cents per square yard, itemized as follows:

Sand, gravel and stone, per sq. yd., costs	\$0.10
Cement, per sq. yd., costs	.30
Labor, per sq. yd., costs	.26

One barrel of cement was enough to lay 100 square feet of the above floor, 2½ inches thick. A similar floor with ½-inch wearing surface on 5-inch concrete costs from \$1.00 to \$1.25 per square yard. Labor for surface dressing costs 15 cents a square yard, while the labor cost of forming side floor gutters is 15 to

20 cents per lineal foot. Cement wall base 10 inches high and ⅝ inch thick costs 12 to 20 cents per lineal foot, the former price being for large quantities. Five laborers and one finisher can lay 600 square feet of concrete floor 6 inches thick in 8 hours. The wages paid to cement finishers and laborers in different parts of the United States and Canada are given in the table on page 420. Labor costs from 20 to 60 per cent of the cost of materials, depending on the thickness of floor and the rate of wages paid.

TAR CONCRETE FLOORS.

A foundation of coal tar or asphalt concrete is the best preservative for wood, for when laid over cement concrete without any protective coating, wood plank and sleepers decay rapidly from dry rot. Several methods of preserving floor lumber have been tried, especially the plan of spreading lime under it, but no preservative is so effectual as tar or pitch, or a combination of the two materials. A concrete floor overlaid with plank is the best for machine shop use; it is solid, without vibration, is comfortable to walk upon, and machines can be screwed to any part of the floor. As there is no air space beneath it, the floor is practically fireproof, is not expensive, and tools falling upon it do not break. It will last for twenty-five years, while plank laid over cement concrete decays in half the time or less. The most approved method of laying a tar concrete floor is as follows:

After grading and leveling the lot and filling soft, spongy places with firm material, first spread a 4-inch layer of screened gravel or stone that has been mixed with tar, using 6 to 10 gallons of tar per cubic yard of stone or gravel, 7 gallons being enough for coarse gravel or 2½-inch stone, while 8 to 10 gallons of tar per cubic yard is needed for ½-inch gravel or stone. The tar should be heated to 200 degrees F., and only enough used so that the mixture can be packed. A roller weighing 300 pounds per lineal foot has been found satisfactory, but tamping with iron rams is sometimes preferred, though a roller makes a flatter surface. In cold weather the sand should be heated by piling it over and around an iron pipe in which a fire is kept burning. Over the 4-inch layer of tar concrete is spread one inch of dry sand, saturated with from 40 to 60 gallons of tar to the cubic yard. The sand should be heated to 250 degrees F. and the mixture spread 1½ inches thick, compressed when rolled to one inch. While this top dressing is warm and soft, 3-inch hemlock plank is laid upon it and pressed or pounded firmly down to exclude air spaces or openings, and the edges of the plank are toe-nailed together; no wooden sleepers are required. A wearing surface of tongue and groove yellow pine or maple is then laid at right angles to the lower plank (Fig. 382).

Cinders are sometimes used in place of stone or gravel for the lower course, but are no saving over stone, for cinders require 15 gallons of tar per cubic yard, or nearly twice as much tar as for stone. Broken stone costs about $1.25 per cubic yard and

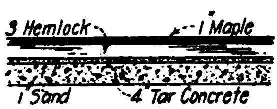


Fig. 382.

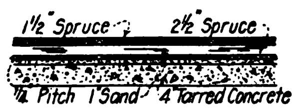


Fig. 383.

cinders 50 cents per cubic yard; but there may be a saving by using cinders for railroad shops and round houses, because the engines produce a surplus quantity and they will cost little or nothing.

Sand without gravel or stone has also been used for the bottom course, but is no saving over stone or gravel, for sand requires 20 gallons of tar per cubic yard, or more than twice as much tar as for gravel or stone. When the ground is hard and firm, 2 or 3 inches of tarred stone may be enough, instead of 4 inches as specified above. Asphalt is sometimes preferred, because it is moisture-proof, does not evaporate like tar and is therefore more permanent. These floors have frequently been made by spreading the top coating of sand and tar over 4 to 6 inches of cement concrete instead of over tar concrete, but tar concrete has proved to be the best. In other cases, a combination of tar and pitch is used instead of tar, using one part of pitch mixed with two parts of coal tar.

A floor of this description, laid in a shop for the Boston and Albany Railway Company in 1898, with spruce for the upper and lower plank courses, is reported to have cost only 18 cents per square foot (Fig. 383). It had a 4-inch tar concrete base overlaid with sand, on top of which was spread ½-inch layer of roofing pitch, with double courses of plank, 2½ and 1½ inches thick, respectively.

Another coal tar floor with foundations 6 inches thick, composed of eight parts of cinders mixed with one part by measure of coal tar covered with 3-inch plank on 3 by 4 inch sleepers, 16 inches apart, cost 8 cents per square foot for the concrete and 16 cents per square foot for the wood, or a total of 24 cents per square foot. A 4-inch base with 1-inch sand covering, laid as specified for Fig. 382, usually costs from 10 to 12 cents per square foot, not including any woodwork, and the complete floor, including wood, from 25 to 35 cents per square foot. Coal tar cost from $3 to $5 per barrel.

The new shops for the Sturtevant Company, at Hyde Park, Massachusetts, have 120,000 square feet of tar concrete floors, with 3-inch hemlock plank laid in pitch.

A very satisfactory shop floor, designed by Davis and Barnes, engineers of Philadelphia, was used by them in several buildings for the Sessions Foundry Company at Bristol, Connecticut (Fig. 395). It has a bottom layer, 4 inches thick, of well tarred broken stone, covered with 1½ inches of tarred sand, in which is imbedded 3 by 1½ inch chestnut strips placed 4 feet apart, the top of the strips being level with the sand; over this is laid a wearing surface of 4 by 1¼ inch tongued and grooved maple.

The new plant of the Chapman Valve Company at Indian Orchard, Massachusetts, the repair shop of the Maine Central Railway Company at Portland Maine, and the Columbian Rope Company at Auburn, New York, all have their main floors built of tar concrete covered with wood.

BRICK FLOORS.

Brick floors have been generally adopted as standard construction for railroad buildings and particularly for round houses, where the pressure on the floor from lifting jacks, trucks and driving wheels is liable to cause injury. Wooden floors in round houses wear out too quickly and concrete floors crack and break under the heavy loads. A good specification for laying brick floors is as follows: First excavate the soil to the necessary depth for a solid foundation and roll or tamp the ground thoroughly, after which one, two or three layers of slag or cinders shall be laid and rolled, each layer 4 to 6 inches thick. The layers shall be thoroughly tamped and rolled before placing the succeeding one. Over the cinders sand shall be spread to a thickness of 1 to 2 inches, depending on the thickness of cinder base beneath it, a 6-inch base having not less than one-inch layer of sand. The sand shall be thoroughly rolled and smoothed to an even grade to receive the brick. Hard vitrified brick shall be laid on edge with staggered joints and an upper half-inch layer of sand spread and rolled. When a waterproof floor is desired, the brick shall be grouted with a mixture of tar and pitch, over which is spread a layer of sand thoroughly brushed and rolled into the joints. A concrete base beneath the brick is preferred by some railroad companies for their round house floors; but for shops with lighter loads, and particularly where machines have special foundations, the concrete base is unnecessary. Brick floors laid over a cinder base cost from 85 cents to $1.15 per square yard.

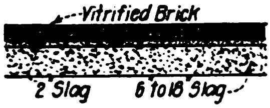


Fig. 384.

ASPHALT FLOORS.

Asphalt is one of the oldest natural products used in building construction. Authorities believe that it was used in building the ark, the tower of Babel and the walls of Babylon. It is stated in Genesis that "the vale of Siddom was full of slime pits," and further that "they had brick for stone and slime for mortar," while in describing the ark it is said that "the ark was pitched within and without with pitch." In modern times asphalt is very extensively used both for street paving and floors, and is used in many monumental buildings, such as the Philadelphia city hall. They are very comfortable to walk upon, do not tire the feet like stone, and are serviceable where a low first cost is not the chief consideration, as the material does not wear away, but is simply compressed. These floors are made by mixing crushed rock asphalt with Trinidad asphalt and sand in the proportion of 60 pounds of broken asphalt mastic blocks with 4 pounds of Trinidad asphalt and 36 pounds of fine gravel and sand, the total mixture weighing 100 pounds. The mixture is heated in kettles up to 400 degrees F. for about 5 hours and well stirred during the period of heating, after which it is taken out and spread. The asphalt mastic, which is sold in blocks weighing from 50 to 60 pounds, contains 86 per cent carbonate of lime and 14 per cent of bitumen, and the blocks, when marketed, bear the maker's name or brand. Rock asphalt, as distinguished from Trinidad asphalt, is a limestone mixed with 8 to 17 per cent of bitumen, and the best is found in workable quantities at Seyssel, France; Limmer. near Hanover, Germany, and at Neuchatel. Switzerland. The mines at Ragusa, Sicily, also produce a rock rich in bitumen, which is largely used for street paving in America. Beds of sandstone containing from 15 to 20 per cent of bitumen are found in strata like coal in several parts of the United States, notably near Santa Barbara, California; in Utah, New Mexico, Colorado and Kentucky, and this impregnated sandstone is quite extensively used for street paving in the Pacific States. The rock asphalt is mined, and prepared for shipping by first grinding it to powder, adding 8 per cent of Trinidad asphalt to prevent burning, and heating for five hours in kettles at a temperature of 350 degrees F. It should be stirred continuously during the period of heating and then molded into blocks weighing from 50 to 60 pounds each, known as asphalt mastic. Asphalt is not volatile at any natural temperature, and is therefore permanent, but there are many imitations of asphalt mastic made of tar and crushed limestone, which are of little value, for the tar evaporates, causing cracks and leaks. Asphalt is not injured by freezing and thawing, and should last for ten years without repairing. It is so elastic that cracks will not form, is waterproof, and as it is laid in sheets without joints, it does not leak, and can be kept clean with a hose. Trinidad asphalt contains

	Per cent.		Per cent.
Bitumen	40	Water	17
Earthy matter	34		
Vegetable matter	9		100

When taken from the asphalt beds in Trinidad, it is melted in kettles, which causes vegetable matter to rise to the top and earthy matter to settle to the bottom. The top is then skimmed and the pure asphalt drawn off and allowed to harden.

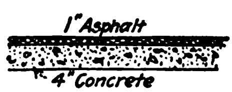


Fig. 385.

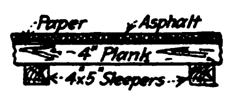


Fig. 386.

For mill floors, one inch of asphalt is laid over a foundation of concrete 3 to 4 inches thick (Fig. 385) or on boards covered with sheathing paper (Fig. 386). The new locomotive shops at Parsons, Kansas, have a portion of the floor in the center of the shop made of sheet asphalt. Rock asphalt floors, not including base, cost from 16 to 18 cents per square foot laid.

WOOD FLOORS.

A very substantial wood floor on which light machines can be placed anywhere without special foundations is illustrated in cross section in Fig. 387. The soil is first excavated to a depth of 18 inches, and after being rolled, and soft, spongy places filled with hard material, an 8-inch layer of cement concrete is spread and rammed. On this is laid 6 by 6 inch timbers, 4 feet apart, which have been previously coated with tar or liquid asphalt. These nailing pieces are carefully leveled up to the required floor grade and the space between them is filled with a second layer of concrete, covered on top with a half inch of lime. On these nail-

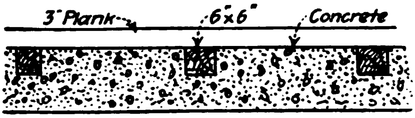


Fig. 387.

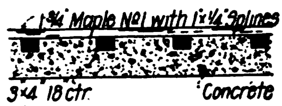


Fig. 388.

ing pieces is laid 3-inch hard pine plank, toe-nailed to sleepers and jointed with 1 by 1¼ inch splines. Where wood floors are used the preservation of the lumber is important. The method of laying plank and sills on a ½-inch layer of lime has been found effective, and should preserve the wood for fifty years. A more recent method of preserving wood is to lay plank and sills on a bed of sand and tar, pressed so tightly into the tar that air is excluded and dry rot prevented. A coating of rosin on the under side of plank and sills has also been used to prevent decay.

A floor similar to the above, but lighter, was used in the Topeka shops of the Atchison, Topeka and Santa Fe Railroad Company. No. 1 maple flooring, 1¾ inch, with 1 × ¼-inch splines, is laid on 3 × 4-inch yellow pine stringers, placed 18 inches apart and imbedded in 6 inches of concrete (Fig. 388).

The erecting shop of the Allis-Chalmers Company at West Allis, Wisconsin, has a plank floor fastened to wooden stringers imbedded in a solid concrete base 2 feet thick, and is strong enough to sustain heavy machinery without removing any part of the floor for special foundations.

The new shops of the Pittsburg and Lake Erie Railroad Company, at McKee's Rock, Pennsylvania, designed by Messrs. A. R. Raymer, assistant chief engineer, and B. A. Ludgate, structural engineer, are illustrated in Fig. 389. The wearing surface is 1⅛-inch tongued and grooved maple over a sub-floor of 2¾-inch yellow pine, spiked to 4x4-inch stringers filled in between them with sand. These stringers are supported on 4-inch layer of cement concrete, made of one part of cement, five of sand and eight of broken stone, and over it is placed five layers of tar felt in hot tar, covered with one inch of sand. At intervals of 5½ feet there are continuous open wire ducts between the nailing stringers for conveying electric power wires to the machines.

A floor used in the railroad shops of the Missouri, Kansas and Texas Railroad Company, at Parsons, Kansas, was laid as follows: On the ground was first placed a 6-inch layer of broken stone, covered with a mixture one inch thick of sand and tar, on which are laid 3 × 4-inch yellow pine nailing pieces previously treated with the zinc process. The spaces between these nailing pieces were filled with dry sand and a 2¾-inch plank floor laid thereon. Over this is placed a layer of roofing felt, covered with a wearing surface of 4 × 1¼-inch dressed white oak (Fig. 390).

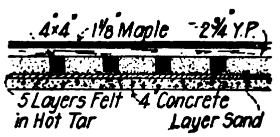


Fig. 389.

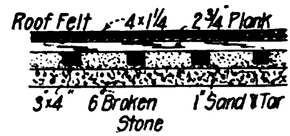


Fig. 390.

A light and cheap floor which was used in the bridge shop of the Pencoyd Iron Works at Pencoyd, Pennsylvania, is illustrated herewith (Fig. 391). The ground was first leveled and covered with a layer of cinders 6 to 8 inches thick, in which slabs or half-round timbers were imbedded every 3 feet, to which was spiked a flooring of 3-inch plank. Both planks and sleepers are coated on the under side with lime to assist in preserving the wood, as noted before. This floor cost the low price of 50 cents per square yard, but it was light, and heavy machines required special foundations.

Illustrations of wooden floors with plank spiked to wood sleepers, imbedded in gravel or stone, are given in Figs. 392, 393 and 394. Where there are two layers of plank, the upper ones should be laid lengthwise of the shop, and these floors laid in stone or gravel beds should last five or six years without renewing. Flooring with separate splines cost less than tongued and grooved lumber and is therefore preferable. The disadvantage of all wood floors is that water used in cleaning them is liable to soak into the wood, causing it to expand and form ridges.

TABLE XXXI.

COST OF WOOD FLOORS (CHICAGO, 1909).

No. 1 yellow pine, 2×6 in., T. and G., costs \$8 per square, laid.
No. 1 yellow pine, 3×6 in., T. and G., costs \$13 per square, laid.
No. 1 yellow pine, $4 \times \frac{7}{8}$ in., T. and G., costs \$7 to \$8 per square, laid.
No. 1 yellow pine, $6 \times \frac{7}{8}$ in., T. and G., costs \$5 to \$6 per square, laid.
White pine, $4 \times \frac{7}{8}$ in., T. and G., costs \$8.50 to \$10 per square, laid.
Clear maple, $2\frac{1}{4} \times \frac{13}{16}$ in., T. and G., costs \$11 per square, laid.

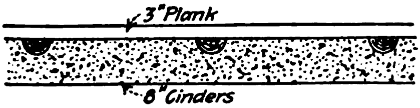


Fig. 391.

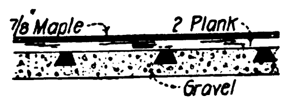


Fig. 392.

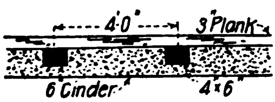


Fig. 393.

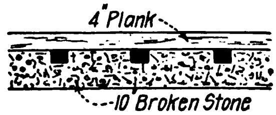


Fig. 394.

One man will lay 3 squares of flooring per eight hour day at the ground level, or $2\frac{1}{2}$ squares per day, including hoisting, on upper floors. The cost of laying is not proportional to the thickness, for while 3-inch plank is heavier to handle, it requires less care than $\frac{7}{8}$-inch pine or maple, and the average number of superficial feet laid by one man per day is about the same for thick flooring as

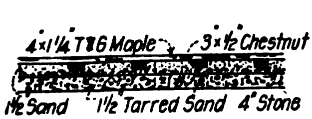


Fig. 395.

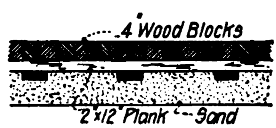


Fig. 396.

for thin. The cost of laying 2 and 3 inch plank is frequently assumed at \$4 to \$5 per thousand, board measure. The cost of floors (Fig. 393) with lumber at \$30 per thousand is 12 cents per square foot, or 16 cents per square foot with lumber at \$40 per thousand. If laid over a 6-inch base of concrete, instead of cinders, it would cost from 25 to 30 cents per square foot.

WOOD BLOCK FLOORS.

A very simple wood block pavement is made by placing hardwood blocks 4 or 5 inches thick on a plank base, fastened to stringers bedded in sand. The freight car repair shop for the

Illinois Central Railroad at Burnside, Illinois (Fig. 396), has a floor of this description, made of oak blocks 4 inches wide, 5 inches high, and 6 to 12 inches long. Beneath the main track rails are 12x12-inch wooden stringers.

A large building for the American Bridge Company, at Ambridge, Pennsylvania, designed under the direction of Mr. James Christie, 330 feet wide and 776 feet long, has for its principal flooring a pavement of 4 × 4-inch beech or maple blocks 8 inches long, set with the grain vertical on a base of one-inch tarred sand, overlying a 6-inch base of tarred gravel (Fig. 397). The site of this building was low and soft, and the filling beneath the pavement was covered with a 12-inch layer of well compacted cinders. Cedar block floors laid on plank over a foundation of gravel cost about 12 cents per square foot. Cost of wood block flooring similar to Fig. 396, when made of new material, is 18 to 21 cents per square foot, but in railroad shops they are sometimes made of old material, at much less cost.

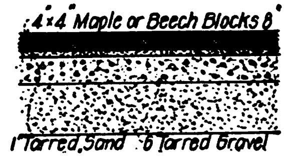


Fig. 397.

SPECIAL FLOORS.

Locomotive shops or car sheds require specially constructed floors with pits 4 to 5 feet deep between the rails, for the purpose of inspection and cleaning the cars. The pits should be well crowned at the center and drained so men can work in them without having wet feet. The edges of the pits must be capped at either side by longitudinal timbers, fastened to the side walls and to the adjoining floors.

CHAPTER XXI.

UPPER FLOORS.

STEEL TROUGH FLOORS.

A very solid floor is made by laying one or two courses of wood flooring on sleepers imbedded in the cinder filling of rolled steel troughs, resting either on the top of girders or framed into them* (Figs. 398 and 399). This floor, known as the Lindsay trough, was first made with uniform upper and lower sections (Fig. 399), riveted together through their sloping webs. The shapes were not satisfactory, however, for on account of the sloping connections, sections when riveted together, would not be the exact required width, and the trough connection holes would not match the holes in the girders. To obviate this difficulty, a joint was made in the upper section and the two parts connected with a cover plate, with a slight provision for width adjustment by play in the upper rivet holes. These troughs were used for upper floors in the fire-proof office building of the Pencoyd Iron Works, and the exposed metal ceiling was painted a light blue, adding greatly to the general light effect of the rooms. The floor is laid on $1\frac{1}{4}$-inch matched pine, over $2\frac{1}{2} \times 3$-inch imbedded strips.

The weight of steel troughs varies from 15 to 40 pounds per square foot, and the safe load, from 200 to 2,500 pounds per square foot, depending on the span and metal thickness. Complete tables of safe loads are given in the hand book of the Pencoyd Iron Works and the Carnegie Steel Company.

A form of trough floor, which is now more used than the one described above, is made of plates and rectangular shapes (Fig. 400), Z bars being used for smaller depths. It is very strong and heavy and is therefore, more used for bridges than for buildings, though it is occasionally suitable for very heavy upper floors.

FLAT PLATE FLOORS.

Flat rolled steel or cast iron floor plates, roughened on the upper surface, are much used for cupola floors in foundries and around iron furnaces. The rolled steel floor plate of the Carnegie Steel Company is made $\frac{5}{16}$ to $\frac{1}{2}$ inch in thickness and weighs from

* Mill Building Construction, H. G. Tyrrell, 1900.

13.8 to 21.4 pounds per square foot. Rolled steel floor plates are thinner and lighter than cast iron, but the latter is more commonly used, especially for foundry charging floors. They are stiffer than steel plate and are made with a rougher surface, so men walking upon them will not slip.

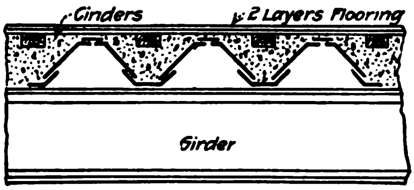


Fig. 398.

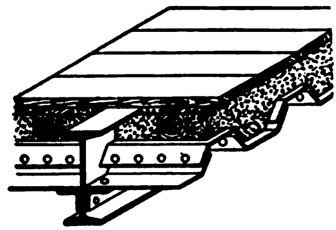


Fig. 399.

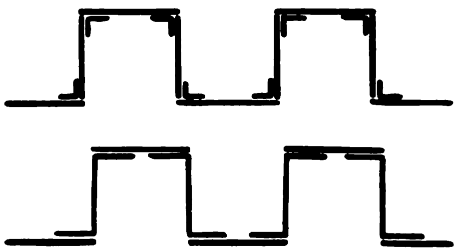


Fig. 400.

METAL ARCH FLOORS.

A metal floor which is cheaper than the Lindsay trough is made by placing curved sheets of corrugated or dovetailed metal between steel floor beams, and filling the space between the curved sheets and flooring with cinder concrete in which nailing strips are imbedded and carefully leveled (Fig. 401). One or two layers of matched flooring are then laid. The curved sheets serve both as metal arches and as forms for the concrete, but after the concrete is hardened, it alone is enough to carry the loads. Corrugated iron arches, No. 18 gage, 6-foot span and 10-inch rise, have been tested to sustain 1,000 pounds per square foot. The thickness of metal for use in building floors depends largely on the presence of fumes or corroding gases, and should be greater when these exist. No. 20 gage is satisfactory for ordinary use, and arches should have a rise of not less than one-twelfth their

Fig. 401.

span. The dovetailed plates known as Ferrolithic, made by the Berger Manufacturing Company, of Canton, Ohio, may be used instead of corrugated iron. No. 24 gage Ferrolithic cost $8 to $10 per square at the factory, and weigh 163 pounds per square.

A segmental floor arch, with beams 10 feet apart, and concrete 3 inches thick at the center, will safely sustain a distributed

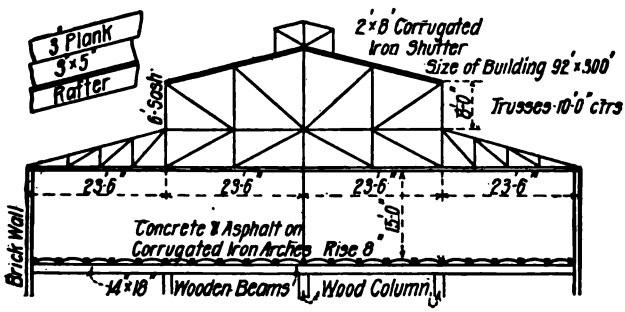


Fig. 402.

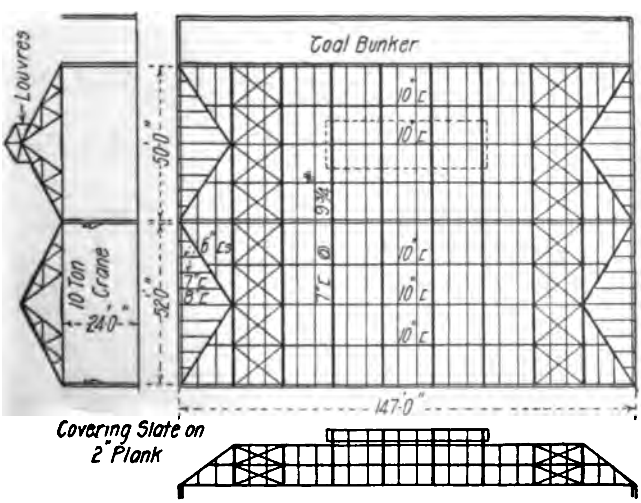


Fig. 403.

load of 250 pounds per square foot, which can be increased by using a greater thickness of concrete at the crown. Dovetailed plates are preferable to corrugated iron, for this purpose, as they may be made partially fireproof by plastering on the under side.

Buildings designed by the author, with corrugated iron floors, are shown in Figs. 402 and 403. Fig. 403, a power house design, has an engine room floor of concrete on corrugated iron, framed out around the engine foundation, and cost 56 cents per square foot in place.

MULTIPLEX STEEL PLATE FLOOR.

Another sheet metal floor made by the Berger Manufacturing Company is illustrated in Figs. 404 and 405. It has 2-inch uniform width grooves, and depths from 2½ to 4 inches, and the metal gages vary from No. 16 to No. 24, either black or galvanized. It is laid either on top of floor beams or on shelf angles fastened to the girder web, and is filled with concrete in which nailing strips are imbedded. The reverse bends at the top and bottom of the sheets add extra strength. It needs no center for placing, but cannot be plastered below, and, like other sheet metal, must be kept painted.

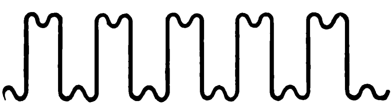


Fig. 404.

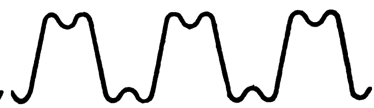
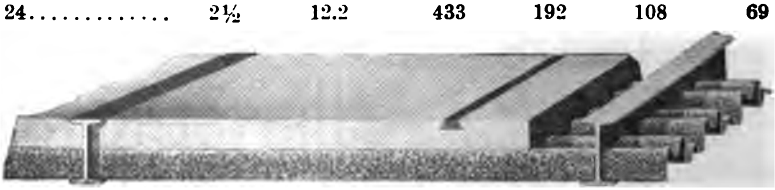


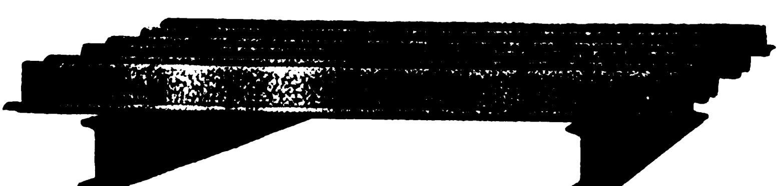
Fig. 405.

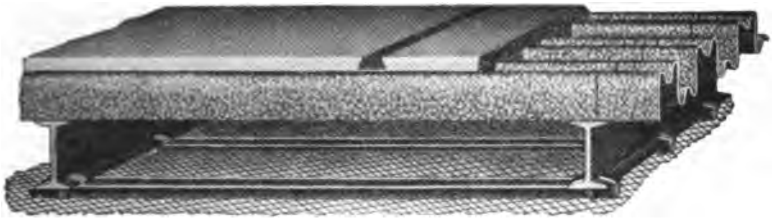
TABLE XXXII.

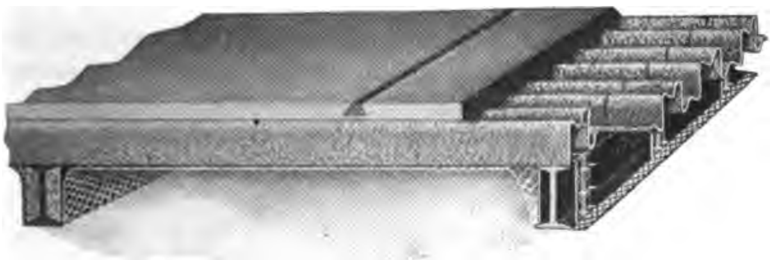
SAFE LOAD OF MULTIPLEX STEEL PLATE, WITH CONCRETE FILLING 1 IN. ABOVE PLATE.

			Span in Feet			
Gage.	*Depth.*	*Weight.*	*4.*	*6.*	*8.*	*10.*
20		18	1,260	550	300	185
24	4	17.3	792	352	198	127
20		17.5	1,115	485	265	165
24	3½	16	720	320	180	115
20		15.3	970	420	230	145
24	3	14	550	244	137	88
20		13.4	675	295	160	100
24	2½	12.2	433	192	108	69









TRIANGULAR SHEET STEEL TROUGH.

A sheet metal trough is made for floors of bridges and buildings by the Youngstown Iron and Steel Company, the troughs for buildings being 2½ inches deep (Fig. 406). The flooring

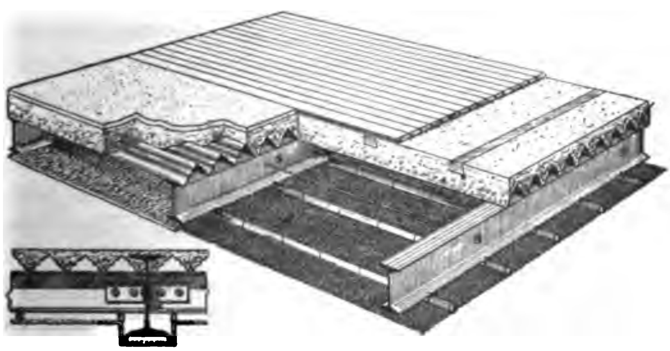


Fig. 406.

weighs when laid, complete with concrete filling and 1½-inch wearing surface, from 32 to 35 pounds per square foot. Like other troughs or corrugated floors, it has twice the stiffness of a solid floor containing the same amount of filling, or it has an average thickness of filling of only one-half its depth with the stiffness of the full depth. The sheets are made in lengths up to 10 feet, with uniform width of 21 inches.

TABLE XXXIII.

WEIGHT OF TRIANGULAR TROUGH FLOORS.

	Lbs. per sq.
No. 16 gage, 2½ in. deep, weight	386
No. 18 gage, 2½ in. deep, weight	313
No. 20 gage, 2½ in. deep, weight	241
No. 22 gage, 2½ in. deep, weight	204
No. 24 gage, 2½ in. deep, weight	168

BRICK ARCH FLOORS.

Brick arches, which were once much used for upper floors, are no longer used to any great extent, as brick or tile floors are not satisfactory in buildings subject to vibration from heavy machinery. Moreover, they are heavy and suitable only for spans up to about 5 feet. They are made of a single 4-inch ring of brick with a rise not less than one-eighth of the span, and are filled above the arch with concrete in which nailing strips are imbedded (Fig. 407).

Fig. 407.

REINFORCED CONCRETE FLOORS.

In addition to the floors made of metal troughs with concrete filling, industrial buildings frequently have reinforced concrete floors supported either on concrete or steel framing. Concrete framing is treated in another chapter and the floor slabs only are considered here. The merits of concrete floors are well known. They are fireproof, free from vibration, and clean, with no opening for rats or vermin.

A great variety of concrete floor systems are in use, including those which have numerous joist, and others with no joist, but with thicker slabs. Ribbed floors with joist are lighter than slab floors, but the latter are thinner and give either more head room or a less height of building for the same clear height of stories, while flat ceilings are preferable to ribbed ones in case of fire. Concrete floors containing tiles are not the best suited for manufacturing buildings subject to the jars from moving machinery, as the tiles are liable to be loosened.

It is common practice in steel frame factory buildings to use beams only at the panels between the columns, using a concrete floor, either flat or ribbed, in spans up to 15 or 20 feet.

The weight of a concrete floor depends on the live load carried and the system used, and varies from 60 to 120 pounds per square foot. Dry cinder concrete weighs from 75 to 90 pounds per cubic foot, though it has sometimes been assumed as low as 50 pounds.

Rods, wire mesh and expanded metal are all used for reinforcing floor slabs, the two latter being most convenient. Wire mesh is economical on account of its high tensile strength combined with its elasticity and ductility, and is best suited for resisting tension stress, because the wires are in straight lines, but heavy expanded metal has a better union with the concrete. Soft or medium steel bars are satisfactory, but not so convenient on account of the number of separate pieces to handle and the difficulty of having them uniformly placed; but high tension brittle bars, resulting from cold rolling or roughening, are not reliable. Plain bars cost \$30 to \$35 per ton, while patented bars cost \$40 to \$45 per ton. Triangular mesh with strands of No. 4 wire, 4¼ inches apart, united with a diagonal weave of lighter wire, weighs 57 pounds per 100 square feet, and cost (in 1909) \$2.30 at the mills. It is shipped in rolls up to 58 inches wide and 600 feet long. No. 10 expanded metal with 4-inch mesh, which is generally used for flat reinforcement, costs \$3.50 per 100 square feet. It is economical in large slabs to use tension members in two directions at right angles to each other, and to make the slabs continuous by extending the metal over the supports and splicing at the point of contraflexure, or about one-quarter of the span length from the beams.

The thickness of floor slab and area of tensile metal depend upon the loads and the allowable working units, but in ordinary practice they are quickly found from the following original formulæ, and the thickness will generally be from 4 to 8 inches:

$$d = \sqrt{\frac{M}{1000}}$$

$$A = \frac{d}{12}$$

where d is the depth of slab from upper surface to center of tension metal,
A = , the area of metal in square inches per foot of width, and
M = , the bending moment in inch pounds.

Concrete in floors costs about \$6 per cubic yard, of which \$1 to \$1.50 per yard is the labor cost for placing.

Floor slabs, 4 to 6 inches thick, not including wearing surface, cost as follows:

Concrete costs	10 to 12 cents per sq. ft.
Forms and labor	8 to 14 cents per sq. ft.
Steel	5 to 7 cents per sq. ft.

The floor concrete in a large Kansas City building, from observation by the writer, was put in at the rate of 50 cubic feet of concrete per man per day; under another superintendent, it had been placed at only half that rate.

The finish or wearing surface on concrete slab may be either one-inch cement of granolithic, costing 6 cents per square foot, or a double layer of matched wood flooring fastened to sleepers imbedded in cinders. Wood flooring is preferred because it is more comfortable to stand and walk upon, and is a better base for machines. Matched factory maple flooring, $\frac{7}{8}$ inch thick, over 2-inch spruce, costs 13 cents per square foot, and $\frac{7}{8}$-inch yellow pine, over 2-inch spruce, 9 cents per square foot. Nailing strips or sleepers cost 4 cents per lineal foot in place, and 2 to 3 inches of cinder fill between the strips cost 3 to 4 cents per square foot.

The second floor of the new templet shop for the Pennsylvania Steel Company has a concrete floor reinforced with expanded metal, supported on 12-inch steel beams $6\frac{1}{2}$ feet apart and 20 feet long. Beams and girders are covered on the under side with concrete. This floor has a $1\frac{1}{8}$-inch maple wearing surface over a one-inch sub-floor, on 3x4-inch strips, filled between with cinders.

The Fairbanks-Morse machine shop at Toronto, Canada, has a balcony floor consisting of a 3-inch concrete slab, supported on reinforced concrete joist 3 feet apart. Beams are 22 inches wide at the top, 6 inches wide at the bottom, and are reinforced by 6 rods, $1\frac{1}{8}$ inch diameter each.

STEEL GIRDER AND TIMBER FLOORS.

Several floors of wood and steel combined are in general use for galleries or upper floors of manufacturing buildings, the most common being a modification of wood mill construction with steel beams capped with nailing pieces and overlaid with plank (Fig. 408). This type is accepted by the insurance companies as a substitute for slow-burning wood construction. The beams must be of the required strength to support the loads and

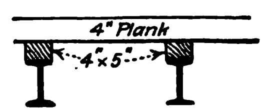


Fig. 408.

the thickness of plank should be as given in Table XXXIV. Plank should be either shiplap or have tongue and groove or splines, the last being preferable. Common practice is to use plank 3 or 4 inches thick, with steel beams 3 to 4 feet apart, capped with 4 or 5 inch wood, hook bolted to the beams.

Another similar method (Fig. 409) had a solid floor made of

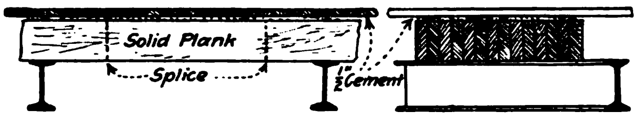


Fig. 409.

planks, laid on edge and spiked together, supported on steel beams. The beam spacing should be small enough so the thickness of timber floor, which can be found from Table XXXIV, is not excessive. The upper surface of the timber will be somewhat rough and irregular, and may be leveled with a ½-inch layer of tar cement, made of one part of tar with one to two parts of sand, covered with a matched flooring of yellow pine or maple laid while the cement is soft. It is economical to make the joints at the points of contraflexure about one-quarter of the span from the beams, rather than by splicing over the beams, for a condition of continuity will then exist and the floor will have about 25 per cent greater strength.

An arrangement is shown in Fig. 410 where heavy riveted floor girders are spaced 10 to 15 feet apart, and in order to secure greater head room the wood joist rest on shelf angles riveted to the girder web. The old practice was to space joist 16 to 20 inches on centers, but a better way is to use larger beams spaced farther apart. The cost of the floor with two layers of pine, not including the steel girders, is 12 to 15 cents per square foot in place.

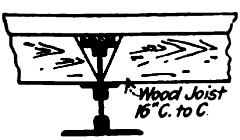


Fig. 410.

Any of the above wood floors may be made more nearly fireproof by adding a ceiling of metal lath and plaster beneath the beams, and if additional fireproofing is desired, an asphalt wearing surface may be used on top, instead of the upper layer of wood. Between double courses of flooring, one or two layers of asbestos paper should be laid, not only as an extra fire precaution but to prevent water used in washing from running through. The new shops of the Sturtevant Company have upper floors of this construction, designed to support 250 pounds per square foot, with 12x16-inch hard pine beams spaced 4 feet apart, resting on shelf angles fastened to the web of 24-inch rolled beams.

SLOW-BURNING WOOD FLOORS.

The principle of this construction is to concentrate wood material in large sizes to secure minimum surface exposure. The required thickness of plank and the spacing of floor beams can be determined from the following table for the strength of plank:

TABLE XXXIV.

SAFE LOAD IN LBS. PER SQ. FT. FOR SPRUCE PLANK OF VARIOUS SPANS AND THICKNESSES, FOR LIMITED DEFLECTIONS.

Load per Sq. Ft.					*Span in Ft.*						
Superficial.	*4.*	*5.*	*6.*	*7.*	*8.*	*9.*	*10.*	*11.*	*12.*	*13.*	*14.*
30	0.9	1.2	1.4	1.7	1.9	2.1	2.4	2.6	2.8	3.1	3.4
40	1.1	1.4	1.6	1.9	2.2	2.5	2.8	3.0	3.2	3.5	3.8
50	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.6	3.9	4.2
75	1.5	1.9	2.3	2.7	3.0	3.4	3.8	4.2	4.5	5.0	5.4
100	1.7	2.2	2.6	3.0	3.4	3.9	4.4	4.8	5.1	5.6	6.0
125	1.9	2.4	2.9	3.4	3.8	4.3	4.8	5.3	5.7	..	..
150	2.1	2.6	3.1	3.7	4.2	4.7	5.2	5.7	..	..	..
175	2.3	2.9	3.4	4.0	4.5	5.2	5.8	..	..	..	..
200	2.4	3.0	3.6	4.2	4.8	5.4	6.0	..	..	..	..
225	2.5	3.1	3.8	4.4	5.1	5.6	..	..	..	..	..
250	2.7	3.3	4.0	4.7	5.4	6.0	..	..	..	..	..
275	2.8	3.5	4.2	4.9	5.6	..	..	..	..	..	..
300	2.9	3.6	4.4	5.2	5.9	..	..	..	..	..	..
325	3.1	3.8	4.6	5.4	6.1	..	..	..	..	..	..
350	3.2	4.0	4.8	5.6	..	..	..	..	..	..	..
375	3.3	4.2	5.0	5.8	..	..	..	..	..	..	..
400	3.4	4.3	5.1	6.0	..	..	..	..	..	..	..

Figures are based on the formula:

$$D = \frac{3 + L^2 (4\ P + W)}{4\ R}$$

where D is depth of plank,
P, superficial load per sq. ft.,
W, weight of plank,
c, factor of 6,
R, modulus of rupture equals 10,000,
L, length of span.

If yellow pine is used, take $\frac{9}{10}$ of thicknesses given above.

Fig. 411 has 5-inch plank supported on 10x12-inch beams placed 8 feet on centers. The second floors of the machine shop and pattern storage buildings of the Sessions Foundry Company have 3-inch tongued and grooved yellow pine plank on 12x18-

inch yellow pine beams. The gallery floors of the Granger Foundry at Providence, Rhode Island (Fig. 412), has a double layer of flooring on 8 × 12-inch beams spaced 5 feet on centers, resting on shelf angles riveted to the web of 12-inch steel beams 15 feet

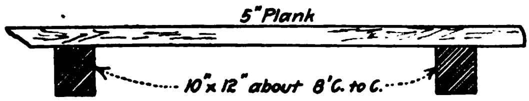


Fig. 411.

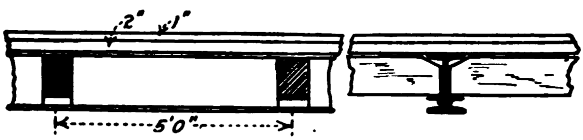
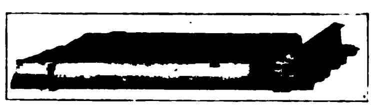


Fig. 412.

apart. The two layers of floor plank should have asbestos or rosin paper between them. If woodwork is painted, it should be thoroughly dry and seasoned before paint is applied.

The cost of wood floor similar to Fig. 412 is as follows:

	Per square.
8×12 in. yellow pine, 6 ft. center to center, costs	$ 6.50
Iron stirrups	3.00
Anchors	2.50
3-in. plank	12.00
Paper	.50
Factory maple flooring	7.00
Total	$31.50



CHAPTER XII.

ROOFS—NON-WATERPROOF.

This chapter describes methods of constructing roofs of planks, concrete or tile, all of which materials require a roofing over them, and the contents of this chapter must not be confused with the later ones on Roofings, which describe materials with which roofs are covered. The discussion here is limited to roof construction above the trusses and purlins, for the strength and spacing of wood, steel and concrete purlins are considered under the subject of framing.

An economic principle in roof design is that the roofing material itself should serve not only as a covering and enclosure, but should be capable of bearing its part of the imposed loads and transferring them by arch or bending action to the walls or trusses. Coverings which act as continuous beams above the trusses and purlins are therefore better than non-continuous coverings, and long planks with edges matched or splined and with staggered end joints are more economical than roofs made of small disconnected parts, such as flat tiles supported on purlins.

WOODEN ROOFS.

Wooden roofs are made of either one or two thicknesses of boards or planks supported on purlins or rafters. When slate or shingles are used, with separate pieces held in place by only two nails and nails in horizontal lines, the plank should then lie parallel to the eave, so the nails will never be driven into cracks between the boards and allow the slate to become loosened. Tar and gravel or composition roofing in large areas may have planks laid in either direction, for if occasional nails are then driven into cracks, the covering will not be loosened. Planks should have supports at intervals not exceeding about 8 feet, and if trusses are spaced further than 8 to 10 feet apart, it is economical to use one or more intermediate jack rafters between the trusses, with nailing pieces bolted to their tops to receive the roof boards. When the roof covering is applied in large sheets or areas, and planks laid in the direction of the slope, parallel to the gables, the planks may then be fastened to purlins spaced 4 to 6 feet apart.

Plank roofs are made of one or two thicknesses, depending on requirements. Buildings in cold climates, with valuable contents and machinery which might easily be injured by condensation water falling from the roof, should preferably have two thicknesses of roof boards, with a layer of building paper between them. An old practice with double thickness roofs is to spread a layer of lime mortar between the boards to make the roof a better non-conductor of heat and more nearly fireproof. If fire should fall upon the roof and burn the upper boards, the mortar might then prevent fire from reaching the lower ones.

A very good non-conducting roof for northern latitudes is

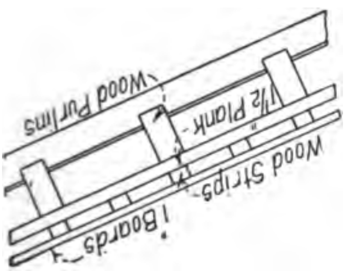


Fig. 413.

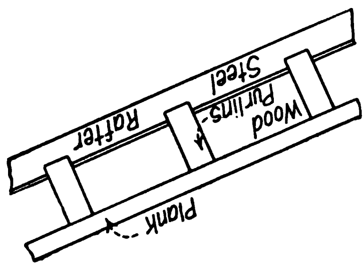


Fig. 414.

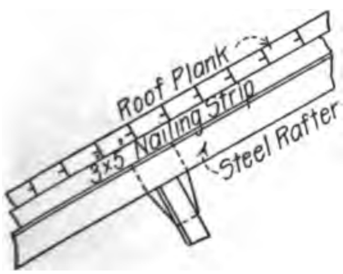


Fig. 415.

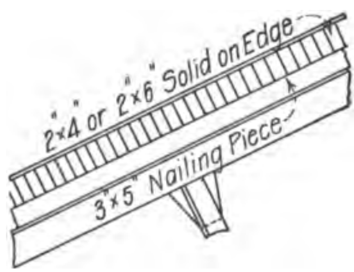


Fig. 416.

made by laying 1x2-inch wood strips, spaced 3 or 4 feet apart, between the upper and lower layers of roof boards (Fig. 414). This arrangement leaves an open air space between the boards and prevents heat from radiating through the roof. One or two layers of building paper should be shingled over the lower boards before the strips are laid.

A very solid wooden roof is made by placing 2x4 and 2x6 inch wood on edge with successive courses spiked together, the whole resting on the rafters and bolted to them at intervals of 1 or 2 feet (Fig. 416), with bolt heads countersunk on the upper side;

the roof is then covered with slag or tar and gravel. This style of roof can be used for long spans, with trusses spaced farther apart than is permissible with 3-inch plank laid flat, and it requires no framing of purlins or jack rafters. It is cheap, non-condensing and slow-burning in construction, and can be built by unskilled labor. The required thickness of plank for different roof loads and purlin spacing is given in Table XXXIV.

REINFORCED CONCRETE ROOFS.

These roofs are made either with separate slabs molded at a factory and delivered to the building ready for placing, or by laying the concrete as a solid monolith on the roof supported during construction by temporary forms or stiffened expanded metal.

Molded reinforced concrete slabs are made in panels 2 to 3 inches thick, 2 to 3 feet wide, and 4 to 6 feet long, the length of slab being made to suit the distance between rafters. The ends of the slabs rest on the upper flanges of beam jack rafters, spaced 4 to 6 feet apart, and the horizontal edges parallel to the eaves should be tongued and grooved (Fig. 417). The vertical joints over the jack rafters should be filled with asphaltic cement to better unite the separate blocks into a solid roof. Countersunk holes for bolts are molded in the concrete when the slabs are cast, and they are fastened to the roof by means of $1\frac{1}{2} \times \frac{5}{16}$-inch band iron clips and $\frac{1}{2}$-inch bolts. When completed, the concrete may be covered with tar and gravel or some form of ready roofing. Slabs of this kind were used in 1906 on the National Guard Armory at New York City.

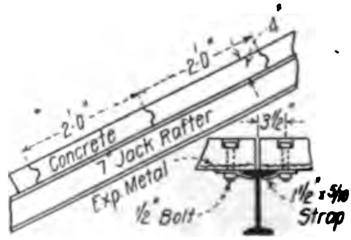


Fig. 417.

MONOLITHIC CONCRETE ROOFS WITH FORMS.

Solid monolithic slabs are made by spreading concrete either on flat expanded metal or wire mesh supports on temporary wood forms, or on some kind of self-supporting stiff expanded metal which needs no forms. There is a great variety of concrete systems, which differ chiefly in the style of reinforcement and the length of span. Many kinds of reinforcement include expanded metal, wire mesh, rods, etc., and the permissible length of slab depends upon the thickness. As it is desirable to have the loads a minimum, the slab thickness for ordinary roofs should not exceed 3 inches, and this thickness, properly reinforced, is strong enough for lengths up to 8 feet.

All concrete roofs must be waterproofed, and they may be covered with slate, tar and gravel, or tile. They are not injured by frost or cold weather. Nails may be driven into the cinder con-

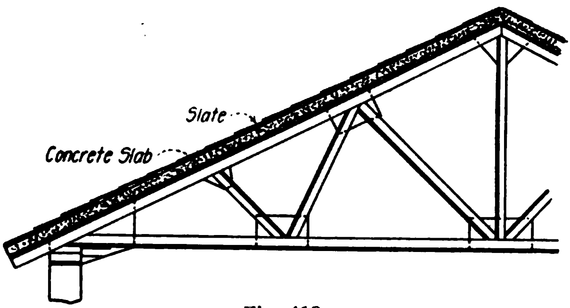


Fig. 418.

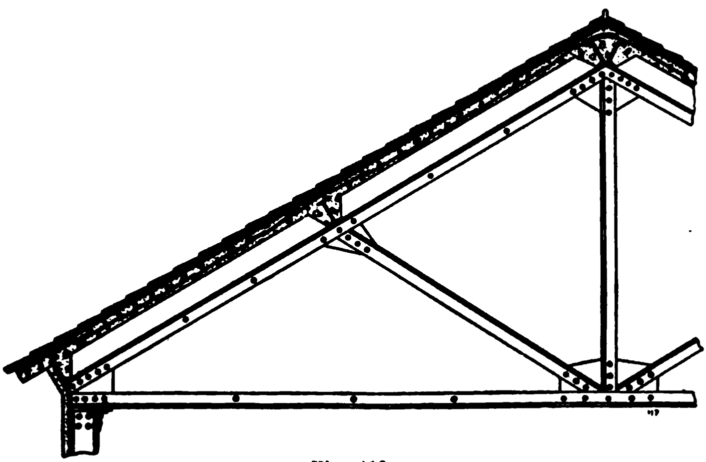


Fig. 419.

crete within two weeks after the concrete is laid, and, like other embedded metal, the nails are preserved. Slabs may be laid directly on rafters without purlins (Fig. 418) when truss spacing does not exceed 10 feet, or on purlins between trusses (Figs. 419 and 420) for a greater truss spacing. Fig. 427 shows the roof on a round house at Moose Jaw, Canada, made of concrete and expanded metal with a ceiling to prevent heat radiation and condensation on the under side. The Coliseum and La Salle Street Station in Chicago have cinder concrete roofs. Fig. 430 shows the application of the Kahn system to roof construction.

Slabs of concrete 3 inches thick, reinforced with expanded metal, cost, in large areas, including concrete and metal only, without covering, 20 to 22 cents per square foot, while smaller areas cost 30 cents per square foot.

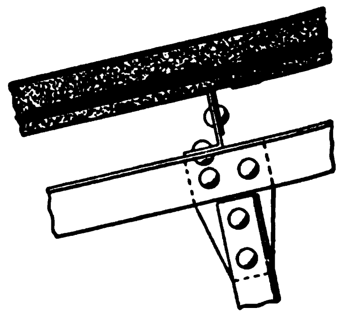


Fig. 420.

The American System uses 3-inch slabs weighing 25 pounds per square foot, reinforced with steel rods, for lengths up to 8 feet (Fig. 421), and 5-inch slabs weighing 39 pounds per square foot, with 1½-inch tees, for lengths up to 16 feet (Fig. 423).

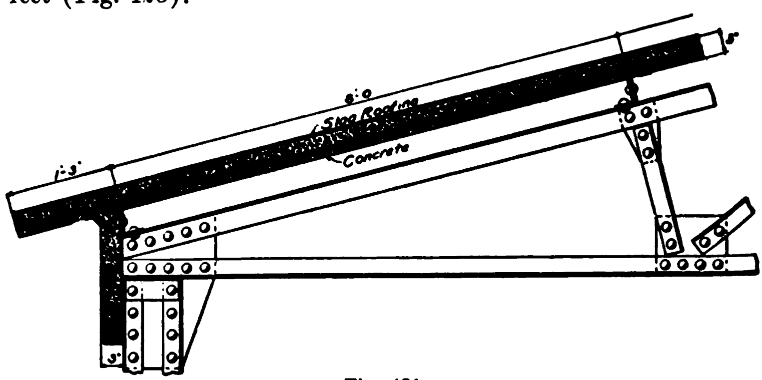


Fig. 421.

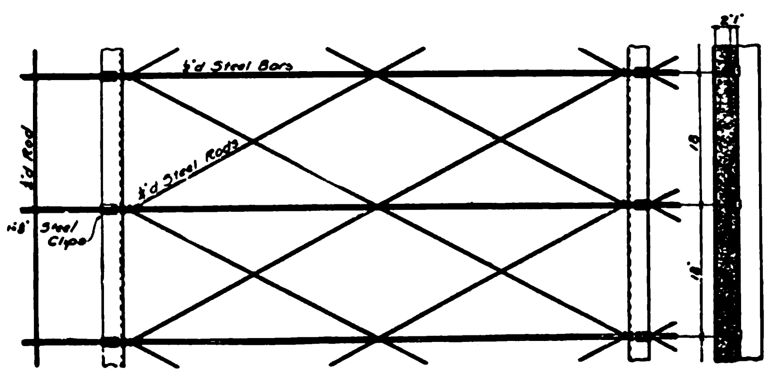


Fig. 422.

MONOLITHIC CONCRETE ROOFS WITHOUT FORMS.

Several kinds of ribbed or stiffened expanded metal are manufactured, and concrete can be spread on these in spans up to 4 or

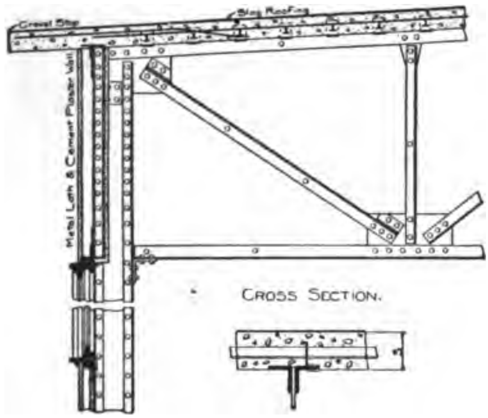


Fig. 423.

5 feet without using wooden forms beneath them. Trussit (Fig. 424) made by The General Fireproofing Company is one inch thick, and No. 24 gage weighs one pound per square foot. The sheets are made in uniform widths of 15½ inches and lengths from 5 to 10 feet, 8 feet being standard. Allowing 4-inch end laps and sheets continuous over two panels, the purlin for 8-foot sheets should be spaced 3 feet 10 inches apart, and 4 feet 10 inches apart for 10-foot sheets. Slabs only 2 inches thick can be used for spans up to 4 feet, and these light concrete slabs not only make the roof itself economical but also require a lighter frame than slabs 3 or 4 inches thick. The roof is light in weight, fireproof, requires no forms, and the concrete adheres perfectly to the metal both on the top and bottom. In this respect it is superior to flat dovetailed sheets where the bond is imperfect. Trussit metal costs 5 to 6 cents per square foot at the factory, and 2-inch slabs complete on the roof, including metal, cost 15 to 18 cents per square foot. This was used on a large building for The Cumberland Steel Company at Cumberland, Maryland.

Fig. 424.

Another stiffened metal lath made by The Trussed Concrete Steel Company is shown in Fig. 425. The ribs are $\frac{13}{16}$ inch high and $3\frac{1}{2}$ inches apart, and are connected with flat expanded metal. The sheets are $10\frac{1}{2}$ inches wide and are made in lengths from 5 to 10 feet.

Fig. 425.

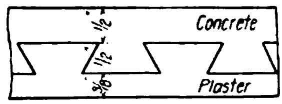


Fig. 426.

TABLE XXXV.

SAFE LOAD IN LBS. PER SQ. FT. FOR SLABS WITH 24 GAGE, STIFFENED EXPANDED METAL (FIGURE 425).

Slab thickness.	*Weight per sq. ft.*	*Moment of resistance.*	*Span in Ft.* 3.	4.	5.	6.	7.	8.
1-in. slab	12	1,540	140	80	52	..	..	..
1½-in. slab	18	2,940	272	152	98	68	..	..
2-in. slab	24	4,280	394	222	142	98	72	..
2½-in. slab	30	6,600	608	342	218	152	112	86
3-in. slab	36	9,840	910	512	326	228	166	128
3½-in. slab	42	11,640	1,080	608	386	270	198	152

Like the one previously described, it requires no temporary forms, and the saving in the centering more than pays for the expanded metal. It is, however, more difficult and expensive to plaster these roofs on the under side than to place the concrete on wood forms, as is done with flat expanded metal or wire mesh.

Metal sheets in dovetail form are also used as roof slab reinforcement (Fig. 426). Sheets are 20 inches wide and 5 to 10 feet long, with corrugations $\frac{1}{2}$ inch high. They are covered on the roof with $\frac{1}{2}$ inch of cement mortar above the metal, and an equal thickness of plaster below. Purlins should be spaced 3 feet 10 inches apart for 8-foot sheets and 4 feet 10 inches for 10-foot sheets. The metal must be blocked up $\frac{1}{2}$ inch above the purlins on narrow strips of wood or metal and fastened to them with clinch nails or clips similar to those used for fastening corrugated iron. A $\frac{1}{2}$-inch thickness of concrete above the metal is enough for purlin spacing not exceeding 5 feet, but for distances of 6, 7 and 8 feet between purlins, the thickness of concrete above the metal should be $\frac{3}{4}$, $1\frac{1}{4}$ and $1\frac{1}{2}$ inches, respectively. The top coat of mortar consists of one part of Portland cement with four parts of sand and fine gravel, spread to a depth of ½ inch over the metal and well worked into the grooves. Plaster for the under side is made by mixing two parts of cement with four parts of sand, and one part of a mixture composed of a pound

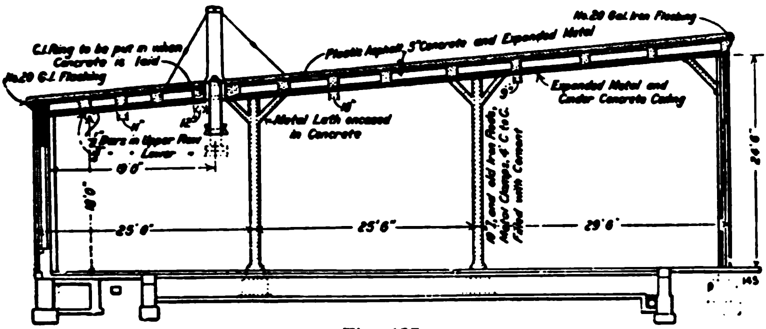


Fig. 427.

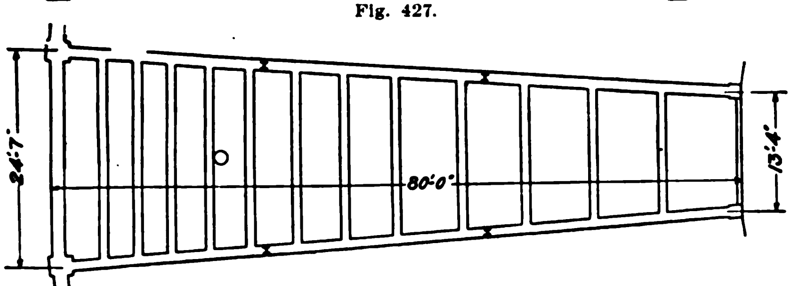


Fig. 428.

of hair to a sack of lime. The mortar and plaster should be allowed to harden for one week, after which a felt and gravel roofing may be applied. Slabs 1¼ inches thick weigh 15 pounds

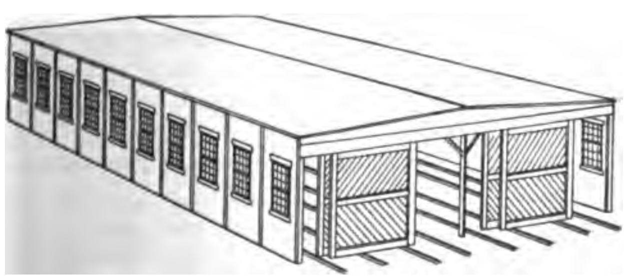


Fig. 429.

per square foot, and cost, in place, $21 per square, though the manufacturers of dovetailed metal claim that it need not cost more than $16 to $18 per square. This kind of roofing slab is not, however, very satisfactory, for it lacks an essential requisite of reinforced concrete—i. e., that the concrete shall surround and grip the metal and not simply be in contact with it. The plaster on the under side of a large roof, inspected by the writer, and covered with concrete slabs and dovetailed metal, fell, and not only covered and injured the machinery but endangered the lives of the workmen.

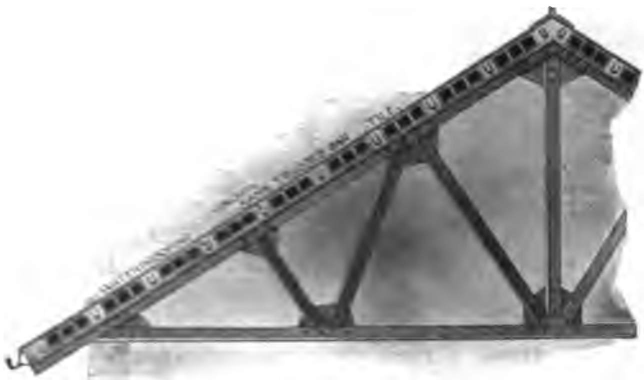


Fig. 430.

TABLE XXXVI.

SAFE LOADS FOR CONCRETE SLABS, REINFORCED WITH METAL DOVETAILED SHEETS.

(Factor of Safety of Four.)

Straight Sheets, Twenty-four Gage, Depth of Corrugation, One-Half In.

Depth of concrete above corrugation. Ins.	*Dead load per sq. ft. Lbs.*	*Live load per sq. ft. Span in ft.* 3	4	5	6	7	8	9	10
½	16	84	52	32	16	..	..	..	..
1	24	206	110	61	35	16	7	..	..
1½	30	355	191	110	66	39	22	10	..
2	36	584	296	252	129	88	58	34	21
2½	42	830	461	277	197	128	83	58	38
3	48	1,174	634	422	274	152	112	72	52
3½	54	1,506	726	506	343	228	157	113	81
4	60	1,658	880	549	359	244	176	124	91
4½	66	1,758	944	584	385	263	186	126	103
5	72	1,868	1,066	646	446	288	220	149	109

TILE ROOFS.

Hollow burnt clay blocks or tiles, sometimes called book tiles because of their shape, supported between lines of tees, are used for roofs, but they are heavy and expensive. The standard block sizes are as follows, the widths being uniformly 12 inches:

12 × 16 × 2 ins.
12 × 18 × 3 ins.
12 × 20 × 3 ins.
12 × 24 × 3 ins.
12 × 24 × 4 ins.

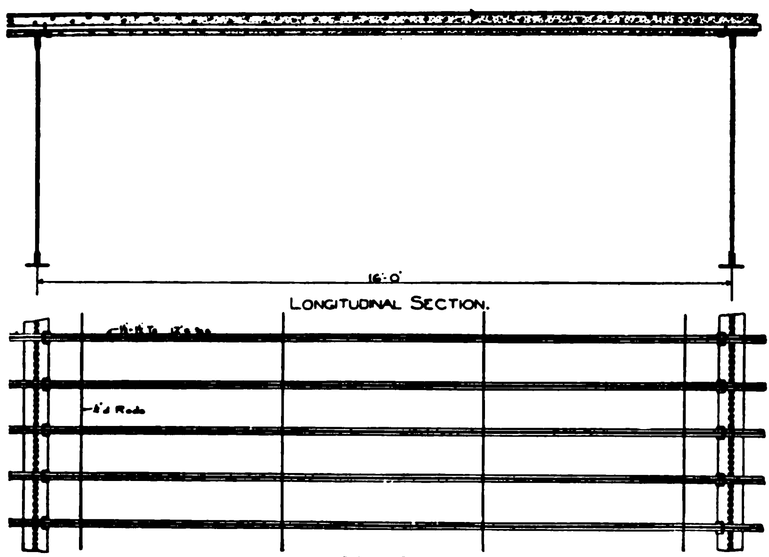


Fig. 431.

Blocks 3 inches thick weigh from 13 to 20 pounds per square foot, depending upon their porosity and the extent to which they are hollowed out. Tees must be placed one inch farther apart than the length of tiles, and as the tiles are porous, they must be covered with some kind of roofing. Nails can be driven into the tile as into wood. When the tees need plastering or fireproofing on the under side, the tiles must then be rabbeted at the bearings to make a level under surface. Porous or hollow tile prevent moisture from condensing on the under side, and they are, therefore, used for power houses and buildings containing valuable machinery which might be injured by the falling of condensation water.

A tile roof with a 7-inch pitch and slate covering was used on the design made by the writer, for a foundry building at Copenhagen, Denmark (Fig. 20). It is also used with five-ply felt covering on a power house for the Chicago and Western Indiana Railway Company at Chicago.

A power house at Charlestown, Massachusetts, 118 feet wide and 92 feet long, with trusses 8 feet apart, has a roof of Guastavino cohesive tile and asphalt covering (Fig. 279).

CHAPTER XXIII.

ROOFINGS—TILE—SLATE—ASBESTOS—WOOD.

TILE ROOFING.

Roofing tile is much cheaper than it was ten years ago, and is, therefore, having a wider use. It is made in a great variety of shapes and colors—red, brown, buff and salmon—and both glazed and unglazed (Fig. 432). The combination of ornamental shapes and colors presents a more pleasing appearance than can be secured with other coverings, but the roofing has a higher cost, and, as it is heavy, requires heavier roof and truss framing to support it. It is fireproof, needs no painting, and is a non-conductor of heat and electricity.

Roofs are prepared in several ways for receiving tile, the most common being to sheathe the surface with boards and cover it with a layer of roofing paper, on top of which are nailed strips of wood 1 inch high and 2 inches wide, spaced to suit the size of tile. If sheathing is not desired, the tile may be laid directly on wood strips or rafters, or if steel framing is used, the larger tile may be supported directly on angle iron purlins without sheathing. They are fastened to the roof either by nailing directly to the boards, with copper wire passed through lugs on the under side of the tiles (Fig. 433) or with spring wire clips (Fig. 434).

Unglazed tiles absorb about 20 per cent of their weight of water and are liable to crack in freezing weather. To prevent absorption, they are also made with a glazed exposed surface at a slightly increased cost, the under side remaining unglazed or porous, and any condensation forming soaks into the tile rather than falling to the floor.

Interlocking tiles make a tighter roof than plain ones, and in all cases the horizontal joints should be laid in elastic roofing cement, using about 40 pounds per square, the cement being colored to match the tiles.

Glass tiles are made in the same shape and size as the usual ones, and can be used where skylight is desired, without breaking the uniformity of the roof surface. They are laid and fastened in exactly the same manner as the ordinary ones.

The weight of roofing tiles varies from 700 to 1,100 pounds per square and the cost from $6 to $30 per square. Spanish tile costs, for the material only, about $18 per square, or $22 per square in place. Ludowici tile costs from $7 to $16 per square for the material only, and the cost of laying varies from $2.50 to $5 per square.

Fig. 432.

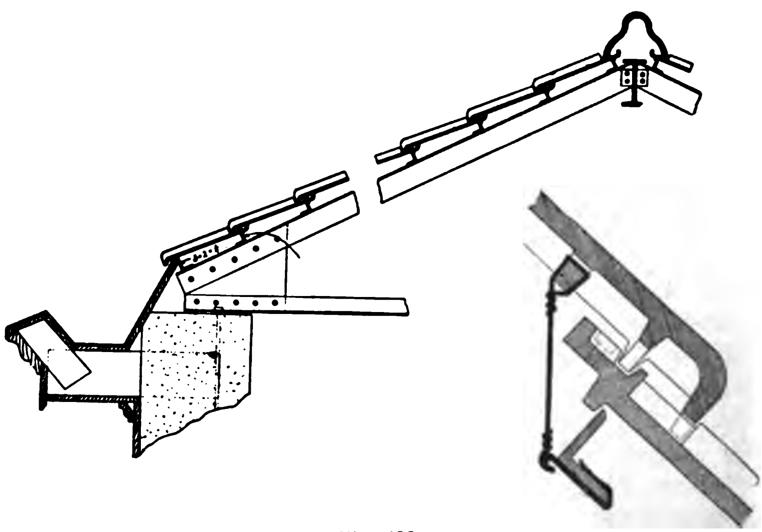


Fig. 433.

The new Atchison, Topeka and Santa Fe Railroad shops at Topeka, Kansas, are covered with Ludowici tile laid on 2 × 2-inch wood strips, every fourth tile being fastened with copper wire.

Reinforced concrete interlocking roofing tiles are made in sizes 26 × 52 inches with 24 × 48 inches exposed to the weather. The concrete is $\frac{7}{8}$ inch thick, strengthened with expanded metal, permitting purlin spacing of 4 feet center to center, without sheathing. They weigh 13 pounds per square foot and are hooked to the purlins, lap 2 inches at the side, 4 inches at the ends, and are laid staggered. They need no sheathing, and their cost as compared with other fireproof roofs is quite low. It is known as Federal Tile.

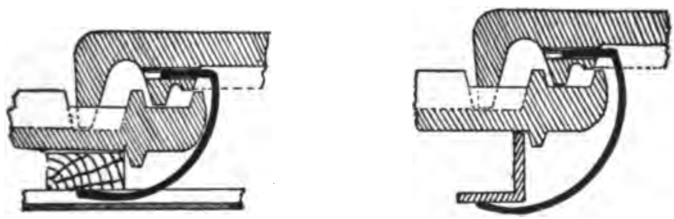


Fig. 434.

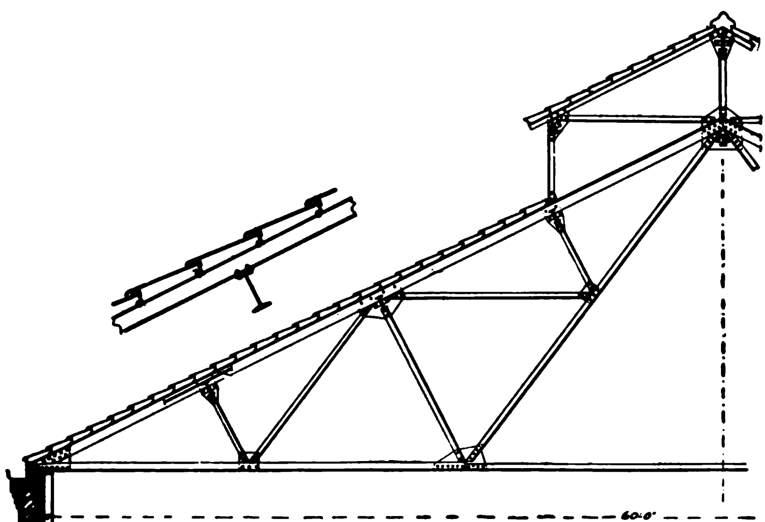


Fig. 435.

SLATE ROOFING.

The best roofing slate in the United States is found near Brownville and Monson, Maine, and in the vicinity of Easton, Bethlehem and Bangor, in Pennsylvania, but other grades are found in Vermont, New York, and elsewhere throughout the country. The Peachbottom and Bangor slates have long held the reputation of being unexcelled, and are the most expensive.

The best quality of slate has a hard surface, a bright luster, and when struck with the knuckle has a clear ring. Softer slates give a dull sound when struck, and as they absorb water they are liable to break in frosty weather, and the nail holes wear, causing the slates to loosen. They must lie flat on the roof and should be of a uniform color.

Slate is suitable when a durable, fireproof covering is desired, and when laid on metal purlins without lining, there is no combustible material. It cannot be used where condensation forming on the under side of the roof would cause injury to the building contents. It should then be lined or ceiled underneath.

SIZE AND THICKNESS.

Slates are made in sizes varying from 6×12 inches to 16×26 inches, or larger for special cases. The large size requires fewer purlins, a less amount of nails, can be laid more quickly than smaller ones, and is more suitable for mill and factory buildings. The smaller size presents a more pleasing appearance on the roof, but on manufacturing buildings this is not important. Slates are made in thicknesses varying from $\frac{1}{8}$ to $\frac{3}{4}$ inch, the usual being about $\frac{3}{16}$ inch.

The following table shows the number of roofing slates required to lay a square, the exposure to the weather on the roof when laid with standard 3-inch lap, the quantity of nails to lay a square and the price per square for carload lots on cars at the quarry:

TABLE XXXVII.

Size of slate ins.	*Number in each square.*	*Exposed when laid, and distance of lath.*	*Nails to square, 3d galvanized.*	*Cost per sq. at quarries.*
24×14	98	10½ ins.	1 lbs. 0 ozs.	$4.20
24×12	115	10½ ins.	1 lbs. 2 ozs.	4.45
22×12	127	9½ ins.	1 lbs. 4 ozs.	4.60
22×11	138	9½ ins.	1 lbs. 6 ozs.	4.70
20×12	142	8½ ins.	1 lbs. 6 ozs.	4.80
20×10	170	8½ ins.	1 lbs. 11 ozs.	5.00
18×12	160	7½ ins.	1 lbs. 9 ozs.	5.00
18×10	192	7½ ins.	1 lbs. 14 ozs.	5.00
18× 9	214	7½ ins.	2 lbs. 1 ozs.	5.40
16×12	185	6½ ins.	1 lbs. 13 ozs.	5.20
16×10	222	6½ ins.	2 lbs. 3 ozs.	5.00
16× 9	247	6½ ins.	2 lbs. 7 ozs.	5.00
16× 8	277	6½ ins.	2 lbs. 12 ozs.	5.00
14×10	262	5½ ins.	2 lbs. 9 ozs.	4.75
14× 8	328	5½ ins.	3 lbs. 3 ozs.	4.75
14× 7	374	5½ ins.	3 lbs. 11 ozs.	4.50
12× 8	400	4½ ins.	3 lbs. 15 ozs.	4.50
12× 7	457	4½ ins.	4 lbs. 8 ozs.	4.25
12× 6	534	4½ ins.	5 lbs. 4 ozs.	4.00

WEIGHTS OF SLATE.

Solid slate rock weighs 175 pounds per cubic foot. Slates of various thicknesses, therefore, weigh as follows:

1/8 in.	1.81 lbs. per sq. ft.
3/16 in.	2.71 lbs. per sq. ft.
1/4 in.	3.62 lbs. per sq. ft.
5/16 in.	4.52 lbs. per sq. ft.
3/8 in.	5.43 lbs. per sq. ft.
1/2 in.	7.25 lbs. per sq. ft.

The weight of slate of various thicknesses in a square when laid is given by Professor Malverd Howe in the following table. The length of slates vary from 12 to 26 inches and the thickness from $\frac{1}{8}$ to $\frac{3}{4}$ inch. Ordinary large slate $\frac{3}{16}$ inch thick will lay, when on the roof, about 650 pounds to the square.

TABLE XXXVIII.

WEIGHT OF SLATE ROOFING.

Length	*Weight in lbs. per sq. ft. for the thickness.*						
in ins.	*1/8 in.*	*3/16 in.*	*1/4 in.*	*3/8 in.*	*1/2 in.*	*5/8 in.*	*3/4 in.*
12	483	724	967	1,450	1,936	2,419	2,902
14	460	688	920	1,379	1,842	2,301	2,760
16	445	667	890	1,336	1,784	2,229	2,670
18	434	650	869	1,303	1,740	2,174	2,607
20	425	637	851	1,276	1,704	2,129	2,553
22	418	626	836	1,254	1,675	2,093	2,508
24	412	617	825	1,238	1,653	2,066	2,478
26	407	610	815	1,222	1,631	2,039	2,445

SUITABLE ROOF PITCH.

Large slates can safely be laid with a less pitch than smaller ones. The least pitch recommended for large sizes is 6 inches per foot. Smaller ones should have a pitch of 7 or 8 inches when laid without cement, but if cement is used it is then safe to use large slate on pitches as flat as 4 inches per foot. On flatter roofs than these, water is liable to be blown up under the slate in driving storms and leak into the building.

Slate is occasionally used as a covering for tar or asphalt roofs on slopes that are nearly flat, but it is merely as a substitute for gravel covering, the waterproofing being done by the asphalt underneath it.

METHOD OF LAYING AND FASTENING.

Slate roofing is laid either directly on boards or on wood or metal purlins, without sheathing. If sheathing is used, it should be either shiplap or tongued and grooved, so no springing or irregularities will occur to break the slates. The boards or sheathing should be covered with a layer of building paper, to assist in making the roof water-tight. When laid on wood strips or purlins (Fig. 436) these should be from 1 to 2 inches wide and from 1 to 1½ inches thick, supported on rafters and spaced the proper distance apart to suit the size of slats. Steel purlins require less framing to support them, and have the advantage of being fireproof. Large slate 24 inches long are most suitable for use over steel purlins, which must be spaced 10½ inches apart.

The first and last courses at the eave and ridge must be short

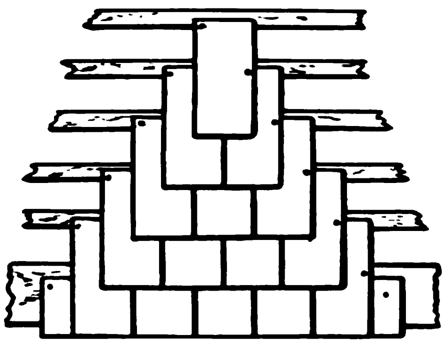


Fig. 436.

slates, and at the eave a lath must be placed under the lower edge of slate to give the same inclination as the other ones. Three inches is the standard lap.

The method known as half slating (Fig. 437), in which the slates are spread apart equal to half their width, is sometimes used when great economy is desired, but the roof is not as tight as when they are laid close together.

Slates are fastened to the roof by passing nails or wires through holes in the slate punched either at the two upper corners for connecting to the upper purlin or near the middle for the center purlin. In the first method, the holes are overlaid by two layers and are therefore more nearly waterproof, but the leverage on the nails is greater, and they are more liable to break and loosen from the roof. In the latter method, with holes near the middle, the slate is held more firmly to the roof, at the loss of one extra layer of shingling. When laid on boards, they are fastened with galvanized iron or copper nails. Black iron nails are not suitable, as they soon rust out, and the slate is loosened. The fastenings are the weakest part of a slate roof, and it is, therefore, desirable to use the best nails even at a higher price to secure permanence. They must not be driven in too hard, for the slate is liable to be cracked or broken. Copper wire instead of nails should be used on metal purlins. A few courses at the eave and ridge, and around chimneys or other openings, should always be laid in slater's cement to prevent leakage, and if the expense will permit, it is better to cement the entire roof. It will make a tighter roof and the rooms beneath will be warmer in winter and cooler in summer. On chemical works or wherever destructive gases or fumes are produced, cemented joints are imperative, for

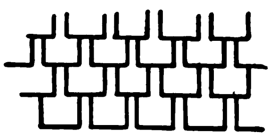


Fig. 437.

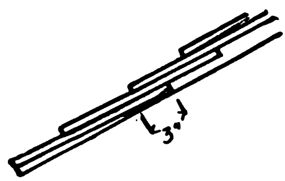


Fig. 438.

any kind of metal fastenings may be destroyed, and the cement is needed to hold the slate.

Punching was formerly done by hand at the building site, but punching and countersinking the holes are now done by machinery at the quarries, with better results and less loss.

METHOD OF FASTENING SLATE DIRECT TO STEEL PURLINS.

As the largest size of slate manufactured is 24 inches long, and, as a general practice, calls for 3-inch minimum lap (Fig. 438), purlins should be spaced not more than 10½ inches on centers for this size slate, and for smaller sizes in proportion. With this spacing, angle irons are the most economical and best shapes to use.

In order to carry the roof load as generally specified, viz., 40 pounds per square foot, it is not practical to space trusses or supports more than 10 feet apart and use angle purlins. Consequently, when it is necessary to use a greater panel, jack rafters can be inserted and still have a span of 10 feet or less for the purlin.

The general method of fastening slate to purlins is to insert either copper, lead or soft iron nails through holes in the slate, bending them over the lower flange of the angle. The holes in the slate can be punched at the quarry, thus making the spacing and laying easy.

The chief merit of slate is its durability. Good slate, well laid, should last from twenty to fifty years or more. It is fireproof and the smooth surface does not collect dust and dirt like flat or

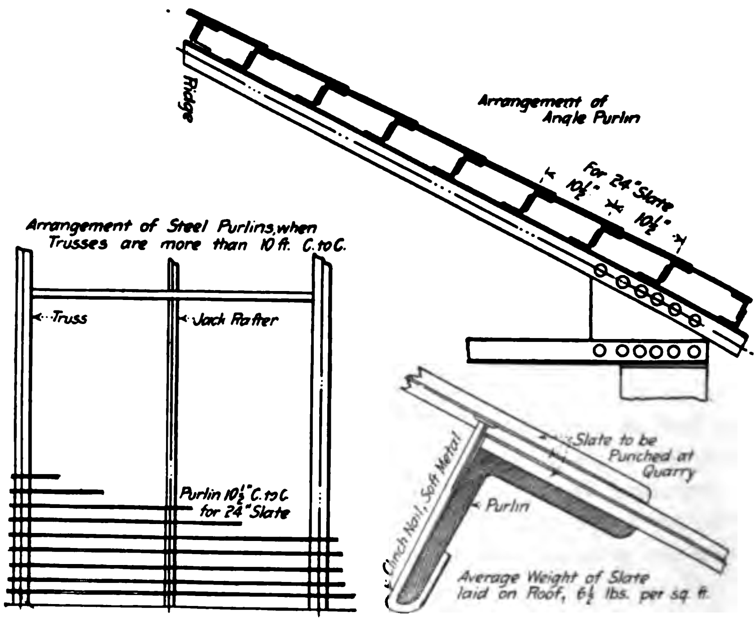


Fig. 439.

rough roofs, and water drained from the roof is clean; but it has the disadvantage of being easily cracked when walked upon or by excessive heat, and high winds may loosen pieces and blow them to the ground, at the peril of passers-by. It is also heavy and expensive, and requires heavier roof framing and trusses to support it, while the steeper pitch makes a greater roof area to be covered. Slate is a good conductor of heat, and unless there is a lining or ceiling beneath it, the rooms will be excessively hot in summer and cold in winter, causing greater expense for heating.

COST OF SLATE ROOFS.

Nails for fastening slate cost as follows:

3d galvanized slate nails per keg	$5.50
4d galvanized slate nails per keg	5.00
3d tinned slate nails per keg	5.75
4d tinned slate nails per keg	5.25
3d or 4d polished steel wire nails per keg	4.00
Copper nails per pound	.20
Zinc nails per pound	.10

Slaters' felt in rolls of 6 squares, per roll	$1.25
Two-ply roofing felt, per square	1.00
Three-ply roofing felt, per square	1.25
Slaters' cement in 25-lb. kegs, per lb.	.10
Punching and countersinking, large slates, per square	.10
Punching and countersinking, small slates, per square	.20

The cost of common slates of various sizes at the quarries is given in Table XXXVII. The best slate at quarries costs from $5 to $7 per square, and red slate, from $10 to $12 per square, including punching and countersinking. A poor quality of black, purple or mixed colors is sold at quarries for $2 to $4 per square.

An experienced roofer will lay from 1½ to 2 squares per day, and the extra cost for laying in cement is from $1.50 to $2 per square. A good roof of blue or black slate, finished complete, will cost from $7 to $13 per square, depending on the quality of slate, distance from the quarries and method of laying.

When slates are punched at the quarry, they cannot be reversed if corners are broken in shipping, and some roofers, therefore, prefer to hand punch the slates at the site, even though this costs 40 cents per square, or double the charge for doing it at the quarry.

One slater with half the time of a helper will lay three squares of straight work in 8 hours, two squares on roofs with hips and valleys, or one square on difficult or crooked roofs.

The following is a cost analysis per square for slate roofing, assuming that a slater and helper put on two squares per day of 8 hours:

Slate, per sq.	$5.00
Freight, 600 lbs.	2.00
Loading and hauling	.20
Felt paper and nails	.20
Slater, 4 hours at 40 cents	1.60
Helper, 2 hours, at 20 cents	.40
Nails	.10
Total	$9.50

If copper nails are used, add 60 cents per square. The cost of freight will vary accordingly to location, while the cost of hauling might be much less in a city than in a rural district.

REINFORCED ASBESTOS CORRUGATED SHEATHING.

This is a comparatively recent product, made and laid similar to corrugated iron, but it is much more durable. The regular $2\frac{1}{2}$-inch corrugations are made $\frac{3}{16}$ inch thick, $27\frac{1}{2}$ inches wide, and in lengths varying from 4 to 10 feet. It is composed of asbestos and Portland cement with a $\frac{3}{4}$-inch reinforcing wire mesh, compressed with heavy hydraulic pressure. It can be cut or sawed like wood, fitted around openings, and nails can be driven through it close to the end or edge without splitting.

It needs no paint, becomes stronger and harder with age, and will not rot or rust like corrugated metal. It is very light, weighing only 2 pounds per square foot, and absorbs only 5 per cent of its weight of water, and can be frozen and thawed again without injury. The under side of the sheets are rougher than the upper side, and condensation does not form so easily as on metal. It is water, fire and vermin proof, is not affected by steam, and will not decay.

It can be used for roofing, siding, partitions, ceilings, or for panels in fireproof doors, and many other places where light sheathing is suitable.

The sheets should have a lap of 1 or 2 inches for siding, and 3 to 6 inches on roofs, depending upon the slope. A lap of 3 inches is sufficient for an 8-inch pitch, but a 6-inch pitch, which is the least recommended, should have a lap of 6 inches.

The maximum allowable purlin spacing for roofs is 30 inches, and for walls 48 inches.

TABLE XXXIX.

PURLIN SPACING FOR SHEETS OF DIFFERENT LENGTHS.

Sheets	4 ft.	long have purlins spaced	21	ins. apart.
Sheets	5 ft.	long have purlins spaced	27	ins. apart.
Sheets	6 ft.	long have purlins spaced	22	ins. apart.
Sheets	7 ft.	long have purlins spaced	26	ins. apart.
Sheets	8 ft.	long have purlins spaced	30	ins. apart.
Sheets	10 ft.	long have purlins spaced	28½	ins. apart.

This roofing is fastened to steel roof purlins with bands and clips similar to corrugated iron (Figs. 440 and 441). The most approved method is by bending 1 by $\frac{1}{8}$ inch band iron around the purlins, and bolting it through the upper corrugation to the roofing sheets with stove bolts passed through 1 by $\frac{1}{16}$ inch lead washers bent down over the corrugation. No. 8 aluminum or copper wire passed through the roof sheets without the use of bolts may be used instead of bands. The sides of sheets may be lapped either one or two corrugations as desired, the latter making a tighter roof. The side laps are bolted together with stove bolts spaced from 10 to 12 inches apart. One corrugation side lap gives an exposure of 25 inches to the weather. A method of fastening to wood purlins is shown in Fig. 440.

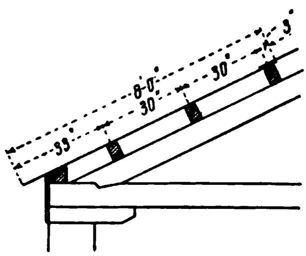


Fig. 440.

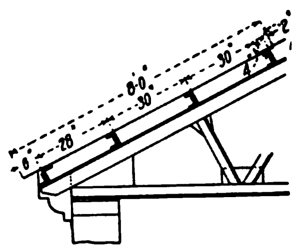


Fig. 440a.

TABLE XL.

AMOUNT OF CORRUGATED ASBESTOS REQUIRED PER SQUARE.

End lap	1	2	3	4	5	6
Side lap, 1 corrugation	111	112	113	115	116	117
Side lap, 2 corrugations	124	125	126	128	129	130

More than 600 squares of this material were used on the new Baldwin Locomotive Works at Eddystone, Pennsylvania, and it is also used on the new buildings for the Indiana Steel Company at Gary, Indiana.

The size with 2½-inch corrugations is sold at 13½ cents per square foot, f. o. b. works in carload lots, or 15 cents per square foot for less than carloads. The cost of laying varies from $2.00 to $3.00 per square, including nails, clips, washers, etc.

This roofing has a high first cost, but as it needs no paint and has little or no maintenance expense, the ultimate cost is no more than other first-class coverings.

Flat sheets of asbestos building lumber, and asbestos shingles 12 to 16 inches square are made by the same manufacturers. The building lumber is 42 inches wide, ⅛ to ⅝ inches thick and 4 to 8 feet long. The ⅛-inch thickness weighs 1 1-3 pounds and costs 10 cents per square foot. The weights and costs of other thicknesses increase in direct proportion.

The shingles are made in three colors, slate, gray and red, and all are manufactured by The Asbestos Shingle, Slate and Sheathing Company, of Ambler, Pennsylvania.

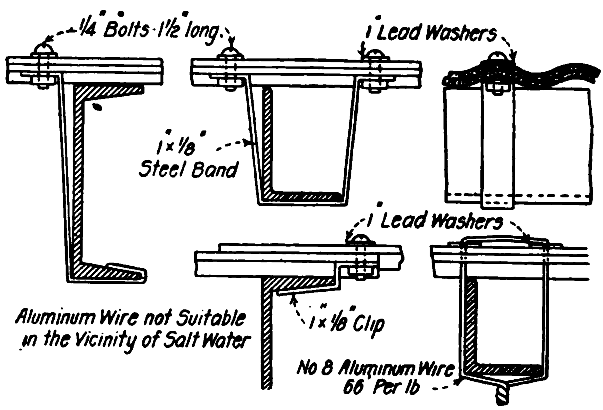


Fig. 441.

WOOD SHINGLES.

Wood shingles are not used to a great extent on modern factories, but they are noted here because of their general use on older buildings. They are made of cedar, redwood or cypress, and sold in bundles containing 250 standard size shingles, 4 by 16 inches, or equivalent. The widths vary from 4 to 12 inches, and the thickness from $\frac{1}{16}$ inch at the top to $\frac{5}{16}$ at the butt. They are laid with exposure to the weather varying from 4 to 6 inches, 4 inches being the usual practice. The number required per square for various weather exposures is as follows:

4	inches to weather requires 900 shingles per square.
4½	inches to weather requires 800 shingles per square.
5	inches to weather requires 720 shingles per square.
6	inches to weather requires 600 shingles per square.

When laid without mortar, a shingle roof must have a pitch of not less than 6 inches per foot, but in mortar the pitch can be less. They must be laid with joints overlapping as nearly as possible half the shingle width, and nailed at the two upper corners with galvanized nails, two to each shingle, requiring 5 pounds of nails per thousand shingles.

The shingles are preserved by laying them in mortar or by coating them on the under side with lime; in the former method they are preserved by the lime in the mortar. Dipping the shingles in stain before laying is a good preservative, and better than painting, for the stain soaks into the grain of the wood.

One man will carry up and lay from two to three thousand shingles per day on large plain surfaces, or from one to two thousand on broken roof area. Cedar shingles cost from $2.25 to $3.50 per thousand and the cost of laying them varies from $1.00 to $2.00 per square. An approximate cost per square for shingles laid 4 inches to the weather in place is therefore as follows:

900 shingles at $3.00 per M	$2.70 per square
Roofing paper	.25 per square
Labor of laying	1.50 per square
Total	$4.45 per square

CHAPTER XXIV.

COMPOSITION ROOFING.

TAR AND GRAVEL ROOFING.

There are several kinds of tar and gravel roofing, differing chiefly in the number of felt layers and the amount and number of tar coatings. The most approved specification for a five-ply gravel roofing is as follows:

On the roofing boards first lay lengthwise of the roof a single layer of dry building paper weighing 7 to 10 pounds per square, the edges lapping 2 inches and tacked with nails and tin washers 2 feet apart (Fig. 442). Over this place two layers of wool felt 36 inches wide weighing not less than 15 pounds per square, shingled over each other, with 17 inches of each layer exposed, the overlapping 17 inches being cemented with tar. Over this entire surface mop a coating of hot tar, and shingle on three more courses of wool felt laid smooth and even, lapping the courses as described above with 10 to 11 inches of each course exposed. The portion of each course, 10 to 11 inches wide under the exposed surface, should be cemented to the course beneath it. Over the finished felt layers put on a top coating of hot tar into which is rolled clean gravel, free from sand or loam, passed through a ⅝ sieve, using ⅙ cubic yard of gravel per square. The amount of tar or pitch used should be from 8 to 10 gallons or 100 to 120 pounds per square. Slag is lighter than gravel and therefore preferable for the top coating.

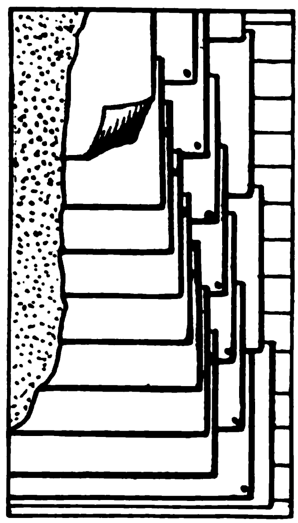


Fig. 442.

A six-ply roof similar to the above may be made by lapping the upper felt layers a greater distance, leaving only 8 inches of each course exposed. A gravel roof well laid with good materials should last from 15 to 20 years.

Other specifications for gravel roofing require the layers of felt to be laid continuously with laps of only 6 inches, the outer 8 inches of each layer being cemented to the one beneath it. This is simpler than first laying two layers with 17-inch laps, covering with asphalt, and laying three more layers of felt with 8-inch lap, as specified above, but the first method is more durable.

A cheaper gravel roof is made by using layers of heavy tarred paper, not cemented together but shingled over each other, with 6 to 9 inches of each layer exposed, and applying over the finished surface a heavy coating of tar or pitch. A still cheaper gravel roof suitable for temporary buildings may be made by using only two or three courses of felt instead of five, but in any case the layer of dry building paper is required against the roofing boards to prevent tar leaking through the roof.

A tar and gravel roof requires a slope of at least ⅜ inch per foot, and not greater than 1 to 1½ inches per foot. If the slope is greater the tar will run in hot weather and obstruct the gutter or down spouts, leaving parts of the roofing felt exposed.

A three-ply gravel roofing should last from 4 to 6 years, and cost from $2.50 to $3.50. A five-ply gravel roofing should last from 8 to 10 years, and cost from $3.00 to $5.00. The best gravel roofing should last from 15 to 20 years, and cost $7.00.

These roof coverings are fireproof, need no painting, and refract heat, making buildings warmer in winter and cooler in summer. They have a small slope, and produce the minimum area of roof to cover, can be walked upon without injury and are noiseless. They are not effected by gas or acid, and have a low cost, making them altogether desirable for mill and factory use. The weight of finished roof varies from 550 to 650 pounds per square, and a cost analysis for a five-ply gravel roof is as follows:

Felt roofing, 75 lbs. at 2 cents	$1.50 per sq.
Pitch, 10 gal. at 11 cents	1.10 per sq.
Gravel, 1/6 yd., at $2.40 per yd	.40 per sq.
Nails, washers, etc	.10 per sq.
Labor	.80 per sq.
Total	$3.90 per sq.

ASPHALT ROOFING.

Asphalt roofing is laid similar to a tar and gravel roof, excepting that the slope should not exceed ½ inch per foot.

Asphalt is superior to tar or pitch because it does not dry and peel or crack like tar, and will not run at any natural temperature. A light three-ply roof is made as follows: One or two layers of dry paper 36 inches wide are first laid lengthwise of the roof over the sheathing boards, with edges lapped 17 inches and fastened with nails and tin washers. Over this is mopped a coating of asphalt roofing cement, using 10 pounds or 100 gallons per square, on top of which is laid a layer of wool roofing felt weighing not less than 15 pounds per square. A final coating of asphalt roofing cement is then applied, into which is rolled clean gravel passed through a ⅝-inch screen. If a thicker roofing is desired an additional layer of felt and asphalt coatings may be applied. When graveled it is practically fireproof. Asphalt roofing is also made in prepared form, and sold in rolls ready for use, as described under "Ready Roofing."

PREPARED OR READY ROOFINGS.

There are a large number of patented roofings on the market, too many to more than briefly mention here. Among them are:

Asbestos Roofing, made by H. W. Johns-Manville Co.
Asphalt Roofing, made by Asphalt Ready Roofing Co.
Asphalt Sand Surface, made by Warren Chemical & Manufacturing Co.
Carey's Magnesia Roofing, made by Philip Carey Manufacturing Co.
Elaterite Roofing, made by Western Elaterite Roofing Co.
Flintkote, made by J. A. & W. Bird & Co.
Genasco, made by Barber Asphalt Paving Co.
Granite Roofing, made by Eastern Granite Roofing Co.
Lythoid, made by Lincoln Waterproof Cloth Co.
Maltgoid, made by Paraffine Paint Co.
Monarch, made by Stowell Manufacturing Co.
Paracote, made by Chatfield & Wood Co.
Paroid, made by F. W. Bird & Son.
Ruberoid, made by Standard Paint Co.
Slag Roofing, made by Warren-Ehret Co.

They are made by cementing together layers of wool felt and canvas with pitch or asphalt, and coating the exterior with fine gravel or broken stone, or with fireproof paint. They are supplied in rolls from 30 to 36 inches wide, and can be laid on pitch roofs with edges lapped and fastened to the roof with nails and washers.

Many of these are excellent roof coverings, and can be placed more quickly than ordinary gravel roofs, as heating and melting the cement or pitch in kettles is unnecessary. They also have an advantage over the usual gravel roofs in being suitable for steep pitches and can be laid by unskilled labor.

ASBESTOS ROOFING.

This is a form of ready roofing, consisting of a canvas center, coated on both sides with waterproof composition, asbestos felt on top, and manila paper on the bottom. It is laid lengthwise of the roof in horizontal courses, lapped 2 inches and cemented together, and fastened to the sheathing with nails and tin washers, which are coated with cement after being driven. The whole is then coated with asbestos paint, using one gallon per square, costing 50 cents per gallon, and it must be repainted occasionally as required. The roofing weighs 85 pounds per square when laid, and its list price is $4.50 per square. It is fire and vermin proof, contains no coal tar, and can be put on by unskilled labor.

Asbestos cement for calking in valleys and around openings or chimneys costs from 5 to 10 cents per pound.

Asbestos felts in rolls 36 inches wide are used also for gravel roofing, and like wool felts, are laid in several courses shingled over each other, with roofing cement between. The asbestos felt is made in three grades, light, medium and heavy, weighing 6, 10 and 14 pounds per square, respectively.

CAREY'S ROOFING.

Carey's prepared roofing is sold in rolls 29 inches wide, in weights of 90 and 115 pounds per square, the former being standard. With each roll are 2 gallons of magnesia paint, ½ gallon of cement and 2 pounds of nails. It consists of a bottom layer of wool felt covered with asphalt cement, on which is placed a layer of burlap coated with elastic paint, which gives the appearance of slate when dry. It is very pliable, is acid proof, and is not easily burned. The raw material costs about $3.00 per square, and laying 50 cents per square additional.

FLINTKOTE.

This is an excellent quality of ready roofing suitable for large mills and factories. It is used on the Birmingham Union Station, the Atlanta Terminal Depot, the Mobile Terminal and elsewhere. It is proof against rats and vermin, and does not need painting more frequently than once in two years. The weight and cost of the three grades made are as follows:

1-ply weighs 35 pounds per sq., and costs $1.80 f. o. b. factory
2-ply weighs 45 pounds per sq., and costs 2.60 f. o. b. factory
3-ply weighs 55 pounds per sq., and costs 3.20 f. o. b. factory

GENASCO'S ASPHALT READY ROOFING.

Asphalt ready roofing in several grades, known as Model, Stone Surface, Whitestone and Smooth Surface, is made by the Barber Asphalt Paving Company.

Model has two layers of felt, one of burlap and four of asphalt, with a top surface of crushed granite, the whole weighing 100 pounds per square. Stone Surface has two layers of felt and two of asphalt with a surface of gravel, and weighs 120 pounds per square. Whitestone has two layers of felt and two of asphalt, and is made one and two-ply, weighing 60 and 75 pounds per square, respectively. Smooth Surface is slate color, has a single layer of felt with asphalt coating on both sides. It is made in four thicknesses, known as ½, 1, 2 and 3-ply, weighing 25, 35, 45 and 55 pounds per square. The two and three-ply are suited for mill and factory use.

GRANITE ROOFING.

This is a prepared or ready roofing containing two layers of wool felt and two of waterproof composition with a top dressing of granite chips. It is sold in rolls 32 inches wide and 41 feet long, containing enough in each roll to cover one square. With each roll is 7 pounds of cement, 1½ pounds of nails and instructions for laying, so it can be placed by unskilled labor. It is a heavy roofing, weighing 140 pounds per square, and costs, complete on the roof, from $2.75 to $3.75 per square. It is fireproof, needs no paint, and can be laid on roofs with greater pitches than 2 inches per foot. This roofing is used on the Pennsylvania Railroad Depot at Washington, D. C., the Lake Shore and Michigan Southern Car Shops at Collinwood, Ohio, and other large buildings.

GRANITE ROOFING SPECIFICATIONS.

Over the roof boards lay two-ply tarred roofing felt weighing not less than 40 pounds per square (Fig. 443). Beginning at the eaves run the first sheet of felt parallel with the eaves, following 1 inch to turn down over the edge. Nail the upper edge of felt with 3-d barbed wire nails through tin washers 12 to 18 inches apart, 1 inch from the edge. The second sheet of two-ply felt should be lapped 10 inches over the first sheet in order to break joints with the sheets above it, but the third and all succeeding sheets of felt should be lapped only 2 inches. After the sheets of felt have been laid, stick the joints with cement and nail the edges with 3-d barbed wire nails through tin discs 12 to 18 inches apart. After covering the roof with two-ply felt lay the granite roofing parallel with the eaves, allowing the first sheet to turn down over the eaves one inch. Draw the sheet out perfectly straight and nail the upper edge of the sheet one inch back from the edge with large head nails 12 inches apart. Lap the sheets three inches at horizontal joints and four inches at vertical ones.

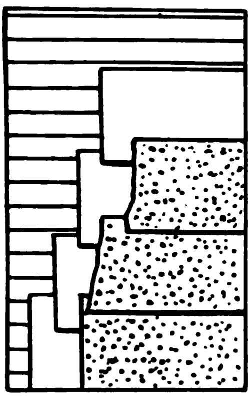


Fig. 443.

After the sheets of roofing are in place, cement between laps with roofing cement prepared and applied as follows: Heat the cement in an iron kettle, having the kettle free from water or any foreign substance. Do not use the cement until it is steaming hot, and then apply with a small mop. If the cement chills or becomes thick while using, heat it again, as it must not be too thick. Nail the laps 3 inches apart and 1 inch back from the edge. On roofs having less than 2-inch pitch per foot, cement between and over all laps or joints, but on roofs with 3 to 6-inch pitch per foot, it is necessary to cement only between the laps and joints. For pitches exceeding 6 inches per foot, put cement between vertical joints only, none being needed between the horizontal joints.

MONARCH ROOFING.

A prepared asphalt without gravel coating known as Monarch Roofing, made by the Stowell Manufacturing Company, in one, two and three-ply, is sold at $1.50, $2.00 and $2.50 per square, respectively, f. o. b. factory ready for using.

RUBBER ROOFING.

This consists of felt paper soaked in a preparation of rubber and rolled. It has a very low cost and is useful principally for covering temporary buildings or sheds, which may have as flat a pitch as 2 inches per foot. It is made in widths of 32 inches and is laid lengthwise of the roof with layers overlapping 2 inches. It is fastened with nails and tin washers or with wood strips placed 2 feet apart, crosswise of the paper. After laying, it is given two coats of chocolate-colored slate paint, the upper one sanded. The slate paint is very elastic, and as it contains no tar it will not crack or peel and does not easily take fire. The covering is a non-conductor of heat and does not make a hot upper story. It costs, complete with nails, paints and sand, from $2.50 to $3.50 per square, depending on the thickness of felt paper used.

RUBEROID ROOFING.

Ruberoid is a prepared roofing consisting of heavy wool felt saturated with a patented waterproof composition and is made by the Standard Paint Company. It contains neither tar, paper, rubber or asphalt, and is pliable and fireproof, will not dry or crack nor run with heat, and can be put on roofs of any pitch, laying it up over the ridge if desired. It is laid with edges lapped 2 inches and nailed through tin washers placed 2 inches apart, which should be covered with cement after being driven. The joints are cemented with "ruberine," which is applied without heating, using $\frac{1}{8}$ gallon per square.

The regular slate colored ruberoid is made in four grades, the weights of which costs f. o. b. factory are as follows:

½-ply, suitable for sheds, costs	$1.40 per sq., and weighs 26 lbs.
1- ply, suitable for barns, costs	1.80 per sq., and weighs 33 lbs.
2- ply, suitable for warehouses, costs ...	2.60 per sq., and weighs 44 lbs.
3- ply, suitable for mills, costs	3.20 per sq., and weighs 54 lbs.

A heavy quality similar to three-ply is also made in red, brown and green, costing $3.20 f. o. b. factory, and weighing 50 pounds per square. The roofing needs no paint when first applied, but should be examined and painted after two or three years. The rolls are 36 inches wide and each roll contains enough nails and ruberine to lay a square. The cost of labor in laying it is 50 cents per square and the total cost is from $2.50 to $4.00 per square, complete, depending on the thickness used.

CHAPTER XXV.

CORRUGATED IRON.

Corrugated iron consists of thin sheets of flat metal, corrugated to give it longitudinal strength. It is made in thicknesses from No. 16, which is $\frac{1}{16}$ inch, to No. 28, which is $\frac{1}{64}$ inch thick, and preserved by painting or coating with zinc or lead, the zinc coating being known as galvanizing.

Corrugated iron is a light and cheap covering, fire and lightning proof, may be quickly applied, and because of its light weight requires a correspondingly light frame. When fastened to the purlins or sheathing it adds stiffness to the entire building frame.

The old method of manufacture consisted of rolling the corrugations, but the modern and better way is to stamp each corrugation separately, as the sheets are then more uniform and will lie closer on the roof. As it has no sharp joints, sheet steel has little or no advantage over iron. Some makes of corrugated iron have one edge of each sheet rolled, as shown in Fig. 444, so there

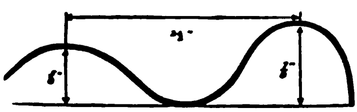


Fig. 444.

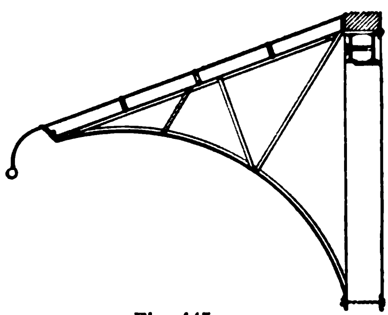


Fig. 445.

will be less spring or tendency to side spreading when it is under pressure or being fastened to the roof, but the usual makes have the corrugations turned down at one side and up at the other. The patent high edge raises the roofing at the joints and gives a paneled effect.

Straight sheets of corrugated iron are used for walls and roofs, laid either over boards or directly on purlins, and it is suitable also for ceilings, fireproof doors, shutters, etc. Curved sheets riveted together at the ends with large corrugations are used for small span roofs without any truss frames other than angle skewbacks for the arch sheets to thrust against, the skewbacks being tied together by occasional rods (Fig. 451). The lengths of span for which this construction is suitable are given on page 120. Curved sheets are also used for sidewalk awnings (Fig. 445) and for floor arches (Fig. 446).

PRESERVATION OF CORRUGATED IRON.

Lack of durability is the chief objection to corrugated iron. When left in its original condition with the iron exposed it is quickly destroyed by rust and corrosion. The methods of preserving it are painting and coating with either lead or zinc, the latter method being known as galvanizing. If painted, it should have one coat of paint or oil at the shop, and after erection all places that are scratched or scraped should be repainted and the entire surface given a second coat. Painting is, however, an unsatisfactory preservative for permanent buildings, for it must be applied every year or two, and even then holes will appear where the painted surface is scratched or broken. The only satisfactory preservative for corrugated iron is lead coating or galvanizing. Where gases or chemical fumes collect, painting is not effective and one of the better preservatives must be used.

Galvanizing consists in coating the steel with a thin layer of zinc, which adds $\frac{1}{6}$ of a pound or about $2\frac{1}{2}$ ounces for each sur-

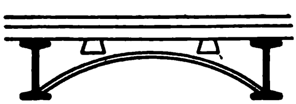


Fig. 446.

Fig. 447.

face coated, or $\frac{1}{3}$ of a pound for both sides. It is applied to the sheets after corrugating, so the process of stamping will not injure the coating. Galvanized sheets should require no painting for four or five years after erection, and then when the surface has been weathered, the paint can be applied. Paint will not, however, adhere to new galvanized surfaces, and if painting is desired immediately after erection, the surface of the metal should be brushed with a solution containing one part of salamoniac, one part of nitrate of copper and one part of chloride of copper, dissolved in sixty-four parts of water, to which is added one part of hydrochloric acid. This will turn the metal black in 12 to 24 hours, and when dry the surface will be ready for painting. Painted surfaces cannot be soldered.

A large boiler shop designed by the author for the Standard Oil Company had the roof and walls covered with lead-coated corrugated iron.

SIZE AND WEIGHT OF SHEETS.

Corrugated iron and steel is made from flat sheets, the weight and thickness of which are given by the United States Standard Metal Gage, adopted by Congress in 1893. The sheets are from 4 to 10 feet long, 26 to 27 inches wide, depending on the depth of corrugation, and are made from flat sheets 30 inches wide before corrugating. The width of corrugation is the distance between centers of bends on the same side or the dimension D in Fig. 447, and the height is the dimension h or total thickness. Three sizes of corrugations are ordinarily used for buildings—5, $2\frac{1}{2}$ and $1\frac{1}{4}$ inches—though 3, $\frac{3}{8}$ and $\frac{3}{16}$ are also made, but seldom used. The $2\frac{1}{2}$-inch corrugation is the standard for roofs and walls, the $1\frac{1}{4}$-inch being used for doors, shutters, partitions or

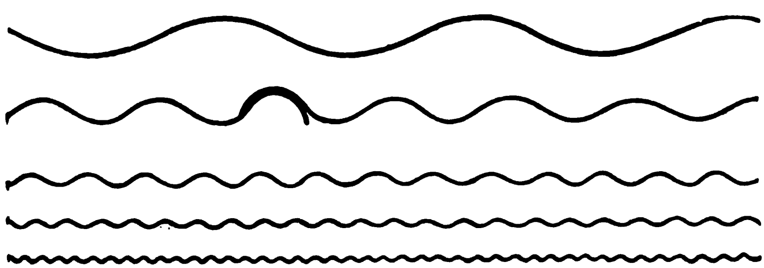


Fig. 448.

wherever a finer detail and better appearance is desired. The 5-inch corrugations are used chiefly for heavy floor arches or where curved sheets are used without trusses for awnings or shelter roofs, the larger and deeper corrugations having the greatest strength. The size of corrugations are shown in Fig. 448. The standard length of sheets is 8 feet, which should be used wherever possible, for they are always kept in stock, but a smaller stock of other lengths from 4 to 10 feet is also kept. The gages commonly used for roof covering are 20 and 22, and for walls 22 and 24.

TABLE XLI.

U. S. STANDARD WEIGHTS PER SQ. FT. FOR METAL ROOFING, 2½-IN. CORRUGATIONS.

Gage	Thickness in in.	Flat sheets Black.	Flat sheets Galv.	Cor. sheets. Black.	Cor. sheets. Galv.
28	.0156	.63	.79	.69	.86
26	.0188	.75	.91	.84	.99
24	.0250	1.00	1.16	1.11	1.27
22	.0313	1.25	1.41	1.38	1.54
20	.0375	1.50	1.66	1.65	1.82
18	.0500	2.00	2.16	2.20	2.30
16	.0625	2.50	2.66	2.75	2.91

TABLE XLII.

WEIGHT PER SQUARE OF CORRUGATED IRON, PAINTED—FOR VARIOUS SHEET LENGTHS.

	Weight per sq., laid, for lengths of					
Gage.	5	6	7	8	9	10
28	83	82	81	80	79	78
26	101	100	99	98	96	95
24	134	131	130	128	127	126
22	166	163	161	159	158	156
20	198	195	193	190	189	187
18	264	260	256	254	252	249
16	331	325	320	318	315	311

Above allows 6 in. end lap and 2½ in. side lap.

TABLE XLIII.

AMOUNT OF CORRUGATED IRON REQUIRED TO COVER ONE SQUARE.

	End lap					
	1 in.	2 in.	3 in.	4 in.	5 in.	6 in.
Side lap 1 corrugation	110	111	112	113	114	115
Side lap 1½ corrugations	116	117	118	119	120	121
Side lap 2 corrugations	123	124	125	126	127	128

2½ in. is ⅝ in. high.

TABLE XLIV.

MEASUREMENTS OF CORRUGATED SHEETS—DIMENSIONS OF SHEETS AND CORRUGATIONS.

Width of Corrugation.	Depth of Corrugation.	Number of corrugations to the sheet.	Covering width of sheet after corrugated.	Width of sheet after cor.	Length of sheets.
5 in.	1 in.	6	24 in.	27 in.	10 ft.
2½ in.	½ to ⅝ in.	10	24 in.	26 in.	10 ft.
1¼ in.	⅜ to ½ in.	19½	24 in.	26 in.	10 ft.
¾ in.	¼ in.	34½	24 in.	26 in.	8 ft.

TABLE XLV.

CONTENTS OF CORRUGATED SHEETS AS FIGURED IN SELLING.

Size of cor.	*Length of sheets.* 5 *ft.*	5½ *ft.*	6 *ft.*	6½ *ft.*	7 *ft.*
5 in.	11¼	12⅜	13½	14⅝	15¾
2½ in.	10⅚	11 11/12	13	14 1/12	15⅙
1¼ in.	10⅚	11 11/12	13	14 1/12	15⅙
¾ in.	10⅚	11 11/12	13	14 1/12	15⅙

Size of cor.	*Length of sheets.* 7½ *ft.*	8 *ft.*	8½ *ft.*	9 *ft.*	9½ *ft.*	10 *ft.*
5 in.	16⅞	18	19⅛	20¼	21⅜	22½
2½ in.	16¼	17⅓	18 5/12	19½	20 7/12	21⅔
1¼ in.	16¼	17⅓	18 5/12	19½	20 7/12	21⅔
¾ in	16¼	17⅓				

The Moment of Inertia, Section Modulus, and Bending Moment for corrugated iron sheets are as given by the following formula:

Moment of inertia, $I = \frac{2}{15}\, d^2\, b\, t.$
Section modulus, $S = \frac{4}{15}\, d\, b\, t.$
Bending moment, $M = \frac{4}{15}\, f\, d\, b\, t,$
using 12,000 pounds as safe working value for f

Safe uniformly distributed load on corrugated iron sheets is given by the following formula:

$$W = \frac{25{,}000\ b\ t\ d}{L}$$

Where W = total safe uniformly distributed load in pounds,
L = length of sheet in inches,
t = thickness of sheet in inches,
d = depth of corrugations in inches,
b = width of sheet in inches.

A formula for the safe load in pounds per square foot on sheets of corrugated iron, deduced from the above, is as follows:

$$W = \frac{1536}{5} \times \frac{f\,d\,t}{L^2}$$

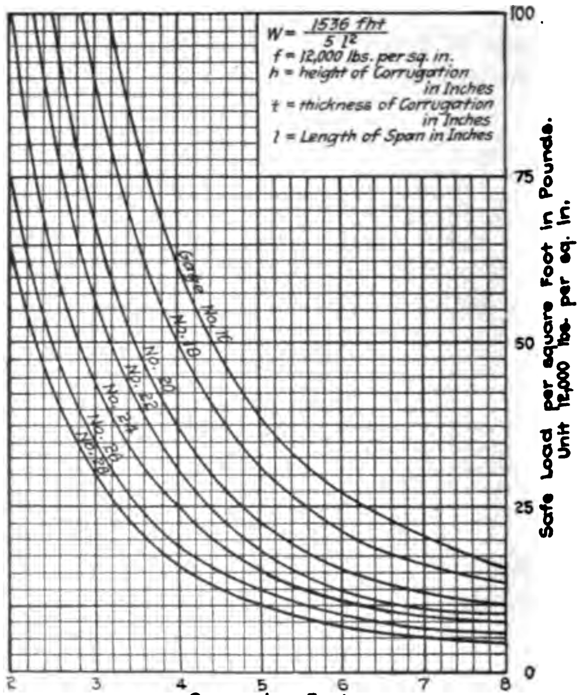
Where W = the safe load in pounds per square foot.

STRENGTH OF CORRUGATED IRON.

Numerous tests have been made to ascertain the strength of corrugated iron sheets, and from the result of these tests formulæ have been prepared. Tests made by the Keystone Bridge Company on sheets of No. 20 gage and 2½-inch corrugations with a clear span of 6 feet, showed that the elastic limit was reached under a uniform load of 30 pounds per square foot, and the ultimate breaking load was 60 pounds per square foot. Experiments made by Mr. Trautwine on 5-inch corrugated iron, 1 inch deep, No. 16 gage, with a clear span of 3 feet 9 inches, showed a safe strength of 350 pounds per square foot distributed.

A development of the formula is shown by the chart in Fig. 449, in which the horizontal ordinates are distances between supports in feet, and the vertical ordinates are safe uniformly distributed loads in pounds per square foot.

The strength of the metal itself can be tested by bending a piece and hammering it flat. If it can be hammered out straight again and flattened, the metal is of good quality.



Safe Load per Square Foot on Corrugated Iron.

Fig. 449.

TABLE XLVI.

SAFE AND CRIPPLING LOAD IN POUNDS PER SQ. FT., RECOMMENDED BY THE PENCOYD IRON WORKS.

	Safe Load. —Span in feet.—				*Elastic Limit.* —Span in feet.—				*Crippling Load* —Span in feet.—			
Gage.	*3*	*4*	*5*	*6*	*3*	*4*	*5*	*6*	*3*	*4*	*5*	*6*
26.........	31	23	18	16	44	34	27	23	69	52	41	34
24.........	37	28	22	19	56	42	34	28	84	63	51	42
22.........	48	36	29	24	71	54	43	36	107	80	64	54
20.........	59	44	36	30	89	67	54	45	134	100	80	67

PURLIN SPACING.

The proper purlin spacing for any given roof load depends on the supporting strength of the corrugated iron and can be taken from the chart (Fig. 449). Roofs should be proportioned for not less than 35 pounds per square foot in northern latitudes, and 30 pounds in southern latitudes. Walls should be proportioned for 10 to 20 pounds wind load per square foot, depending on their exposure. The maximum allowable purlin spacing for non-continuous sheets is as follows:

TABLE XLVII.

MAXIMUM PURLIN SPACING FOR WALLS AND ROOFS.

	Walls.	*Roofs.*
No. 26 gage, maximum distance between purlins..	3 ft. 6 ins.	2 ft. 6 ins.
No. 24 gage, maximum distance between purlins..	4 ft. 0 ins.	3 ft. 0 ins.
No. 22 gage, maximum distance between purlins..	4 ft. 6 ins.	4 ft. 0 ins.
No. 20 gage, maximum distance between purlins..	5 ft. 0 ins.	4 ft. 6 ins.
No. 18 gage, maximum distance between purlins..	6 ft. 0 ins.	5 ft. 0 ins.
No. 16 gage, maximum distance between purlins..	7 ft. 0 ins.	5 ft. 6 ins.

It is preferable, however, to have sheets span the distance between two sets of purlins, and as 10-foot sheets are the maximum length used, the greatest distance between purlins, after allowing for a 6-inch joint lap, is 4 feet 9 inches.

Other considerations which effect the purlin spacing are referred to in Chapter XIV.

ROOF PITCH FOR CORRUGATED IRON.

A corrugated iron roof with sheets lapping 6 inches should have a pitch of 6 inches per foot, but in no case should the pitch be less than 4 inches per foot unless the joints are laid in roofing cement. In any case cement joints are desirable, but they are unnecessary where a proper slope is given.

LAYING CORRUGATED IRON ON ROOFS.

Nos. 26, 27 and 28 corrugated iron are too light to use without lining, and must be laid over sheathing boards or on strips 2 feet apart. Heavier gages may be laid on boards or directly on purlins unless the prevention of condensation is important, and then sheathing may be preferred, although fireproof linings are available.

If warm air or steam coming in contact with the under side of roofing causes condensation, or if gases or corroding fumes are liable to destroy the metal, a layer or two of roofing paper should then be placed over the boards. The sheets should have an overlap of one corrugation at the sides when laid on boards, and one and one-half when laid directly on purlins, as shown in Fig. 450. The end lap should be 6 inches for a 6-inch pitch roof, and 8 inches for 4-inch pitch, and the joints should be coated with thick metallic paint to prevent water from entering during driving storms. If the worst storms come from the north, the north sheets should be lapped on the edges over the south sheets, and vice versa if the prevailing storms come from the south. Where several sheet lengths are used, the longest should be next the eaves, and the shorter ones at the ridge. Stamped corrugated iron can be laid more quickly and easily than rolled sheets, owing to its greater uniformity. All fitting and cutting of sheets should be done on the building rather than at the shop. Sheets will generally lay 24 to 24½ inches to the weather. Curved sheets without trusses may be used for spans up to 30 feet (Fig. 451).

LAYING CORRUGATED IRON ON WALLS.

Nos. 22 or 24 corrugated iron is the thickness generally used on building sides when the metal is fastened to steel purlins, but if the walls are subject to blows, a heavier gage is then preferable. The metal must not touch the ground, but must have a base board or concrete footing as shown in Fig. 477. Sheets on walls should have one corrugation side lap and 4-inch end lap. When corrugated iron is fastened to wooden studs instead of purlins (Fig. 452), the studs must be placed 24 inches apart.

FASTENING CORRUGATED IRON.

Side laps should be riveted together with iron rivets, one to two feet apart, or closer if required. The end joints on roofs must be fastened at alternate corrugations, and similar joints on walls not more than 8 inches apart. Fastenings must pass through the top of corrugation (Fig. 450), rather than through the bottom. One maker specifies that when corrugated iron is laid on boards there shall be not less than 25 6d. nails per sheet, and another specifies 1½ pounds per square.

The usual methods of fastening corrugated iron sheets to purlins is shown in Fig. 453. The one marked A is the most used, because best suited for angles and purlins. It consists of No. 10 wire clinch rivets ⅛ inch in diameter with a head at one end, driven through the roofing and bent around the purlin on the under side. Angle purlins are used more than any other shapes, and clinch rivets are therefore the most common connection. A more secure method of fastening corrugated iron to purlins is shown in Fig. 453, C to F, where bands of ¾-inch hoop iron are passed under the purlins and riveted or bolted to the roofing sheets. This method is suitable for purlins of any form—angles, channels, beams or Z bars—but is more expensive than the method shown in A.

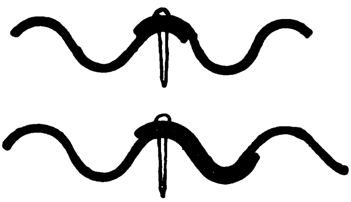


Fig. 450.

Two men are needed in making these connections, one on the roof and the other below it holding the riveting iron and bending or clinching the wire nails. Sheets should be firmly held to the frame so they will not be blown off or loosened by the wind. A table giving the required length of clinch rivets for purlin angles of different sizes is as follows:

Fig. 451.

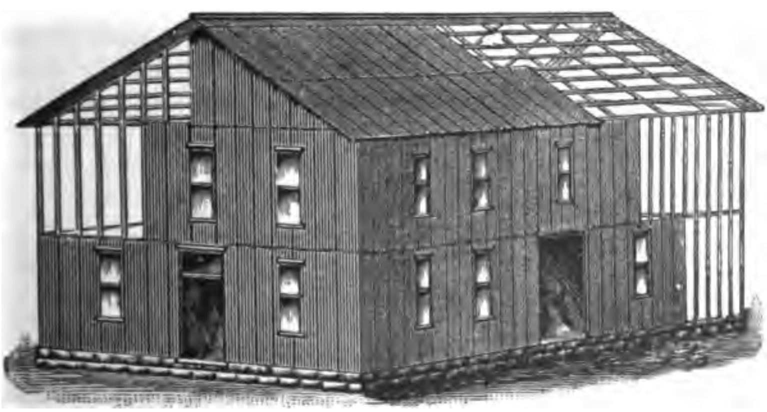


Fig. 452.

TABLE XLVIII.

SIZE OF CLINCH NAILS FOR DIFFERENT SIZES OF ANGLE PURLINS.

Purlin.	2x2.	2½x3.	3½x3½.	4x4½.
Length of nail.............	4	5	6	7
Number of nails, per lb.....	48	38	33	27

The method of fastening with $\frac{3}{4}$-inch No. 18 iron clips, bolted, shown at G and F, is convenient in some places, but it is not secure and not as desirable as the previous ones. Thin lead washers $\frac{5}{8}$ inch diameter and $\frac{1}{16}$ inch thick should be used in all cases under the heads of nails or bolts, and should be drawn tight against the corrugated iron to prevent leaks.

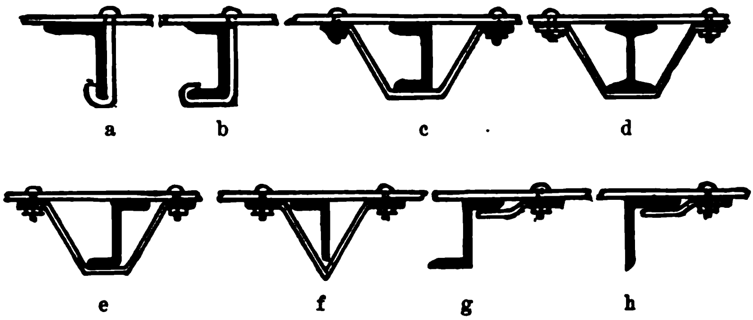


Fig. 453.

STANDING SEAM CORRUGATED IRON.

An improved form of corrugated iron is now made (Fig. 455) which avoids the necessity of punching nail holes in the exposed surface, which punching has always been a weak feature of the covering. The new form has 5-inch corrugations and the edges are turned up, making standing seams $1\frac{1}{2}$ inches high, over which a cap is placed, turned down one inch at each side.

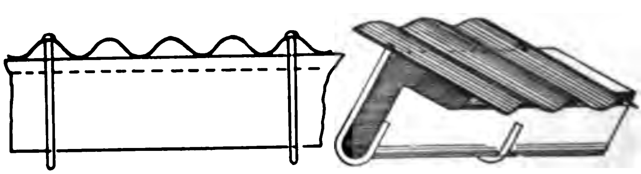


Fig. 454.

The method of applying is similar to standing seam steel or tin roofing, using short cleats where laid over roofing board and long anchor cleats when laid directly on purlins. In the latter case, the anchor or strap is passed around the purlins and hooked over the standing edges of the two adjoining sheets, which are afterward covered with a continuous cap. The cross seams are lapped the same as ordinary corrugated iron.

COST OF CORRUGATED IRON.

Black or painted corrugated iron costs 3 cents per pound and galvanized corrugated iron 3½ cents per pound. The cost per square for United States gages of both black and galvanized corrugated iron is therefore as given in Table XLIX.

The cost of corrugated steel sheets is 25 cents per square more than given in the above table for iron. If painted with asphalt or graphite paint instead of iron oxide, the price will be increased further by another 25 cents per square. These prices are for small lots, and carloads will cost about 10 per cent less. Curved

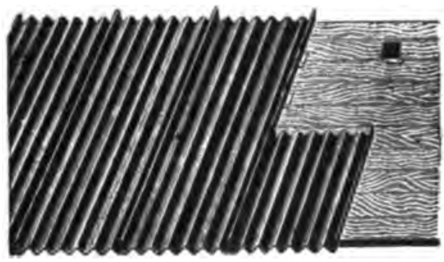


Fig. 455.*

sheets cost 20 per cent more than straight ones. Odd lengths are charged at the price of the next longest even foot.

Black wire clinch nails cost....................	10 cents per sq.
Galvanized clinch nails cost....................	15 cents per sq.
Cleats and bolts cost..........................	25 cents per sq.

The cost of labor for erecting corrugated iron varies from $1 per square for large areas and straight work to $2 or $2.50 for smaller roofs or those which require a larger amount of fitting, and depending also on the method of attaching to the purlins. Bolting is cheaper than riveting and clinch nails cheaper than either.

TABLE XLIX.
WEIGHT AND COST OF CORRUGATED IRON PER SQUARE (100 SQ. FT.).

	Black		*Galvanized*	
Gage.	*Weight in lbs.*	*Cost.*	*Weight in lbs.*	*Cost.*
28......................	69	$2.20	86	$3.70
27......................	77	2.35	93	3.75
26......................	84	2.55	99	3.80
24......................	111	3.33	127	4.60
22......................	138	4.10	154	5.60
20......................	165	4.85	182	6.40
18......................	220	6.50	236	8.20
16......................	271	7.30	286	9.50

Extra charge added to base prices for Black and Galvanized Iron.

* From Gary Iron & Steel Co.

Corrugation	$0.05	Goheen's carbonizing coating	.30
Red oxide paint	.10	Curved steel	.25
Graphite	.20		

ASBESTOS COVERED SHEETS.

Sheets of flat and corrugated iron covered on both sides with asbestos felt are made by the Asbestos Protected Metal Company of Canton, Massachusetts. The asbestos paper is cemented to the metal with pure black asphalt compound, containing no coal tar or its products, equal in thickness to five coats of paint, and applied under pressure at a temperature of 600 F. The covering is made in white, gray and terra cotta colors, and is suitable for either driven into sheathing boards or hooked around steel purlins. partitions.

Flat sheets can be laid parallel to the eave on roof boards which are either close together or slightly separated, commencing preferably at the ridge to avoid soiling the sheets by working over them. When the roof has a comparatively flat pitch, all joints must be cemented, but on steeper pitches cement is needed only at the ends. Cement will adhere only when the sheets are dry, and corrugated sheets must be fastened through the upper corrugation, preferably with special concave head nails made for the purpose, either driven into sheathing boards or hooked around steel purlins.

The asbestos covering is not saturated, and experiments by the writer showed that it resists fire while it remains intact, but continued heat melts the asphalt paste under the felt, and the formation of gas loosens and breaks the covering. When fire has once reached the asphalt, the covering is quickly peeled off and the asphalt burns with prolific flame and dense black smoke.

Extensive experiments were made by the Pennsylvania Railway Company at Jersey City to ascertain the value of paraffin paper with paint as a preservative for metal. The metal is first coated with a tacky paint and then covered with paraffin paper, which is then painted. The experiments show it to be a good preservative against rust, especially in the presence of salt water.

The manufacturers' prices, at the factory, on 2½-inch asbestos-protected corrugated metal, either white, gray or terra cotta, are as follows (list subject to 10 or 15 per cent discount):

	Per square.		*Per square.*
No. 28	$ 9.50	No. 22	$13.75
No. 26	10.25	No. 20	16.00
No. 24	12.25		

ANTI-CONDENSATION LINING.

A lining should be used under slate or metal where condensation might form and cause injury to the building contents. When the roof has board sheathing, one or two layers of building paper or roofing felt over the boards are sufficient, but where slate or metal is fastened directly to steel purlins, there must be a support for the paper lining. Some builders have used a series of separate wires, No. 10 gage, spaced 8 to 12 inches apart, crosswise of the purlins; but a better method is to stretch a light wire mesh with 2 to 2½ inch openings tightly over the purlins, the eave and ridge purlins being trussed, if necessary, to resist the tension from the wire. Poultry netting has been used, but it is not the best, for the longitudinal wires are not straight, and the fabric will stretch, allowing the covering to sag. A better kind of wire fabric is one with straight longitudinal wires connected by a light cross weave. After this is tightly stretched and fastened to the purlins, it is covered with successive layers of asbestos and tar paper, shingled over each other to shed water which might collect from condensation.

The composition of the roof from the covering downward is as follows:

1. Corrugated iron.
2. Tar paper.
3. Asbestos paper.
4. Wire netting.

This lining was used by the writer on numerous buildings prior to 1900, but is not entirely satisfactory, for leakage finds its way through the lining paper at the nail and bolt holes, and condensation forms on the bolts and clips beneath the wire.

Another form of condensation lining for corrugated iron consists in cementing a layer of asbestos felt ½ inch thick to the under side of the sheets, the lining following the corrugations of the metal, and therefore having a supporting strength by itself. The weak feature of this lining is that the cement softens when water-soaked, and the asbestos will peel off in places and leave the metal exposed.

without joining. Excepting that the standing seams for roll roofing are made on the roof or at the building site, the general method of applying it is similar to that already described for sheet steel roofing, and the weight and cost are also about the same. The freight charges are less for shipping steel in rolls than in crates, because there is no freight to pay on the crating

Fig. 458.

lumber; to offset this saving, there is an increased labor cost in forming the standing seams by hand labor on the building instead of forming by machinery at the shop. When roofs have a pitch of 3 inches per foot or more, it is more convenient to use sheets with factory-made standing seams, and when the sheets pass over the ridge, no capping is needed.

V CRIMPED ROOFING.

This is another sheet steel roofing supplied either in black or galvanized, in widths of 28 inches and lengths up to 10 feet. Instead of having standing seams for side joints, the edges are crimped in V shape (Fig. 459), and lap over each other, being

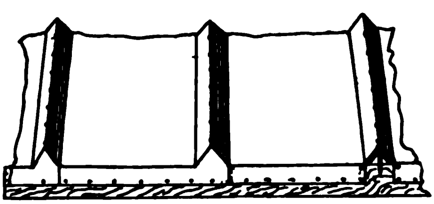


Fig. 459.

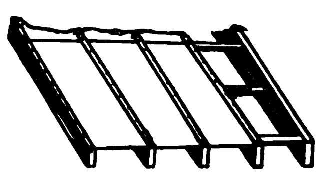


Fig. 460.

nailed to triangular wood strips on the roof. It can be laid directly over wood rafters without sheathing, and when so laid is one of the cheapest roof coverings on the market. When sheathing is not used, the rafters must be spaced 2 feet apart on centers, with strips framed between them level with the rafter tops, spaced to suit the cross joints (Fig. 460). Intermediate cross pieces midway between the horizontal seams should be used when sheets are long, to prevent them from sagging. A lining of asbestos paper or felt should be laid over the boards wherever condensation may occur, and unless extreme economy is desired, better results are obtained by laying the metal on sheathing boards instead of open rafters. It is easily and quickly applied, as one man can lay from 8 to 10 squares per day. Sheets lay 24 inches in width and are nailed through the inclined edges into the triangular strips of wood. When received at the building, the ends are clipped ready for lock jointing, and at the eave the sheets are bent down and nailed over the edge board. This form of roofing is suitable for roofs with a minimum pitch of 2 inches per foot, and can be used on steeper pitches if desired. No. 27 gage weighs 83 pounds per square and in small quantities costs $3.10 per square for painted sheets, or $5.50 per square for galvanized sheets.

METAL SHINGLES.

These are not extensively used on manufacturing buildings, but are suitable for factory offices or wherever a paneled roof effect is desired. They are made of either tin or terne plate or of painted sheet steel, and have the usual merits of metal roofs, being light and not easily broken. They are made in a great variety of styles and patterns, many of which present a very attractive appearance. They can be laid only on pitch roofs, and weigh from 90 to 110 pounds per square, not including roof sheathing.

	Per square.
Charcoal tin shingles, 10×14 ins., painted, cost............	$ 6.50
Sheet steel shingles, 10×14 ins., lead coated, cost..........	9.75
Thorn's I. C. charcoal shingles (tin), cost.................	$ 8.50 to 9.75
Thorn's sheet steel shingles, lead coated, cost..............	10.75 to 13.75

TIN AND TERNE PLATE ROOFS.

The material known as tin plate is light iron or steel, coated on the surface with tin. The old and better method of tin coating was to submerge the sheets in a tin solution until the surface of the steel was thoroughly coated. In the newer method, the sheets, after being coated, are passed between adjustable rollers which regulate the thickness of the coating. The finished sheets look alike, but those having the thickest coating are the most durable and the most expensive. Charcoal iron and Bessemer steel are both used, but the former is preferred.

Terne plates are similar products coated with lead or a combination of tin and lead instead of tin, and they are the kind most used, though they are less durable and cheaper than tin plate. If the roof must be walked upon, some other kind of covering is preferable to tin, for travel is likely to break the soldered joints. It is best suited for flat or small pitch roofs, on which workmen can stand while soldering and making the seams.

Both tin and terne plates are made in three standard sizes, 10×14, 14×20 and 28×20 inches; the larger ones, requiring fewer seams, are the least expensive and best suited for factory buildings. The three grades are marked IC, IX, XX, corresponding to Nos. 30, 28 and 26 gages, respectively. Tin and terne plates are sold in boxes containing 112 sheets in each box. The weight of a box of 14×20-inch sheets is 107 pounds for IC tin plate and 135 for IX plate, and twice these weights for sheets 20×28 inches.

With flat seam, a box of 14×20 in. sheets covers..............192 sq. ft.
With flat seam, a box of 28×20 in. sheets covers................339 sq. ft.
With standing seam, a box of 14×20 in. sheets covers..........169 sq. ft.
With standing seam, a box of 28×20 in. sheets covers..........370 sq. ft.

Tin and terne plate roofing weighs from 62 to 75 pounds per square when laid, depending on the quality and size of sheet used. These plates are laid over sheathing on roofs of any pitch. On flat slopes the joints must all be soldered, but on steeper ones soldering is needed on the cross joints only, the sides being folded. It is fastened to the roof by sheet metal clips which are soldered or folded in the joints, the outer end of clips being nailed to the roof, and the exposed surface has no perforations. For long sloping roofs, the cross joints may be made at the shop and strips delivered at the building in rolls of the proper length to reach from ridge to eave. The roofing should be laid on felt or asbestos paper to reduce the noise and prevent condensation. All joints must be locked and soldered on roofs that are flat or nearly so. Smaller sheets are preferable for flat roofs that are subject to occasional travel, because the greater number of seams increases the strength of the covering and prevents it from buckling or sagging. Valleys, gutters and downspouts should be made of IX grade, which is thicker and more durable than IC, though the IC grade is best suited for roofing sheets requiring sharp bends for the standing seams.

Two good roofers will lay from 1½ to 3 squares per day of 8 hours.

Sheets should be painted on the under side before laying, and the upper exposed surface soon after completion, one gallon of paint being required for 400 square feet of surface. Paint will adhere better to the metal if it remains unpainted for a month or two, so the rain will wash the surface. Benzine and gasoline are effective in removing grease, when paint must be applied immediately. Tin roofs should be painted every two years, and when well laid with good plates and soldered joints, should last from 30 to 40 years.

Tin and terne plate roofing costs from $7 to $12 per square, depending on the location and the grade of tin plate. When made of small sheets, the cost is about 25 per cent greater than from large ones, on account of the greater number of seams. Soldered joints cost 50 cents per square more than standing seams.

STANDARD SPECIFICATIONS FOR TIN ROOFING ADOPTED BY THE NATIONAL ASSOCIATION OF SHEET METAL WORKERS.

Roof Incline. (a) If flat-seam, the roof shall have an incline of ½ inch or more to the foot.

(b) If standing-seam, it shall have an incline of not less than 2 inches to the foot.

(c) Gutters, valleys, etc., shall be designed with sufficient incline to prevent water standing in them or backing up far enough to reach the standing seams.

Sheathing Boards. These shall be of good, well seasoned dry lumber, narrow widths preferred, free from holes and of even thickness. Boards shall be laid with tight joints, or tongued and grooved with nail heads well driven in. Green hemlock, chestnut, oak and ash are not recommended.

Sheathing Paper. Not necessary where the sheathing boards are laid as specified above, but if used, it shall be waterproof. No tar paper or others containing acids are allowed. No nails shall be driven through the sheets.

Flat Seam. If the sheets are laid singly, the size shall be 14×20. The sheets shall be fastened to the sheathing boards by cleats, using three to each sheet, two on the long and one on the short side. There shall be two 1-inch barbed wire nails to each cleat, no nails to be driven through the sheets. If put on in rolls, the sheets shall be made up into long lengths in the shop, the cross seams locked together and well soaked with the solder. The rolls shall be applied the narrow way, fastened to the roof with cleats spaced 8 inches apart, cleats locked into the seam and fastened to the roof with two 1-inch barbed wire nails to each cleat.

Standing Seam. The sheets shall be put together in long lengths in the shop, the cross seams locked together and well soaked with solder. All standing-seam roofing shall be applied the narrow way, fastened with cleats spaced one foot apart. One edge of the course shall be turned up 1¼ inches at a right angle, when the cleats shall be installed. The next course shall have the adjoining edges turned up 1½ inches. These edges shall be locked together, and the seams so formed shall be flattened to a rounded edge.

Valleys and Gutters. These shall be of IX tin and formed with flat seams, using sheets the narrow way.

Flashings. Wherever practicable, flashing shall be let into the joints of the brick or stone work and cemented. If counter-flashings are used, the lower edge of the counter part shall be kept at least three inches above the roof.

All solder used on the roof shall be of the best grade, bearing the manufacturer's name, and guaranteed one-half tin and one-half lead, using nothing but rosin as a flux, and well sweated into all seams and joints.

Painting. All painting shall be done by the roofer. Before laying, all tin shall be painted one coat on the under side. The upper surface of the tin roof to be carefully cleaned of all rosin, dirt, etc., and immediately painted. Paint to be of pure metallic brown iron oxide, or Venetian red as a pigment, mixed with pure linseed oil. No patent driers or turpentine to be used. All coats of paint to be applied with a hand brush and well rubbed on. Apply a second coat two weeks after the first, and a third coat one year later.

General Instructions. No substitution of a cheaper grade of tin will be allowed. The object of these specifications is to provide tin roofs of the same durable, satisfactory nature as those generally obtained in former years by the use of high-grade material and thorough, first-class workmanship. The roofer is expected to do good work, and only a first-class job of roofing will be accepted.

No unnecessary walking over the tin roof, or using the same for storage of materials, shall be allowed at any time. It is recommended that workmen wear rubber shoes when on the roof. Wherever possible, tin shall be laid with standing seam, which allows for expansion and contraction.

To keep the roof in good condition, subsequent painting will hardly be necessary at shorter intervals than three to five years, or even longer, depending upon local conditions.

Since gutters are the natural receptacles for dirt, leaves, etc., they should be swept out and painted every two or three years.

CHAPTER XXVII.

CORNICES AND FLASHING.

Metal cornices are always made to special order, and exact measurements for making them must, therefore, be given, for they cannot be exchanged if made wrong. They are suitable as a finish for the main eaves or on the eaves of monitors, but they should be plain, or nearly so, without ornamentation such as modillions or dentils. A few cornice designs are shown in Fig. 461.

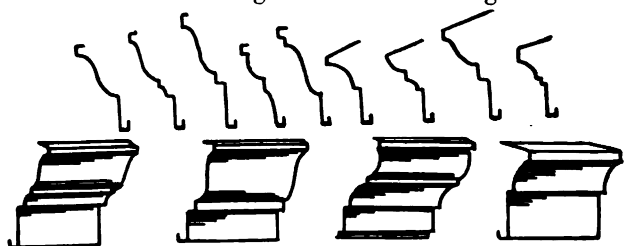


Fig. 461.

The cost of cornices is estimated by the superficial square foot, which depends directly on their perimeter. The perimeter or girth of that part of the cornice outside of the wall surface is equal to $H + 2P$ where P is the cornice projection and H the height, as shown in Fig. 462. Any part of the cornice toward the left of the building face must be added to the length of the perimeter as given by the formula. No. 24 galvanized iron plain cornices cost from 10 to 12 cents per square foot in place. Cornices made of No. 16 ounce copper cost 30 to 35 cents per square foot. Ornamental shapes with modillions and dentils might cost twice these amounts.

Some forms of ventilator cornices are shown with the ventilator detail in Figs. 576 to 585.

GABLE CORNICES.

These should be made to correspond in a general way with the eaves. Some common forms are shown in Figs. 463 to 466. Fig. 463 was used on a large forge shop in New England, designed by the writer in the year 1908, but the effect is clumsy and not so neat as a molded cornice, which costs no more.

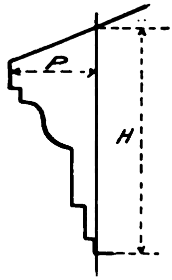


Fig. 462.

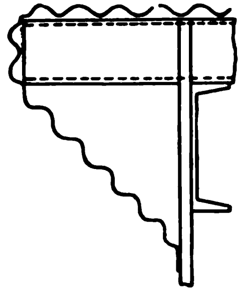


Fig. 463.

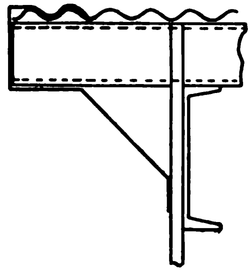


Fig. 464.

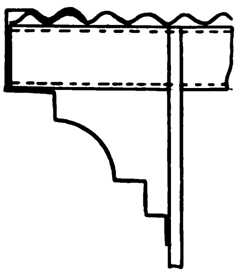


Fig. 465.

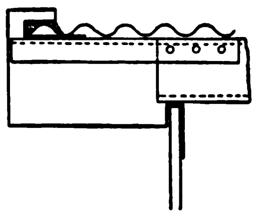


Fig. 466.

Fig. 467.

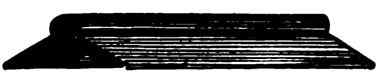


Fig. 468.

Fig. 469.

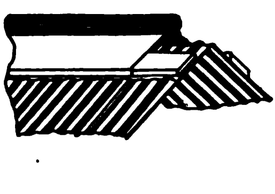


Fig. 470.

Fig. 471.

METAL FLASHINGS.

Metal flashing details can be shown better than described. It is important that hips, valleys, chimney openings and wall joints be tight, for if not, a roof which might otherwise be first class may be rendered useless. Flashing should be with sheet steel or copper, for iron will crack in making sharp bends.

RIDGE ROLLS.

These are made in a great variety of patterns, many of which are quite ornamental, but the ornamental ones are better suited to steel market or other buildings with architectural features (Figs. 30 and 34) than for ordinary mills. A few plain ridge details are shown in Figs. 467 to 470, the roll at the crown giving a finished appearance. For use over corrugated iron, either the aprons of the capping must be corrugated or wood fillers must be fitted into the roofing beneath the ridge cap. The wood fillers are supplied by the corrugated iron makers and cost 2 cents per lineal foot, and galvanized ridge rolls cost from 5 to 10 cents per foot for plain designs as shown, or 10 to 20 cents per foot for ornamental ones. They should be at least No. 24 gage.

HIP AND VALLEY FLASHING.

Hips are covered with regular ridge rolls over special wood filling pieces in the corrugations, and are nailed through the cap and sheathing, and fastened either to the steel ridge rafter or to a beveled wood capping piece over it (Fig. 471).

Valleys are flashed with wide sheets of flat metal, using either a heavy galvanized steel, IX terne plate or copper. Valleys require

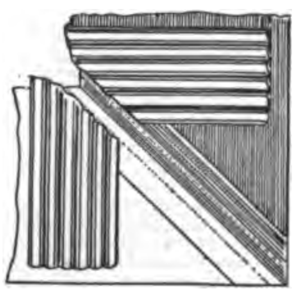


Fig. 472.

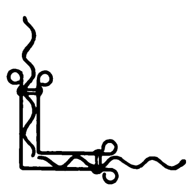


Fig. 473.

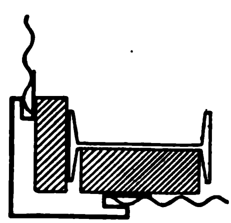


Fig. 474.

more careful attention than ridges, on account of the greater amount of water in them. The flashing should be carried well up under the sheathing and riveted thereto, the vertical distance from bottom of valley to edge of flashing being not less than 8 inches (Fig. 472).

CORNER CAPPING.

Details of corner capping for buildings are shown in Fig. 473. They are used either inside or outside of the building to cover the corner corrugated iron joints, and the edges of the capping are rolled as shown, so no sharp or ragged metal edges will appear. Each angle of the capping is 6 inches wide and is fastened to the siding with rivets 6 inches apart.

Figs. 474, 475 and 476 show other forms of corner capping, the first having grooves to receive and cover the edges of the siding sheets, and the last is similar to ordinary ridge rolls. Their application is more fully shown in Fig. 477.

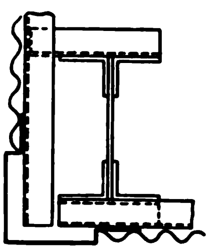


Fig. 475.

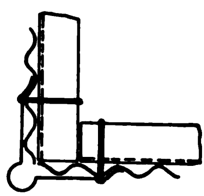


Fig. 476.


Fig. 477.

CHIMNEY AND WALL FLASHING.

Around brick chimneys, flashing is laid under the roofing and turned up against the chimney, the edge being hammered into brick joints and cemented. Against gable or fire walls parallel to the corrugations, iron roofs are flashed with sheets of metal (Fig. 478). Flashing for walls standing normal to the corrugation is shown in Fig. 479.


Fig. 478.


Fig. 479.

DOOR AND WINDOW CASING.

Figs. 480, 481 and 482 show metal casings for wood window and door frames, which are best when formed at the shop and shipped ready for placing. Some builders prefer to send this metal to the building in flat sheets and bend it there to fit the windows, but the result is never so neat as when bends are made by machines at the metal shop. The work done by hand tools at the site invariably shows irregularities that greatly injure the appearance. The three views show window jambs, caps and sills.


Fig. 480.

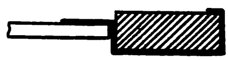


Fig. 481.

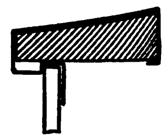


Fig. 482.

CHAPTER XXVIII.

GUTTERS AND DOWNSPOUTS.

GUTTERS.

Gutters for mill buildings are made in several forms, some of which are here described and illustrated. Those at the eaves may be either hanging, box wall, roof or combination gutters, and valley gutters are also made in several ways.

TABLE LI.

SIZE OF EAVE GUTTERS.

Use 5-in. eave gutters for roof slopes up to 20 ft.
Use 6-in. eave gutters for roof slopes up to 40 ft.
Use 7-in. eave gutters for roof slopes up to 60 ft.
Use 8-in. eave gutters for roof slopes up to 80 ft.

The above are roof slopes or half the span of double pitch roofs. A small gutter with a large slope will keep itself clean and free from sediment, when larger but flatter ones will become clogged.

Gutters are usually made of galvanized steel, though charcoal iron at a slightly higher price is more durable. Nos. 27 or 28 gage, which is commonly used on residences, is too thin, and no metal less than 24 gage is recommended for manufacturing buildings. Copper gutters are more durable, but are not as much used on mills because of their higher cost.

The slope of gutters is generally made one inch in 10 feet, but it must never be less than one inch in 15 feet, for water would not have sufficient flow to keep the gutters clean. When conditions will permit, a slope of one inch in 5 feet is preferable, but this amount may not always be available.

Galvanized iron gutters erected in place cost about 2 cents for each inch of girth per lineal foot of gutter; therefore, an 8-inch girth costs 16 cents per foot, and a 10-inch, 20 cents. The price of the usual size galvanized iron gutters varies from 15 to 35 cents per lineal foot, complete. Copper gutters, 16 ounces, cost 15 cents per square foot for the material and 35 cents per square foot erected in place.

Fig. 483.

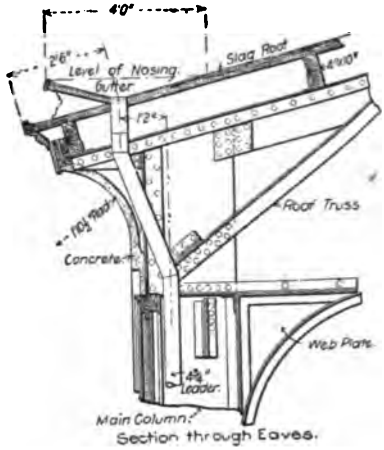


Fig. 484.

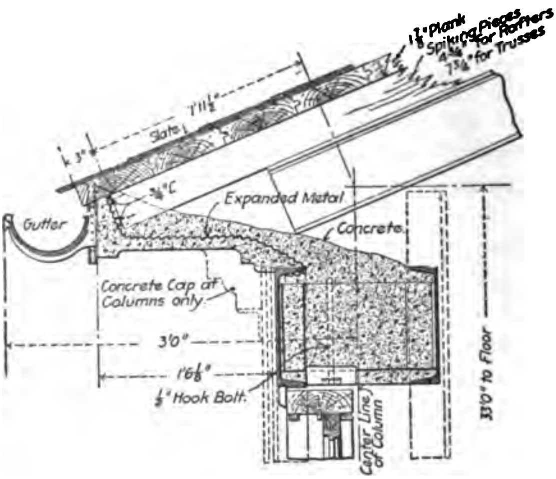


Fig. 485.

Fig. 486.

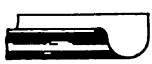


Fig. 487.

Fig. 488.

Fig. 489.

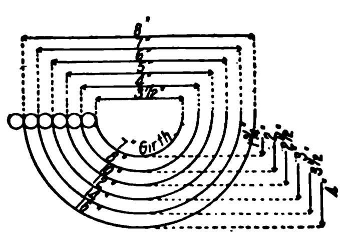


Fig. 490.

HANGING GUTTERS.

These gutters are made in 10-foot lengths and shipped in crates containing 25 pieces in each crate. Unless otherwise ordered, they are made with slip joints, as this kind requires no soldering, are more easily erected, and are not affected by contraction and expansion. Lap joints cost ½ cent per foot less than slip joints, but are not as satisfactory. Fig. 489 shows the standard makes of hanging gutters, with both single and double bead.

TABLE LII.

APPROXIMATE PRICES FOR HANGING GUTTERS, NOT ERECTED.

3 -in.	trough, galvanized steel or charcoal iron, costs	4 cents per ft.
3½-in.	trough, galvanized steel or charcoal iron, costs	4 cents per ft.
4 -in.	trough, galvanized steel or charcoal iron, costs	5 cents per ft.
4½-in.	trough, galvanized steel or charcoal iron, costs	5 cents per ft.
5 -in.	trough, galvanized steel or charcoal iron, costs	6 cents per ft.
6 -in.	trough, galvanized steel or charcoal iron, costs	7 cents per ft.
7 -in.	trough, galvanized steel or charcoal iron, costs	8 cents per ft.
8 -in.	trough, galvanized steel or charcoal iron, costs	10 cents per ft.

These prices are ¾ cent per lineal foot for every inch of girth. Standard inside and outside miter pieces for both slip and lap joints are kept in stock by the makers, ready for placing.

GUTTER SUPPORTS.

Several methods of supporting hanging gutters are shown on page 302. Figs. 491 and 492 show malleable cast iron brackets, fastened to the eaves with adjustable circular supports, which may be raised or lowered to suit the gutter slope. The brackets

*Fig. 491.

Fig. 492.

* From Eller Mfg. Co.

are fastened to the eave with bolts or nails or they may be driven into the wood facings. This kind of bracket costs

$5 to $6 per 100 for 5-inch gutter.
6 to 7 per 100 for 7-inch gutter.
7 to 9 per 100 for 10-inch gutter.

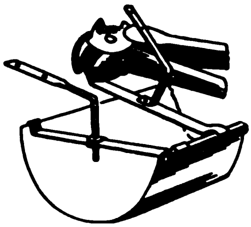


Fig. 493.

Fig. 493 shows steel bar hangers with adjustments to regulate the gutter slope. The suspension bars are nailed or bolted to the roof and the cross bars grip the side of the gutters. They cost about $1.50 per gross.

Galvanized wire eave trough hangers (Fig. 494) are easily applied and cost from $2 to $3 per gross.

Figs. 495 and 496* show two forms of hanging gutter at the

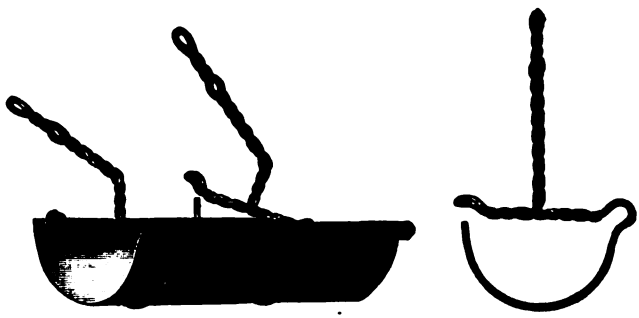


Fig. 494.

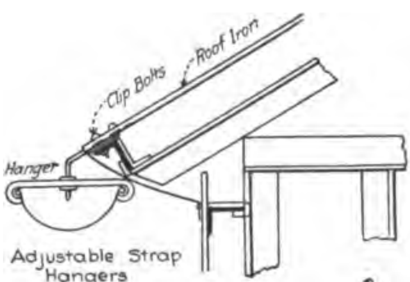
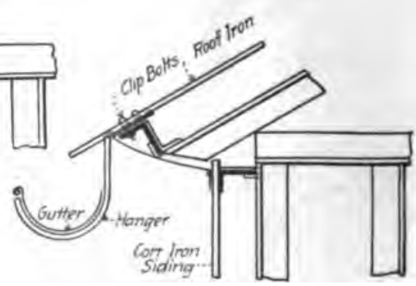


Fig. 495.



Adjustable Hanging Gutter.
Fig. 496.

* Mill Building Construction, H. G. Tyrrell, 1900.

eave of a building covered with corrugated iron. Supports for hanging gutters must be spaced not over 4 feet apart.

BOX GUTTERS.

Several forms of box gutters are shown in Fig. 497, and one at the eave of a mill building with brick walls (Fig. 498*). They cost generally from 10 to 20 cents per lineal foot, and double this amount in place.

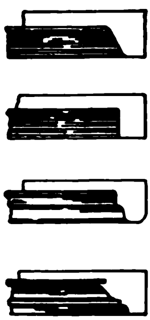
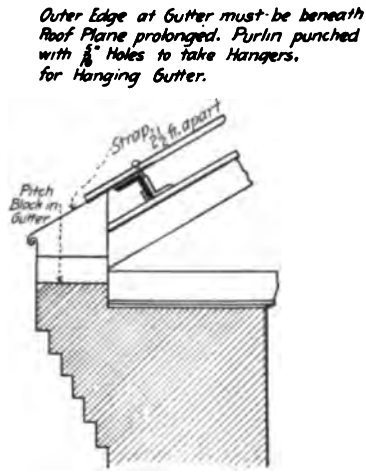


Fig. 497.



Details of Iron Gutters.

Fig. 498.

ROOF GUTTERS.

These are made of galvanized steel in two shapes (Figs. 499 and 500), and come in 8 and 10 foot lengths. The hangers are placed so as to leave no nail or screw heads exposed. They cost from 8 to 15 cents per lineal foot.

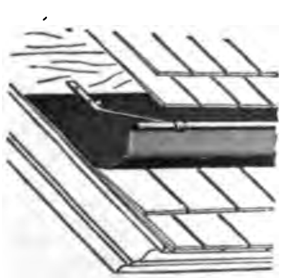


Fig. 499.

Fig. 500.

COMBINATION ROOF GUTTERS.

These gutters serve the double purpose of gutter and cornice and they require no hangers or braces. They are made in two sections, the upper one being sloped (Fig. 501) to give the proper grade. The first illustration shows the parts separated and the second one the two parts in position.

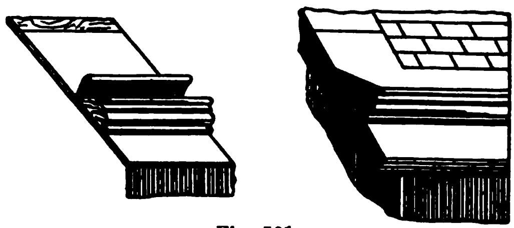


Fig. 501.

VALLEY GUTTERS.

Fig. 502* shows designs for single and double valley gutters, especially suitable for mill buildings. The lining is supported by a series of bent angle bars, spaced 3 to 4 feet apart and fastened to the roof purlins, the dimension "a" varying with each support to suit the grade of gutter. The horizontal bottom width of gutter is therefore greater at the high end than at the low. The

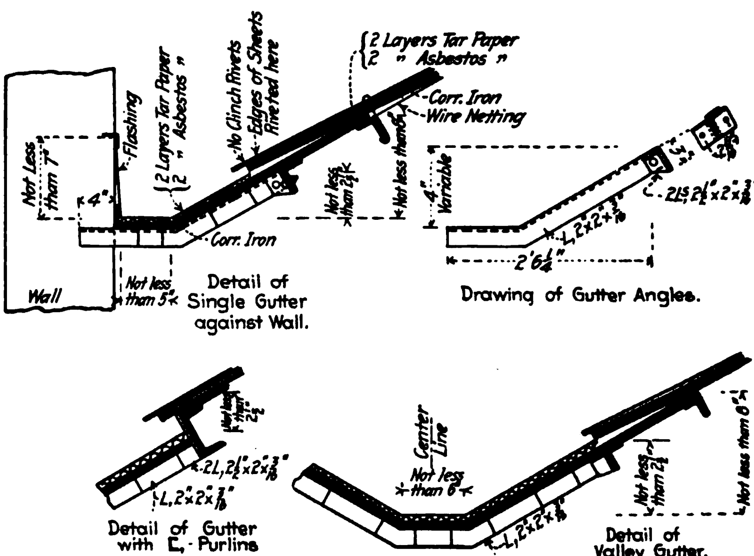


Fig. 502.

gutter is lined first with sheets of corrugated iron, to give the bottom stiffness, and these are covered with heavy flat galvanized sheets, passing up under the roofing to the next purlin. With the dimensions shown on drawing, water must be 8 inches deep in the gutter before it would leak through into the building. Half gutters adjoining walls are flashed up against the brick work with flashing driven into the brick joints and cemented. When carefully built, the valley gutters give excellent satisfaction. They cost complete, including the double lining and supports, about 10 cents per superficial foot.

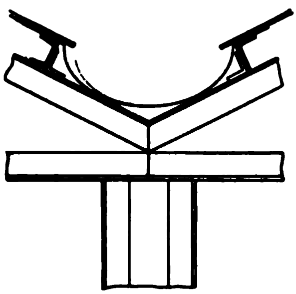


Fig. 503.

A suspension valley gutter made of No. 20 flat galvanized steel is shown in Fig. 503. The slope is easily adjusted and the gutter is less expensive than the one last described, but it is not as rigid, and may be injured in cleaning it.

DOWNSPOUTS.

Wherever ice forms, downspouts should be corrugated, for they can then freeze up without bursting. In warm climates, where ice never forms, smooth downspouts may be preferable. Galvanized steel downspouts are made in 10-foot lengths, and copper spouts in 8-foot lengths, and they are shipped in crates containing twenty-five pieces in each. Galvanized metal should be not less than No. 24 gage.

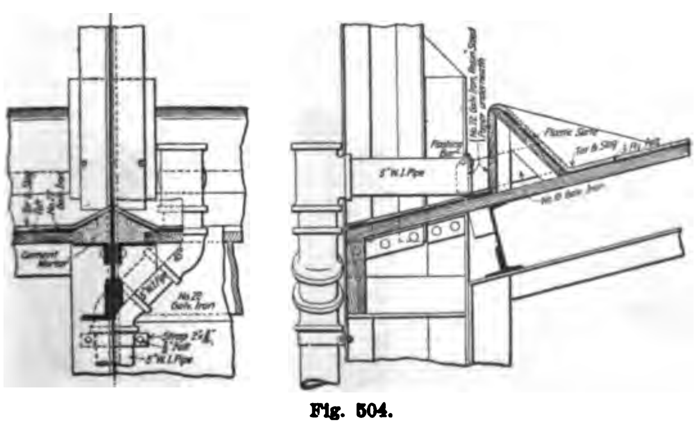


Fig. 504.

The general rule for the size of downspouts is to provide one square inch of pipe for 100 square feet of roof surface. In island climates or along the coast, where rainfall is often excessive, the area of spouts may be increased 25 per cent.

TABLE LIII.

SIZE OF GUTTERS AND DOWNSPOUTS.

One-half roof span	10	20	30	40	50	60	70	80
Size of gutter in in	5	5	6	6	7	7	8	8
Size of downspout in in	3	3	4	4	5	5	6	6
Spacing of downspout in ft	50	50	50	50	40	40	40	40

3 -inch downspout will serve 1,000 square feet of roof surface.

TABLE LIV.

COST OF NO. 24 GALVANIZED STEEL CORRUGATED DOWNSPOUTS.

Size.	*Cost delivered. Cents per ft.*	*Cost erected. Cents per ft.*
2-in	6	10
3-in	7	15
4-in	8	20
5-in	9	25
6-in	10	30

Fig. 505.

Fig. 506.

Fig. 507.

Fig. 508.

Fig. 509.

Fig. 510.

The erected prices include fitting, freight, cartage and erection labor, and are approximate only.

Copper spouts are more durable, but not generally used on account of their higher cost. Copper, 16 ounce, costs, for the material only, 15 cents per pound, and spouts erected in place cost 30 to 35 cents per pound.

TABLE LV.

COST OF 16-OUNCE COPPER DOWNSPOUTS.

2 ×3 in.	40 cents per ft.	3½×5 in.	65 cents per ft.
2 ×4 in.	50 cents per ft.	4 ×5 in.	70 cents per ft.
3 ×4 in.	55 cents per ft.	4 ×6 in.	75 cents per ft.

CHAPTER XXIX.

VENTILATORS.

The subject of ventilation is discussed in Chapter IX and only the details will be treated here. Change of air in a building is secured by one of the following methods:

(1) Forced drafts through ducts from blowers.
(2) Monitor ventilators, such as windows, shutters or louvres.
(3) Movable windows in saw-tooth roofs.
(4) Continuous side openings in plane of roofs.
(5) Individual metal ventilators.
(6) Box skylight openings.
(7) Wall ventilation.

The first method, by means of forced air currents, is discussed in connection with heating systems and saw-tooth window ventilation is fully explained in Chapter XVII.

Roof and wall openings are explained and illustrated in Chapter IX. Continuous openings beneath the eave, covered with ½-inch screen wire mesh, are shown in the illustration for tropical market buildings (Figs. 30 and 34), and the continuous side openings admit a free flow of fresh air, which passes out at the roof monitors.

Box skylight ventilators are illustrated in Chapter XXXI, on skylights. The only methods that will be included here are, therefore, individual ventilators and monitor ventilation through windows, shutters or louvres.

INDIVIDUAL METAL VENTILATORS.

Natural air currents to some extent are induced by placing metal ventilators, preferably at the ridge or highest point, to draw off the foul and heated air which rises and collects under the roof. These are self-acting, with no expense for operating. They are made of galvanized sheet iron or copper and in a variety of styles. They must have dampers or regulators, so air circulation can be checked or stopped when desired, and their construction should be such that back draft into the building is impossible. The dampers should be easily operated without noise, and so made that they cannot be clogged with snow or ice. The most approved styles have dampers made of a sliding or telescoping sleeve, operated by a cord and pulley and closed by being drawn up against the cover. The ventilator tops are either sheet metal or wire glass tightly set into the metal siding, thus forming a combination ventilator and skylight. The latter are preferable, for they not only admit extra light but permit the interior of the metal tube to be inspected, and always show whether it is open or closed.

The best makes of ventilators with glass tops have drips or gutters under the edge of the glass and inside around the bottom. The glass must, however, be tightly set so no water from outside can leak through. When glass tops are used, a sliding or telescoping damper is better than a revolving pipe damper, for the latter, when closed, obscures the skylight.

The following table gives dimensions, weight and cost of galvanized iron ventilators from 12 to 72 inches in diameter, the costs being for the best makes. Cheaper ones can be bought for one-half the prices given, while copper will cost twice as much:

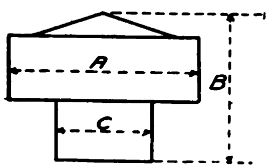


Fig. 511.

TABLE LVI.

DIMENSIONS, WEIGHT AND COST OF GALVANIZED IRON VENTILATORS.

A.	*B.*	*C.*	*Area.*	*Weight.*	*Gage.*	*Price, Galv. Iron.*
12	17	20	113	19	22	$ 5.00
14	21	23	153	22	22	7.50
16	24	26	200	26	22	10.00
18	26	30	254	31	22	12.50
20	29	33	314	37	20	15.00
24	34	40	452	50	20	18.00
30	43	50	706	100	20	25.00
36	52	60	1,017	145	18	37.00
42	60	70	1,386	200	18	54.00
48	69	80	1,809	330	18	62.00
54	77	90	2,390	390	16	75.00
60	86	100	2,827	470	16	80.00
66	94	110	3.456	550	16	90.00
72	104	120	4,071	625	14	100.00

Some of the best makes of circular metal ventilators have fusible links in the cords which hold them open, and in case of fire they close automatically and stop all draft. Metal ventilators are suitable for use on saw-tooth roofs with fixed windows, and on boiler houses or shops which are excessively warm (Figs. 512 to 519).

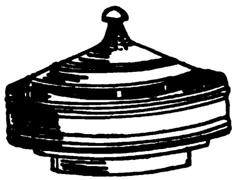


Fig. 512.

Fig. 513.

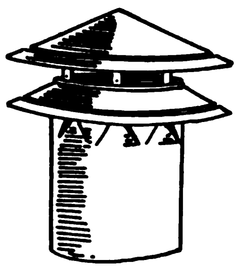


Fig. 514.

Fig. 515.

Fig. 516.

Fig. 517.

LOUVRES.

Louvres are bent sheets of metal fastened into frames, the sheets lapping over each other enough to exclude snow and rain. They are occasionally used on the sides or ends of buildings, but oftener on monitors, where a large amount of continuous ventilation is needed. They are made both fixed and movable, but the latter forms are rarely used, as movable shutters are preferred. Movable louvres (Figs. 520 and 521), on account of their light weight, are easily rattled by the wind, and as they cost more than steel shutters, they have no advantage over them. Louvres are best suited to buildings such as rolling mills, forge shops, or wherever smoke and gas is found, requiring permanent openings in the roof for their removal. They must be firmly held in place, so the wind will not cause them to rattle, tear them loose, or close the openings, rendering them useless.

Fig. 518.

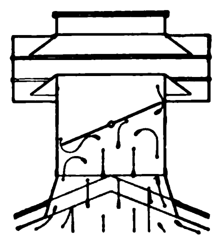


Fig. 519.

The thickness of metal should not be less than No. 22 gage for black or painted iron or No. 24 gage for galvanized, and the distance longitudinally between supports must be proportioned to the strength of the louvre sheets.

The required area of open space in the louvre frame can be determined by making the area of opening per 100 square feet of floor surface according to the following table: As buildings increase in height, they are more easily ventilated and require a proportionally smaller area of roof ventilation:

TABLE LVII.

REQUIRED AREA OF LOUVRE OPENINGS IN SQ. FT. PER 100 SQ. FT. OF FLOOR SURFACE, FOR VARIOUS BUILDING HEIGHTS.

	Height in ft. to eave.			
	20	*30*	*40*	*50*
Mills	12	10	8	6
Forge shops	14	12	10	9

The above areas are 60 per cent more than needed in openings where the air currents are unobstructed by the louvre slats.

Some common forms of louvres are shown in Figs. 520 to 524. Fig. 522* is a very neat form made of No. 24 galvanized sheets,

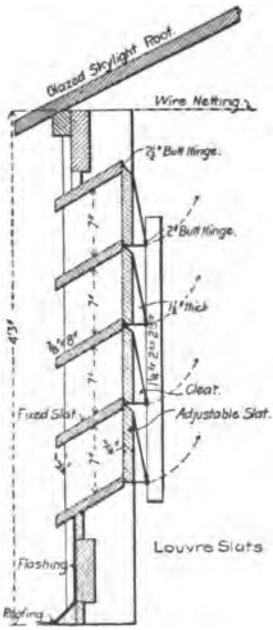


Fig. 520.

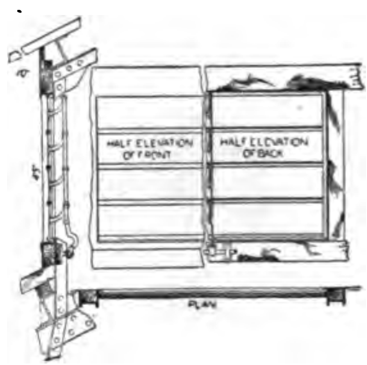


Fig. 521.

11 inches wide, with edges rolled. They require supports not greater than 49 inches apart, and as the ends are lapped from $\frac{1}{4}$ to $\frac{1}{2}$ inch, the greatest sheet lengths are 4 feet $1\frac{1}{2}$ inches. The slats are fastened through $\frac{5}{16}$-inch holes to angle uprights by $\frac{1}{4}$-inch screw head bolts, $\frac{3}{4}$ inch long, and they are separated by louvre blocks $1\frac{5}{8}$ inches long by each vertical support, which prevents them from closing under wind pressure. The design is defective

* Mill Building Construction, H. G. Tyrrell. 1900.

in having no bolts or ties to prevent interior wind pressure from spreading the metal slats and causing them to rattle. The illustration shows the detail for louvres adjoining both corrugated iron siding and wood window sash.

Fig. 523 shows another design for continuous louvres which are made in 10-foot lengths. The slats are made with straight bends without curves and they are tied together with bolts, and

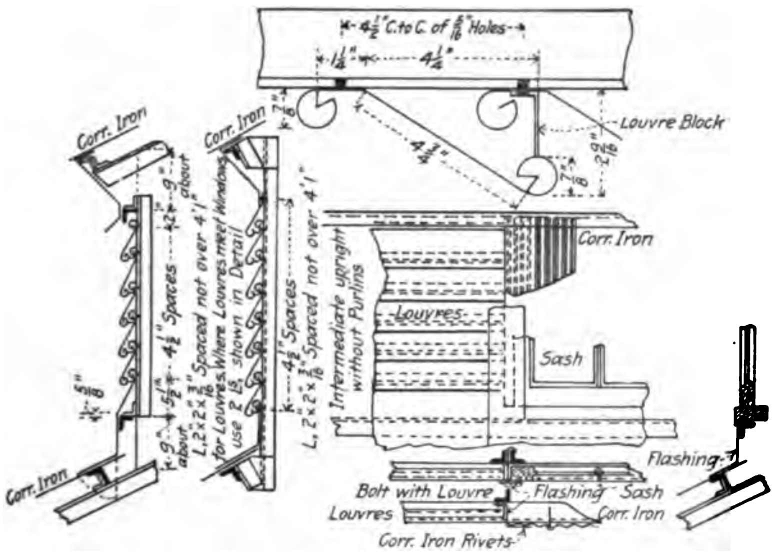


Fig. 522.

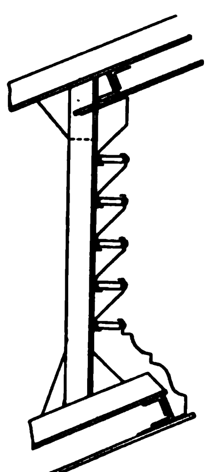


Fig. 523.

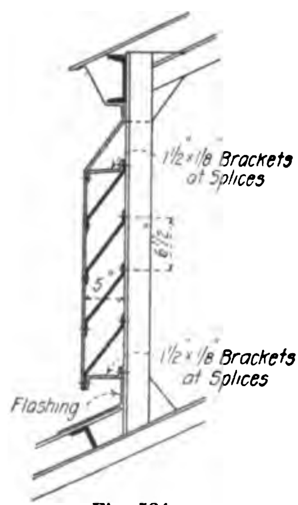


Fig. 524

separated by short sections of pipes. The lower section is bolted to the uprights and rests on the side roof, while the upper one is molded in the form of a cornice and fastened to the roof purlin. Fig. 524 shows another set of louvres, which are held out from the vertical by braces at the top and bottom and united on the outer face by $1\frac{1}{2} \times \frac{1}{8}$-inch straps at the joints. They are made of No. 22 gage metal in maximum length of 7 feet. The lower louvre slat is set not less than 6 inches above the adjoining roof, so the opening will be effective. Fixed galvanized iron louvres cost complete in place about 40 cents per square foot.

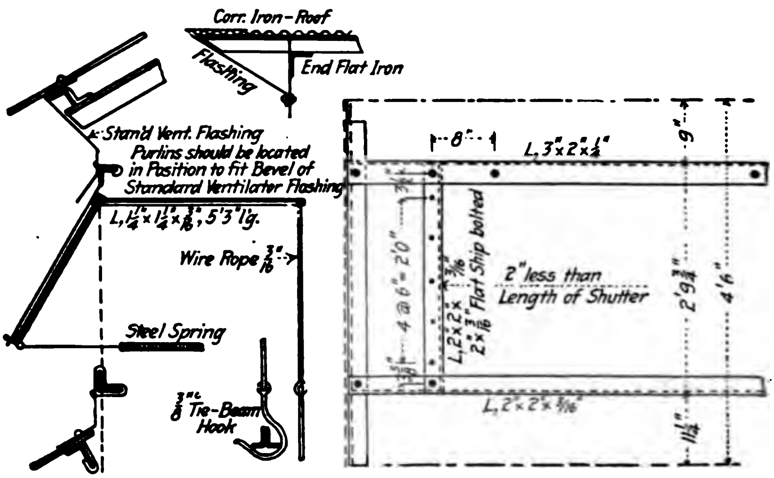


Fig. 525.

SHUTTERS.

Ventilator shutters (Fig. 525*) in monitor sides may be made of flat or corrugated iron, Nos. 12 to 14 gage being suitable for flat plate shutters and No. 22 for corrugated. but in either case it is preferable to have the sheet galvanized. When the shutters are galvanized, all flashing, bolts, clips, clinch nails, or other fastening, any part of which shows on the exterior, must also be galvanized.

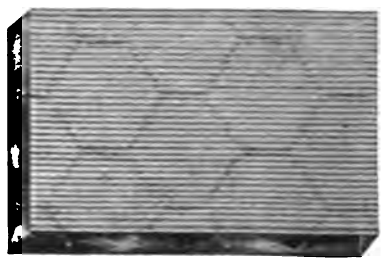
The shutters are made in a uniform width of 30 inches and lengths varying from 5 to 10 feet, and are stiffened with a light border frame of $1\frac{1}{2} \times \frac{3}{16}$-inch angles with intermediate cross angles 2 to 3 feet apart. Fig. 525 shows the framing for a standard angle shutter 8 feet long. They are suspended from the upper monitor purlins, using two hinges for lengths of 7 feet or under and three hinges for greater lengths, and are held in closed position with brass springs, as shown, one spring serving the two opposite shutters. They are opened by a $\frac{3}{16}$-inch wire rope attached to a light angle iron lever fastened to the center of each shutter, and are held open by hooking the wire rope under some of the roof framing, or by attaching it to a wall cleat near the floor. Shutters hinged at the top are less liable to leak than trunnioned shutters, though the latter, on account of being balanced, are easier to operate. The hinged shutters, as shown, lap at the ends and bottom over the framing, and are waterproofed at the top by wide projecting flashing which serves also as a monitor cornice.

CHAPTER XXX.

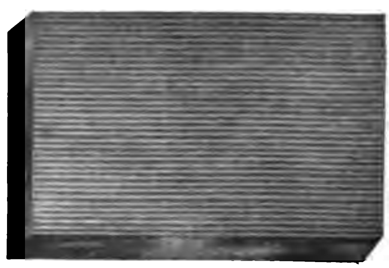
GLASS.

There are three kinds of glass in general use for lighting, known as sheet glass, plate glass, and prisms, the last being very little used for factory buildings, on account of its high cost.

Sheet glass is made in single and double strength, with thicknesses of $\frac{1}{16}$ and $\frac{1}{8}$ inch, respectively, and is suitable for use where liability to breakage is small, in sizes up to about 6 square feet. It is made in three grades, known as AA, A and B, the AA being



ROUGH. RIBBED WIRE.



ROUGH WIRE. RIBBED.

Fig. 526.

the best and B the poorest quality. A and B qualities are the kinds generally used for manufacturing buildings.

Plate glass is made in thicknesses from $\frac{3}{16}$ to $\frac{3}{4}$ inch, and should be used for skylights and large window panes, or wherever thinner glass is unsuitable.

TABLE LVIII.

WEIGHT PER SQ. FT. OF PLATE GLASS.

1/8 in. thick, weighs	2	lbs. per sq. ft.
3/16 in. thick, weighs	2½	lbs. per sq. ft.
¼ in. thick, weighs	3½	lbs. per sq. ft.
3/8 in. thick, weighs	5	lbs. per sq. ft.
½ in. thick, weighs	7	lbs. per sq. ft.
5/8 in. thick, weighs	8½	lbs. per sq. ft.
¾ in. thick, weighs	10	lbs. per sq. ft.

The best thickness of plate glass for different sizes is as follows:

12× 48 or 15×40 inches	3/16 in. thick
15× 60	¼ in. thick
20×100	3/8 in. thick

Many skylight makers, however, use ¼-inch thick plate glass for widths of 20 to 24 inches, and find it satisfactory.

Plate glass is made either plain or reinforced with wire, and the surface is either polished, rough, ribbed, or maize (Fig. 526). Wire glass is preferable for skylights, for if the glass is broken the imbedded wire netting holds the glass together and prevents its falling. It is also valuable for retarding fire, for while plain glass breaks with heat and leaves draft openings in the walls or roof, the wire glass, even when broken, remains in position. Wire glass costs more, and is 20 per cent less effective for lighting than plain glass, but a greater area overcomes the latter objection, while the extra cost is a small item in an entire building.

Rough and ribbed plate wire glass (Fig. 526) are the kinds best suited for factory use, and particularly for skylights. Light is not so well diffused through rough plate as through ribbed glass, but rough plate is preferred by many because it is easier to clean. The ribs of fluted glass become clogged with dust and soot, and unless it is thoroughly and frequently washed, the dust will obscure more light than a roughened surface. The ribs should be placed on the inside or outside of the building, according as one or the other is more accessible for cleaning, and the ribs should be vertical on side windows, and parallel with the roof slopes on skylights; but for double glazing the ribs should face each other and be crossed. Factory glass has twenty-one ribs per lineal inch. Careful experiments show that ribbed glass diffuses light better than any other kind, but as there is no benefit from ribbing both sides, one side is made smooth. The best method of glazing side windows is to use ribbed glass in the upper sash, and plain double-strength sheet glass in the lower ones. The new shops of the Sturtevant Company are glazed in this way.

Double glazing causes a great saving of heat in winter seasons and is extensively used in northern latitudes. The Fiberoid plant at Springfield, Massachusetts, has double glazed windows, and the Great Northern Railway shops at St. Paul have double glazed skylights, with $\frac{1}{4}$-inch ribbed plate glass above, and double-strength sheet glass below, with wire netting underneath. A saw-tooth roof built for the Farr Alpaca Company at Holyoke, Massachusetts, has double glazed sash on the roof, with $\frac{1}{4}$-inch ribbed glass inside and double-strength sheet glass outside.

COST OF GLASS.

Price lists are issued by the glass manufacturers, which, in 1908, were subject to the following discounts:

Sheet glass	90 and 45%
Polished plate glass under 5 sq. ft....................	75, 10 and 5%
Polished plate glass between 5 and 10 sq. ft............	80 and 5%
Polished plate glass over 10 sq. ft....................	80 and 10%

The cost of sheet and polished plate glass varies with the size of sheet, but is approximately as follows:

Double strength sheet glass....................	\$ .06 to \$ .10 per sq. ft.
Polished plate wire glass, either side over 40 in...	1.25 per sq. ft.
Polished plate wire glass, either side 24 to 40 in..	.90 per sq. ft.
Polished plate wire glass, either side under 24 in.	.60 per sq. ft.

The cost of setting sheet glass is from 15 to 20 per cent of the cost of the glass, or from $1\frac{1}{2}$ to $1\frac{1}{4}$ cents per square foot. The cost of setting plate glass is about 5 per cent of its cost.

Ribbed and maize glass is sold at a uniform square foot price, independent of the size of the sheets, and the prices are as follows:

$\frac{3}{16}$ plain ribbed glass........................	9 to 12 cents per sq. ft.
$\frac{3}{16}$ maize glass	18 cents per sq. ft.
$\frac{1}{4}$ ribbed or maize wire glass..................	21 cents per sq. ft.

The cost of erecting or laying skylight glass is from 8 to 10 cents per square foot.

CHAPTER XXXI.

SKYLIGHTS.

Skylights are used in buildings, the widths of which are too great to receive sufficient light from the sides, and are generally needed when these widths exceed 50 to 60 feet. Many forms of skylights serve the double purpose of lighting and ventilating, the latter feature being discussed later in connection with the various forms or makes.

The proportion of roof which should be covered with glass varies from 25 to 50 per cent, depending on the use of the building and other conditions which are explained in Chapter IX. A building for rough work or storage will not need as much light as a machine shop or mill where fine work with much detail is carried on.

The common forms of skylights are as follows, each form being described separately:

(1) Glass Skylights in Plane of Roof.
(2) Individual Box Skylights.
(3) Glass Tile.
(4) Prisms.
(5) Translucent Fabric in Plane of Roof.

Skylight glass is held in position and made water-tight in two general ways:

(1) By being laid in putty or cement.
(2) By the use of felt packing in the joints, compressed with springs and bolts.

As glass sheets are seldom absolutely flat, laying them in putty or cement prevents the sheet from breaking and at the same time closes all openings and makes the roof water-tight, but the method has the disadvantage of causing the putty to grip the glass, and vibration in the building from the movement of cranes or machinery often results in broken skylights. Vibration sometimes causes the putty and cement to break and fall out, leaving larger openings for leakage than if no putty or cement were used. To obviate this difficulty, other methods have been devised for holding the glass by laying it on strips of felt or packing instead of in cement or putty, while still other methods are used by which the glass is placed between metal surfaces and leakage through the joints is carried off in gutters. In any case, the safety of workmen demands either the use of wire glass or a strong wire mesh stretched below plain glass to catch falling pieces in case of breakage.

On box skylights, or wherever conditions will permit, the roof should have a slope of 8 inches per foot or one-third pitch, and even on flat skylights should never be less than 2 inches per foot.

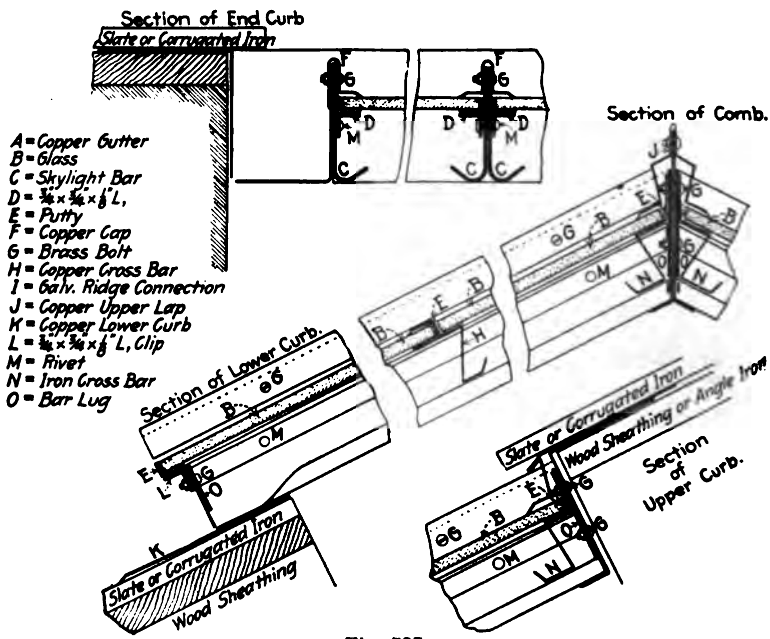


Fig. 527.

One-third pitch is the common practice. On roofs which have a comparatively flat pitch, it assists greatly in making the skylights water-tight to place them at the ridge and give them a greater pitch than the rest of the roof, as shown in Figs. 26 and 107.

BARS.

Skylight bars are made of rolled steel, cast iron, galvanized sheet steel, copper and wood. The essential features are the flange, gutters and caps, and they differ chiefly in these particulars. Cast iron is not much used, as the rolled steel bars are stronger and cost no more, and wood bars cannot be used on fireproof buildings. Their use is restricted largely to small greenhouses and conservatories, or to temporary non-fireproof buildings. The kind of skylight bars suitable for fireproof factory buildings are, therefore, rolled steel or sheet metal, either galvanized or copper. Sheet metal has the advantage of being light and cheap, and forms a more elastic bed for the glass than rolled steel bars, but it is not so strong or durable. Many sheet metal bars are formed by folding a single sheet into the desired shape, so the finished bar has only a single joint.

Figs. 527 to 554 show skylight bars and details, for both rolled steel and sheet metal, with or without putty.

Fig. 527 shows details of a skylight with rolled steel bars and glass laid in putty. The bars are made of No. 10 to No. 14 gage metal, and the upper caps are copper or galvanized iron, fastened with brass bolts and nuts. Expansion is provided between the adjoining bars, which can be used for spans up to 12 feet without intermediate support. The illustration shows the application of the skylight to both ridge and side roof construction.

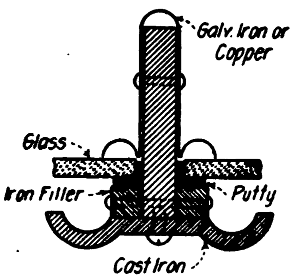


Fig. 528.

Fig. 528 shows a very simple form of skylight bar made from a vertical rolled steel bar with a cast iron gutter tap-screwed to the lower side. The glass is laid in putty and the ridge is covered with a cap of galvanized iron or copper. The size of the vertical bar is made to suit the length of span, and when this length is too great for a single length of glass, the sheets of glass are then overlapped, and the thickness of iron fillers made to correspond.

Fig. 529 shows the Anti-Pluvius skylight made by the G. Drouve Company. It consists of a series of rolled steel bars to support the glass, spaced about 20 inches apart, and strong enough for spans up to 8 feet. For lengths greater than 8 feet, intermediate purlins are needed. Stirrup irons are screwed into the main bars, 16 to 20 inches apart, with their tops at the proper elevation to support the glass. On these stirrups is laid a $1\frac{1}{2} \times \frac{1}{8}$-inch iron plate, and the glass is cushioned between strips of felt held in place by sheet metal guides and compressed with springs over brass stud bolts in the stirrups. Over the joints is an inverted bridge bar, on which to walk. When sheets of glass overlap, the stirrups are then placed at different elevations for the upper and lower sheets. There is no contact between the glass and the iron bars, and therefore no condensation on them.

Fig. 530 shows the Lupton bar, which, on account of its shape, has a high bending strength; the glass is lapped and bars and

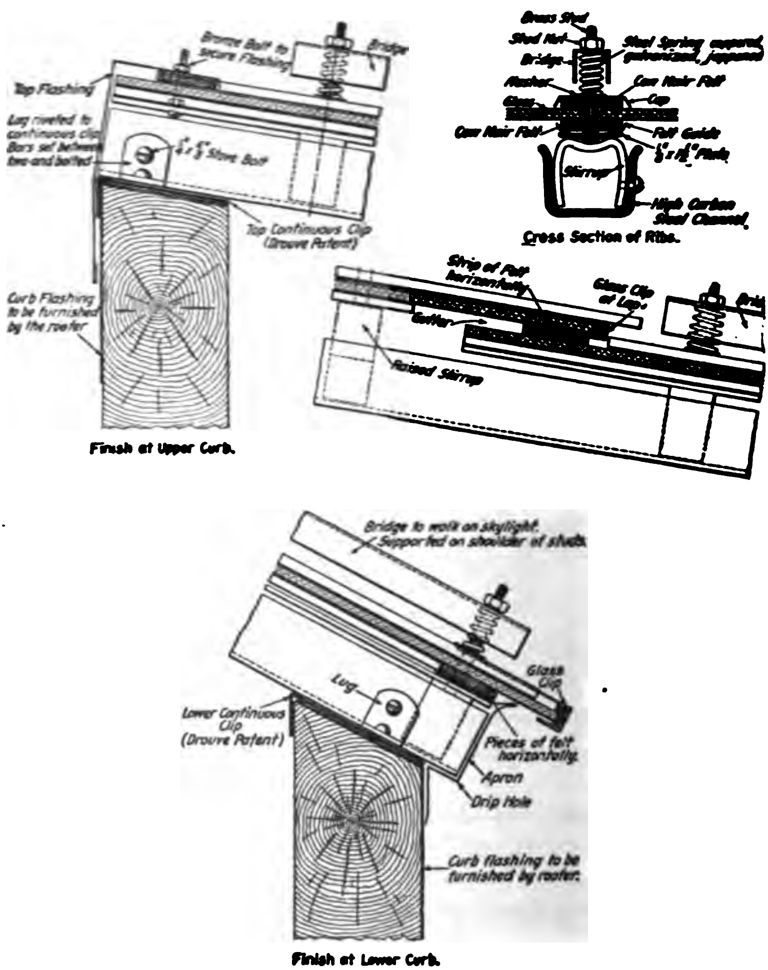


Fig. 529.

caps are offset to match. The swivel stud holds the cap properly in alignment, while saturated oakum is placed between glass and metal, and prevents the glass coming in contact with the main bar and forming condensation. The joints are covered with a copper cap held in place with brass nuts.

Figs. 531 and 535 show the Van Noorden steel skylight. The channel bars are bolted to the roof purlins through lugs which have depressions in the side at intervals of 18 inches to form seats for spring clips, through which brass bolts are passed which hold the galvanized iron or copper caps tightly on the glass. The absence of putty in forms of this kind allows the glass to move slightly without breaking, during the operation of heavy cranes and machinery which cause vibration in the entire building. Some skylight bars of this form have frequent perforations in the sides of the bar and the cap, so they act both as skylight and ventilator.

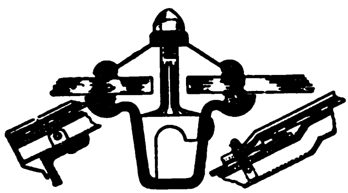


Fig. 530.

Figs. 532, 533 and 534 are other forms of Van Noorden Company's bars, in which the glass is supported without being in contact with the main bars, and are therefore less liable to condensation than those shown in Fig. 531.

Fig. 536 shows the steel skylight bar of the American Machinery Company. It is a simple anchor shape, varying in depth from $1\frac{1}{2}$ to 6 inches, with glass bedded between strips of felt. The 6-inch one is strong enough for spans up to 15 feet.

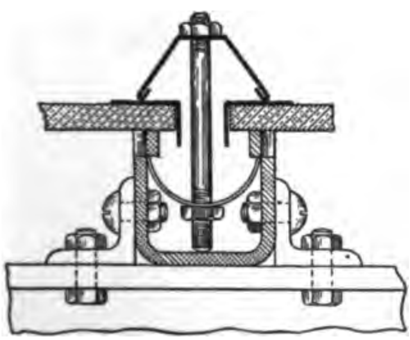


Fig. 531.

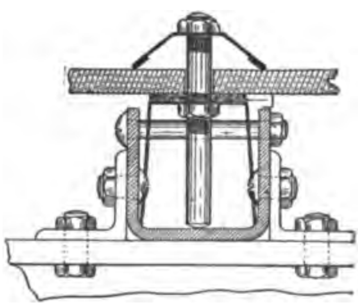


Fig. 532.

Fig. 537 shows a very simple form of puttyless steel skylight rib, which was used by the author on several mill buildings. It can be made in any structural shop from common shapes. The upper and lower members are $1\frac{1}{2}$ by $1\frac{1}{2}$ by $\frac{3}{16}$ steel angles, the glass being bedded between strips of felt. The lower angles,

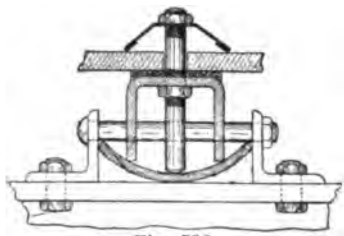


Fig. 533.

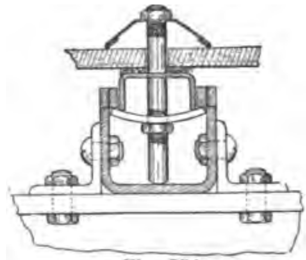


Fig. 534.

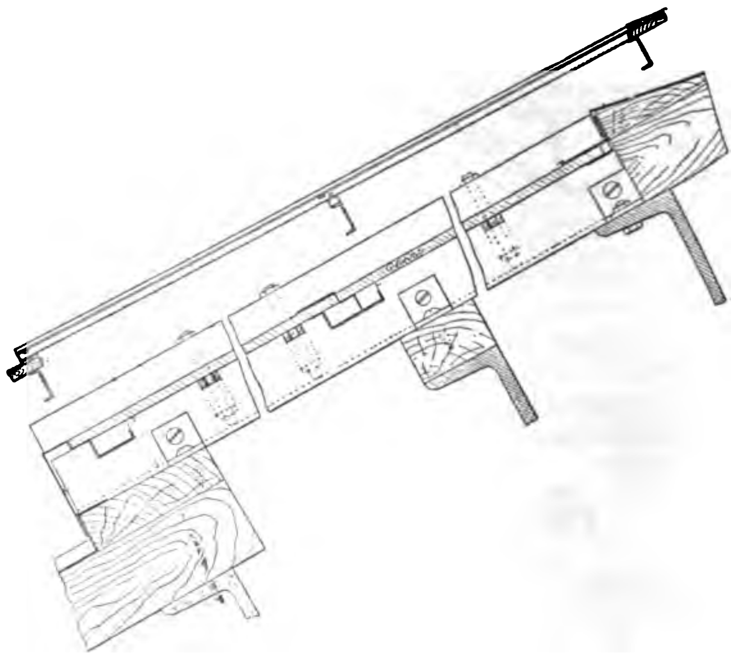


Fig. 535.

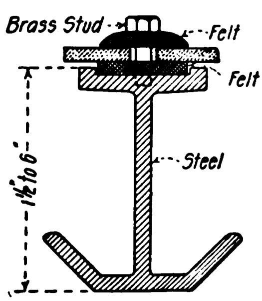


Fig. 536.

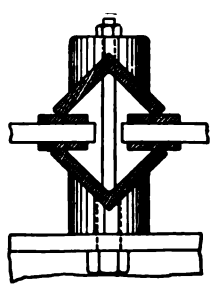


Fig. 537.

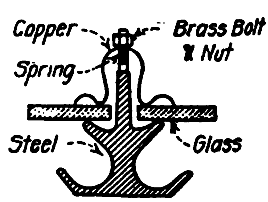


Fig. 538.

which serve as glass supports and gutters, rest in small castings on the purlins, and the upper angles are bolted through similar castings on the ridge.

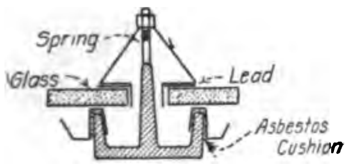


Fig. 539.

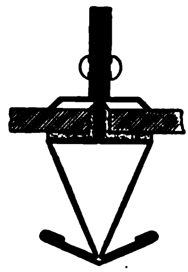


Fig. 540.

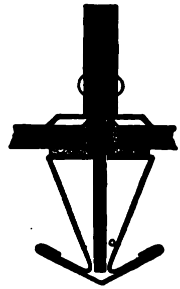


Fig. 541.

Fig. 538 is made by the National Skylight and Ventilator Company, and used without putty, the glass being held on the steel bar with nuts screwed down on the spring caps. The bolts are fastened to the steel bars by being dovetailed into them.

Fig. 539 is the puttyless skylight bar of the National Venti-

Fig. 542.

lating Company. In addition to the features shown in previous ones, it has asbestos cushions beneath the glass and outside sheet metal condensation gutters.

Figs. 540 and 541 are two forms of sheet metal bars with glass laid in putty, the latter having a flat steel center. The bar as shown in Fig. 541, when made of No. 24 galvanized iron, is strong enough for spans up to 8 feet, and when of No. 18

galvanized iron, is strong enough for spans from 10 to 12 feet. The system is shown in perspective in Fig. 542.

Fig. 543 shows the puttyless sheet metal ventilating bar of the Lyster Sheet Metal Company. It is similar to those last described excepting that there are numerous openings in the side and cap, and it acts as skylight and ventilator at the same time.

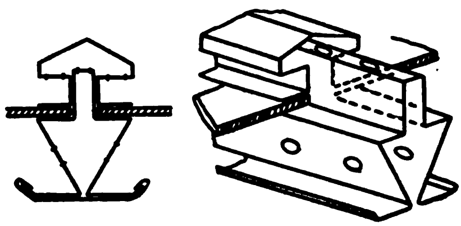


Fig. 543.

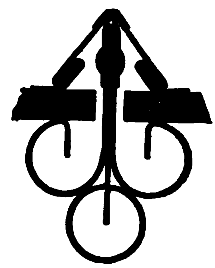


Fig. 544.

Figs. 544 and 545 show the Vaile and Young puttyless sheet metal skylight bar for short and long spans respectively, the light one being strong enough for spans up to 8 feet.

Fig. 546 shows skylights with bars and framing made of wood, and is suitable only for temporary or non-fireproof buildings.

COST OF FLAT SKYLIGHTS.

The cost of flat skylights depends chiefly on the length of spans and corresponding weight of bars, and varies generally

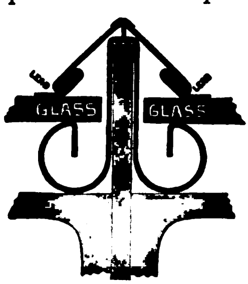


Fig. 545.

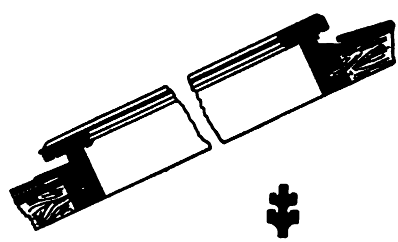


Fig. 546.

from 40 to 60 cents per square foot, including all material in place.

Large skylights with steel channels and copper caps weigh 8 pounds per square foot and cost from 50 to 60 cents per square foot erected. When bars and caps are made of galvanized iron, the cost will not exceed 30 to 40 cents per square foot in place. The cost of erecting skylights is 8 to 10 cents per square foot.

BOX SKYLIGHTS.

Box or individual skylights are made in small areas and placed on curbs standing at least 6 inches above the plane of the roof. They are made in several forms with single and double pitch, as shown in Figs. 547 to 552. The standard slope used on box skylights is 8 inches rise per foot or $\frac{1}{3}$ pitch. A double pitch box skylight 12 feet wide would therefore have a rise of 4 feet. The curbs are raised above the roof level for the purpose of flashing them and preventing slush and snow from leaking in, and their tops are generally level.

Fig. 547.

When it is desired to combine ventilating with lighting, the skylights are placed on high curbs which have movable sash or louvres in the side; or one or more glass panels on the top may be hinged, though the latter method is liable to cause leakage. Side ventilator windows may be opened or closed in sets, with mechanism similar to the device used for monitor windows described in Chapter XXXIII. High box skylights should have eave gutters and spouts at the corners so water will not run down on the sash or louvres. Wire glass is preferable to plain glass, but when plain is used a wire netting must be placed beneath it.

The Pennsylvania Railway Locomotive shop at Wilmington, Delaware, has roof skylights as shown in Fig. 553. They are not continuous and are placed only between the trusses and not over them.

The hipped turret skylight with ridge ventilator, movable side sash and locking apparatus (Fig. 548) costs from $1.25 per

Fig. 548.

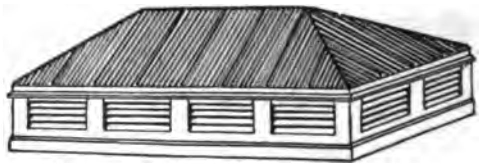


Fig. 549.

Fig. 550.

Fig. 551.

Fig. 552.

horizontal square foot for 8 × 14-ft. size, to $2 per horizontal square foot for 4 × 6-ft. skylight.

The hipped turret skylight with stationary louvre ventilators in the sides (Fig. 549) costs from 80 cents per horizontal square foot for 8 × 14 ft. size, increasing to $1.25 for 3 × 5 ft.

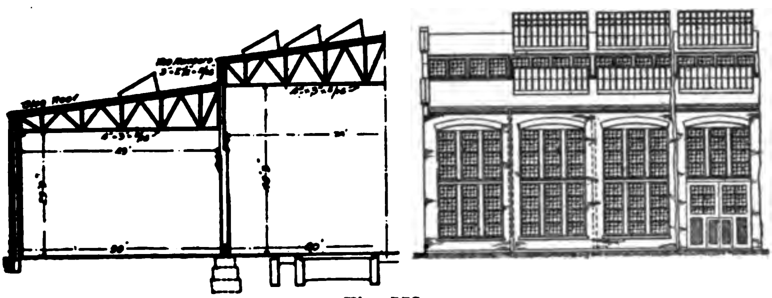


Fig. 553.

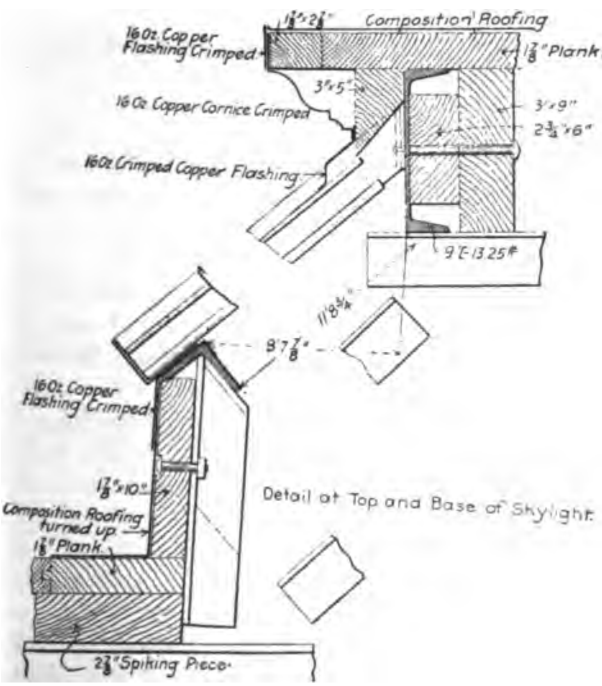


Fig. 554.

Double pitched turret skylights without side ventilators (Fig. 550) cost from 40 cents per horizontal square foot for 7 × 12 ft. to 65 cents per horizontal square foot for 2 × 3 ft.

Double pitch box skylights (Fig. 551) cost from 35 cents per horizontal square foot for large sizes to 75 cents for small ones.

Single pitch box skylights (Fig. 552) cost 25 cents per horizontal square foot for 8 × 12-foot size, increasing to 40 cents for minimum size.

The above costs for box skylights are based in all cases on the use of galvanized sheet metal bars.

TILE SKYLIGHTS.

Several tile manufacturers make glass tiles similar to opaque ones (Fig. 432). The glass tiles cost from 50 to 60 cents each, and they may be either scattered over the roof, alternating with opaque ones, or they may be assembled in blocks or strips similar to ordinary glass skylights. They produce an attractive appearance, but are too expensive for common factory use.

Prism lights may also be occasionally used on manufacturing buildings in crowded city districts, where direct sunlight is prevented by adjoining buildings, but their use is too limited to merit further description here.

TRANSLUCENT FABRIC.

This is a flexible substitute for glass skylight made of a light wire mesh imbedded in a thin oil composition, only thick enough to cover the wire. The wire mesh is made of No. 26 gage, and the mesh has 12 openings per lineal inch. The composition is amber colored, and it admits a large proportion of light well diffused. Its chief merit is its flexibility, for it can be used on steel frame buildings where glass skylights would be broken. The action of jib and shop traveling cranes, steam hammers or other heavy machinery causes the framing of steel buildings to spring so much that glass skylights are frequently broken, and not only incur expense for replacing them but cause leaks; and falling skylights are a danger to the workmen. The fabric will not take fire unless exposed to excessive heat, and then the oil composition burns with profuse black smoke. All things considered, it is probably as satisfactory as glass. In hot weather the composition softens somewhat and collects soot and dirt, and it must, therefore, be frequently cleaned. It is made in sheets 3 feet 3 inches wide, 6 feet 3 inches or 7 feet 3 inches long, and the strips are laid lengthwise of the roof, the horizontal seams lapped 2 inches. It is fastened with 1¼-inch (3d) nails, using 1¼ pounds per hundred feet of seam.

Fig. 555* shows a method used by the author for laying translucent fabric on the roof of a monitor, and the material was first used on a forge shop in the East, designed by him in 1897. A light wood frame was placed over the angle purlin with wood rafters 6 feet apart and nailing pieces bolted to the purlins. The

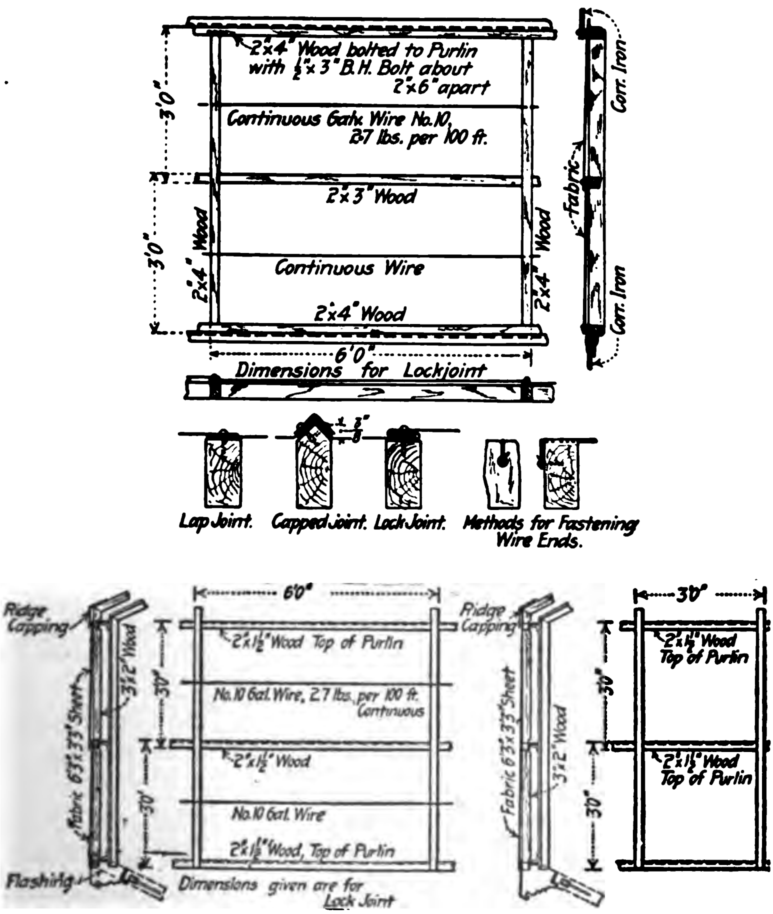


Fig. 555.

sheets were laid lengthwise of the building and overlapped 2 inches, at the center longitudinal purlin. The shop had 12-foot truss panels, and the fabric sheets were, therefore, made 6 feet 3 inches long, allowing 3 inches for the joints. Two lines of No. 10 galvanized wire were stretched midway between the longitudinal

* Mill Building Construction. H. G. Tyrrell. 1900.

purlins, and fastened at the ends to prevent the cloth from sagging. Joints at right angles to the eave were locked, and the ridge was covered with metal ridge capping. At the eave was placed a neat galvanized iron cornice with an outer drip carried up on the roof under the fabric and nailed to the wood purlin cap. It is now manufactured by the P. J. Ferguson Company, Norfolk Downs, Quincy, Massachusetts, and costs 10 cents per square foot, f. o. b. factory, or 22 cents per square foot with nails and wire, erected in place, but not including the cost of framework. It has since been used on the Tennessee Centennial Exposition Building at Nashville, and on many of the buildings for the Trans-Mississippi Exposition at Omaha in 1898. A building for the Atchison, Topeka and Santa Fe Railroad at Topeka, 155x850 feet, has translucent fabric skylights at the ridge, and the General Electric machine shop at Schenectady, built in 1904, has 40 per cent of the roof thus covered.

CHAPTER XXXII.

WINDOWS.

SIDE WALL WINDOWS.

The windows in mill buildings may be supported by wood or steel studs or purlins covered with sheathing, or they may be built into walls of solid stone, brick or concrete. Sometimes window frames are set on a solid base wall, built up to the level of the window sills, and supporting a framed wall above them. The details of frames and windows depend largely upon the nature of the walls.

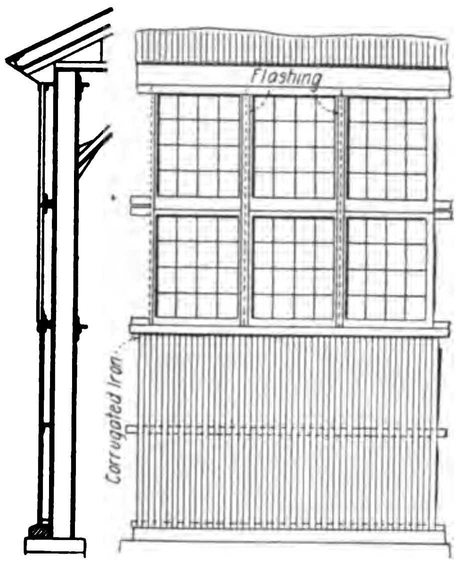


Fig. 556.

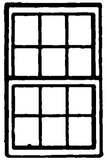
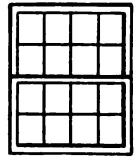
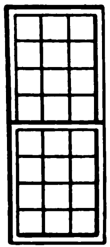
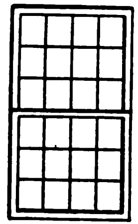
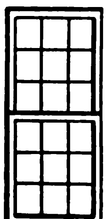
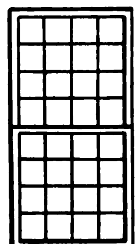
WOODEN SASH.

The proper dimensions for sash of different sizes are as follows: Sash 5 × 6 feet and larger should be 2 inches thick, have ½-inch mullion, with 3-inch stiles and top rails, and 5-inch bottom rail; sash 4 × 4 feet to 5 × 6 feet should be 1¾ inches thick, have ⅜-inch mullions, 2½-inch stiles and top rail, and 4-inch bottom rails; and those smaller than 4 × 4 feet should be 1½ inches thick, have ¼-inch mullion, 2-inch stiles and top rail, and 3-inch bottom rail.

The following table gives the dimensions of ordinary single window sash:

TABLE LIX.

DIMENSIONS OF ORDINARY SINGLE WINDOW SASH.

Style	Number of Lights.	Size of Glass.	Total Size.	Area.	Style	Number of Lights.	Size of Glass.	Total Size.	Area.
	12..........	10"x12"	2'-10"x 4'- 6"	13'		16..........	10"x12"	3'- 8"x 4'- 6"	17'
	12..........	10"x14"	2'-10"x 5'- 2"	15'		16..........	10"x14"	3'- 8"x 5'- 2"	19'
	12..........	12"x14"	3'- 4"x 5'- 2"	17'		16..........	12"x14"	4'- 4"x 5'- 2"	22'
	12..........	12"x16"	3'- 4"x 5'-10"	19'		16..........	12"x16"	4'- 4"x 5'-10"	25'
	12..........	12"x18"	3'- 4"x 6'- 6"	22'		16..........	12"x18"	4'- 4"x 6'- 6"	28'
	18..........	10"x12"	2'-10"x 6'- 6"	18'		24..........	10"x12"	3'- 8"x 6'- 6"	24'
	18..........	10"x14"	2'-10"x 7'- 6"	21'		24..........	10"x14"	3'- 8"x 7'- 6"	28'
	18..........	12"x14"	3'- 4"x 7'- 6"	25'		24..........	12"x14"	4'- 4"x 7'- 6"	33'
	18..........	12"x16"	3'- 4"x 8'- 6"	28'		24..........	12"x16"	4'- 4"x 8'- 6"	37'
	18..........	12"x18"	3'- 4"x 9'- 6"	32'		24..........	12"x18"	4'- 4"x 9'- 6"	41'
	24..........	10"x12"	2'-10"x 8'- 6"	24'		32..........	10"x12"	3'- 8"x 8'- 6"	31'
	24..........	10"x14"	2'-10"x 9'-10"	28'		32..........	10"x14"	3'- 8"x 9'-10"	36'
	24..........	12"x14"	3'- 4"x 9'-10"	33'		32..........	12"x14"	4'- 4"x 9'-10"	43'
	24..........	12"x16"	3'- 4"x11'- 2"	37'		32..........	12"x16"	4'- 4"x11'- 2"	48'
	24..........	12"x18"	3'- 4"x12'- 6"	41'		32..........	12"x18"	4'- 4"x12'- 6"	54'

When clearance will permit, sash may be strengthened by extending the stiles an inch or two above and below the top and bottom rails.

The best sash and frames are made of white pine, and without glass or paint, $1\frac{5}{8}$-inch sash posts from 5 to 7 cents per square foot, and $1\frac{3}{4}$-inch from 7 to 12 cents per square foot. Glazing with single strength glass costs from 6 to 8 cents per square foot, or

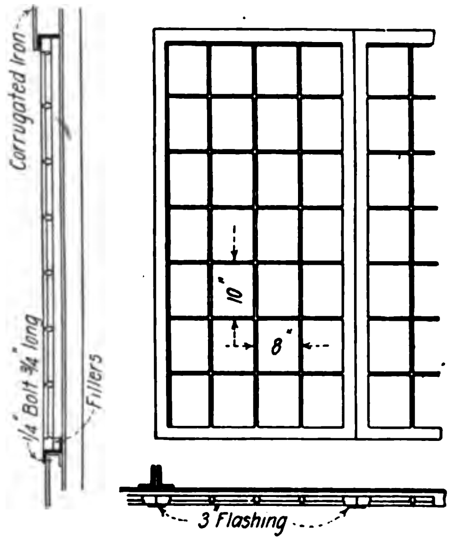


Fig. 557.

8 to 10 cents for double strength glass. The above prices are for sash only, without frames, f. o. b. Chicago. It is usual to estimate sash, glazed, painted and erected in place at 25 cents per square foot.

CONTINUOUS SASH.

A design for a foundry made by the author (Fig. 21) has 10 feet of continuous wood sash bolted to steel purlins (Fig. 556), and other details for sash on side walls are shown in Figs. 557 and 558.

WOOD WINDOW FRAMES.

A detail for window frame and casing, supported by steel purlins, is shown in Fig. 559*. The outstanding legs of the steel window angle are cut away, permitting the members to fit closely over the steel purlins to which they are fastened with countersunk bolts. The wood frame and casing is bolted to the steel

* **Mill Building Construction. H. G. Tyrrell. 1900.**

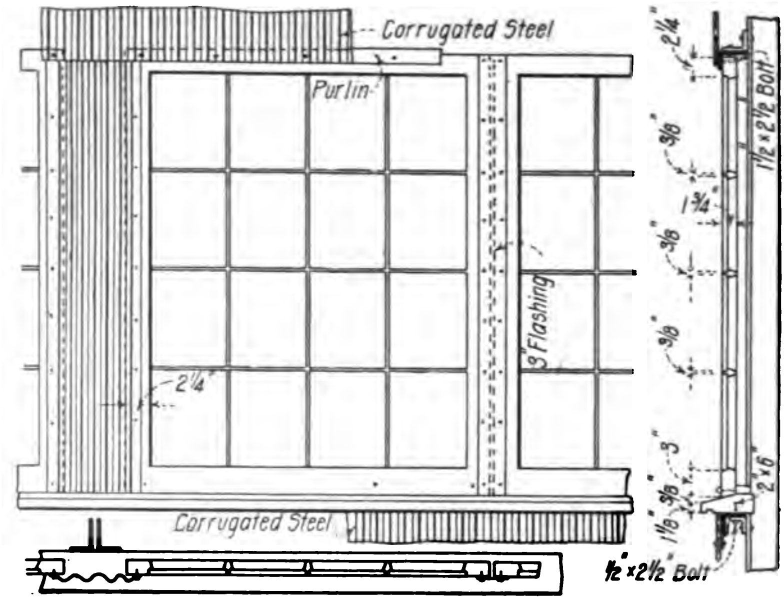


Fig. 558.

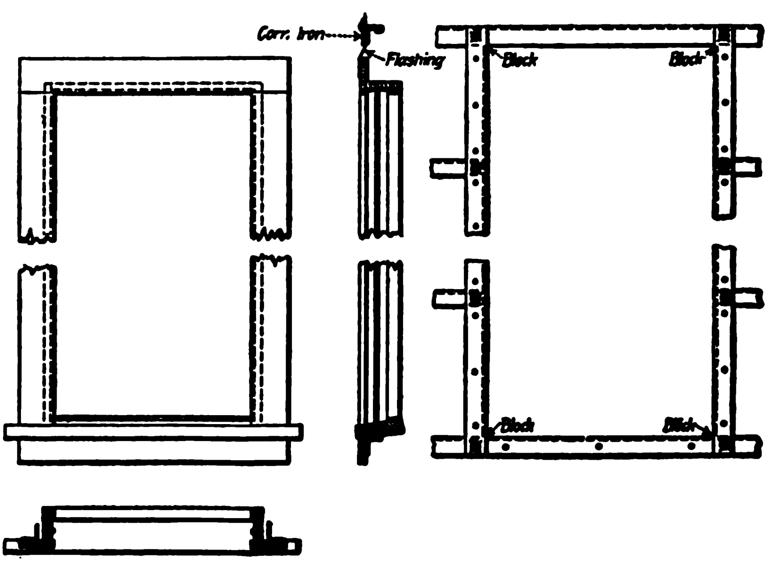


Fig. 559.

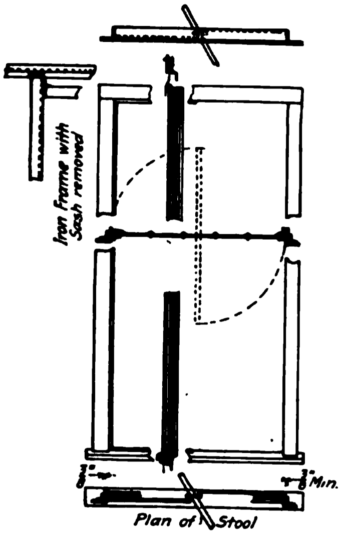


Fig. 560.

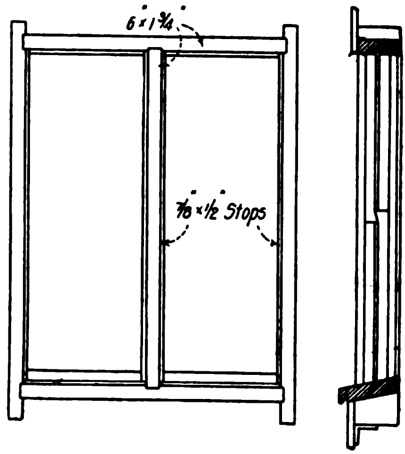


Fig. 561.

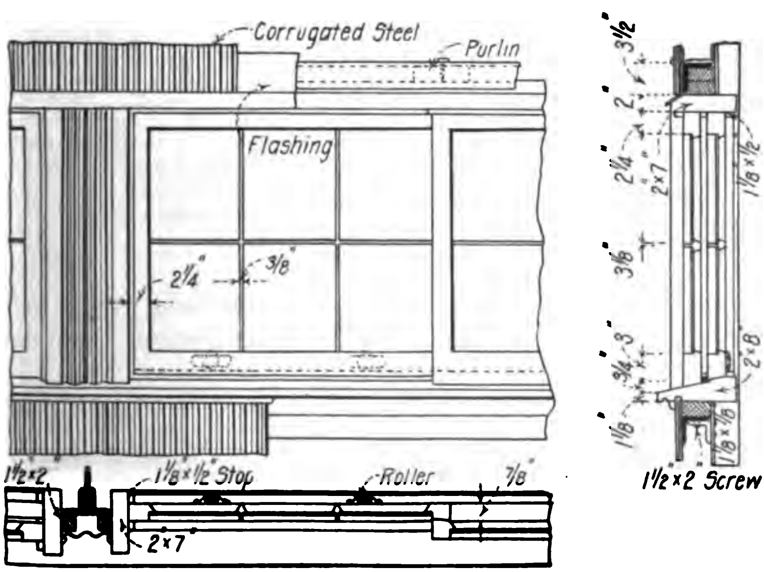


Fig. 562.

through $\frac{5}{16}$-inch holes about one foot apart, and the casing may be made more nearly fireproof by being covered with sheet metal (Figs. 480, 481 and 482).

Fig. 560 shows details for vertical trunnioned sash in wood frames, supported by steel purlins. The window frame is bolted to the steel work and the casing may be covered with sheet metal. Fig. 561 shows a mullion wood window frame for corrugated iron wall with sash omitted.

Figs. 562, 563 and 564 are details for windows in steel walls,

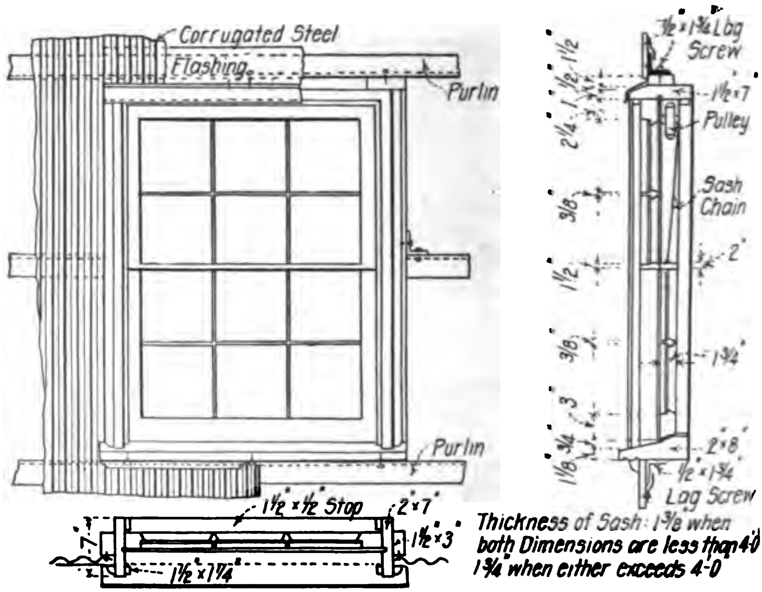


Fig. 563.

which are rolling, counterbalanced, and double hung, respectively. Counterbalanced windows are economical on account of having plain frames and requiring no weights.

Details for a wood window frame in a brick wall are illustrated in Fig. 565.

These frames usually have from twenty-four to forty lights or panels, and the size of wall openings for windows with 10 × 12-inch glass are as follows:

NUMBER OF LIGHTS.

24	4×7 ft. 0 in.
28	4×8 ft. 1 in.
32	4×9 ft. 1 in.
40	4 ft. 10 in. × 9 ft. 1 in.

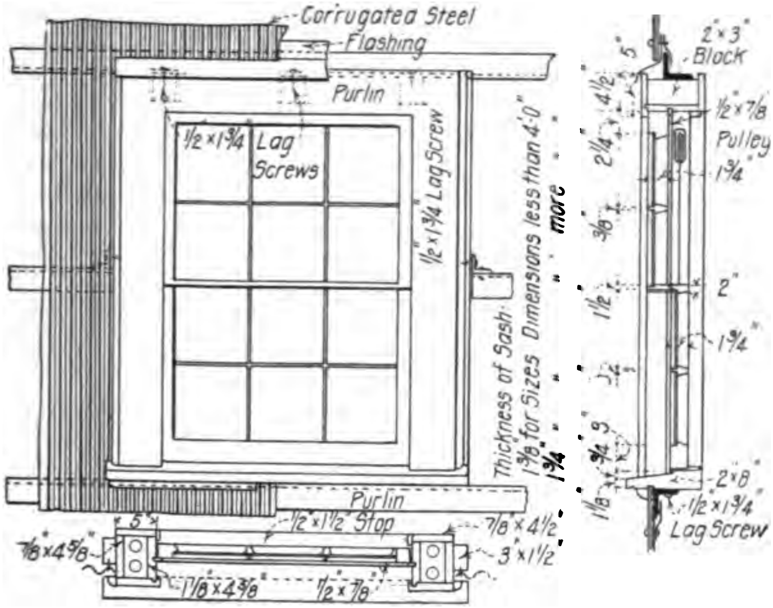


Fig. 564.

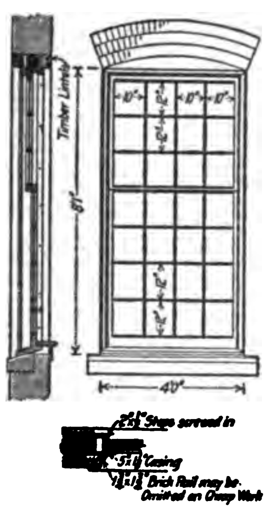


Fig. 565.

Wood window frames should have sills and pulley stiles from $1\frac{1}{8}$ to $1\frac{3}{8}$ inches thick, with $\frac{1}{2}$-inch parting strips, and the joints should be put together with white lead paint. The sills should be grooved on the under side to form a drip.

COST OF WOOD FRAMES AND WINDOWS.

In estimating windows, it is convenient to use prices including all details, such as sash, frames, glass, painting, sills, hardware and setting. Approximate prices for common size windows in place, including the above items and double strength glass, with cost of paint, are as follows:

Windows 3×7 ft. 6 in. in brick walls cost	$16.50
Windows 3×7 ft. 6 in. in frame walls cost	12.50
Windows 2 ft. 6 in. × 6 ft. 6 in. in brick walls cost	14.50
Windows 2 ft. 6 in. × 6 ft. 6 in. in frame walls cost	10.00

The cost of setting window frames is usually one-third of the cost of material.

An itemized cost estimate for a plain 3 × 6-foot wood window without casing, in brick walls, is as follows:

Box frame	$3.10
20 sq ft. sash, at 6 cents	1.20
16 sq. ft. glass, at 7 cents	1.12
5 ft. stone sill, at 60 cents	3.00
5 ft. stone lintel, at 40 cents	2.00
Paint, 55 sq. ft., at 2 cents	1.10
Weights, 110 lbs., at 1¼ cents	1.38
20 ft. chain, at 4 cents	.80
4 pulleys, at 15 cents	.60
Lift and lock	.50
Erection	2.00
	$16.80

Box window frames in brick walls with $1\frac{3}{4}$-inch sash and double strength glass, including weights, hardware, paint and setting, together with stone still and lintel, cost 75 cents per square foot of brick opening. Similar windows in frame walls, which require no stone sill or lintel, cost 50 cents per square foot. Windows with plank frames, fixed sash, and no weights or hardware, will cost less.

METAL SASH AND WINDOWS.

Sheet metal sash and frames are made in a variety of ways, a few of which are shown in Figs. 566 to 571. Fig. 566 shows inside and outside views of metal windows in brick walls with single trunnioned sash, while Fig. 567 is a similar window with double sash, and Fig. 568 is a mullion window in concrete walls

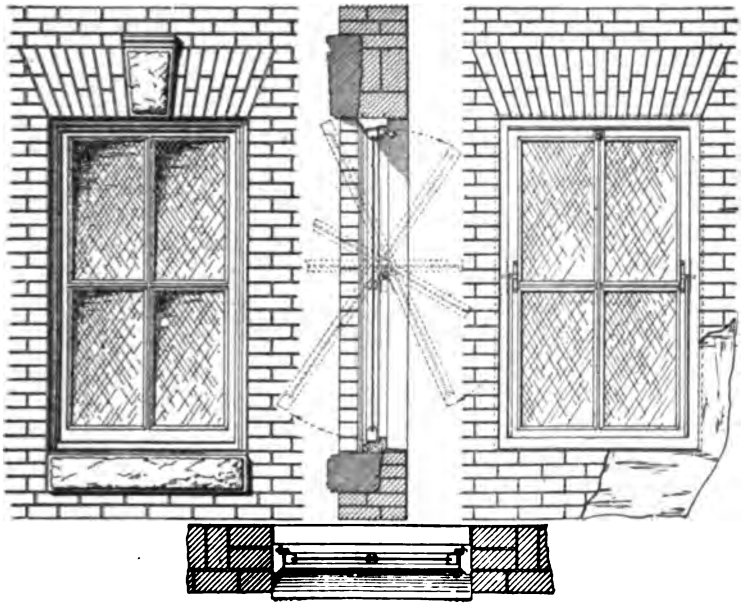


Fig. 566.

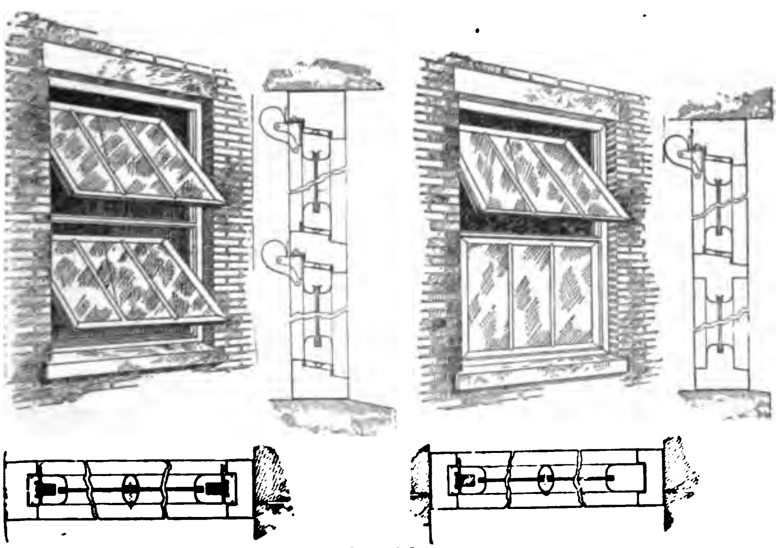


Fig. 567.

with double trunnion sash. Figs. 569 and 571 are views of double hung metal sash in metal frames.

With iron or sheet metal frames and wire glass, steel fire shutters are no longer necessary, and the extra cost of the fireproof windows is no greater than the combined cost of wood windows and shutters. Some makers of sheet metal windows use fusible links in the cord which holds the windows open, and in case of fire the soft fusible metal melts and allows the windows to

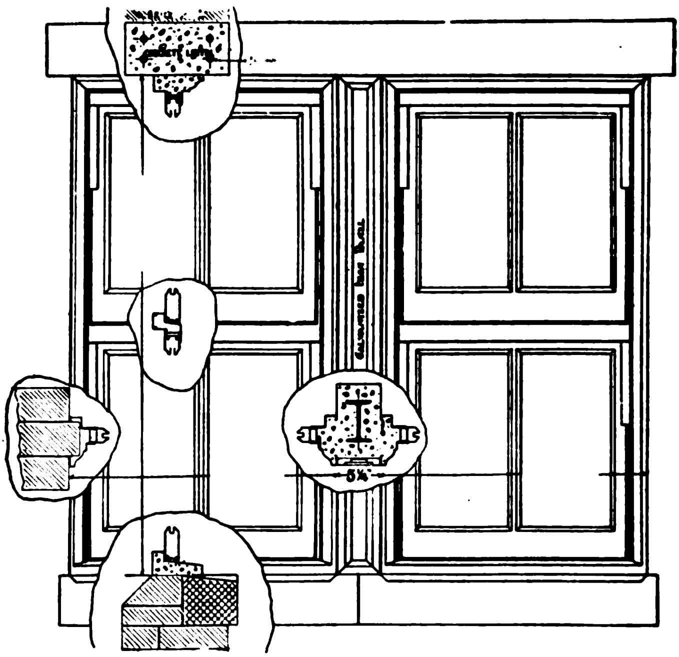


Fig. 568.

close from their own weight. The device is an excellent one, for it closes openings which would cause draft and add impetus to a fire.

Metal windows including sash and frames without glass cost 55 cents per square foot with double hung sash, and 40 cents per square foot with trunnioned sash. Rough plate glass costs 21 cents per square foot, and plate wire glass 95 cents, while setting glass costs 5 cents per square foot more. The cost of complete metal windows will therefore be the combined costs of metal and glass, as given above, depending on the kind of windows and glass selected.

The Allis-Chalmers pattern shop and storage building at West Allis, Wisconsin, has wire glass in iron frames and is a typical example of fireproof window construction.

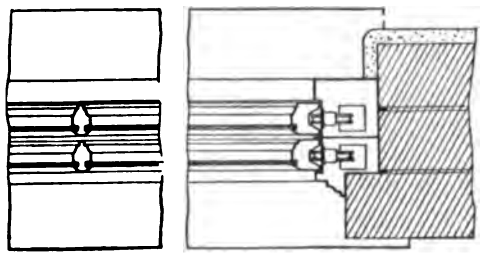


Fig. 570.

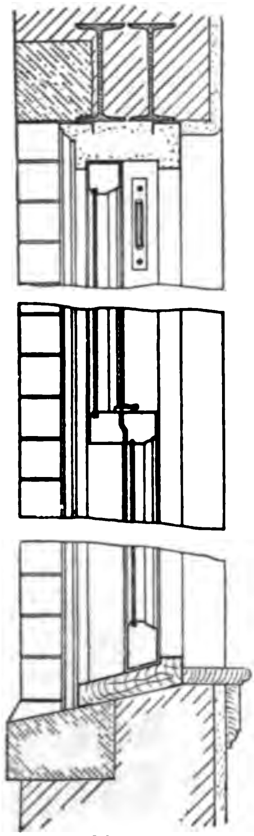


Fig. 569.

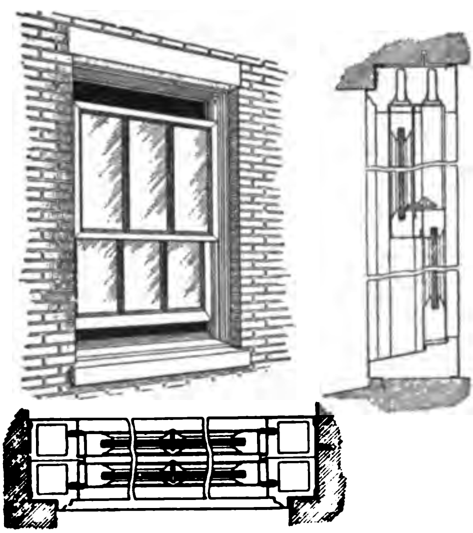


Fig. 571.

STEEL SASH.

Window sash with solid rolled steel bars are coming into general use for manufacturing buildings. They are stronger and more durable than sheet metal sash and offer greater resistance to fire.

Fig. 572 shows details of patent steel bars made by the Detroit Steel Products Company. The bars are soft steel and vertical ones are split at the point where muntins cross, and the horizontal muntins, which are notched at intersection, are passed through slots in the vertical ones, and the expanded web of vertical munwith double tru- ... hung metal sa- ... bars, thus hold- ... with pins through ... further with putty.

With iron ... shutters are ... proof windo- ... dows and ... fusible lin- ... case of fir- ... made to swing on side

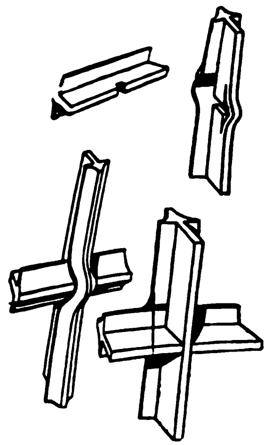
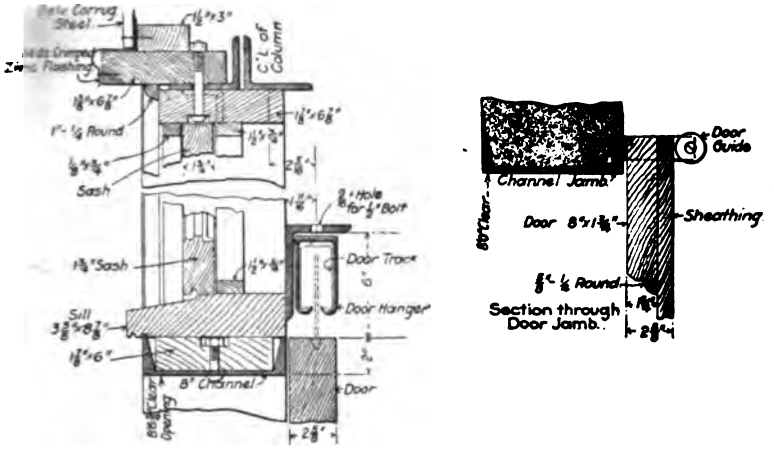


Fig. 572.

Fig. 573.

trunnions (Fig. 573). Steel sash cost 20 to 40 cents per square foot at the factory, not including glass, and about 3 cents per square foot for erection in large quantities. A large manufacturing building in Ohio, the plans of which were prepared in 1902, partly by the writer, had steel sash made on 1-inch channels, the glass being held in place by small flats and angle bars. Other details of windows and doors are shown in Figs. 574 and 575.



Section through Door Transom.

Fig. 574.

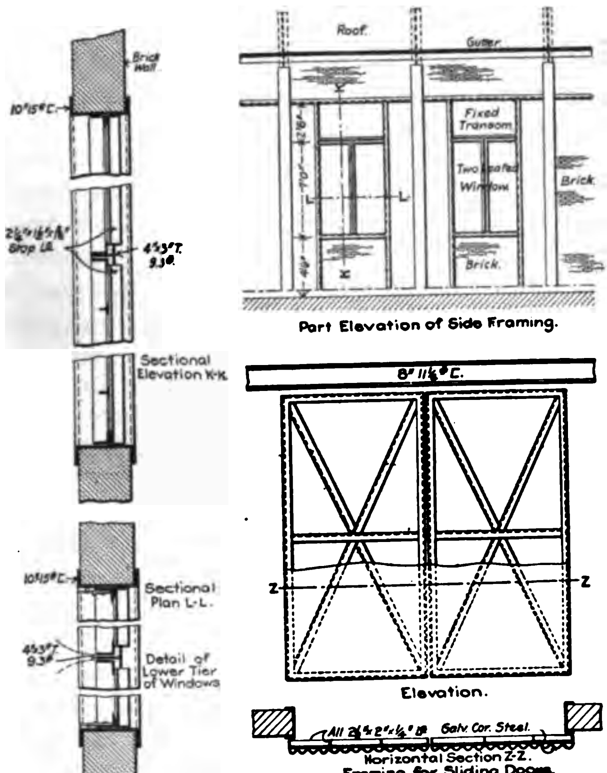


Fig. 575.

tins is driven back into notches in the horizontal bars, thus holding the bars together. Glass is held in position with pins through holes drilled in the webs of bars, and secured further with putty. If side ventilation is desired, the sash are made to swing on side

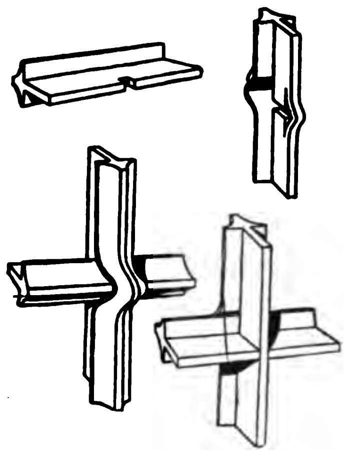


Fig. 572.

Fig. 573.

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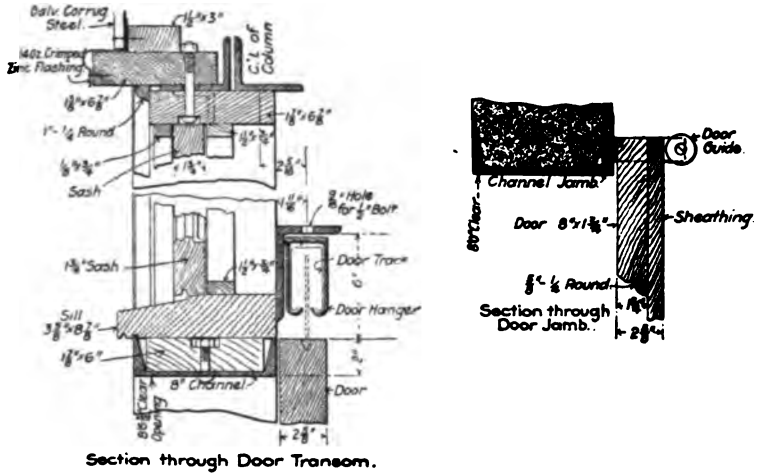

Fig. 574.

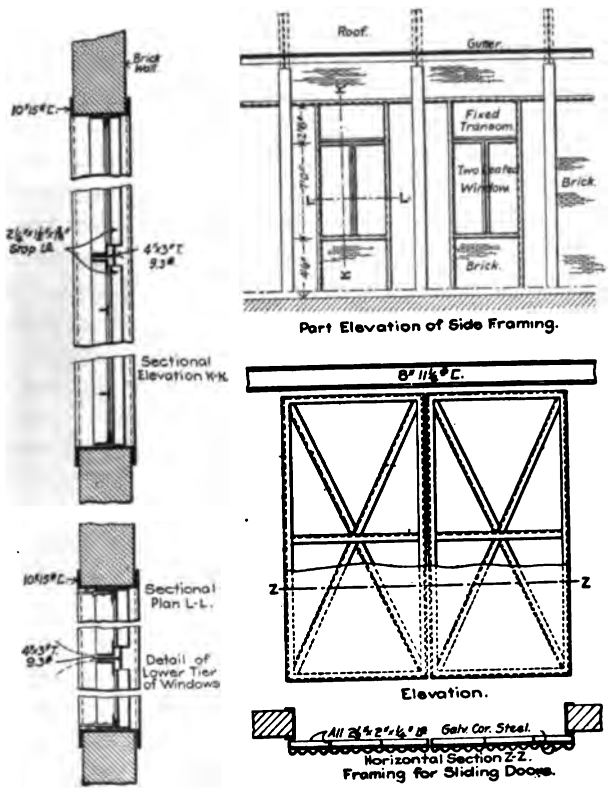

Fig. 575.

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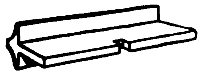
If side ventilation is desired, the sash



se of lighting and ven-
for lighting and nar-
dth suitable for lighting
steam collects under the
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the roof is not required,
ough.
effective for ventilating as
able purpose of ventilating
able.
respond with the walls and
have corrugated iron cov-
me, preferably the small cor-
with plank or gravel, wood
ore appropriate.
be either wood or sheet metal,
window frames should be so
at the mill and shipped to the
frames, like other manufac-
ade in factories than by hand
of building them during erec-
The choice between wood or
ends upon the fireproof require-
buildings where sparks occur
the roof, and metal frames and

covered with sheet metal and
480, 481 and 482) and such
anized to correspond with the
preferred.
fixed or movable, depending on
If the monitor is for lighting
ators on the ridge, the sash may
small amount of ventilation is
make only part of the sash movable,

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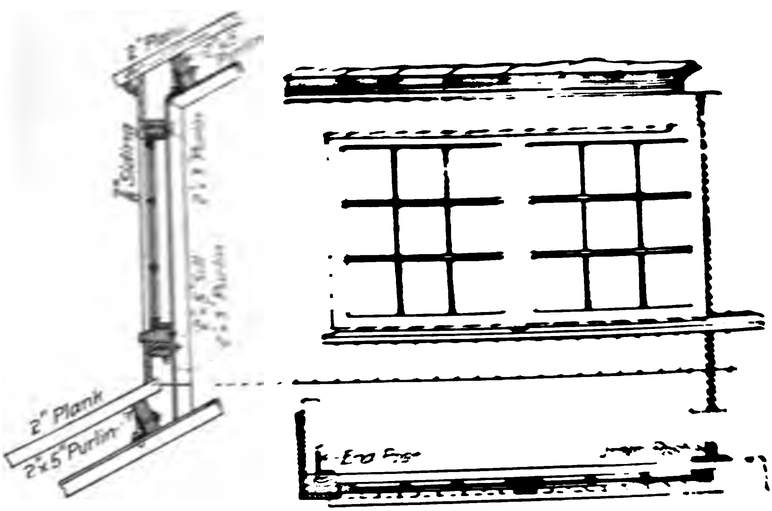


Fig. 577.

CHAPTER XXXIII.

MONITOR WINDOWS.

Monitors are used for the double purpose of lighting and ventilating. Wide monitors are most effective for lighting and narrow ones for ventilating; and when the width suitable for lighting the floor is so great that foul air, gas or steam collects under the roof, it may then be necessary to add a second narrow ventilation monitor on the ridge. When light from the roof is not required, a narrow ventilation monitor may be enough.

Shutters on monitors are quite as effective for ventilating as windows, but the windows serve the double purpose of ventilating and lighting, and are therefore preferable.

The monitor sheathing should correspond with the walls and roof of the main buildings, and if these have corrugated iron covering, the monitor should have the same, preferably the small corrugations; but if the roof is covered with plank or gravel, wood monitor sheathing would then be more appropriate.

The sash, frames and casing may be either wood or sheet metal, and the purlins or supports for window frames should be so arranged that frames can be made at the mill and shipped to the building ready for placing. Window frames, like other manufactured products, cost less when made in factories than by hand labor at the site, and the practice of building them during erection is wasteful and unsatisfactory. The choice between wood or metal for the frames and casing depends upon the fireproof requirements. Forge shops or similar buildings where sparks occur should have little or no wood in the roof, and metal frames and casing are then preferable.

Wood window casing may be covered with sheet metal and made more nearly fireproof (Figs. 480, 481 and 482) and such covering should be black or galvanized to correspond with the sheathing, galvanized metal being preferred.

Monitor sash may be either fixed or movable, depending on the requirements of ventilation. If the monitor is for lighting only, with individual metal ventilators on the ridge, the sash may then be stationary, or if only a small amount of ventilation is needed, it is economical to make only part of the sash movable,

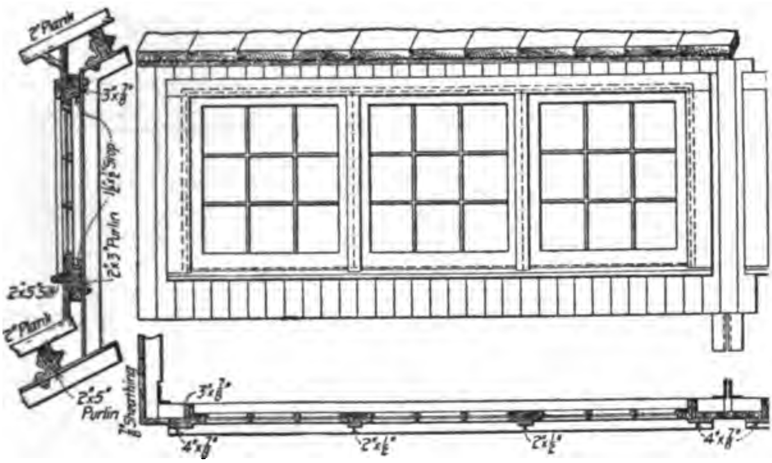


Fig. 576.

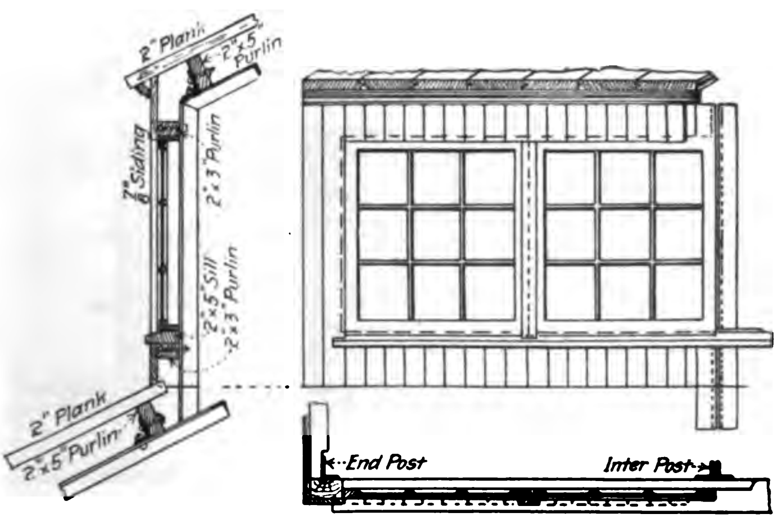


Fig. 577.

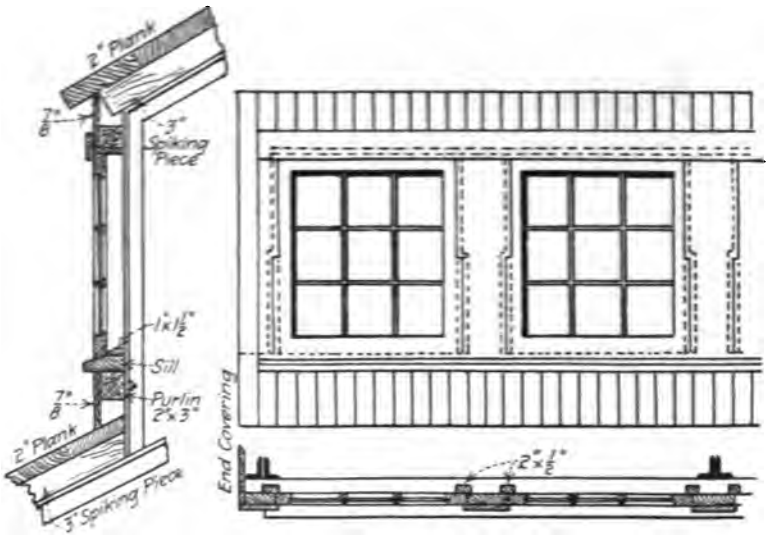


Fig. 578.

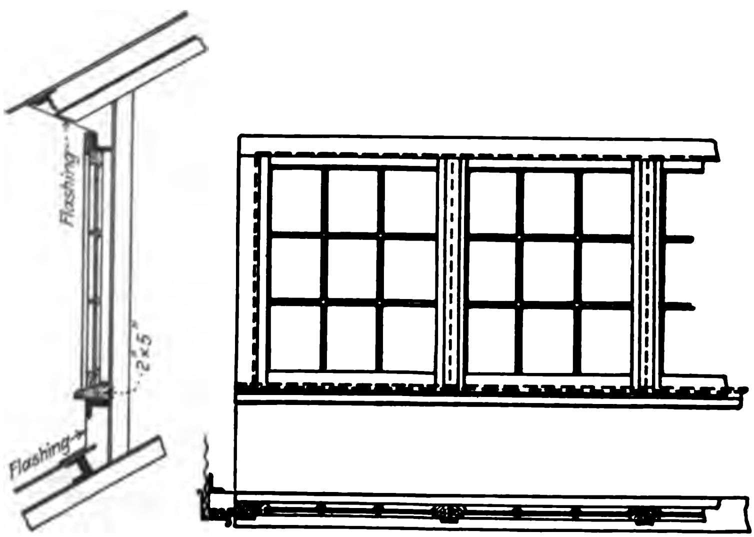


Fig. 579.

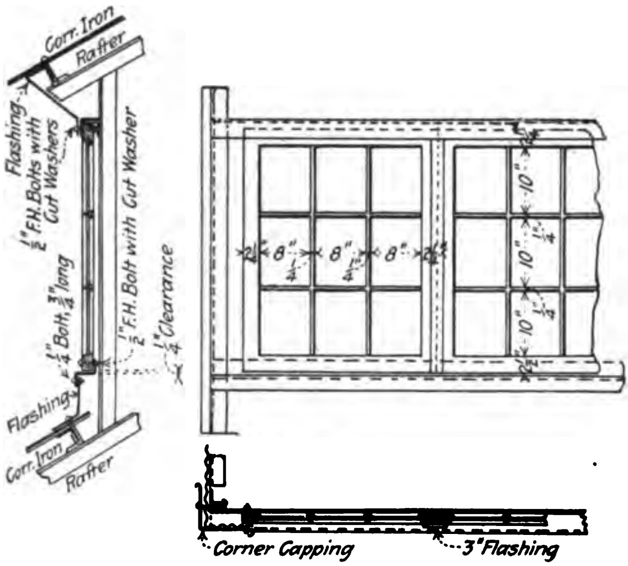


Fig. 580.

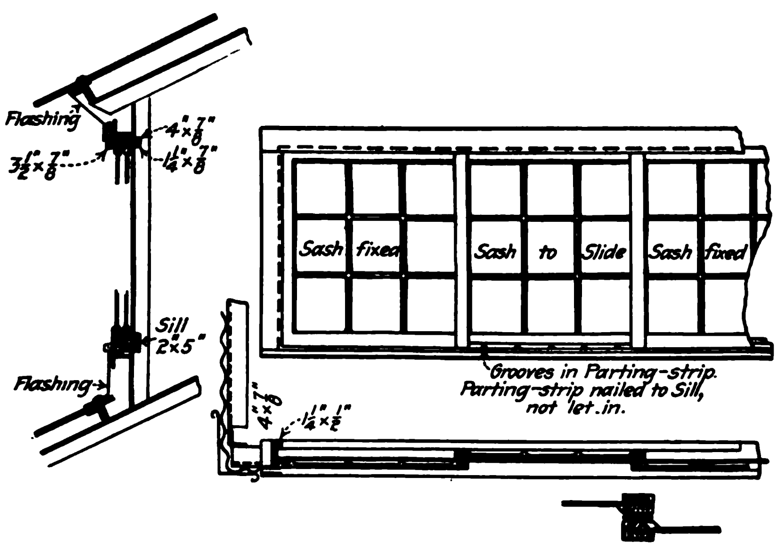


Fig. 581.

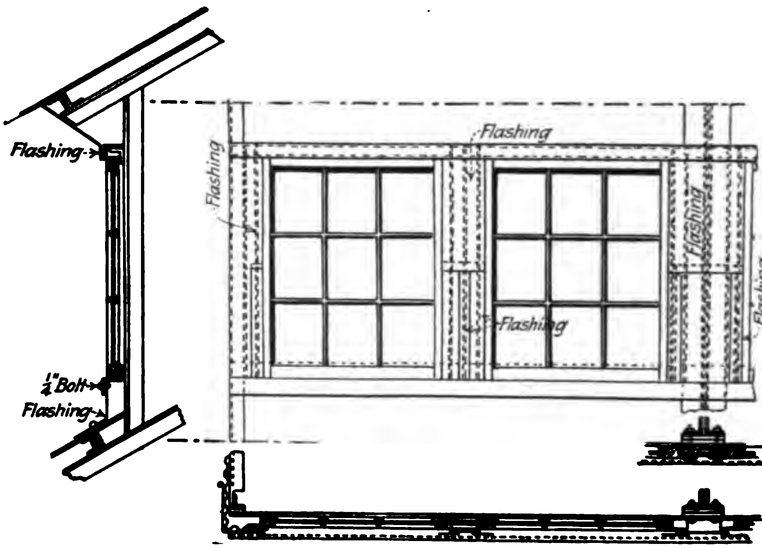


Fig. 582.

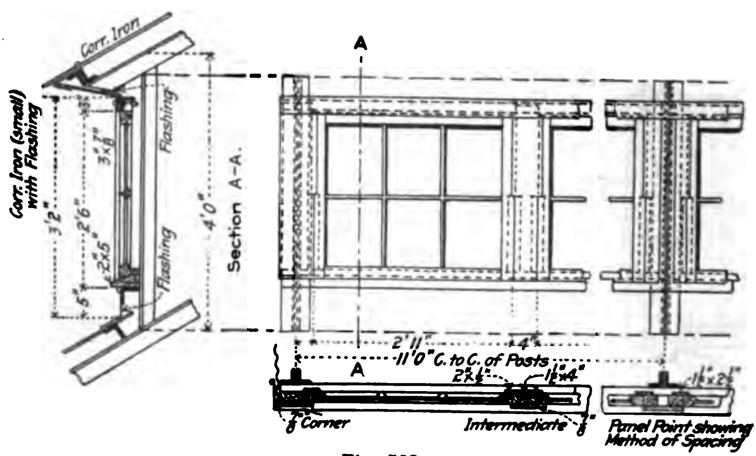


Fig. 583.

and the remaining ones stationary. Movable sash are either sliding, hinged or trunnioned. When a large amount of ventilation is needed, sliding sash should not be used, for they leave only a part of the monitor side open. Sash which are hinged at the top or bottom are more nearly water-tight than when they are trunnioned, but as trunnioned sash are balanced at their centers they are easier to operate. Trunnioned sash, when open, may also interfere with the inside clearance, unless the monitor fram-

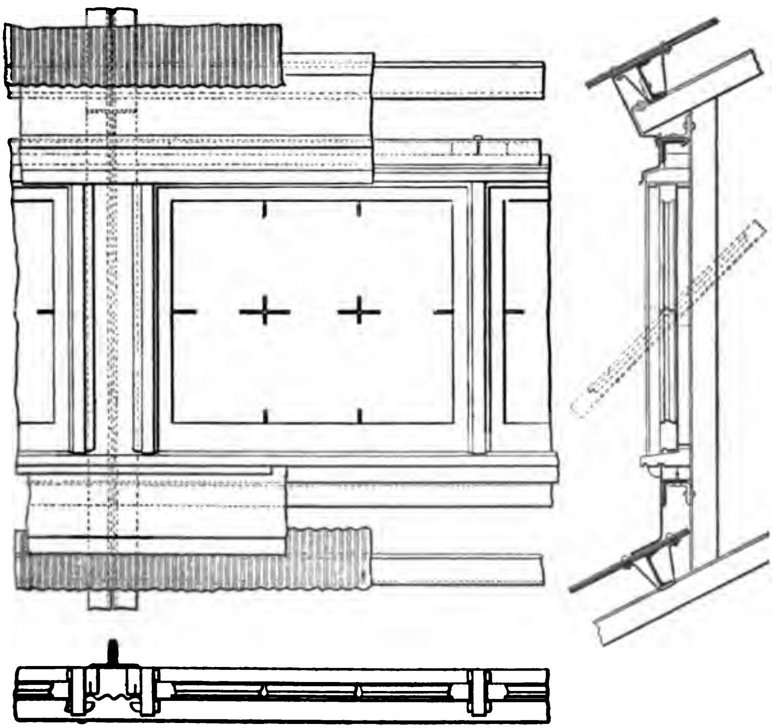


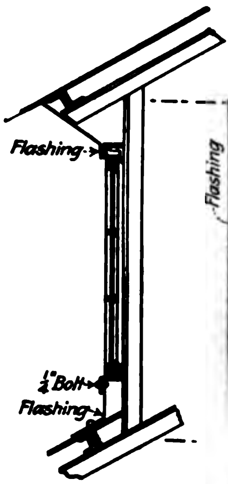
Fig. 584.

ing is arranged as in Fig. 8. Figs. 576 to 585 show monitor window framing in wood and metal for both fixed and moving sash.

Figs. 576 and 577* show stationary windows with and without casing and wood frames and sheathing, while Fig. 578* is similar but has pivoted sash. Figs. 579 and 580* have fixed sash, with and without frames and casings, and metal sheathing. Figs.

* Mill Building Construction. H. G. Tyrrell. 1900.

...rable sash,
... alternate sash
... 582* is made
... sash. Fig. 583



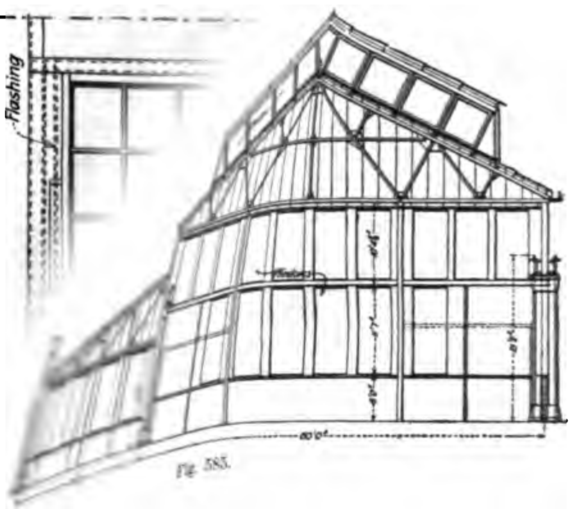


Fig. 585.

... with trunnioned sash. Fig. 584
... Company's standard monitor fram-
... or movable. Fig. 585 shows the cross
... plant of the Jones and Laugh-
... The trusses are spaced 19 feet 7 inches apart
... glass windows in the sides cover every

WINDOW OPENING MECHANISM.

... by sliding them horizontally or vertically
... them at the edges, or by turning them
... trunnions. Those which slide past each
... available for ventilation, and are
... for monitor use. Hinged windows
... to be water-tight, but are harder
... Side wall windows hinged at the
... not water-tight, and if swinging
... by the wind. The usual method
... is therefore to either slide them
... them on trunnions, the latter method

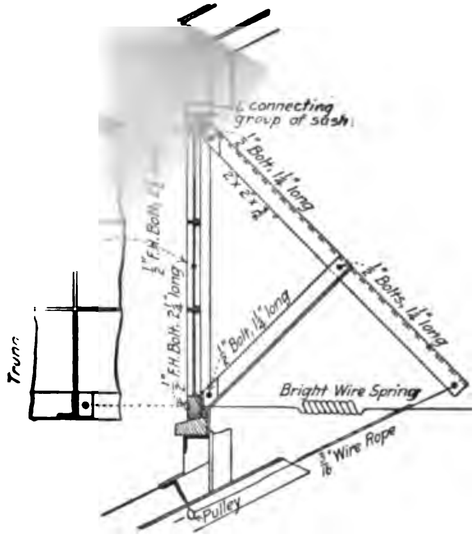


Fig. 586.

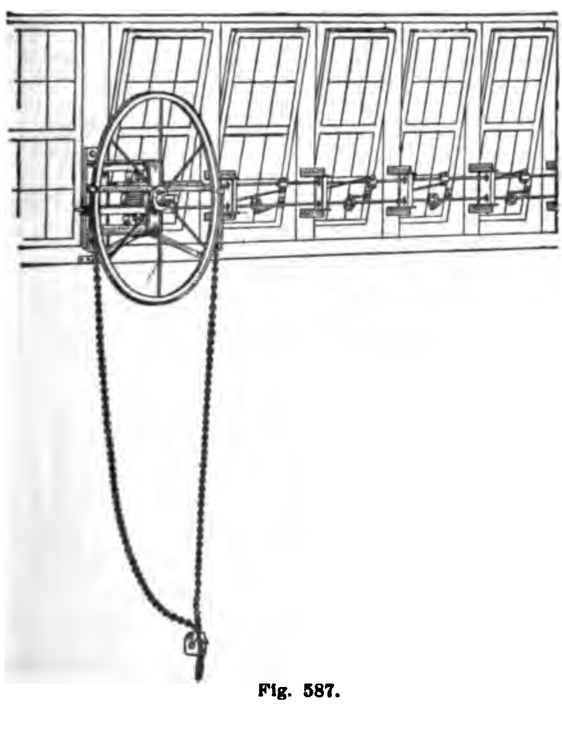


Fig. 587.

581 to 584 show metal-covered monitors with movable sash, Fig. 581 has wood sash, frames and casing, with alternate sash sliding horizontally past the fixed ones, while Fig. 582* is made without frames or casings, and has trunnioned sash. Fig. 583

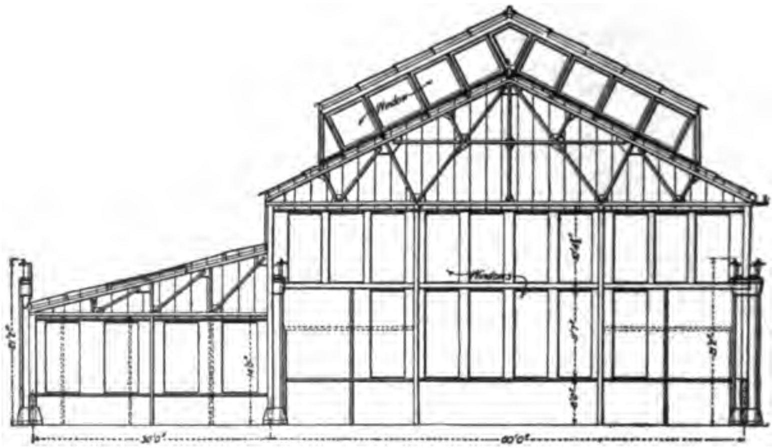


Fig. 585.

has wood frames and casing, with trunnioned sash. Fig. 584 shows the American Bridge Company's standard monitor framing for sash, either fixed or movable. Fig. 585 shows the cross monitors used on the new Keystone plant of the Jones and Laughlin Steel Company. The trusses are spaced 19 feet 7 inches apart and monitors with ribbed glass windows in the sides cover every third panel.

WINDOW OPENING MECHANISM.

Windows are opened by sliding them horizontally or vertically past each other, by hinging them at the edges, or by turning them horizontally on center trunnions. Those which slide past each other have only one-half the area available for ventilation, and are therefore not best suited for monitor use. Hinged windows swinging outward are most likely to be water-tight, but are harder to operate than balanced ones. Side wall windows hinged at the edges and swinging inward are not water-tight, and if swinging outward, are liable to be broken by the wind. The usual method of operating side wall windows is therefore to either slide them past each other or to balance them on trunnions, the latter method

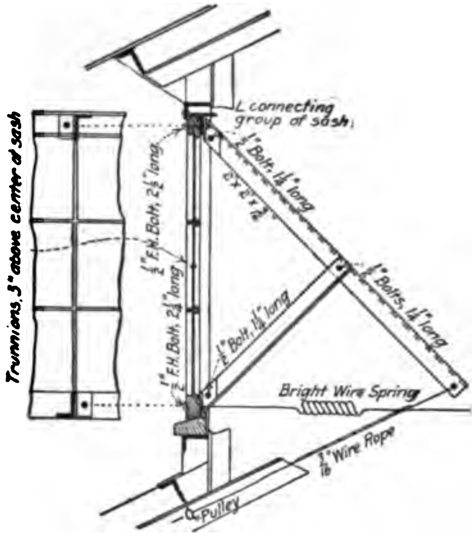


Fig. 586.

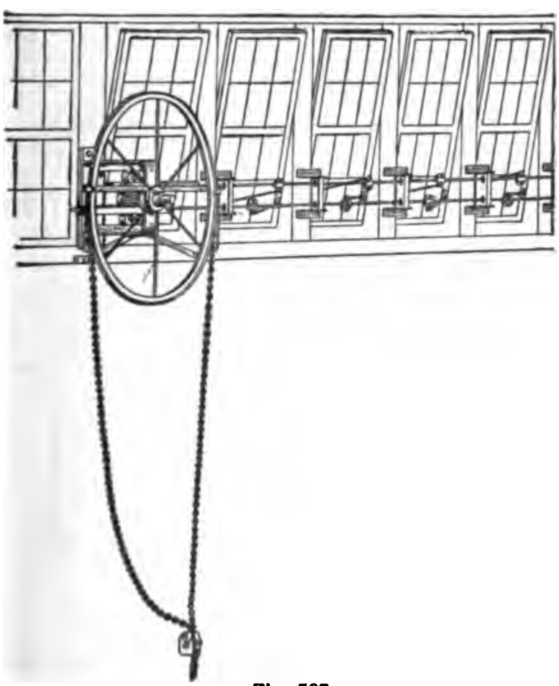


Fig. 587.

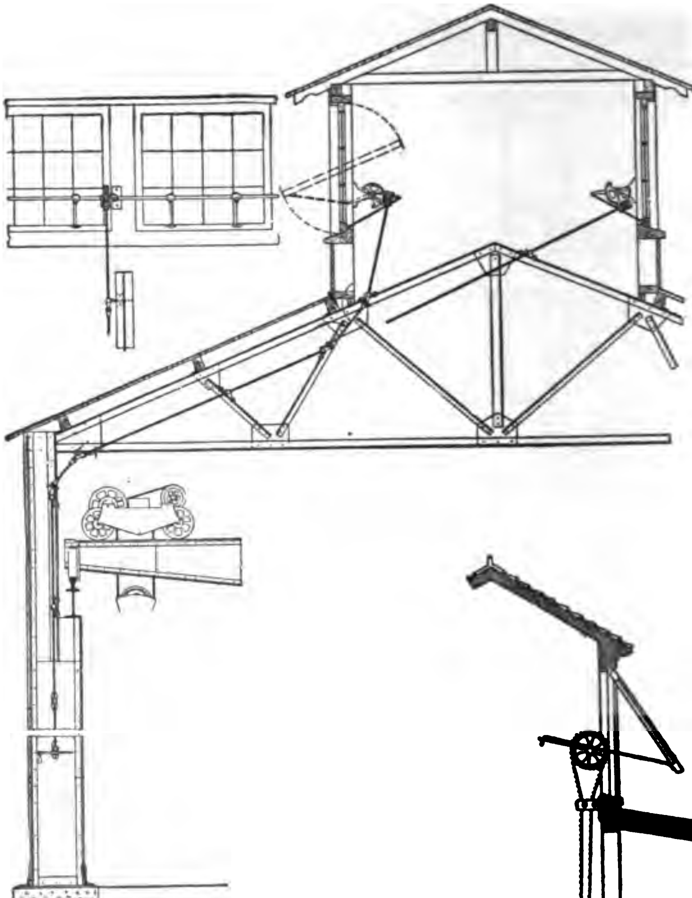


Fig. 588.

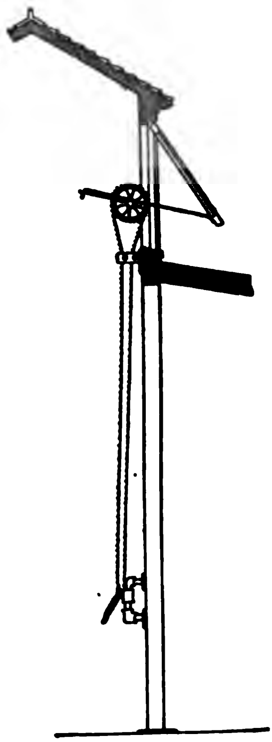


Fig. 589.

being preferred when large ventilation is desired. Windows which are suspended and slide vertically past each other should be arranged in pairs, one sash balancing the other, for the expense of window weights will then be saved.

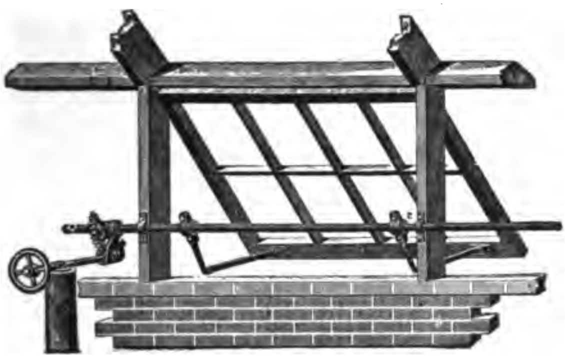


Fig. 590.

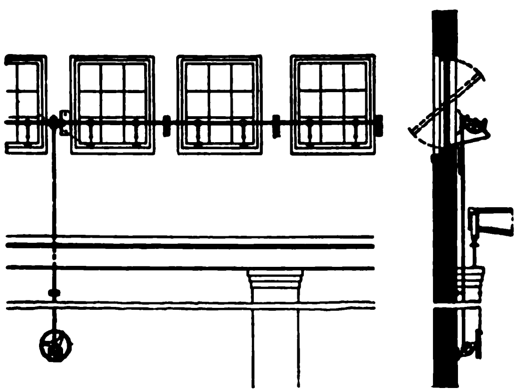


Fig. 591.

A very simple mechanism for operating monitor windows, which is similar to that in Fig. 525, is illustrated in Fig. 586. It should be used when the operating cord from the lever leads down under the roof to the side walls and thence to the floor. Its cost is small, for the levers can be made in a structural shop, but it has the disadvantage of permitting one cord and lever to open only the windows in one panel, though it is more effective when one cord and lever are used for two sash, one on each side of the monitor. When two or three sash on each side of the monitor are operated in sets by one lever, the several sash on each side must then be rigidly connected by a continuous angle bar bolted to the upper rails, and the lever must be placed near the center of the set, with springs fastened at the middle of the end sash to close the windows automatically. Two pulleys are needed, one below the ventilator window and another at the side wall below the roof.

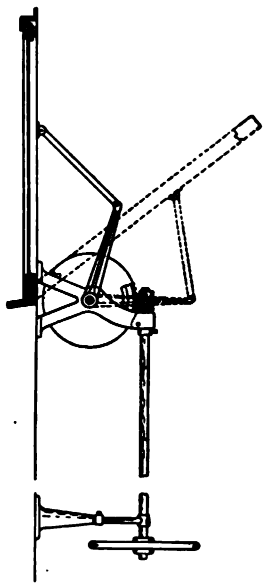


Fig. 592.

Other methods of opening monitor sash are shown in Figs. 587 to 590. Fig. 587 is the Lovell window operator, in which two lines of pipe supported on rollers are moved back and forward by a pinion between two racks, turned by a chain wheel. Fig. 599 is the usual worm and gear mechanism turning a continuous shaft, to which are fastened extension arms connected to the lower sash rails. Fig. 588 is the Lord and Burnham method of opening monitor windows, by means of shafts brought down on the side walls with universal couplings in order to avoid obstruct-

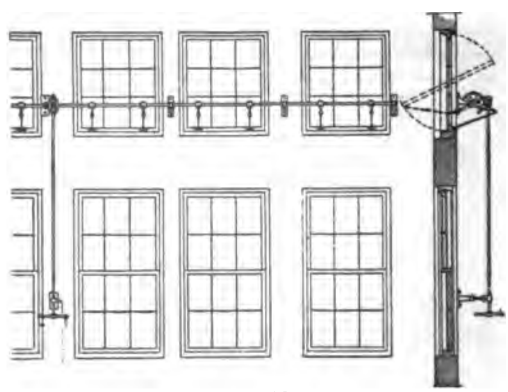


Fig. 593.

ing the traveling crane. When the rods connect to windows on the opposite side of the monitor, the operator can then observe the position of the windows that he is moving. Figs. 591 and 592 show other applications of the same mechanism for opening clear story windows with shafts and hand wheels brought directly down beneath the windows and fastened to columns or pilasters near the floor.

Figs. 593 and 594 illustrate similar apparatus for opening side wall windows both in single and in triple lines.

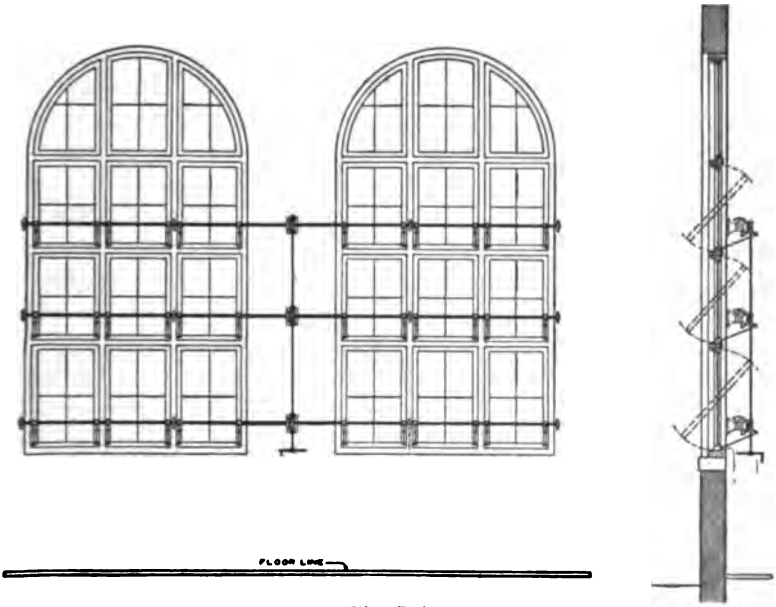


Fig. 594.

CHAPTER XXXIV.

DOORS.

The number and location of doors in a manufacturing building must be determined by the needs of travel, with a greater number for buildings in which many people are housed, and a smaller number where there are few employees. The doors for general entrance and exit should be separated, so crowding will not result from travel in two directions. It is a mistake to have too many doors and passageways through a shop, for each passage occupies valuable floor space. Doors for manufacturing buildings are made either of plain wood, wood covered with metal, corrugated iron, corrugated asbestos board, or light reinforced concrete. The best plain wood doors are made of white pine. Thin slabs of reinforced concrete are used in some forms of patent folding doors, examples of which are those for the Terminal Warehouse Company of Kansas City (Fig. 613), the weight of which for 8 × 8-foot openings is 1,600 pounds. Many forms of doors, particularly plain wooden ones, may have large glass panels in the upper halves, which not only serve to admit light, but permit a person on one side of the door to observe approaching objects on the other side.

The size of doors depends upon the size of material brought into the building and the products shipped out, and upon the need of admitting trucks or cars. Entrance doors for the largest box cars should be not less than 16 feet in height and 12 feet in width. Structural works and bridge shops need doors for shipping manufactured products large enough to permit flat cars loaded to their maximum height and width to pass through them. As large doors are usually located on the principal avenues of travel through the shop and need to be open only part of the time, it is often convenient to insert a small door in the large one for the use of pedestrians, as shown in Fig. 619, framing details of the smaller door being shown in Fig. 620. This arrangement is not entirely satisfactory, for the lower framing angle of the large door must not be cut for the smaller one, and pedestrians, in using the small door, must step over the framing of the larger one, which is always inconvenient and sometimes the cause of accident.

Doors may be classified generally into three kinds: (1) one-piece doors, either hinged, rolling on horizontal tracks, or counter-weighted to rise vertically; (2) doors which are made in two or more pieces and open by folding together; (3) coiling or rolling doors made of wood or sheet metal slats.

Exit doors, in factory buildings with a large number of employees, should open outward for safety in case of fire, as specified by the city building laws. Entrance doors, or those for only occasional use, are more convenient and less liable to injury when

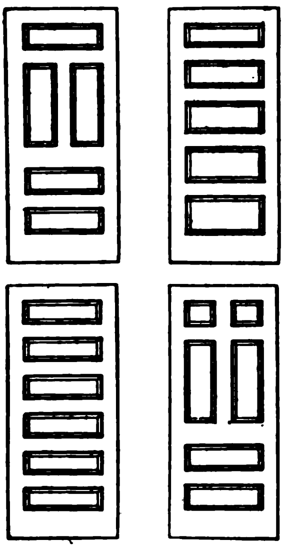


Fig. 595.

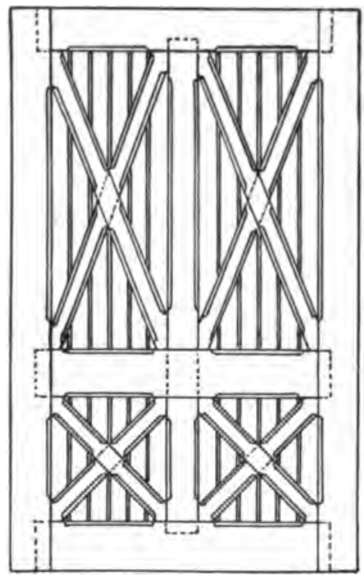


Fig. 596.

opening inward. Horizontal sliding or rolling doors on brick walls are more conveniently placed on the inside of the building, while similar doors on corrugated iron walls are better on the outside, for the corrugated iron doors then lie nearer to the plane of the wall sheathing, and in opening there is less liability of interfering with steel columns or other framing. The space over the door should be water-proofed with a metal hood, inserted under the wall sheathing and bent out to cover the door track (Fig. 604). Figs. 605 and 606 show alternate methods for suspending rolling doors on the inside of a building, in one case the door frame being made with wooden jambs and casing, and in the other, the jambs and head casing consisting of steel channels with webs turned toward the opening, as designed and used by the author on a forge shop in 1896.

Doors with height not exceeding 8 feet can be hinged at the sides for single doors up to 4 feet in width, and double doors up to 7 or 8 feet wide. Larger sizes up to 20 feet square must either be suspended to move vertically, roll horizontally, or coil above the doorway.

Wherever serious liability to fire exists, doors should be equipped with automatic closing apparatus, consisting of a fusible soft metal link in the counterweight chain which holds the door open. These links melt at a temperature of 160 degrees and the doors close by gravity. The pattern shop and storage building at the West Allis plant of the Allis-Chalmers Company is a good example of fireproof construction, in which automatic closing doors are used.

WOOD PANEL DOORS.

Ordinary panel doors (Fig. 595) are made in single leaves up to 3½ feet in width, and in double leaves to about 5 feet, and are made in three grades, known as A, B and C, the first being

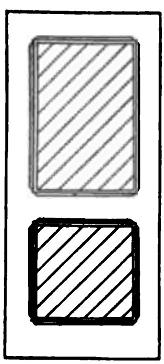


Fig. 597.

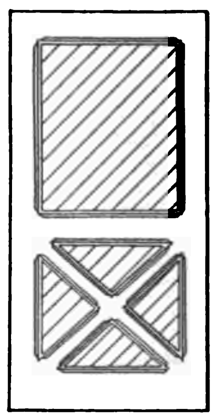


Fig. 598.

the best quality. Single doors suitable for factory use cost from $2 to $10 each, depending on the thickness, kind of wood, and finish. They are usually made in two thicknesses, 1⅜ and 1¾ inches, respectively, with a height of 2½ times their width. The width of side and top stiles is usually ⅙ the width of opening.

BATTEN DOORS.

Figs. 596, 597 and 598* show three views of wood batten doors, the smaller being suitable for 3 feet in width, while the second can be used for widths of 6 feet, and the last up to 14 feet. These doors are made with stile and rail halved or mortised together at the joints. The inner edges should have $\frac{3}{8}$-inch chambers as shown. Fig. 596 is drawn for a door 8 feet in width; wider doors should have two or more intermediate stiles, spaced 3 to 4 feet apart. The sheathing should either be screwed to the frame or fastened with large head wire nails, bent over and thoroughly clinched into the battens. Tables LX and LXI give the proper size of material and hardware for doors of different dimensions, from 5 × 8 feet to 14 × 20 feet.

TABLE LX.

PROPER SIZES OF MATERIAL FOR DOORS UP TO 14X20 FT.

Size of doors in ft.	*Stiles ins.*	*Top ins.* (Rails)	*Center ins.* (Rails)	*Bottom ins.* (Rails)	*Diagonals ins.*	*Sheath ins.*
5× 8 or less	4×1¼	4×1¼	4×1¼	6×1¼	4×1¼	4×⅞
6× 8 to 7× 8	7×1¼	7×1¼	6×1¼	8×1¼	4×1¼	4×⅞
7× 8 to 10×10	7×1½	7×1½	6×1½	8×1½	4×1½	4×⅞
10×10 to 14×14	8×2	9×2	8×2	10×2	5×2	4×⅞
14×14 to 14×20	9×2½	9×2½	8×2½	10×2½	5×2½	4×⅞

TABLE LXI.

DIMENSIONS OF HINGES AND APPURTENANCES FOR DOORS OF DIFFERENT SIZES. STANLEY WORKS HEAVY HINGES.

Size of doors in. ft.	*Plain. Strap ins.*	*Plain. T. ins.*	*Galv. Strap ins.*	*Galv. T ins.*	*Screws. Door ins.*	*Screws. Jamb ins.*	*Bolts ins.*
3× 6 or less	10	10	10	10	1¾	2	½
3× 6 to 3× 8	16	16	16	16	1¾	2	½
3× 8 to 4×10	24-in. strap hinge				½-in. lag screws		½
4×10 to 5×12	30-in. strap hinge				½-in. lag screws		½
Over 5×12	36-in. strap hinge				½-in. lag screws		½

TABLE LXII.

TOTAL WEIGHT OF METAL COVERED DOORS PER SQ. FT. IN LBS.

Size of iron.	*Weight 3 in. thick sheathing. Black Iron.*	*Weight 3 in. thick sheathing. Galv. Iron.*	*Weight 2 in. thick sheathing. Black Iron.*	*Weight 2 in. thick sheathing. Galv. Iron.*
No. 16	10.69	11.37	8.87	9.55
No. 18	9.41	10.09	7.59	8.27
No. 20	8.27	8.95	6.45	7.13
No. 22	7.71	8.39	5.89	6.57
No. 24	7.23	7.91	5.41	6.09
No. 26	6.91	7.59	5.09	5.77
No. 28	6.59	7.27	4.77	5.45
No. I C Tin	6.47	...	4.65	...
No. I X Tin	6.72	...	4.90	...

* H. G. Tyrrell, Engineering News, April 11, 1901.

Glass panels (Fig. 599) can often be used to advantage in large wooden doors, and diagonals in the upper half must then be omitted and sheathing placed at an angle of 45 degrees to the vertical, as in smaller doors. They may be covered inside and out with flat galvanized iron, if fire risk is excessive.

Doors which are made to slide either horizontally or vertically should lap 2 inches over the building frame at the top and side, and must therefore be 4 inches wider than the opening and 2 inches higher. Without hardware and opening apparatus or expense of placing, they cost from 25 to 30 cents per square foot.

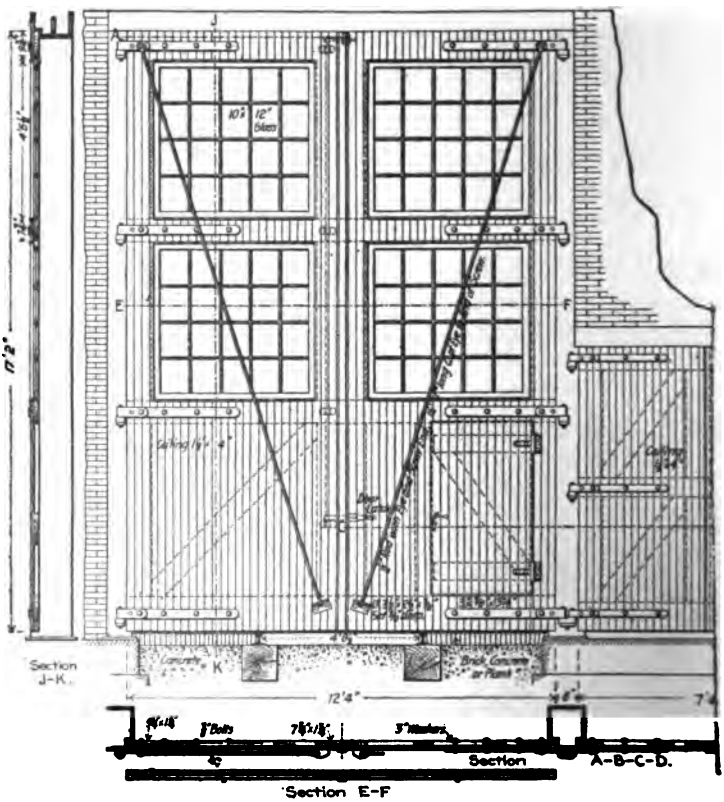


Fig. 599.

TIN CLAD DOORS.

These are made of two or three thicknesses of $\frac{7}{8}$-inch tongued and grooved wood sheathing (Fig. 600), and are covered on the sides and edges with sheet steel or tin. The weight per square foot for two and three ply doors with metal covering of different thicknesses is given in Table LXII. The sheathing must be well fastened together with wire nails driven tight and clinched. A door of this kind with inclined track, held open by weight and cord in which is inserted a fusible link, is shown in Fig. 601. In case of fire, the link melts and the door shuts automatically by rolling on the inclined track and is held closed by the iron socket

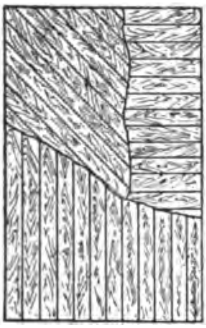


Fig. 600.

Fig. 601.

near the floor. Two-ply fire doors cost 18 cents per square foot for woodwork only, and 38 cents per square foot with tin covering, while three-ply doors cost 27 cents per square foot for the wood-

Fig. 602.

Fig. 603.

work and 47 cents complete with tin casing. Hardware costs about $3 per door and painting about $1 extra, and the labor of erection costs another $3.

CORRUGATED IRON DOORS.

Fig. 602 illustrates a pair of iron doors made of flat plate or corrugated iron; each door is suspended by three hinges to an

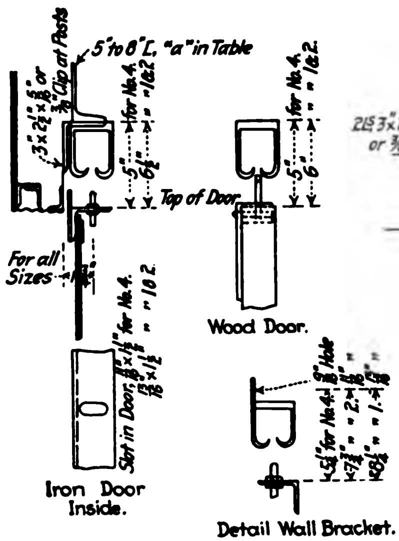


Fig. 605.

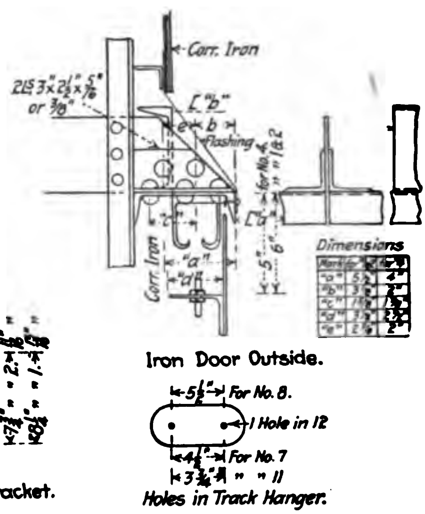


Fig. 604.

iron channel frame built into and bolted to the brickwork, as in Fig. 603. Corrugated iron doors are stronger for the same weight than those made of flat iron, though the construction details with

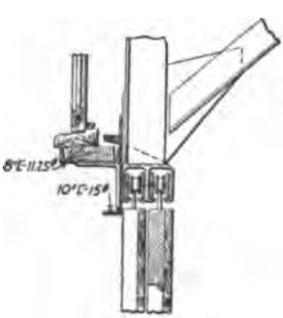


Fig. 606.

Fig. 607.

flat iron are simpler and more easily made than with corrugated iron. The frame for a corrugated iron door is shown in Fig. 575 Fig. 604 gives details for hanging a corrugated iron door on the outside of an iron building, while Fig. 605 shows corresponding details for hanging it inside, which details were designed and used by the writer in the building of a structural plant. Small corrugated iron doors present a better appearance when made 1¼-inch corrugations, but larger ones, requiring greater strength, should be 2½-inches wide. The cost of doors without hardware or erection is from 20 to 30 cents per square foot, depending on the size of the door and the presence or absence of a small door inside the large one (Fig. 619).

SWING SLIDING DOORS.

Swing doors used on freight sheds at Madison, Wisconsin, are shown in Fig. 607. They can be made of wood, corrugated iron or wood covered with tin, and are opened by being revolved into a horizontal position above the doorway, where they offer no obstruction to the moving of goods, but leave the entire side of the building open. They are suspended by chains from the bottom of the door, and are revolved into a horizontal position when lifted by the action of rods, the ends of which are fastened to the wall

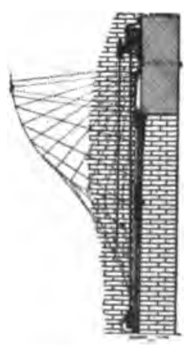


Fig. 608.

and to the doors, and are operated by chain and sprocket wheels. They can be equipped with fusible links, to allow them to close in case of fire.

HORIZONTAL FOLDING DOORS.

A form of door which is now quite popular is the horizontal folding door illustrated in Fig. 608. It is made of wood, steel, asbestos board, or reinforced concrete, is hinged to the wall at the upper edge, and made with upper and lower sections which are hinged together and the whole counterweighted. When raised

Fig. 609.

by a hand chain and wheel, the two sections fold together, the bottom part of the lower section rising vertically and the hinges or outer portions of the door describing a curve.

These doors are well suited for buildings such as freight sheds, warehouses, wharf buildings, etc., where all doors may be needed

Fig. 610.

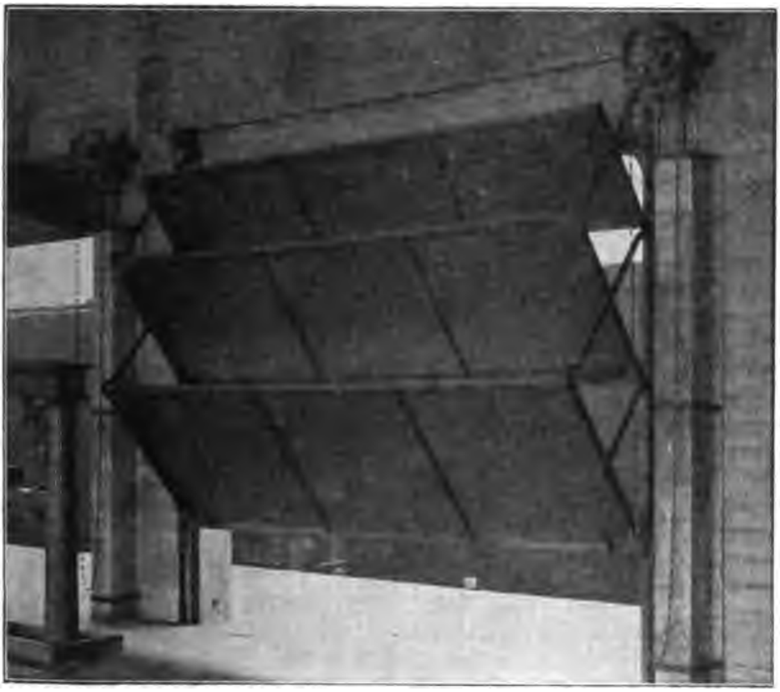


Fig. 611.

Fig. 612.

Fig. 613.

open at the same time, and the whole side available for handling and loading goods. The doors, when open, are folded up and out of the way, and are not occupying valuable storage space. When made of wood, they may be paneled, or can be covered with galvanized iron, with glass panels in the upper leaf. Doors, including operating mechanism, cost about 75 cents per square foot, and erection about 15 cents per square foot additional.

THE RITTER FOLDING DOOR.

This patent door is made in three or more sections (Figs. 612, 613 and 614), and is opened by being folded inside the building with successive leaves piled upon each other. It is balanced by counterweights hanging in boxes, to prevent goods from obstructing or interfering with the movement of the weights or the operation of the door. As the doors occupy a large proportion of the wall surface, the upper two or three leaves may be filled with glass panels. They are well suited for use on engine houses where additional light is needed on the low or inner side. They are operated by chain and sprocket wheel and the width between adjoining doors for wheel and counterweight does not exceed 18 inches. They can be equipped with automatic closing apparatus, which assures positive action in case of fire. At no period of their operation do they occupy valuable space, and when partly open the leaves act as louvres and admit air while they exclude rain.

Fig. 614.

SPECIAL PIER SHED DOOR.

A special folding door used on several Hudson River pier sheds is illustrated in Fig. 615. It was designed to suit the requirements of ocean steamships, receiving and delivering goods at the

Chelsea piers, and is made in two sections, so it can be entirely open or either section open with the other closed. The upper section is hinged at the top, and the lower one moves up and down

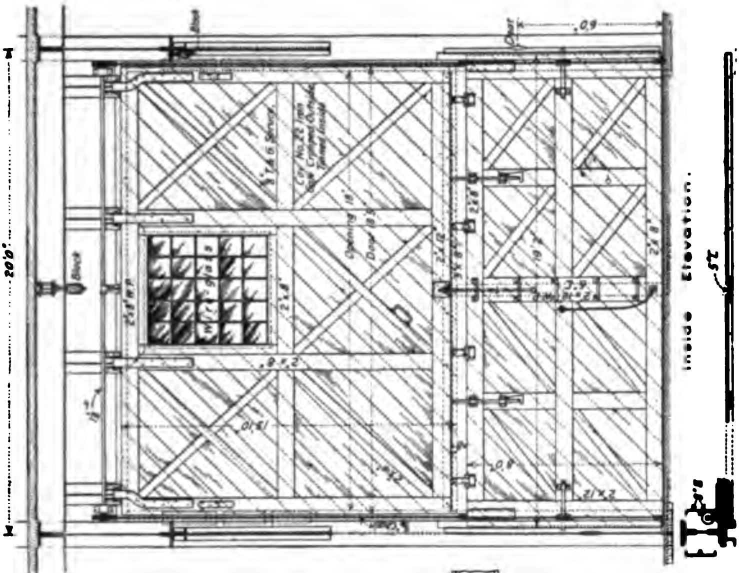
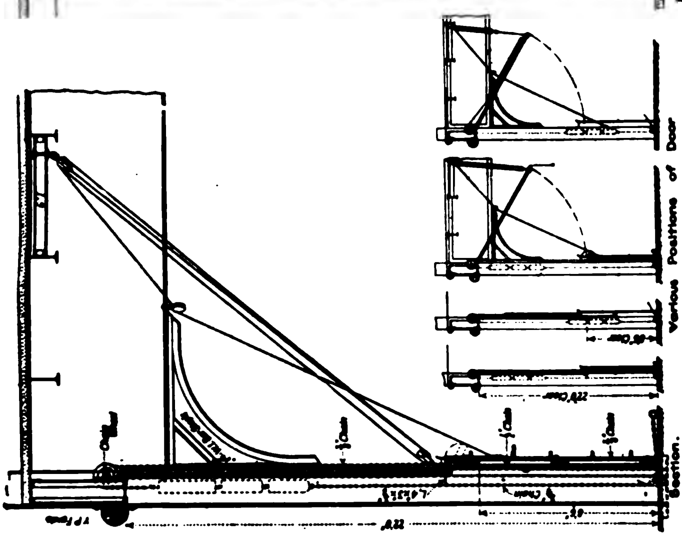


Fig. 615.



in grooves on the building columns and is balanced by chain and counterweight. The doors were originally operated by a chain and hand hoist, but as they are very large and heavy, opening by hand power was too slow, and plans were made for installing electric hoisting apparatus with line shafting to move several doors at one time. When all the doors are open, the entire side of the building is free for handling goods, a width of only 24 inches being required at the columns for guides, hoisting apparatus and counterweights. The jambs consist of two 8-inch channels on each side of a column, bolted together through their flanges and serving not only as jambs but also as counterweight

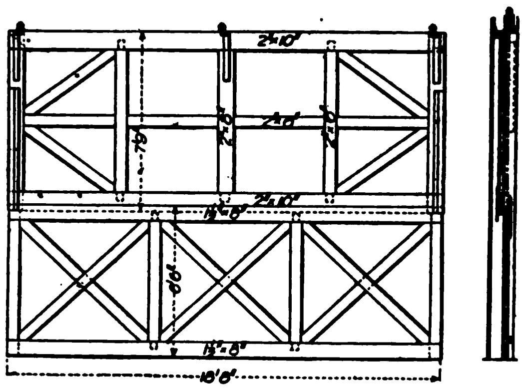


Fig. 616.

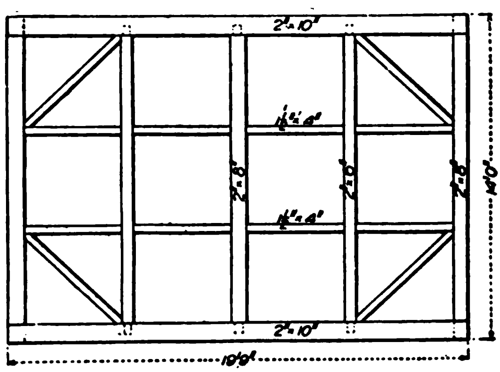


Fig. 617.

boxes. When the upper section of the door is open, and the lower section closed, ventilation is secured, while the contents of the building are protected from river thieves. The doors are covered on the outside with No. 22 gage galvanized crimped iron and on the inside with tin.

ROLLING DOORS.

Several views of rolling doors are illustrated in Figs. 618 to 622. They are made of metal or wooden slats, which are fastened

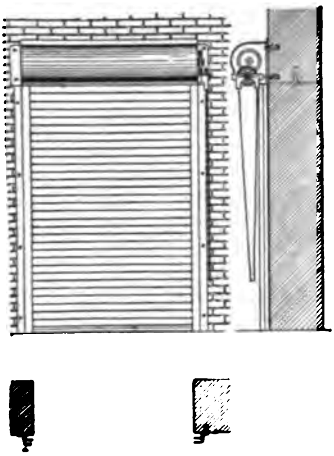


Fig. 618.

Fig. 619.

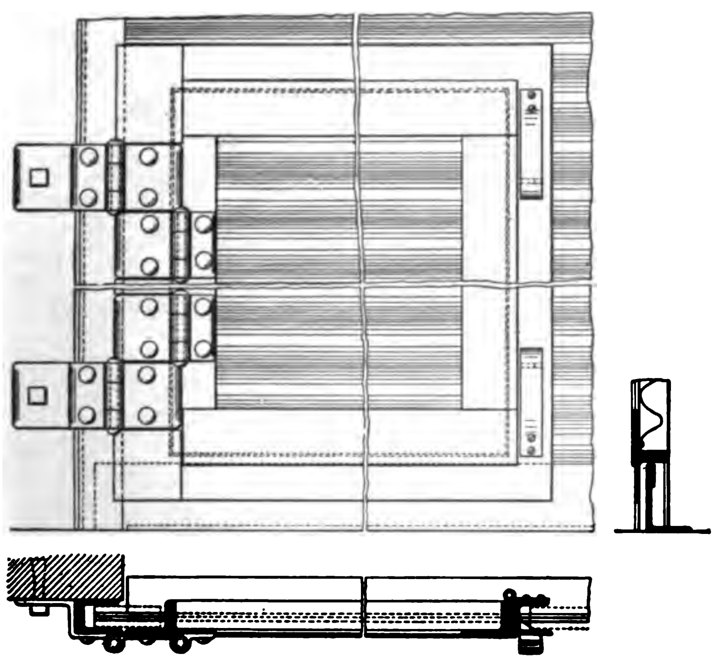


Fig. 620.

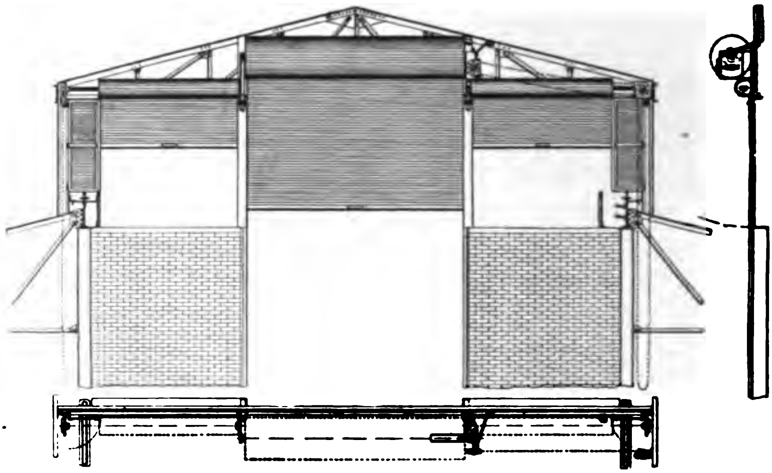


Fig. 621.

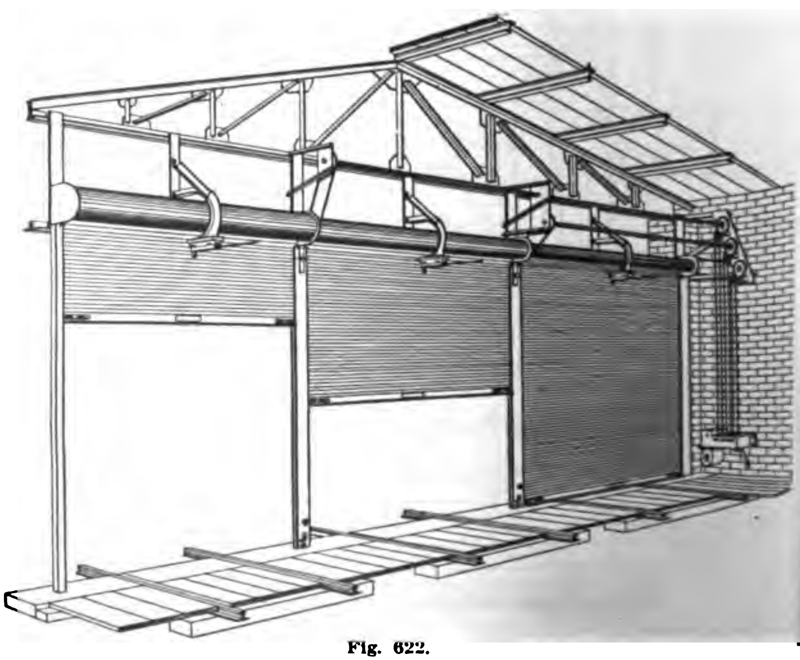


Fig. 622.

together, sliding between the side guides, and when open are rolled in coils overhead. They can be placed either inside or outside of the building, or in the doorway between the jambs, and small doors up to 5 or 6 feet in width can be opened by hand, while larger ones are equipped with chain hoists. They are counterbalanced by springs to facilitate their operation, and can have fusible links to close automatically should fire occur. Fig. 619 is a large steel rolling door for occasional use, with a smaller one fitted into it for pedestrians, which must be unbolted and removed when the large door is open. The market building with continuous arched side openings, illustrated in Fig. 32, was planned for continuous lines of rolling shutters. The end of a shop (Fig. 621) enclosed with folding steel shutters can be thrown open to permit the traveling crane to pass out of the building to the shipping yard. The two intermediate posts or shutter guides are hinged at their upper ends and, when the doors are opened, are revolved up into a horizontal position, leaving a clear space for the traveling crane. A similar arrangement for use on car sheds is illustrated in Fig. 622; the shutters are operated either singly or together by an electric motor, and, when raised, the guides are drawn up under the roof, leaving an unobstructed trolley wire connection.

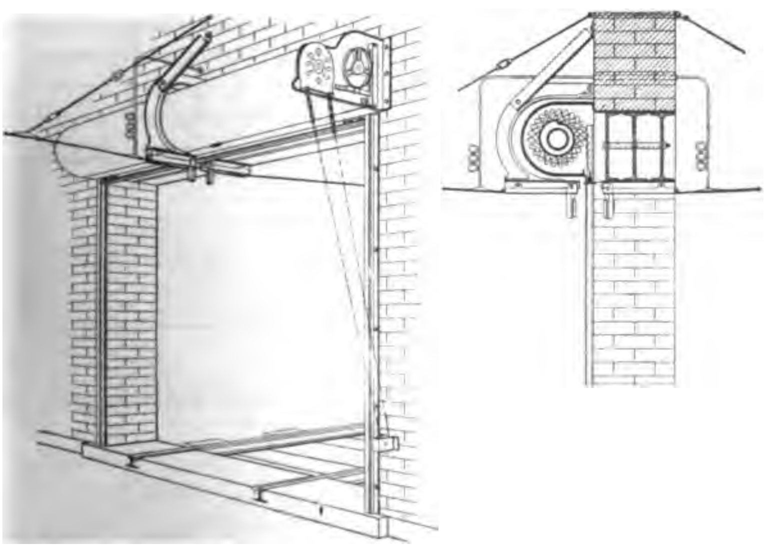


Fig. 623.

CHAPTER XXXV.

FACTORY FOOT BRIDGES.

Foot bridges connecting factories or other buildings are frequently a great saving of time and labor. It often occurs that the different buildings of a manufacturing establishment are located on both sides of a street. Goods must pass, in the course of manufacture, through several buildings before being completed, are brought into one building on the ground floor, and after passing up through the various floors of one building, cross over to an adjoining building and down through the various stories to the ground again. In this way the goods are elevated and lowered only once in each building, or twice in all. Without the connecting foot bridges for the upper stories of the adjoining buildings,

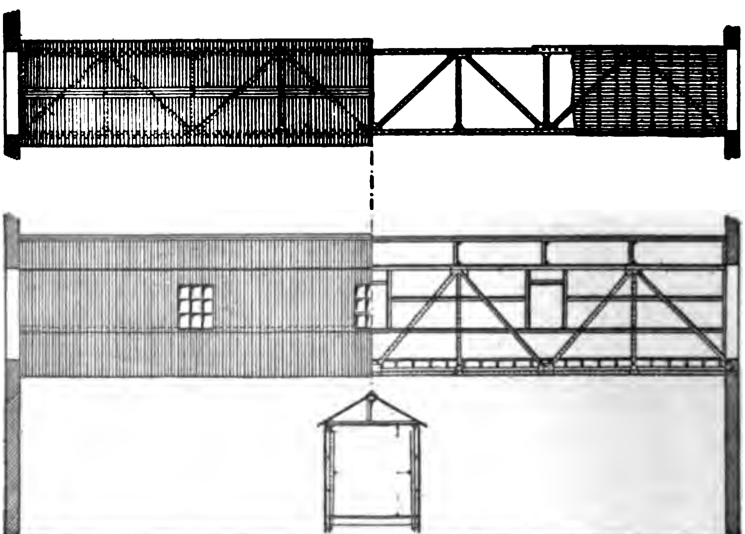


Fig. 624.

it would be necessary to elevate and lower the goods in each of the two buildings, making four transfers.

Elevated foot bridges are a great saving of time and energy. They make it possible to move goods back and forth from place to place with ease and without undue loss of time. Formerly, when these bridges were made of wood, the framing was heavy and expensive for spans long enough to cross ordinary streets, but now that they can be framed of steel with small bars and shapes that are not cumbersome, and at the same time safe, they are worthy of more general use. Buildings joined in this way with numerous bridges are almost as convenient as if the several buildings were all in one, and at the same time they possess the advantage of being lighted from side windows, which cannot be done where the entire floor space is under one roof. Well lighted buildings not only save the cost of artificial lighting but also facilitate production. Numerous small separate buildings, connected with passages on the lower floors, and with covered foot bridges in the upper stories, afford both better sunlight and ventilation.

The covered foot bridges shown in the accompanying illustrations (Figs. 624 to 626) are framed of steel and covered with corrugated iron. Where the location will permit, they may be lined on the inside with wood sheathing, and finished in the same general style as the buildings they connect. Those shown

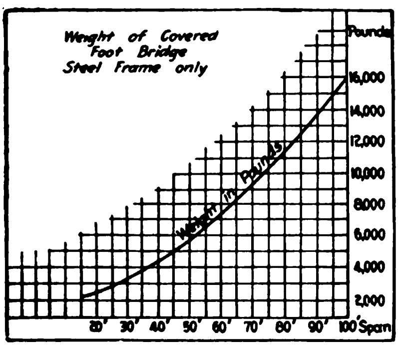


Fig. 625.

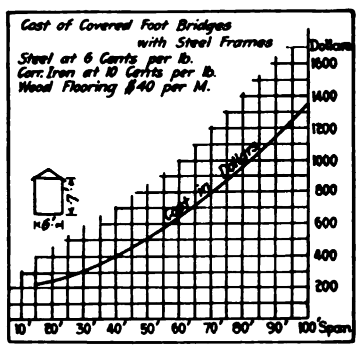


Fig. 626.

are intended more especially for ordinary factory use, and are covered on the outside with corrugated iron without any inside lining. They are framed entirely of steel, with wood for the flooring only.

The curves give the weight of steel (Fig. 625*) and the total cost (Fig. 626*) for spans varying from 15 to 100 feet, for a uniform width of 6 feet. In figuring the cost of these bridges, steel in place has been taken at 6 cents per pound, corrugated iron at 10 cents per square foot and wood flooring at $40 per thousand.

* H. G. Tyrrell, in Carpentry and Building. 1905.

These costs are only approximate, depending upon the local price of the several items included.

They are proportioned for a floor load of 60 to 80 pounds per square foot of floor area. Where it is necessary to transfer heavy weights from one building to another, these capacities may be increased proportionately. It is sometimes convenient to provide for the carriage of small trucks on a pair of rails, or a trolley to carry loads overhead.

It is well to have the bridges lighted, and this can best be done by alternating the windows on the two sides.

The illustrations show bridges from 20 to 80 feet in length, which will cover all ordinary cases.

CHAPTER XXXVI.

PAINT.

Paint consists of a liquid or vehicle, either fixed or volatile, thickened with a pigment or base, the materials being such that when spread in a thin layer and allowed to dry, an impervious film results, which excludes air and moisture. Other substances, called driers, are added to assist the paint in hardening, and stainers are used for coloring. There must be enough liquid or vehicle to hold the pigment in suspension and allow every particle of it to be surrounded, the theory being that the vehicle only is in contact with the painted surface.

Paint should spread smoothly and evenly, and the first coat should cover the surface. It should be adhesive, economical, tough, elastic, and should dry in a reasonable time. It should not be effected by heat or cold, rain, snow or wind, and must resist the action of smoke and fumes. It must contain no solvents and nothing that will corrode the iron, must be non-poisonous, durable and waterproof. It must not blister, crack or scale, and must retain its color and composition. It should have power to extract dampness or moisture from the metal, and not be easily ignited. First coats should dry harder and more quickly than later ones, but the difference in time of drying should not be great. Priming coats should preserve the metal and prevent oxidation, while later ones should protect the lower ones from the elements. Paint must work easily under the brush to form a film of even thickness, and must dry simultaneously and not more quickly on the surface than underneath. Paint is more durable in air than in water, but its merits depend chiefly upon the care with which it is applied.

VEHICLES.

The most important ingredient of paint is the liquid binder or vehicle. Water, linseed oil, turpentine, liquid japan driers. benzine with asphaltum and tar, have all been used, but about 90 per cent of metal paints are made with linseed oil. It is generally accepted as the best vehicle, except under ground or in permanently damp locations. Nut and poppy oil are sometimes used, but are not as satisfactory. Other patented vehicles are used, but their merits are due chiefly to the linseed oil which they contain. Investigation of the failure of paint in the New York subway proves that steel paints made of linseed oil and pigments are useless in the presence of vapor, abnormal humidity and condensation. Turpentine and benzine, when mixed with oil, reduce its durability, and should not be used in paint for iron and steel.

Linseed oil is made by compressing flaxseed and collecting the product. Pure oil is transparent, has a sweet taste and no smell, and, as it improves with age, should not be used until it is six months old or more. It requires four to six days to dry, and during the drying process passes from liquid to solid.

BOILED LINSEED OIL.

To hasten the drying of raw linseed oil, it was formerly heated alone, or with driers, such as red lead or litharge. The resulting oil then dried in twelve to twenty-four hours, or five to ten times faster than raw oil. With the recent process, more rapid drying is secured by the addition of manganese driers at the proper temperature, and, though boiling does not occur, the product is known as "boiled oil." The treated oil is darker in color than the original and weighs 7½ pounds per gallon. Drying results not from evaporation, but by the absorption of oxygen from the air, with an increased weight of 15 to 20 per cent, and the process of drying converts the oil into a tough and elastic film. Boiled oil produces a glossier finish than raw oil and is better suited for exterior work exposed to the weather. The oil should be both commercially and chemically pure. The addition of turpentine makes the oil thinner and permits it to dry faster, but the turpentine is only a thinner, and not a drier.

Linseed oil is often adulterated with 25 to 50 per cent of other substances, as fish oil, petroleum, cottonseed oil, etc., the presence of which can be detected by the smell. Buying in sealed cases directly from the makers removes the possibility of adulteration by middlemen and dealers.

Raw linseed oil costs (1911) 90 cents per gallon, and boiled oil 95 cents, and it is the most expensive part of oil paint. Paint made of pure linseed oil cannot be sold with profit to the makers and dealers for less than $1.00 to $1.10 per gallon, and the so-called oil paints selling at less than the cost of the oil, evidently cannot contain pure linseed oil.

PIGMENTS OR BASES.

While linseed oil is generally accepted as the best vehicle for paint, there is no agreement among engineers and paint makers in reference to pigments or bases. White and red lead, zinc white, iron oxide, carbon and graphite are all used with various degrees of success. The vehicle alone is not hard and thick enough to resist abrasion, and must be strengthened by some other substance called a base. The chief function of the base is, therefore, to increase the thickness of the paint, to make it stronger, and to protect the oil film from injury. Oil contracts in drying, causing minute surface pores to form, and these are filled or partly filled by the base. Bases should be neutral or inert, not subject to chemical change, and should be finely ground. The paint should contain only enough pigment so every particle of pigment will be surrounded and envěloped, so the vehicle only will be in contact with the surface. A layer of paint with pigment is three times thicker than a layer of oil.

WHITE LEAD.

White lead has been used for many centuries, and is referred to by ancient writers before the Christian era. It contains 70 per cent carbonate of lime and 30 per cent hydrate of lead, and is made either by dissolving sheet lead in acetic acid, or mixing lead oxide (litharge) with water and 1 per cent of acetate of lead. Pure white lead is a heavy powder, white when made, but turning gray when exposed. It is soluble in dilute nitric acid, but not in water. It has a substantial body, is dense and permanent, and is used as a base for all colors. It is not recommended as a base for metal because it needs too frequent renewals, but it is the best known pigment for wood preservation. As white lead and zinc are the pigments for all light colored paints, white lead is much used for top coats on steel framing when a light finished color is desired. For exterior surfaces exposed to the weather, it should be combined with zinc oxide. White lead does not combine chemically with linseed oil, but is a mechanical mixture. It is sold in powder, but more commonly as a paste, which is composed of dry white lead with 9 per cent by weight of linseed oil. Five gallons of linseed oil added to 100 pounds of paste makes 6½ gallons of paint, weighing 21.3 pounds per gallon; 15 pounds of lead paste and 6.3 pounds of oil makes one gallon of paint. Three coats of white lead paint are as effective as five coats of zinc oxide. White lead is often adulterated with sulphate of baryta, lead sulphate, gypsum, zinc oxide, and chalk. Sulphate of baryta, the most common adulterant, is a heavy, dense, white substance, and can be detected by its gritty feeling when rubbed in the hands.

ZINC OXIDE.

This is the base for all zinc paints. It takes longer to dry than white lead, and costs more, but makes a thicker paint film, and retains its color better. It is more permanent than lead, but liable to peel. One gallon of zinc paint contains 9.5 pounds of zinc oxide and 5.7 pounds of oil weighing 15.2 pounds.

RED LEAD.

Red oxide of lead minium is made by heating lead oxide (litharge) to 600 degrees F. It is poisonous, is effected by sulphur fumes, and is therefore unsuitable where smoke and fumes occur. Red lead dries very fast and must be mixed by hand every day as required, or it will harden in the keg or pail. As a result of rapid drying, it is less permanent than other paints, and it cracks, permitting water to enter. When used as a first coat, it should be covered with upper coats of other paints. Red lead is often adulterated with chalk, lime, oxide of iron, and brick dust. Twenty pounds of red lead pigment, mixed with 5½ pounds of linseed oil, makes a gallon of paint. One gallon of linseed oil weighing 7½ pounds should therefore contain from 28 to 33 pounds of pigment. Some manufacturers make ready mixed red lead paint which does not harden or settle in the case or pail, and which they recommend as excellent for priming coats on steel. Raw linseed oil must be used with red lead, for the paint itself is a rapid drier. A paint of combined red lead and lampblack is made by mixing 12 pounds of red lead and 10 ounces of lampblack with each gallon of raw linseed oil, the pigments being mixed dry before adding the oil, and no turpentine, benzine or driers should be used.

IRON OXIDE.

Iron oxide, either alone or with other materials, has been more used for metal paint than any other pigment, and the theory that it promotes corrosion is incorrect. There are three common oxides of iron: (1) the black magnetic oxide, not often used as a pigment; (2) anhydrated sesquioxide of iron, or red hematite, varying in color from dark brown to bright red; and (3) the hydrated sesquioxide of iron, or rust, known as brown hematite. The oxide of iron as used for pigments often contains from 40 to 70 per cent of clay, and it should contain very little hydrated sesquioxide of iron, a good proportion being 25 per cent anhydrated sesquioxide of iron and 75 per cent clay. The objections to iron oxide paints are that the pigments contain sulphur and phosphorus, unless the ore has been roasted to drive them out, and the sulphur is injurious to the iron. The paint is also a poor protective in the presence of salt water. All paints which contain more than 5 per cent of carbonate of lime are said to be attacked and disintegrated by sulphur fumes from burning coal, and the majority of iron oxide paints contain more than this amount. Iron oxide paint weighs 12 to 14 pounds per gallon.

DRIERS.

Driers are used to make the oil or vehicle dry more rapidly, the most common ones being zinc sulphate, acetate of lead, litharge, red lead, and binoxide of manganese. Only enough are needed to make the paint harden. Liquid driers are sold in such strength that 5 to 10 per cent added to raw oil paints makes them dry in twelve to twenty-four hours, but more than 10 per cent should not be used. None are needed when painters' boiled oil is used which contains driers, but when raw oil is used for thinning, they are necessary because, unaided, one or two weeks will be required to harden them. Hardening should not be forced by excessive driers or heat, for the paint film is then liable to crack. Structural steel paint should contain no liquid driers, neither turpentine, benzine nor thinner, for such additions to oil lessen its permanence.

SOLVENTS.

Spirits of turpentine is the principal solvent. It is a volatile oil distilled from the turpentine gum of pine trees, and is a limpid and colorless liquid with a strong odor. It weighs 7 pounds per gallon, and dries in twenty-four hours. When spirits of turpentine is used without oil, the resulting paint surface has a dull finish. Little or no turpentine should be used on surfaces exposed to weather. Benzine, which is a mineral oil weighing 6.1 pounds per gallon, is sometimes used instead of turpentine. The market price of turpentine is 40 cents per gallon.

STAINERS.

If the desired finish color is different from the base, other pigments must be added, which are called stainers. The principal ones are as follows:

Browns are mostly iron oxides, and include burnt umber and burnt sienna, from Umbria and Sienna, in Italy, and Spanish brown.

Reds include Indian red, which is ground hematite ore; Venetian red, made by heating ochres; vermilion or sulphide of mercury, Chinese red, etc.

Blacks are mostly carbons in some form, and include lampblack, ivory black and bone black, which are soots from burning these substances.

Blues are Prussian blue or prussiate of potash; cobalt blue, made by roasting cobalt ore; blue ochre, blue lead, and indigo blue, made from plants.

Yellows include chrome yellow, yellow ochre or clay colored with iron, and raw sienna, which is clay colored with manganese.

Greens are made by mixing yellow and blue, the most permanent ones being made from copper and arsenic.

JAPANS.

Japan, when properly applied, is the best known protective for metal surfaces. Black japan is made of asphalt, linseed oil and copal rosin, usually Kauri thinned with turpentine, and is the familiar coating on door locks and hinges with a smooth black polish. The metal is dipped in japan, and then baked for several hours in an oven. The more linseed oil and the less drier that it contains, the more durable will the coating be, but to make the coating harder when baked, extra drier is often added. It was formerly used for small articles only, but investigations now under way show that it may soon be applied to large surfaces. Japan can only be applied in the shop, but when this coat is effective, later ones are not necessary. The duration of steel structures with ordinary paint protection does not usually exceed twenty-five to fifty years, and when considering that the same structures would last indefinitely if protected with such a coating as japan, the extra expense would be ultimate economy. Up to the present time, however, the process of application is not sufficiently developed to make its use practical for structural steel work.

VARNISHES.

Varnish is made by dissolving gum or resin in oil, turpentine or alcohol, the gum acting like the base in paint. When the vehicle dries or evaporates, it leaves a smooth, solid and transparent film of resin. Linseed oil should be used as the vehicle for outdoor or exposed work, but turpentine at a less cost is sometimes used for inside surfaces. The quality of the varnish is determined by the amount of gloss, and is best with linseed oil. The interiors of power houses which contain expensive machinery are frequently varnished and finished as a show place for visitors.

Steel floor channels under the wood block pavement on the Williamsburg bridge at New York, after being washed and pickled in dilute acid, were dipped in hot varnish enamel and then put in ovens and baked at a temperature of 400 degrees F. For two or three weeks after being placed, six or eight hundred workmen with wheelbarrows walked daily over the enameled metal without injuring the surface.

SPECIAL STEEL PAINTS.

There are many excellent prepared paints for steel, but also many worthless makes, and as some paint makers recommend their products for all conditions, care should be taken in selecting them. It is better to accept the judgment of an engineer or architect, or some other competent and disinterested person.

Steel paints are made of linseed oil, asphalt, tar and varnish, the oil paints having pigments of lead, zinc, iron oxides, carbon, lampblack or graphite. For ordinary structural work, oil paints are the best. Sheet metal should have a priming coat of red lead, covered with later coats of iron oxide or carbon, preparations of tar being avoided. Corrugated iron or other metal sheathing should receive only one shop coat, for if painted two coats the sheets will stick together, and the paint peel off. Steel in foundations or other damp places exposed continually to moisture or condensation should be coated with asphalt paint or varnish.

PRINCE'S METALLIC PAINT.

This is made from blue magnetic iron ore, mined in Carbon County, Pennsylvania, and contains 50 per cent of iron peroxide, 25 per cent of limestone and 25 per cent of sulphur. The ore is broken, roasted and ground to a fine powder, in which form it is sold at $20 to $40 per ton. The roasting reduces its weight by one-third. One gallon of linseed oil mixed with 7½ pounds of pigment, after standing twelve hours, measures 1.2 gallons of paint. It is made in one color only—a reddish brown. The composition and cost of the mixed paint per gallon is as follows:

6¼ lbs. mineral, at 1½ cents per lb.	$ .09½
6¼ lbs. raw oil at 90 cents per gal.	.56
Labor in applying	1.00
Total cost per gal. applied	$1.66½

One gallon covers 700 square feet, and costs 22 cents per square for one coat applied.

ASPHALT PAINT.

Asphalt is a substance midway between coal and oil, and is composed chiefly of carbon. It dissolves in linseed oil, is very adhesive to wood or metal, and has a good covering capacity. Asphalt paint is made by dissolving the asphalt in paraffin, petroleum naphtha, or benzine, and after applying the mixture, the volatile oils evaporate, leaving a coating of asphalt. It is applied hot at a temperature of 300 to 400 degrees F., preferably on a hot surface, and costs 80 cents to $1 per gallon. Steel waterproof floors are frequently covered with asphalt one inch thick.

DURABLE METAL COATING.

This is a black asphalt varnish, made by Edward Smith and Company, and composed of asphaltum, linseed oil, turpentine, and Kauri gum, without pigments. It is sold in liquid form ready for use, and requires neither thickening nor stirring, though in cold weather it is more easily applied when heated. It is said to contain neither tar, naphtha nor benzine, and dries slowly by oxidation, requiring not less than thirty-six hours for the first coat and a week for complete hardening. One gallon will cover 400 square feet, and it costs $1.50 to $1.70 per gallon, by the barrel.

P. & B. PAINT.

This is a black paint, composed of asphaltum dissolved in bisulphide of carbon, made by The Standard Paint Company. It has a volatile vehicle which dries immediately when applied, leaving a coating somewhat similar to japan. It is sold in liquid form ready for use, contains no tar or oil, and when applied dries quickly. It is made in three thicknesses; a gallon of the first covers 250 square feet and costs $1.20, while one gallon of the thickest covers only 100 square feet, and costs $1 per gallon. This paint is elastic and can be used on brick or concrete as well as steel.

COAL TAR PAINT.

A very cheap paint, which may sometimes be satisfactory, is made by mixing eight parts, by volume, of coal tar with one to two parts of Portland cement and one to one and one-half parts of kerosene oil. The kerosene oil and cement are first mixed to a thin cream and then poured into the tar. As tar has but little value, and is often burned for fuel, the resulting paint costs not over 10 to 15 cents per gallon. It adheres well to black and to galvanized surfaces, and when the kerosene dries it leaves a coating of cement and tar. This paint is used for coating steel work at the United States Navy Yards.

Similar mixtures are made by using benzine instead of kerosene, and chalk or lime instead of cement. It is a good wood preservative, but is inflammable and is a common and inferior substitute for asphalt paint.

CARBONIZING COATING.

This is an excellent coating for steel, composed of carbon and oxide of lead bases, and linseed oil without volatile oils or driers. It has great adhesion to steel, is not affected by sulphur fumes, and gives protection for 10 to 15 years without renewal. One gallon of paint is required for every 5 or 6 tons of steel work. It costs $1.50 to $1.70 per gallon and spreads over 1,500 square feet, or twice the usual spreading area of paint.

GRAPHITE PAINT.

Natural graphite is found in Canada, Mexico, Ceylon, and in several localities in the United States, the Canadian graphite being considered the best. It occurs in two forms, granular and foliated, the former being best suited for paint making. It is the lightest pigment known, and is permanent and flexible. The kind found in northern Michigan, known as Superior graphite, contains from 10 to 90 per cent of foreign matter, mostly silicates and iron oxides. Another pigment, known as "electric graphite," is made by heating anthracite coal in an electric furnace, the product being 90 per cent carbon.

Graphite paint is made by mixing the pigment with boiled linseed oil, to which is added a small amount of manganese, litharge or red lead. Two pounds of dry graphite with one gallon of oil make a gallon of paint weighing 9 pounds. It dries slowly as compared with other paints, for one gallon of linseed oil will take 20 pounds of red lead, but not more than 2 pounds of graphite.

CEMENT COATING.

Cement coating as a substitute for paint is made by mixing materials in the following proportion by weight. Pure red lead 12 parts, Portland cement 32 parts, linseed oil 4 parts, and drier 2 parts. This is mixed to a paste, like putty, and applied to the clean metal surface with a trowel, being laid $\frac{1}{16}$ to $\frac{1}{4}$ inch thick. The process in detail is as follows: First clean the metal surface thoroughly; then apply a coat of red lead paint and allow it to set; after this apply a heavy coat of japan drier and spread the cement paste over the drier while it is green. The japan drier must not be allowed to dry before the paste is applied. After the cement has hardened, it should be given a final coat of red lead paint. The coating described takes three times as long to apply as ordinary paint, and costs, including cleaning material and labor, 8 cents per square foot, but it protects metal exposed to sulphur and fumes, particularly the fumes and blast from locomotive stacks, and lasts four times longer than ordinary paint. If an engine stack is within 2 or 3 feet of the coated metal, the blast may be so severe as to require a protection of sheathing boards to prevent the cement from breaking. Cement mortar without oil or lead lacks elasticity and is easily cracked or broken.

COMPARATIVE MERITS OF STEEL PAINTS.

Experiments made when painting steel work of the elevated railway at Harlem, New York, with seventeen different kinds of paint, showed red lead, iron oxides, carbon and graphite to be about equal, with slight preference for the last two. Thick coats are preferable to thin ones, and large spread capacity is therefore no advantage, for any kind of paint may be made to spread by adding thinners. Red lead is an excellent preservative, and is suitable for priming coats, but when exposed to gas or sulphur must be covered with other paint as an external protection. Lead and iron oxides combine chemically with linseed oil, while carbon and graphite do not combine, but simply mix. Silica protects as well as any other pigment, but when used alone, is hard to spread and drags under the brush; but graphite mixed with it acts as a lubricant. Carbon and asphalt can be ground very fine, and are neutral.

PAINT FOR WOODWORK.

The woodwork on the exterior of shop buildings should be preserved by painting, and interior woodwork painted, oiled or varnished; very little turpentine should be used on exterior surfaces. The first or priming coat may be clear oil, or thin paint made by adding an equal volume of raw linseed oil to the regular mixture. A gallon of paint will cover only half as much area on the first coat as on later ones, because the bare wood surface absorbs the oil. The first or priming coat should be colored, and if the final one is white, each succeeding coat should be lighter than the previous one. Turpentine may be used in intermediate coats, but not in the first nor the final one.

A cheap oil finish or varnish is made from common rosin, linseed oil and benzine, the surface being rubbed or sandpapered between successive coats. Shop interiors are better lighted when they are painted a dark shade to a height of only a few feet above the floor, and the remaining surfaces white or a light color.

PAINT FOR BRICK OR CEMENT WALLS.

Brick and concrete absorb moisture and are therefore improved by waterproofing, and the flat color effect of concrete walls is relieved by painting. An oil paint suitable for walls is made by mixing one part each of white sand and quicklime with two parts of wood ashes, the whole being passed through a fine screen. To this mixture as a base, enough raw linseed oil may be added to make a thin paint which can be applied with a brush. If color is desired, it is added to the oil before mixing with the base.

Another oil paint for walls is made by mixing 100 pounds of clean sand, 100 pounds of white lead, 20 quarts of raw linseed oil, 4 pounds of raw umber, 1 pound of drier and 1 pint of turpentine. When mixed to proper consistency, it can be applied with a large brush.

An oil wall paint known as Bay State Brick and Cement Coating has a cement base mixed with volatile oil, which evaporates. It contains no lead, glue or water, and is made in white or colors. It can be applied to a damp surface, will not absorb water, dries with a dull finish, and may be scrubbed to remove dirt. It is made only in liquid form, ready for use, and never in paste.

COLD WATER PAINT.

Cold water paints cost much less than oil paint, and for some purposes are quite as effective. They are sold in the form of powder, costing 6 to 10 cents per pound, and after mixing are applied with a kalsomine brush. Five pounds of powder make one gallon of cold water paint and cover from 300 to 400 square feet of first coat on smooth boards, and 150 to 200 square feet on rough boards, brick or concrete. Two good makes are Magnite, made by J. A. and W. Bird and Company, Boston, and Asbestine, made by Johns-Manville Company.

A good cold water paint is made by mixing one bushel of lime, two bushels of Portland cement, half a bushel of white sand, and a barrel of water, and adding 6 pounds of sulphate of zinc previously dissolved in water. It must be well mixed to the consistency of paint, and applied with a whitewash brush. Coloring may be added if desired.

WHITEWASH.

Whitewash is pure white lime mixed with water and it adheres better when applied hot. It is easily washed off by rain and needs frequent renewals. The wash may be hardened to prevent cracking by adding to each bushel of lime 1 pound of salt and 2 pounds of zinc sulphate. It may be tinted by adding to each bushel of lime, 4 to 6 pounds of ochre for cream color, 6 to 8 pounds of raw umber and 3 to 4 pounds of lamp black for buff or stone color, and 6 to 8 pounds of umber, 2 pounds of Indian red and 2 pounds of lamp black for fawn color.

KALSOMINE.

This wash is made of Paris white, glue and water, colored as desired, and applied with a brush. One gallon covers 150 square feet, and one coat of sizing and one of kalsomine costs 60 to 80 cents per square.

CHAPTER XXXVII.

PAINTING.

Painting is for the purpose of preserving structural materials and beautifying or decorating them. Shop interiors are painted white to increase the inside lighting and give them a cleaner appearance.

PRESERVATION OF MATERIALS.

The amount of money being invested in modern shops is so large that the preservation of the wood, concrete and steel of which they are built is an important matter. Steel and iron, which are replacing wood for framing and covering, are susceptible to rust, and aluminum, copper and other non-rusting metals are too expensive for structural purposes. Thin metal sheathing for walls and roofs must be painted and protected, or it will be rusted through in two or three years. Many steel structures, especially some near the sea coast, built less than twenty years ago, are already so damaged by rust and corrosion that they must either be cleaned by sand blast and repainted, or replaced by new ones, before another decade. Steel work exposed to salt water spray, or in damp places under ground, is especially in danger, and should be well protected; wherever possible, the covering or fireproofing should be removable in places for inspection. Some of the greatest bridges are already so badly injured with rust that before many years parts of them near the water must either be strengthened or replaced with new material, notwithstanding the constant service of painters employed upon them. The paint used on the steel framing in the New York subway is now peeling off to such an extent as to prove it useless in damp places underground.

Up to the present time, the preservation of materials, especially of iron and steel, has not received the attention that it deserves. There is little agreement or uniformity of specifications, the designer either using his favorite paint or permitting the contractor to apply whatever he may choose. Structural steel is often exposed to the weather for a year or more without oil or paint, and is then used for building purposes without cleaning, the rust being covered with a coat of paint. Framing made of such material must be of short duration.

Rust is the result of oxygen from water or moisture uniting with iron to form hydrated oxide of iron. It starts beneath the paint, and as rust occupies twice the volume of the iron which it contains, it loosens the paint and the latter falls off, leaving the metal exposed. Rust absorbs 24 per cent of its own weight of moisture, but if oxygen, carbonic acid gas and moisture are kept away, iron cannot rust.

METHODS OF PRESERVATION.

Metal is preserved by covering it with an impervious film of paint or enamel, by galvanizing or coating with zinc or lead, and by imbedding it in cement concrete, or coating the surface with cement mortar. Methods of producing a non-oxidizable surface on iron or steel, by electric treatment, are described in Kent's Mechanical Engineer's Pocket Book, but are not in general use.

CLEANING.

It is very important that metal surfaces be cleaned before paint is applied. The benefit from painting depends more on having a clean surface than on the quality of the paint or on any other consideration. Poor paint on a clean surface is better than the best and most expensive paint on a rusty surface. Applied on a wet surface over rust, scale and grease, no paint, however good, will preserve the metal, for it will peel off and the expense is wasted.

Mill scale is the first coating that must be removed. It does not loosen immediately after rolling, but must be dislodged with scraper or stiff wire brush (cost, $4 per dozen). Grease and dirt can be washed off, or removed by pickling in dilute acid, and rust, with a steel scraper and sand blast. Galvanized sheet iron and tin smeared with grease and chemicals used in coating them can be cleaned by washing with soap and water or with benzine. After washing, the plate must be wiped with cotton or waste to remove the grease, for should it remain, it will spread in a thinner layer, and dry as the benzine evaporates. Deep-seated rust spots can be removed with a painter's gasoline-burning torch (Fig. 627), which converts the rust into peroxide of iron, and it can then be brushed off. Old paint and varnish can be scraped or burnt from the surface.

PICKLING.

A method of cleaning steel work prior to painting is as follows: First wash the metal in 10 per cent solution of caustic alkali or soda to remove grease, and then dip in boiling water to remove the alkali, after which the metal is put in a hot 10 to 20 per cent solution of sulphuric acid, allowing it to remain until all rust is gone, usually 5 to 15 minutes; weaker acid takes a longer time to act. The metal is then taken out of the acid and washed with hose and water jet under a pressure of 100 pounds to the square inch. The acid must be completely removed or more harm than good is done by the operation. To insure neutralization of any remaining acid, after the metal is washed with clean water, it should be placed in a hot 10 per cent solution of carbonate of lime or soda and again washed, after which it is put in a drying oven. The whole process of pickling costs from 50 cents to $1 per ton of steel work, depending on the facilities for doing the work and the cost of transferring the pieces from the riveting to the pickling shop and back again.

SAND BLAST CLEANING.

This is the most effective way of cleaning steel that is coated with scale, rust or oil paint, the only objection to it being the cost

Fig. 627.

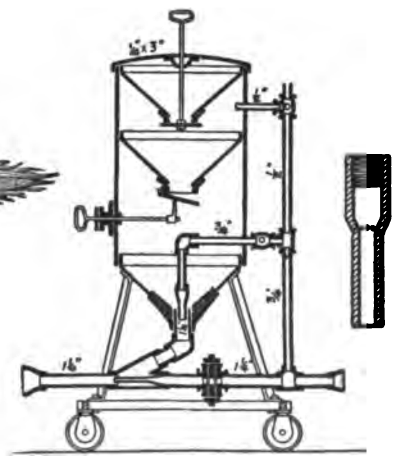


Fig. 628.

and the extra time required. The equipment consists of one or more air compressors, capable of delivering 250 cubic feet per minute for each nozzle, driven with electric motor or engine, and a sand and air tank, with 2½-inch rubber hose and metal nozzles (Fig. 628). Portable air compressors are preferable for field cleaning. The tank is kept under pressure of 20 to 25 pounds per square inch, producing a velocity of sand and air at the nozzle of 300 feet per second. Nozzles of ½ inch diameter are used, which are soon worn to ¾ inch or more. The sand should be coarse and dry, and can be used three or four times before being discarded. One cubic foot of sand is required for every 3 square feet of surface cleaned, and 10 cubic feet of sand per ton of steel. The nozzles are held 6 or 8 inches from the surface and the operators have helmets with glass fronts, to protect their eyes and lungs. The sand blast leaves the surface clean and dry, but as a thin film of rust forms immediately, the cleaned surface must be painted within two or three hours. The practice is to spend the first six hours of each day in cleaning, and the remaining hours in repainting this surface.

One man can clean 80 square feet of old painted work per hour at a cost for labor and material of 3 cents per square foot. Cleaning new steel at the shop, coated only with light rust and mill scale, costs ½ cent per square foot, or $1 to $2 per ton.

Sand blast cleaning of 50,000 square feet of steel framing for the elevated railroad at Harlem, New York, cost, under experimental conditions, 10 to 15 cents per square foot, but could be repeated for half that amount. The steel had been painted with four coats, and 12 tons of old paint, rust and scale was removed at a cost of $10,000, not including repainting. The cost of sand blast cleaning the steel coal pockets at the Key West Naval Station, including labor, material and machine painting with tar and cement, was 4.4 cents per square foot.

MAKING AND APPLYING PAINT.

Paint is sold in cans or barrels, mixed and ready for use, or as a paste in 25, 50 and 100 pound kegs, which needs thinning and stirring, and pigments are sold in powdered form. Paste is thinned by adding, to every 10 pounds, three or four pints of oil. The best mixing is done in a machine, but red lead, because of its rapid drying, must be mixed by hand as required for use.

The proportion of ingredients depends on the surface to which the paint will be applied, whether wood, concrete or metal, and whether rough or smooth, a porous surface needing more oil than an impervious one. Turpentine is sometimes added to paint for exterior surfaces exposed to the sun, to prevent it from blistering, and also over old work to make the new paint adhere.

The colors on manufacturing buildings are selected more for utility than for decorative effects, though in some cases the latter are desirable. The interior of large pumping stations or power houses containing valuable machinery is frequently finished to harmonize with the excellence of the machines. Such walls are often lined with enameled brick, or painted a light color and enameled. Inside lighting is increased from 25 to 50 per cent by light-colored interior walls and roofs. The best practice is as noted under "Painting for Woodwork." Light colors are made with bases of zinc or lead, and when such a finish is desired on steel, the first and second coats should be dark preservative paints. It is convenient for inspection to specify that successive coats shall be of slightly different colors, for it is then easier to see what parts have been painted and there is less chance of missing parts of any coat. As the best preservative paints are black, colors are secured at a slight sacrifice of permanence.

Paint is applied either by hand brushes, by compressed air machines, or by dipping. Dipping is suitable only for shop coats and is used chiefly for bolts and other small parts, though some shops use emersion for large riveted sections, leaving the metal in hot paint for about 15 minutes, at a temperature of 200 degrees F. All things considered, hand painting with brushes is the most satisfactory.

AIR BLAST PAINTING.

A compressed air painting machine consists of a tank for 100 pound pressure, supplied with air by means of a hand pump, and rubber hose for supply and discharge. (Fig. 629). Each machine is provided with a spray pipe, cock and nozzle, an extra tip, a 200-pound pressure gage, galvanized sieve, suction and discharge hose, and is worked by two men, one at the pump and the other directing the nozzle. The largest size machine, costing $40, is equal to the work of thirty men with brushes, while the smallest size, costing $25, is equal to the work of ten men, and will cover 800 square feet of painted surface per hour. Painting coal sheds at Key West, Florida, with cement and tar paint, put on with air machines, showed that each gallon of paint put on by compressed air covered 145 square feet of surface. Machine painting has the disadvantage of conveying moisture and air to the surface, is wasteful, and soils the floor and surroundings. Hand painting with brushes is therefore generally preferred.

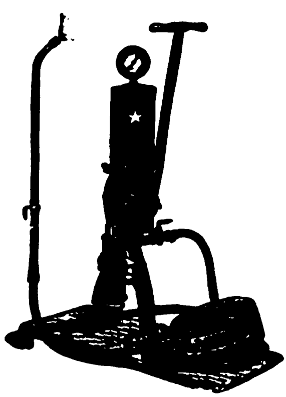


Fig. 629.

SHOP COATS.

The success or failure of painting depends upon the first coat. If it is applied over a wet or greasy surface, coated with scale, rust or mud, the first and succeeding coats will certainly peel off, leaving the metal exposed. The first coat should be applied on the clear grayish-white metal surface, with paint or metal hot. The paint may be heated by suspending pails of it in hot water. The permanence of mill marks on steel shows the benefit of applying paint to a hot surface, for it then spreads better and adheres more firmly. Some prefer to have metal oiled at the rolling mill while it is hot and kept under cover until manufactured, and again oiled or painted before shipping. The disadvantage in this is that the mill scale is not then removed, and when it peels brings the oil and paint with it. Others do not even oil metal until after erection, preferring rust to mill scale. Days with the proper atmospheric conditions should be chosen for applying the first coat. The air should be dry and clear, so dampness or dew will not form on the surface to be painted, and the temperature should be 50 degrees F. or more. Several thin coats are better than a less number of thicker ones, for pores in the earlier coats will be filled by succeeding ones. Each coat should be thoroughly dry before applying another. Column bases or other inaccessible parts should be painted before setting. Turpentine is often added by the workmen to make the paint thinner and easier to spread, but this should be avoided. Rivet heads, projecting points and edges should be given a second partial coat, which is allowed to dry before the final field coats, for the brush drags over edges and projections, leaving less paint than on flat surfaces.

TABLE LXIII.

PAINT.

Pigment and oil—	*Iron Oxide.*	*Red Lead.*	*White Lead.*	*Graphite.*	*Asphalt*	*Carbon.*
Vol. in gals.........	2.6	1.4	1.7	2.	4.	....
Weight in lbs.......	32.7	30.4	33.	20.5	30.	....
Lbs. of pigment per gal. of oil.......	24.75	22.40	25.	12.50	17.25	....
Sq. ft. covered first coat..	650.	700.	500.	600.	300.	1,000
Sq. ft. covered second coat	700.	1,000.	700.	800.	500.	1,500
Sq. ft. covered two coats.	375.	400.	300.	400.	250.	650
Cost per gal.............	$ .53	$ 1.25	$ .85	$ 1.10	$ .40	$1.50
Cost 100 sq. ft. first coat	.10	.18	.17	.14	.13	.15
Cost 100 sq. ft. second coat	.07	.13	.12	.10	.08	.10

The covering capacity of paint is frequently exaggerated, and depends on the thickness of the mixture and the smoothness of the

* Prices are based on raw linseed oil costing 60 cents per gal.

surface. It can always be increased by the addition of thinners, and may vary 50 per cent more or less from the areas given in the above table.

Light structural work averages 250 square feet, and heavy structural work 150 square feet of surface for every ton of steel, and in estimating the amount of paint required for two coats, it is customary to allow one gallon for every ton of light steel work, and half a gallon for every ton of heavy steel work. One gallon of tar at 300 degrees F. covers 220 square feet of surface. The volume of mixed paints exceeds that of oil by 20 to 75 per cent.

COST OF PAINTING.

The cost of painting is made up of two factors: (1) cost of materials, and (2)cost of labor in applying it. The cost per gallon of several kinds of paint is given in the table on page 394, and the cost of applying it depends (1) on the rate of wages paid to workmen, and (2) the amount of surface that a man can paint per day. A table of wages paid to laborers and painters in different parts of North America, which is subject to change, is given on page 420. Laborers receive from $1.25 to $3 per day, and painters from $2.75 to $4.50 per day. Structural paint can sometimes be applied by common laborers, but in many places the operation of trade unions may necessitate employing regular painters at a higher rate. Generally the cost of applying paint is two to three times the cost of the materials. From 80 to 90 per cent of the total cost is for the labor and the linseed oil. Mixed paint that is sold at a less price per gallon than the cost of linseed oil cannot contain pure oil, which is the chief essential of a good product. The average amount of surface that can be painted by a man in one eight-hour day is as follows:

First coat on tin or metal roofs............	2,000 sq. ft. per day
First coat on wood buildings..............	1,000 sq. ft. per day
First coat on structural steel	300 to 500 sq. ft. per day

A day's work on second or subsequent coats is 80 per cent of the amounts given above.

The cost of painting steel structural work with three coats of graphite at $1.10 per gallon, one coat being applied at the shop and the other two after erection, with shop labor at $1.50 per day, and field labor at $2.50 per day, is as follows:

COST PER TON OF PAINTING STRUCTURAL STEEL.

One shop coat.	*Heavy work.*	*Light work.*
Cost of paint per ton of steel	$ .33	$ .55
Cost of labor per ton of steel	.15	.20
Cost per ton of one shop coat	$ .48	$ .75
Two coats after erection.		
Cost of paint per ton of steel	$ .47	$ .78
Cost of labor per ton of steel	.80	1.10
Cost per ton of 2 erection coats	$1.27	$1.88
Total cost per ton of 3 coats	$1.75	$2.63

Generally, one shop coat of graphite paint costs 50 to 75 cents per ton of steel, while two field coats cost from $1.25 to $1.75 per ton. Two field coats of iron oxide paint will cost from $1 to $1.50 per ton. Coating with tar at 10 cents per gallon, and labor at $1.50 per day, costs 50 cents per ton for heavy steel work to 80 cents per ton for light work.

Present union prices for painting woodwork with oil paint are as follows:

One coat work	$1.35 per 100 sq. ft
Two coat work	2.00 per 100 sq. ft.
Three coat work	2.75 per 100 sq. ft.

Cold water painting by compressed air, including material and labor, costs $1 per 100 square feet.

CHAPTER XXXVIII.

PAINTING SPECIFICATIONS FOR STRUCTURAL STEEL.

1. All structural iron and steel, from the time of rolling till it is oiled or painted, shall be kept under cover and protected from the rain and weather.

2. It shall be piled on skids, and care taken to avoid scraping or injuring oiled or painted surfaces.

3. Steel shall never be laid on the ground, either at the works or at the building site.

4. Corrugating of sheet metal shall be done before oil or paint is applied.

5. All metal shall receive one coat of either linseed oil or paint at the shop.

6. A shop coat of oil (if used) shall be applied to the structural shapes at the mill while the metal is hot, and it shall then be stored under cover on skids till needed in the riveting shop.

QUALITY OF OIL AND PAINT.

7. Oil shall be of the best quality of raw (or boiled) linseed oil, chemically and commercially pure. Raw oil shall contain no turpentine, benzine, thinners or driers of any kind.

8. Paint shall be the kind specified. Mixed paint is preferred to that made from paste or powder.

9. All linseed oil and mixed paint shall be bought direct from the manufacturers, and shall be delivered at the works or building site in original sealed cases or barrels, accompanied with a signed certificate, from the manufacturers, of the number of cases shipped, and the price paid for same, and this certificate shall be delivered to the engineer on demand.

10. The original cases shall be opened in the presence of the engineer or owner or their representative, and tested if desired.

11. Paint shall contain no thinner of any kind, and turpentine or benzine shall not be permitted on the premises for any purpose, excepting with written permission of the engineer, and then only in the amount specified.

CLEANING.

12. All metal, before assembling, and after it has been cut, punched and bored, shall be thoroughly cleaned, and all rust, loose scale, mud, dirt and grease removed, either by washing, pickling, scrapers, chisels, wire brushes, or the sand blast. If more than light surface rust exists, it shall be heated with a burning torch until the oxide is converted.

13. The clear grayish-white surface of the metal shall be exposed before oil or paint is applied.

SURFACES IN CONTACT.

14. Before assembling, all surfaces which will be in contact shall be thoroughly cleaned and given a coat of paint or oil, and all small cavities which will be inaccessible after riveting shall be filled with cement.

SHOP COAT.

15. All surfaces, before painting, shall be dusted off with a bristle brush, cotton cloth or waste.

16. Pins and turned surfaces shall receive a coat of white lead and tallow.

17. All other surfaces shall receive a full coat of linseed oil or paint, applied not later than three hours after the surface has been cleaned.

18. Small parts such as loose plates, bolts, rivets, etc., shall be dipped in the liquid oil or paint.

19. Painting on cars will not be permitted, excepting to touch up points that have been scraped in loading.

20. Shop marks shall be neatly painted and compactly arranged, and when dry they shall be covered, for protection, with a coat of boiled linseed oil.

APPLYING PAINT.

21. Hand painting with brushes shall be preferred to machine painting.

22. Shop painting shall generally be done under cover in a warm atmosphere, preferably from 60 to 80 degrees F., and never out of doors excepting in bright sunshine.

23. The paint or oil shall be hot when applied, and the metal shall preferably be warm.

24. Paint shall be well spread out with brushes in a smooth and even coat, well worked around rivet heads, angles and corners.

25. All surfaces, before painting, shall be clean and dry and

free from moisture, and no painting shall be done in damp, freezing weather.

26. Paint shall be thinned by heating rather than with turpentine.

27. Proper facilities shall be given for inspection, which shall be done only by the engineer or his agent.

28. When steel work is ready for painting, the inspector shall be notified, and no painting shall be done until the surface and the weather conditions have been approved.

29. Brushes shall be large sized, round or oval bristle brushes, 2 or 2½ inches in diameter. Flat brushes, or any over 3½ inches wide, will not be permitted.

SHIPPING.

30. Painted material shall not be exposed to the weather until it is dry, or until it has formed a good initial set, and shall not be loaded on cars until at least twenty-four hours after being coated. It must be carefully piled and arranged so the painted surface will receive the least possible injury.

FIELD PAINTING.

31. After erection, steel work shall be inspected and cleaned from mud, dirt, scale and rust. Sheet metal shall, if necessary, be washed with soap and water or benzine, and galvanized iron shall be washed or allowed to weather for several weeks, before painting.

32. Small cavities or inaccessible places shall be filled with cement, and all rusty spots or scratched places, corners, projecting parts, like bolt and rivet heads, and the edges of angles, shall be given a partial coat, spread 1 or 2 inches past the edges. When this partial coat is dry, the entire steel work shall be given one or two complete coats of paint, with at least five days intervening between successive applications.

33. All coats shall preferably be of a slightly different color.

34. Surfaces of metal sheathing corrugated iron and cornices, which are inaccessible after placing, shall be given a second coat before erection.

35. All field coats shall be done by skilled labor.

36. If light colors are desired for the final coats, the steel shall then receive two coats of paint, tinted as desired, made by mixing equal parts by weight of white lead and zinc oxide with a vehicle composed of one part hard varnish rosin, two of linseed oil and a thinner.

37. Samples of the proposed paints must be submitted at least

three months in advance, and no paint shall be used until it has been accepted and approved, but the paint which is used must be the same as the sample approved, and no other.

38. If the shop coat consists of oil, the steel work may then be allowed to remain from one to six months before recoating, and after all mill scale is off, it shall be inspected, cleaned and painted as described above.

PAINTING OF OLD WORK.

39. All dirt, dust, scale and loose paint shall first be removed, using a hot blast blow torch, or sand blast, if necessary.

40. Deep-seated rust spots, not accessible to a scraper, tool or chisel, shall be heated with a burning torch, and when the rust is decomposed, it shall be removed with a brush.

PENALTY.

41. If inspection of oil or paint shows it to be different or inferior to that approved and specified, the contractor shall then pay the expense of testing, and shall clean off and remove all paint already applied, and shall repaint the surface with the proper material, without extra compensation.

PART V

ENGINEERING AND DRAFTING DEPARTMENTS OF STRUCTURAL WORKS

CHAPTER XXXIX.

THE ENGINEERING DEPARTMENT.

INQUIRIES.

Inquiries for designs and estimates on steel structures are received with the mail in the general office, and referred to the engineering department. These may include, besides mill buildings, all kinds of steel cage factory, warehouse and office buildings, and business blocks with only partial frames. There may be requests also for designs and estimates for standpipes, water towers, floors, platforms, observation stands or any kind of plate and bar construction, ordinarily made by bridge and structural works. Many inquiries are received from architects and others who are seeking information, but are not prospective purchasers, and the officers of the company must decide to what extent these will receive attention. Companies which intend retaining the good will of all interested in their business will probably make accommodation designs and estimates, even though an extra estimator be needed for this purpose. Other companies may consider the expense unwarranted, as there are too many quotations to prospective buyers to permit doing accommodation work. Approximate estimates are usually close enough for this purpose, and it is better to make them than decline the inquiries.

Invitations to tender on construction work must be carefully considered before being accepted. The work may be too large, too small, or have insufficient financial security, or the chances of securing a contract may be too remote to be worth the labor. The manager and engineer must decide whether or not it is best to prepare the estimates.

ORGANIZATION AND OFFICE.

The engineering department of a structural works will comprise a chief engineer and such assistants as he may need, depending on the capacity of the works and the amount of estimating that is needed to keep the shops supplied. A small plant can be kept busy by one estimator, while a larger one may do enough work to keep several engineers busy in securing it.

It will be assumed that the engineering department can use the services of several men, two or three assistants competent to design and estimate, others for listing quantities and figuring weights, and two or three draftsmen making general show drawings.

The chief engineer will give his principal attention to outlining the designs and selecting economical ones. He must examine designs made by his assistants and check the weights and costs by rules and formulæ, to see that estimates contain no great mistakes. Time will not generally permit checking estimates in detail, but they should be examined carefully enough to avoid serious errors. Care must be taken in checking, to see that all items are included and the large figures correct. There are unfortunate cases on record where one-half of a symmetrical building was estimated, but the result was not multiplied by two, or some large item like the sheathing or purlins was omitted, and the submitted price was disastrously low. Mistakes of this kind can be easily discovered, and there is no excuse for their occurrence if careful assistants are selected.

The draftsmen in the engineering department must make neat and attractive drawings, even though they have little knowledge of construction detail. They must do good lettering and printing, for the drawings are the final result of the engineer's work, and the success or failure in securing a contract may depend on the care with which the design is illustrated. Each engineer must have a drawing table, and a desk for computations. Roll top desks are not suitable, as the tops interfere with spreading out the plans. Desks should have tiers of drawers at the sides, and there should be other drawer cases for finished sheets. The engineering department should contain an abundant supply of literature on structural engineering, together with bound series of engineering and trade journals, and data of every available kind relating to designs, weights and costs. All engineering index volumes should be at hand in order that subjects may be investigated and similar designs examined in the various technical reports and journals.

The estimates and drawings must be numbered and recorded in a card index so they can be quickly found. Estimates can be placed in letter files, either consecutively or under subjects, putting those for buildings of the same kind together. In the latter classification, all foundry building estimates would be in one file, machine shops in another, store houses in another, etc. The index cards should be ruled with places for various data, so a large number of estimates can be glanced over quickly on the cards, without the necessity of examining the actual papers.

OFFICE METHODS.

There is much time and energy wasted in useless refinement in the design of ordinary steel structures. Mathematics is thought by many to be the height of engineering, while it is only an assistant to judgment. Arbitrary loadings are assumed, which in many cases are not realized within 50 per cent or more, and from these assumptions, calculations are carried out to decimals. The following extract in this connection is taken from the preface of Trautwine's Engineers' Handbook: "Comparatively few engineers are good mathematicians, and in the writer's opinion it is fortunate that such is the case, for nature rarely combines high mathematical talent with that practical tact and observation of outward things so essential to a successful engineer. There have been, it is true, brilliant exceptions, but they are very rare. But few even of those who have been tolerable mathematicians when young can, as they advance in years, and become engaged in business, spare the time necessary for retaining such accomplishments. Let the savants work out the results, and give them to engineers in intelligible language. We can afford to take their word for it, because such things are their specialty. The judgment of an experienced designer is often preferable to the conclusions of a mathematician, inexperienced in practical work.

Stresses for ordinary trusses may be more quickly figured by using the coefficients given in several mill handbooks. If these do not suit the form of truss, new ones may easily be determined, and all such coefficients should be preserved for future use.

Where there are several figures to be multiplied or divided by the same number, the use of a slide rule or calculating machine will save much time. In other cases, figuring can be done as easily and quickly in the ordinary way. It is also a saving of time with less liability to error to perform all similar calculations on various truss members consecutively. For example: first find all the shears; second, all the moments; third, all the inclined web stresses; fourth, all the chord stresses; fifth, all the required tension areas; sixth, all the required compression areas, etc., without waiting to finish the consideration of any one piece.

The estimator will have curves at hand giving the weight of trusses for a variety of loadings. To find the weight of a truss, intermediate between those for which curves are available, it will be close enough for approximate estimates to interpolate. Care must be taken, however, to see that the loads are of the same general class. The weights of steel in a building for heavy cranes cannot be compared with a similar one without cranes, nor a roof in northern latitudes with one of the same size in the south.

When bids are asked on a design furnished by the owner, it may be an advantage to also submit a price on an alternate one. Some shops can fabricate riveted work cheaper than they can make pin-connected trusses, and if a price is asked for a pin-connected truss, it will doubtless interest the buyer to receive a lower price on a riveted one.

In order to have a systematic way of recording all the principal data in connection with any building, the following blank heading will be found convenient for estimate sheets. The blank spaces for size of span, loads, etc., should all be filled, and any other information not provided for in the heading should be written on the first page, together with any governing extract from the specifications which seriously affect the design. These must appear on the first page, so a review of the estimate can be quickly made:

PRELIMINARY STUDY SHEET.

................1910 Estimate No.........
Name................................ Sheet........of........
Size.........Area..........Height..........No. Stories.........
Distance between Trusses.........Pitch.........Covering.........
No. Pieces.......span clear........effective.......extreme........
Purlins.............. Rafters.............. Monitor.............
.... Compression...... ....
Specification........... Tension.......... Material..........
Live Load per sq. ft..
Dead load per sq. ft..
Designed by ....
Estimated by ....
Drawing by ....

The sheets may be ordinary cap size, 8 by 13 inches, and the paper should be a thin, strong linen, suitable for blueprinting, cross ruled as shown in $\frac{1}{8}$ inch squares. On this paper the design is studied out on a small scale; large sheets or scales are not suitable for studies of this kind, for attention is not so easily concentrated when sketches are spread over a greater area. Office tables and reference sheets generally, to be of the greatest use, should be made small. A reference sheet, 6×8 or 8×10 inches, that can be easily handled, will be used where a larger one would not.

After the general design has been studied on a small scale line diagram, a cross section should be made to $\frac{1}{4}$ or $\frac{1}{8}$ inch scale, to show general details. These and all stress sheets should be carefully made with india ink. All the principal operations connected with the calculations should be preserved for reference, but multiplication may be done on scrap paper. All principal dimensions must be written in ink.

DESIGN.

In these notes on office methods, questions of design need be considered only briefly, for the subject is more fully treated in other chapters. The fact that prices submitted on the bidder's own plans frequently vary from 25 to 50 per cent above the lowest, clearly shows that skill and care are needed; and yet it is generally recognized among the building trades, that estimators of structural iron work are as a class the most careful and accurate of all.

The experienced designer will use standard parts wherever possible to reduce to a minimum the amount of stress sheet work. Trusses, columns, purlins, etc., for all ordinary purposes can be computed and tabulated and will not require refiguring, and if special trusses are needed, they can be computed from standard truss coefficients.

STEEL CAGE COLUMN SPACING.

As the weight of steel in this class of buildings is principally in the floors, it follows that the greater the number of column tiers, within reasonable limits, the less will be the weight of steel. Roughly speaking, about three-fourths of all the steel is in the floors and the remaining one-fourth in the columns. Hotels and office buildings can have columns fairly close together, for they can be placed in the partitions where they cause no obstruction. On the contrary, stores or public halls will permit only the fewest possible number, or none in view. Halls or office buildings may have stores in the lower story, and then the columns in the upper stories must be carried on heavy girders at the second floor. Office buildings have also been designed with few tiers of columns, so partitions may be changed or removed to suit the tenants, leaving an unobstructed floor area. Warehouses for the storage of ordinary goods can usually have fairly close spacing of 12 to 16 feet. Before the position of the columns can be fixed, there will, therefore, be many considerations. It is sometimes economical to cantilever the principal cross beams and splice these beams at the points of contraflexure. A twelve-story apartment house, with small rooms, designed by the writer, had columns spaced 10 feet apart inside the partitions. This produced a very light frame, the weight of which, including floors, columns and complete frame for the outside walls, was only 14 pounds per square foot of floor area. Another similar building, eleven stories high, in which the columns were spaced 25 feet apart, weighed 28 pounds per square foot of floor area. The latter was an office building, and was proportioned for heavier loads than the hotel, but the principal reason for the greater weight of steel was the wider columns spacing; both had complete steel frames for the outside walls.

The practice of designing columns in the lower stories to carry only a portion of the sum of all maximum floor loads above is reasonable and is allowed by the building laws of some cities, though not by all. According to the percentages allowed by the New York building law, the saving in the column amounts to about 10 per cent. This will be from 2 to 3 per cent of the entire weight of steel.

BEAM SPACING.

The distance between floor joist will depend largely on the kind of fireproofing used. Most of the concrete systems permit beam spacings from 10 to 15 feet, but for terra cotta block it should not exceed about 5 to 8 feet. Many architects use these latter distances to make the framing suitable for any system. It requires less steel to use wide spacing with deeper beams. The thickness of floor may, however, be limited, and it then becomes necessary to use a shallower beam and smaller spacing.

As the fireproof companies do not advertise their prices, it will be wise for the architect or engineer to make several different arrangements of beams for a typical floor, and secure prices on the fireproofing for these designs. He can then combine the costs of steel and fireproofing, and select the cheapest arrangement. He should at the same time receive prices for fireproofing one tier of inside columns, to assist him in choosing the best column arrangement.

Wall girders spaced two or three stories apart are frequently as satisfactory and have less weight of steel than when provided at every story. Another common practice is to proportion outside columns to carry the floor loads only, making the wall of sufficient thickness to be self-supporting. It is necessary to provide a channel against the wall to carry the floor, whether the walls have columns or not, though some prefer to use a continuous flat plate built into the brickwork and projecting about 2 inches inside to support the floor, while others use a brick corbel instead.

Whether to build the outside walls of solid brick, or to use a steel frame with a thin brick wall merely as a curtain, will depend on the following conditions: First, which method in itself, apart from any consideration of available floor space, is the cheaper; and

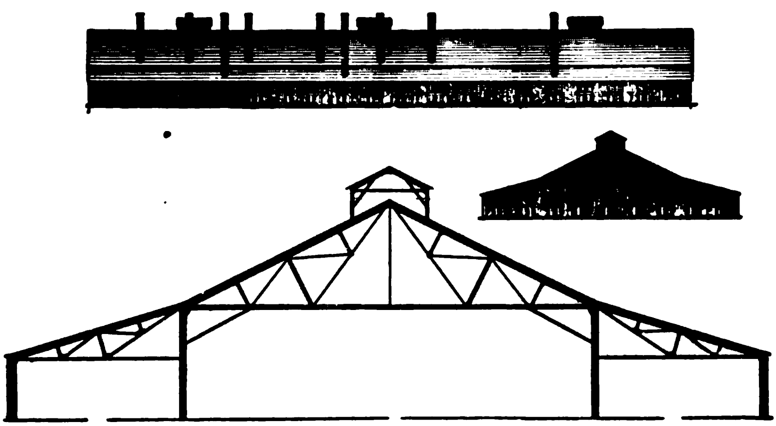


Fig. 630.

second, if the steel frame and curtain wall be more expensive, whether or not the increased floor space secured by thinner walls will compensate for the extra cost of construction. This second consideration will occur only when the lot area is limited and land values high. If additional land can be secured at a reasonable price, the question of increasing floor space by decreasing the wall thickness would not be considered.

Nearly all large business blocks and public buildings contain more or less iron and steel for beams, columns, wall plates, anchors, etc. It is frequently the custom to make the principal floor beams of steel, using wood for other beams and joist. In such cases the parts must be proportioned to carry safely their maximum loads, and, in large cities, to conform with the building laws.

SHOW DRAWINGS.

After the general design has been carefully studied, a small scale drawing should be prepared, that the buyer who may not be familiar with building details may see the general style of construction. Care should be taken, in making general drawings and show plans (Figs. 630, 631 and 632), to have them neat and attractive, for even though a design contain much merit, if it be

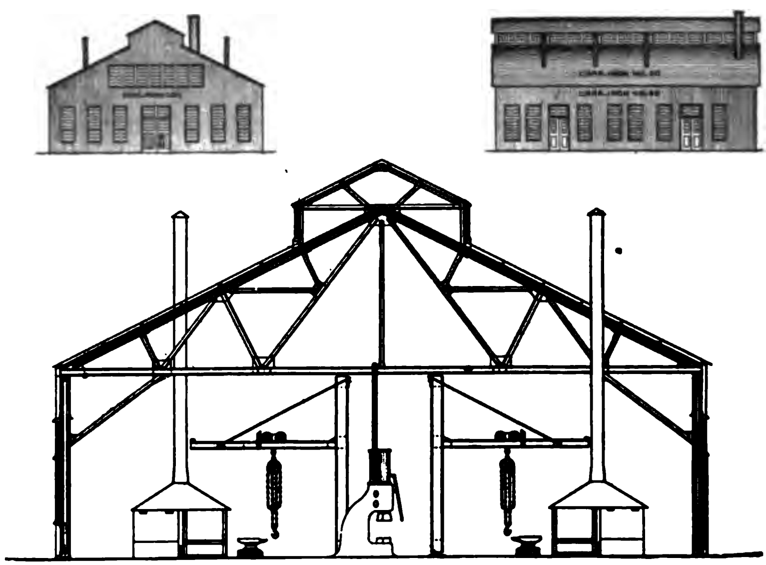


Fig. 631.

accompanied with a carelessly made picture, it may be passed by and a more attractive plan accepted instead.

After the design has been made, it should be reviewed to see where improvements are possible. Additions or reductions should be made, extra bracing added where necessary, or the weight reduced where judgment will permit. The capacity of the original design will probably be kept up to the buyer's specifications, and deductions computed, which can be made if the capacity of certain parts are decreased. For example, an owner may think that he requires a building to carry a 50-ton crane, but when the cost is considered, is willing to use a crane of 30 or 40 tons instead. All suggestions like this will interest a prospective buyer, and will increase the chances of securing the work. If the estimate is made on a design submitted by the buyer, alternate ones would doubtless be attractive.

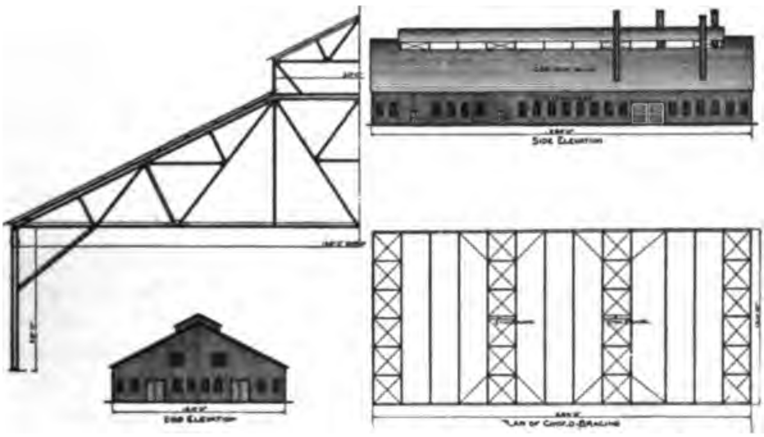


Fig. 632.

Every estimate should be analyzed as soon as possible after it is completed, preferably by the one who made it, and the results preserved as a basis for other estimates of a similar kind. These analyses should be kept on cards or thin linen paper in loose-leaf books, and classified under different headings. Thin paper is preferred, as it can be printed. By the use of these summaries, approximate estimates for new work can be prepared in a very short time.

CHAPTER XL.

ESTIMATING QUANTITIES.

APPROXIMATE ESTIMATES.

Quantities may be estimated, either approximately by empirical rules and formulæ, or exactly, by writing down the actual amounts. In many cases, the approximate method is sufficient, and at all times it forms a valuable check or guide on the final results. An experienced estimator will have weight tables for all kinds of steel structures, on a square foot basis, so that approximate estimates on new work can be made quickly. In preparing approximate estimates for a proposed new building, care must be taken to compare with estimates for structures of the same kind and for similar use. An approximate estimate for a building with heavy traveling cranes cannot be made by comparison with a similar building without cranes, nor a single-story building with a multi-story one, or short spans with long ones. The comparison should be with structures as nearly like the desired one as possible. A few rules for approximate estimating, from the author's private records, will be given.

The weight of roof trusses for various spans, pitches and loadings is given by the original charts in Part II, and the weight of trusses and plate girders for spans of any length, and loads up to 4,000 pounds per lineal foot, is given by Figs. 119 and 120. These charts cover all kinds of loadings in ordinary construction.

A formula for the weight of roof trusses to sustain a total load of 40 pounds per square foot is as follows:

$$W = \frac{12}{D} + \frac{L}{20}$$

where W, is the weight of steel in pounds per square foot or area covered;
L, the length of span inside walls in feet;
D, the distance in feet between centers of trusses.

The weight of steel framing in mill buildings, including trusses, columns, purlins, bracing, etc., is approximately as follows:

Framing for roofs covered with corrugated iron weighs from 4 to 6 pounds per square foot of exposed surface, while the framing for heavier roofs, covered with slate or plank, will weigh from 6 to 9 pounds per square foot. These weights are for roofs and side walls only, and do not include crane supports, floors or any other parts, excepting the plain enclosure. The weight of steel framing in walls, including columns, girths, purlins and bracing, will seldom exceed 4 to 6 pounds per superficial foot.

The additional weight of steel required to support traveling cranes in a building will vary from 3 to 6 pounds per square foot of the entire floor area, depending principally on the capacity of the cranes and the column spacing. This weight may be more closely approximated by allowing 100 pounds of steel per lineal foot of building, for every 5 tons' capacity of cranes. These weights are in addition to the regular steel framing in the roof and walls.

If the weight of steel be given in pounds per square foot of ground floor, or area covered, instead of per square foot of exposed exterior surface, the weight will then be approximately as follows:

	Lbs. per sq. ft. of ground.
Simple roofs without cranes, corrugated iron covering	6 to 10
Light shops with cranes	8 to 14
Heavy shops with cranes, slate or plank covering	12 to 20

The steel framing in roofs similar to Fig. 429 in spans from 80 to 200 feet weighs from 8 to 12 pounds per square foot of exposed surface, or from 9 to 16 pounds per square foot of ground covered, including steel purlins, which weigh from 2 to 4 pounds per square foot of roof.

None of the above weights include the steel in floors, which may vary from 8 to 25 pounds per square foot, depending on the arrangement of beams, the floor capacity and the distance between columns.

Multi-story office and warehouse buildings, not over eleven stories high, designed according to modern building laws, with columns 15 feet apart, for various imposed loads, have steel frames weighing as follows:

TABLE LXIV.*

	Lbs. per sq. ft.		*Lbs. per sq. ft.*
Buildings for imposed loads of	60	with outside frames	14
Buildings for imposed loads of	60	without outside frames	9
Buildings for imposed loads of	100	with outside frames	23
Buildings for imposed loads of	100	without outside frames	15
Buildings for imposed loads of	250-350	with outside frames	28
Buildings for imposed loads of	250-350	without outside frames	18

* H. G. Tyrrell, Architects' and Builders' Magazine, Jan., 1903.

From the above, an approximate estimate of the weight of steel in any proposed new multi-story building may very quickly be made. The total weight of floors increases in direct proportion to the number of stories, while the weight of columns increases more rapidly.

The weight of cast-iron column bases given in Table XXIV, Chapter XIV, is useful when estimating steel in tall buildings.*

The steel framing in coal and ore pockets with plank lining weighs from 150 to 200 pounds for each ton of coal or ore in the bins, or 3 to 4 pounds per cubic foot of contents. When pockets have $\frac{1}{4}$-inch steel plate lining, the weight of steel is then from 200 to 250 pounds for every ton of coal or ore.

The weight in pounds of iron stairs with two steel stringers and cast treads and risers (not including railings), per vertical foot of building, is $70 +$ width in feet $\times$ 50. Cast risers $\frac{1}{4}$ inch thick weigh 8 pounds, and treads $\frac{3}{8}$ inch thick, 18 pounds per lineal foot.

Spiral iron stairs with treads 33 inches wide, weigh 120 pounds per vertical foot, and fire escapes, including stairs and platforms, have an average weight of from 70 to 100 pounds per vertical foot.

Iron lattice railing weighs from 15 to 50 pounds per lineal foot, and pipe railing usually from 8 to 18 pounds per foot.

EXACT ESTIMATING.

Exact estimates should be made when time will permit or when their importance will warrant, and are usually necessary when tendering on contract work. It is desirable for the bidder to visit the site and personally examine the condition of the soil and surroundings, but there is seldom time for such excursions, and grade and ground lines on the plans must be followed instead.

The various kinds of work should be listed in their natural order, beginning with excavations and foundations, continuing with masonry, steel framing, roofing, etc., and ending with minor items such as painting, plumbing and electric lighting.

A convenient ruling for paper on which to figure quantities is given below, the various kinds of material being kept in separate columns.

* H. G. Tyrrell, Architects' and Builders' Magazine, Jan. 1903.

ESTIMATE SHEET.

............................1910.

Name.................................. Estimate No..........

Sheet........of .....

Location................................

Owner...................................

No. of Pieces.	Material.		Weight Per ft.						

Beam work may be divided according to the following classification:

Beams punched in either web or flange.
Beams punched in both web and flange.
Beams coped or framed.
Double beams bolted together with separators.
Plain beams not punched.

Beam fittings, such as separators, bolts and connections, should be kept separate, as a special price is charged for them. An extra price may be made for beams 18 inches deep and over, and these should also be separated from beams 15 inches deep and smaller. Where only a rough estimate is required, it will be convenient to use one column for each different weight, and write down the total length when figuring off the beams. For example, in place of writing 2 I-beams, 15 inch @ 42 pounds per foot, $\times$ 24 feet long, simply write the total number of lineal feet (48) in the 42 pound column.

It is easier to figure off only one piece, or if the section is symmetrical like a double pitch roof truss, then figure off only half. The total number of pieces may be given in the weight summary. The weight of truss details is usually found by adding 20 to 35 per cent to the weight of main members, but the total weights, including details for all ordinary trusses, can be taken directly from the charts. The weight of rivets varies from 3 to 6 per cent of the whole, and allowance may be made for column caps and bases by adding 2 or 3 feet to the length of the column.

LISTING MISCELLANEOUS ITEMS.

It is frequently necessary to include in the steel contract such material as lumber, paving, doors, windows, and occasionally the entire mason and carpenter work. It is the custom to place the contract for the whole building with the contractor whose share is the largest. Therefore, with steel frame buildings, where steel is the largest single item, all the other kinds of material must be included. If there is much other work, it is better to secure subbids, but if little, this may not be necessary. Windows should be listed with outside dimensions, stating if sash are hung or fixed, with the size and number of lights in each. Windows in the side of monitors are operated from the floor either by cords or shafts and gears, and the number to be opened must be stated. Gutters and conductors are listed by the number of lineal feet and size; roofing by the number of square feet; paving by the square yard; railing by the number of lineal feet and the weight per foot; lumber by the number of feet board measure, keeping different kinds separate.

Wall anchors fastening floor joist to masonry are spaced about 10 feet apart, and plate anchors 5 feet apart. The number and size of other mason's and carpenter's anchors are too uncertain to classify, and where these items are large, should be figured from a schedule, but where their weight is small compared with other work, the experienced estimator will include a lump sum to cover them.

If the estimate is on a design prepared by others, an approximate estimate should be made on another, for the purpose of checking the economy of the original one, for one designer can often save on the work of another.

CHECK LISTS.

In order to know that all items have been included, it is convenient to have a check list at hand for reference, which may be reviewed before making the summary. If any items have been omitted, they may then be included.

TABLE LXV.

CHECK LIST—BUILDINGS.*

- Bed Plates
- Brackets
- Crane Rods
- Columns
  - End
  - Crane
  - Clear story
  - Lean to
  - Main
- Finish Angles
- Floor
  - Beams
  - Joist
  - Plates
- Girders
  - Crane
  - Plate or Lattice
- Knee Braces
- Purlins
  - End
  - Gable
  - Roof
  - Side
- Rods
  - Longitudinal Ties
  - Lateral
  - Sag Ties
  - Sways
  - Ties
- Separators
- Struts
  - Bottom Chord
  - Crane
  - Eave
  - Rafter
    - Sway
- Trusses
  - Lower Chords
  - Rafters
  - Struts
  - Suspenders
  - Ties
- Ventilators
  - Braces
  - Circular
  - Frames
  - Trusses
- Wall Plates
- Anchor Bolts
- Bolts
- Cotters
- Clips
- Corrugated Iron
- Crane Track
- Doors
- Door Frames
- Flashing
- Gutters and Downspouts
- Louvres
- Name Plates
- Pins
- Paint
- Rivets
- Railing
- Ridge Capping
- Stairs
- Sheet Metal Work
- Sheeting Rivets
- Wood Work
- Windows

FINAL CLASSIFICATION.

In all operations, uniform methods should be adopted as far as possible. Therefore, in making the final classification, it is convenient to have a blank form such as given below, one of which may be filled out for each estimate. The cost of stock is first considered by giving the weight of each kind, figured at the current price per pound. The cost of drawings and templets is then found by giving the number of sheets which are figured at a certain price per sheet. The cost of labor is next computed, by giving the number of pounds of trusses, girders, columns, castings, beams, machine work, etc., each being figured at its own pound price. Miscellaneous items bought from other makers are figured by themselves, and paint is estimated by giving the number of gallons. Then follows the cost of transportation, including freight,

GENERAL SUMMARY.

......................1910.

Name.................................... Estimate No.........

Location................................ Sheet..........of........

Materials.	Quantities.	Unit Price.	Total Cost.
Stock—			
Plates, sheared	....	....	....
Plates, rolled edge............	....	....	....
Bars, common	....	....	....
Bars, refined	....	....	....
Angles	....	....	....
Beams, 24 in................	....	....	....
Beams, 20 in................	....	....	....
Beams, 15 in. and under........	....	....	....
Z bars	....	....	....
T bars	....	....	....
Eye bars	....	....	....
Cast iron	....	....	....
Rivets	....	....	....
Bolts	....	....	....
Pins and rollers...............	....	....	....
Steel joist	....	....	....
Office and Shop Labor—			
Drawings	....	....	....
Templets....................	....	....	....
Trusses	....	....	....
Girders	....	....	....
Columns	....	....	....
Bracing	....	....	....
Beams, coped or framed........	....	....	....
Beams, punched	....	....	....
Beams, plain	....	....	....
Beams, with separators.........	....	....	....
Steel joists, punched at mill.....	....	....	....
Machine work	....	....	....
Cast shoes, etc................	....	....	....
Fence	....	....	....
Fence posts	....	....	....
Paint, 1st coat................	....	....	....
Miscellaneous Items—			
Lumber	....	....	....
Spikes	....	....	....
Doors	....	....	....
Windows, etc.	....	....	....
Erection—			
Steel	....	....	....
Steel joists	....	....	....
Paint, 2d coat................	....	....	....
Lumber	....	....	....
Lumber joists	....	....	....
Lumber staging	....	....	....
Bolts, staging	....	....	....
Fence	....	....	....

teaming, railroad fares for erection crew, and finally the cost of erection labor. By separating all the items in this way, a close estimate is secured. It is of much greater importance to have all items included, than to have a fine classification, though the latter is desirable. One or two important items omitted from an estimate might easily cause a greater difference in the total than would result by figuring the entire riveted steel work at some even unit price such as $70.00 per ton, and while varying shop costs are given, the most important part of an estimate is to see that all items are included and a small amount added for contingencies. If there is any doubt about certain parts, they may be figured separate from the rest.

Finally, it should be definitely stated on the summary sheet, just what items are included and what are not. These should all be specified so the buyer may know exactly what is and is not covered by the price.

CHAPTER XLI.

ESTIMATING COSTS.

APPROXIMATE COST ESTIMATES.

Approximate cost estimates are sufficient for many purposes, and can be made in less time than exact ones. They are found from the cost units per square foot of floor area and per cubic foot of contents, for buildings of various kinds, given in Chapters VI and VII.

Approximate costs are also found from the weights in the preceding chapter, multiplied by their respective unit prices. Both methods can be used, one being a check upon the other.

CLOSE COST ESTIMATES.

To arrive at close estimates all the various items that make up the final cost must be considered separately, including designs, drawings, materials, shopwork, freight, hauling, erection, painting, etc. It simplifies office work to use uniform methods wherever possible, and the quantities and cost units should therefore be written for each estimate on a blank form similar to that on page 413. The paper is conveniently ruled in columns, and there is space left for additional items such as doors, windows, etc.

The cost of the engineering department, including designs and contracting expenses, may vary from one half of one per cent to one per cent of the estimates, and this amount should be added to each estimate.

Drawings should be figured at $15 per sheet, or according to the tonnage costs for drawings given in Chapter XLVI.

COST OF MATERIALS.

The cost of materials varies according to the condition of the market, and these costs are frequently reported in the engineering papers and trade journals. If the prices quoted are those at the mill where they are produced, freight charges from the mill to the shop must be included, in addition to the cost of freighting the finished products from the shops where fabrication is done, to the building site.

TABLE LXVI.

PRICE OF STRUCTURAL STEEL, AT THE MILLS, PITTSBURG, PA. (DECEMBER, 1910.)

Beams 3 to 15 in	$1.45 per lb.
Beams, over 15 in	1.55 per lb.
H shapes over 8 in	1.65 per lb.
Angles 3 to 6 in., over ¼ in. thick	1.50 per lb.
Angles over 6 in	1.55 per lb.
Angles 3×3 and upward, less than ¼ in. thick	1.70 per lb.
Tees 3 in. and over	1.60 per lb.
Zees 3 in. and over	1.50 per lb.
Angles, channels, tees, under 3 in	1.45 per lb.
Deck beams and bulb angles	1.75 per lb.

The cost of material on the cost sheet should be the mill price, with freight charges added from mill to shops where the structural work is fabricated, or the cost of material delivered at the shops. When material is required in too short a time to permit waiting for rolling it in exact lengths, it is then customary when cut from long stock lengths to charge from .2 to .3 of a cent more per pound.

Prices on brick, cement, lumber, etc., are given in Chapter XLII, but they should be revised to suit the time and place, as market prices vary in different localities. In the South and West where it is plentiful, good timber costs less than in the North and East, where it must be hauled. The cost of other materials is given in greater detail under their proper headings.

COST OF LABOR AND SHOP WORK.

The cost of shop work depends largely on the cost of labor, which varies with location. The wages paid to mechanics in the building trades in various parts of the United States in 1910 are given in Table LXVII.

TABLE OF WAGES PER DAY OF EIGHT HOURS (1910).

TABLE LXVII.

Cities.	Masons.	Stone Cutters.	Cement Finishers.	Hoisters.	Bricklayers.	Structural Iron Workers.	Ornamental Iron Workers.	Carpenters.	Roofers.	Tile Setters	Lathers.	Plasterers	Plumbers.	Steamfitters.	Steamfitters' Helpers.	Gasfitters.	Sheet Metal Workers.	Electricians.	Painters.	Laborers.	Hod Carriers.
Boston, Mass....	4.80	4.00	4.00	3.60	4.80	4.00	4.00	3.75	3.25	4.80	4.00	4.80	4.50	4.50	1.50	3.60	3.25	3.50	3.30	2.40	2.40
Providence, R. I..	3.50	4.00	3.25	3.00	4.50	2.75	3.25	3.25	2.00	4.50	3.20	4.40	4.00	3.00	1.75	3.20	3.25	3.00	3.00	2.00	2.00
Buffalo, N. Y....	4.00	4.00	3.20	3.00	4.50	4.00	2.40	3.20	3.00	4.50	3.00	4.00	3.50	3.50	2.00	3.50	3.50	3.20	3.50	1.75	1.75
Rochester, N. Y..	4.50	4.00	3.00	3.00	4.50	4.00	4.00	3.50	4.00	3.00	3.40	4.50	3.50	3.50	1.50	2.50	4.00	3.25	3.00	1.75	2.00
Schenectady, N. Y.	4.00	3.20	2.75	2.75	4.00	3.75	3.75	3.20	4.00	2.75	3.20	4.00	4.00	4.00	2.00	4.00	3.50	3.25	3.20	1.75	2.00
Albany, N. Y....	4.80	3.60	4.00	3.00	4.50	4.00	4.00	3.20	4.00	4.00	4.00	4.80	4.00	4.00	2.00	4.00	4.00	3.50	3.00	2.50	2.50
New York, N. Y..	4.50	5.00	5.00	5.50	5.60	4.50	4.50	5.00	4.00	5.00	4.50	5.50	5.00	5.00	3.00	5.00	4.50	4.50	3.50	2.80	3.00
Jersey City, N. J.	5.25	5.00	5.00	5.00	5.25	4.50	4.50	4.00	4.00	5.00	5.00	5.25	4.50	4.50	3.00	4.50	4.00	4.00	3.60	3.00	3.00
Newark, N. J....	5.25	4.80	3.00	4.80	5.25	4.50	4.50	4.00	3.75	4.00	4.40	5.25	4.50	4.00	2.00	4.00	4.00	4.00	3.75	2.75	2.75
Wilmington, Del..	3.60	4.00	4.50	3.20	4.10	4.00	4.00	3.20	2.75	3.60	2.75	4.00	3.20	3.20	2.75	3.20	2.75	2.75	3.20	1.50	2.75
Philadelphia, Pa.	4.00	4.00	3.60	4.50	5.00	4.50	4.50	3.50	3.20	4.40	4.40	4.75	4.40	3.20	1.75	2.75	3.20	3.60	3.20	1.50	2.50
Scranton, Pa.....	3.00	3.60	4.00	2.40	4.40	4.00	4.00	2.75	3.25	4.00	4.00	4.00	3.75	3.60	2.00	3.75	3.60	3.25	3.25	1.60	2.00
Youngstown, O...	3.60	3.50	3.25	3.00	4.80	3.60	3.50	2.40	2.50	4.00	3.50	3.20	3.00	3.00	2.00	3.00	2.50	2.50	2.75	1.75	1.75
Pittsburg, Pa....	4.25	4.00	3.50	4.00	5.00	4.00	4.00	3.75	3.00	4.50	3.25	4.25	4.50	4.00	2.25	4.50	3.50	3.50	3.50	2.50	2.50
Baltimore, Md...	4.50	3.75	4.00	4.00 to 5.00	3.50 to 5.00	4.00	4.00	3.25	3.25	4.00	3.00	4.50	3.50	3.50	2.00	3.50	3.00	3.50	2.75	2.40	2.40
Washington, D. C.	5.00	4.00	4.00	4.00	5.00	4.00	4.00	4.00	4.00	4.00	2.50	5.00	4.00	4.00	2.25	4.00	4.00	4.00	3.50	1.50	2.50
Wheeling, W. Va.	4.80	4.00	3.20	3.60	4.80	4.00	4.00	3.00	3.00	4.00	3.50	3.50	3.75	3.75	1.25	3.75	3.00	3.20	3.50	2.50	2.50
Cincinnati, O....	4.50	4.50	3.20	3.00	5.00	4.00	4.00	3.60	3.00	4.00	5.00	5.00	4.00	4.00	2.25	4.00	3.00	3.25	3.50	2.00	3.00
Columbus, O.....	4.00	4.00	3.00	3.50	5.00	4.80	3.25	3.50	3.00	3.20	4.00	4.50	4.00	4.00	1.50	2.75	2.75	3.00	2.75	2.50	2.75
Cleveland, O.....	4.80	4.00	4.00	4.00	4.80	4.00	4.50	3.50	2.50	4.00	4.00	4.50	5.00	4.00	2.00	4.50	3.00	3.50	3.00	2.25	2.25
Toledo, O.......	4.00	4.00	4.00	2.40	4.80	3.20	2.00	3.00	2.00	4.25	3.20	4.00	4.00	4.00	1.60	4.00	3.00	3.00	3.00	1.60	2.25

Louisville, Ky....	4.50	4.00	3.00	1.75	4.80	3.00	2.25	3.25	2.00	4.00	4.00	5.00	4.00	4.00	1.25	4.00	2.50	3.25	3.00	1.75	2.50
*Atlanta, Ga.....	3.60	3.50	3.75	3.20	3.60	3.20	3.75	2.60	2.00	3.60	2.00	3.60	3.50	3.50	1.60	2.60	3.00	3.00	2.75	1.25	1.25
Birmingham, Ala.	4.80	3.60	4.50	4.00	5.00	5.00	5.00	3.20	3.00	5.00	3.00	4.50	5.00	5.00	2.50	5.00	3.75	3.50	3.75	1.50	1.50
New Orleans, La.	5.00	3.75	3.25	4.00	5.00	4.00	4.00	3.25	2.40	5.00	4.00	4.00	4.50	4.50	1.40	4.00	3.25	3.60	3.00	1.75	2.60
Galveston, Tex...	6.50	5.00	6.00	4.00	6.50	5.00	5.00	3.60	3.60	6.00	4.50	5.00	5.00	5.00	2.00	5.00	3.20	3.60	3.60	2.00	2.50
Jackson, Miss....	4.80	4.00	4.00	2.50	4.80	3.20	3.20	2.75	3.25	4.00	2.50	4.00	5.50	4.00	1.60	5.40	3.25	3.25	2.40	1.25	1.25
Memphis, Tenn..	5.60	5.60	3.25	4.00	5.60	4.00	4.00	3.60	3.25	4.50	4.00	5.00	5.00	5.00	2.40	2.50	3.25	3.50	3.60	1.20	2.40
Kansas City, Mo.	4.80	4.50	4.00	4.00	5.50	4.50	4.50	3.20	3.00	5.00	4.00	5.50	5.00	5.00	2.00	5.00	3.50	3.50	3.60	2.25	2.75
St. Louis, Mo....	4.80	4.50	4.25	5.00	5.60	4.00	5.00	4.80	4.50	4.50	5.00	6.00	5.25	5.50	3.00	5.25	4.50	5.25	4.00	4.00	4.50
Indianapolis, Ind.	3.75	4.00	2.50	3.50	5.25	4.00	4.00	2.00	2.50	4.00	3.25	4.00	4.00	4.00	2.00	3.25	3.25	3.00	3.00	2.00	3.50
Chicago, Ill......	5.40	4.50	5.60	5.60	5.40	5.00	4.80	4.80	4.75	5.25	5.25	5.50	5.50	5.50	3.00	5.50	4.50	5.50	4.50	3.00	3.00
*G. Rapids, Mich.	4.00	3.50	3.00	2.50	4.50	4.00	4.00	3.00	3.00	4.00	3.60	4.00	3.00	3.00	2.00	3.00	2.50	3.00	3.00	1.25	1.75
Detroit, Mich....	4.50	4.00	3.00	2.25	4.50	3.00	3.00	3.00	2.50	4.00	3.25	4.50	3.75	3.75	2.00	3.00	3.00	3.00	3.00	1.75	1.75
Montreal, Can....	3.50	2.00	2.75	2.00	3.50	2.50	2.25	2.50	2.25	2.00	2.50	3.00	2.50	2.50	1.25	2.50	2.25	2.75	2.50	1.50	1.50
Toronto, Can.....	4.00	4.00	3.20	2.75	4.00	2.25	2.50	2.75	2.40	4.00	3.25	4.00	3.50	3.50	1.25	3.20	2.75	2.40	2.75	2.00	2.40
Milwaukee, Wis..	4.80	4.00	4.00	4.00	4.80	4.00	4.00	3.00	3.25	4.50	4.00	4.80	4.50	4.00	2.00	4.50	3.00	3.00	3.00	2.40	2.40
Duluth, Minn....	4.80	4.50	4.00	3.60	5.25	4.00	4.00	3.60	3.60	4.00	4.00	5.00	5.00	4.80	2.50	5.00	3.75	3.75	3.60	1.60	2.40
St. Paul, Minn...	4.00	4.50	2.75	2.50	4.80	3.00	3.00	3.25	3.00	3.50	4.00	4.50	4.00	4.00	2.75	4.00	3.25	3.25	3.50	1.75	1.75
Minn'polis, Minn.	4.80	4.50	2.75	3.25	4.80	4.00	3.60	3.60	2.25	3.50	4.00	5.00	4.00	4.00	2.00	3.20	3.50	3.00	3.50	1.60	1.60
Omaha, Neb.....	5.00	4.00	4.00	3.00	5.00	4.00	4.00	3.25	4.25	4.00	3.50	5.00	5.00	4.50	2.00	4.50	3.50	3.25	3.50	2.00	2.00
Denver, Colo.....	5.00	5.00	4.00	4.00	6.00	4.50	3.25	4.80	3.20	5.00	4.25	5.50	5.00	5.00	2.50	5.00	4.50	4.25	4.00	3.25	3.25
S. Lake City, Utah	5.00	4.00	5.00	4.00	6.00	5.00	5.00	4.50	5.00	5.00	4.00	5.00	5.00	5.00	2.50	5.00	4.50	3.50	4.50	2.50	3.50
Tacoma, Wash...	5.00	5.60	4.00	3.60	6.00	4.50	4.50	4.00	5.00	5.60	5.00	6.00	5.60	5.60	2.50	5.60	5.00	4.00	4.00	2.50	3.50
Seattle, Wash....	6.00	5.60	5.00	5.00	6.00	4.50	4.50	4.00	5.00	6.00	4.00	5.50	6.50	6.50	3.00	6.50	4.00	3.50	4.00	2.75	4.00
Portland, Ore....	4.50	5.50	3.50	4.00	6.50	3.00	3.00	3.25	3.25	4.00	5.00	6.00	4.75	4.75	2.50	4.50	4.50	3.25	3.50	2.25	2.25
S. Francisco, Cal.	7.00	5.00	6.00	6.00	7.00	5.00	5.00	5.00	5.75	6.00	5.00	7.00	6.00	6.00	3.00	6.00	5.50	5.00	4.50	4.00	4.00
Los Angeles, Cal..	5.00	5.00	3.50	3.00	5.00	3.50	3.50	3.00	3.00	3.50	4.50	5.00	4.00	4.00	2.50	4.00	3.50	3.00	3.50	3.00	3.00

* Nine-hour day.

The cost of making wood templets averages $12 for each sheet of drawings.

TABLE LXVIII.

COST OF SHOP WORK, NOT INCLUDING DRAWINGS OR OFFICE EXPENSES.

	Cents.	
Built columns, 500 lbs. weight or less	.80 per lb.	
Built columns, weighing more than 500 lbs. each	.70 per lb.	
Trusses, weighing less than 1,000 lbs. each	1.00 per lb.	1.2
Trusses, weighing from 1,000 to 2,000 lbs. each	.90 per lb.	1.
Trusses, weighing from 2,000 to 3,000 lbs. each	.80 per lb.	
Trusses, weighing more than 3,000 lbs. each	.70 per lb.	
Plate girders, heavy	.60 per lb.	= 1.3
Plate girders, light	.50 per lb.	
Riveted bracing, struts, etc	.70 per lb.	
Punched purlins	.20 per lb.	

Columns made of H shapes, rolled by the Bethlehem Steel Company, have a less shop cost than those made from separate shapes riveted together, but a higher pound price is charged for the material, so the saving by their use is small.

Beams and channels can be purchased from the rolling mills, punched and framed, according to submitted drawings, and shipped directly to the building site and, wherever possible, it is economy to buy in this way as the additional cost of handling and freight charges are saved. The following charges must, therefore, be added to the base prices given above, when beams and channels are punched or framed at the mills.

TABLE LXIX.

		Cents.
(1)	For cutting to length with less variation than plus or minus ⅜ in	.15
(2)	Plain punching one size hole in web only	.15
(3)	Plain punching one size hole in one or both flanges	.15
(4)	Plain punching one size hole in either web and one flange or web and both flanges	.25
(5)	Plain punching each additional size hole in either web or flanges, web and one flange or web and both flanges	.15
(6)	Plain punching one size hole in flange and another size hole in web of the same beam or channel	.40
(7)	Punching and assembling into girders	.35
(8)	Coping, ordinary beveling, including cutting to exact length, with or without punching; including the riveting or bolting of standard connection angles	.35
(9)	For painting or oiling, one coat, with ordinary paint or oil	.10
(10)	Cambering, beams and channels and other shapes for ships or other purposes	.25
(11)	Bending, or other unusual work, shop rates.	
(12)	For fittings, whether loose or attached, such as angle connections, bolts and separators, tie rods, etc	1.55

Tie rods in all cases where estimated upon in connection with beams or channels are to be classified as fittings.

It is cheaper to field rivet a few connection angles to heavy beams and order the beams with punching only, rather than pay the higher charge for punching and riveting. The few connection angles would then be sent with other riveted material from the structural shop.

The cost of shop work varies considerably, depending on the equipment, and it is needless to use cost units with too fine a gradation.

COST OF FREIGHT.

When the shop that is manufacturing the structural work is a long distance from the source of raw material, which comes chiefly from the Pittsburg district, freight charges must be paid; first, for shipping raw material to the shop, and second, when shipping the manufactured products from the shop to the building site. As raw material can be loaded on cars more compactly than riveted sections, it is economical to have the fabrication done at a plant near the proposed building, so freight charges will be chiefly on raw material.

TABLE LXX.

FREIGHT RATE PER 100 POUNDS, ON STRUCTURAL STEEL FROM PITTSBURG. (DECEMBER, 1910.) IN CARLOAD LOTS.

Pittsburg to New York	16	cents per 100 lbs.
Pittsburg to Philadelphia, Pa	15	cents per 100 lbs.
Pittsburg to Boston	18	cents per 100 lbs.
Pittsburg to Buffalo	11	cents per 100 lbs.
Pittsburg to Cleveland	10	cents per 100 lbs.
Pittsburg to Cincinnati	15	cents per 100 lbs.
Pittsburg to Chicago	18	cents per 100 lbs.
Pittsburg to Indianapolis	17	cents per 100 lbs.
Pittsburg to St. Paul	32	cents per 100 lbs.
Pittsburg to St. Louis	22	cents per 100 lbs.
Pittsburg to New Orleans	30	cents per 100 lbs.
Pittsburg to Kansas City	42½	cents per 100 lbs.
Pittsburg to Birmingham, Ala	45	cents per 100 lbs.
Pittsburg to Coast cities	80	cents per 100 lbs.
Pittsburg to Denver	92½	cents per 100 lbs.

The ability to make low prices on steel structural work depends largely, if not entirely, on the freight charges. A shop east of Pittsburg cannot compete for western work against western shops, for raw material must then be shipped east from Pittsburg and the finished product reshipped west again. The tender of the eastern shop would exceed western prices by the freight charge from Pittsburg to the eastern shop and back again. Shops can, therefore, compete for work only when they are located in the vicinity of the proposed new building, or when a shipment, going from the Pittsburg district to the building site, could pass their shop without much extra cost.

There is greater variation in erection costs than in any other part of the work, for differences of 20 to 30 per cent will sometimes occur, depending upon how well the drawings have been made and manufacturing executed.

The cost of erecting beams and columns in buildings with brick walls is from $6 to $10 per ton, and if the mason does the hoisting, the remaining cost of erection would then be from $4 to $8 per ton. Erecting steel work in buildings with several stories, including hoisting and painting, costs from $8 to $10 per ton when the trusses are riveted and all other joints bolted, while heavy mill buildings will cost from $11 to $15 per ton. The erection of small buildings with all joints bolted, the parts of which can be hoisted with gin poles, will not exceed about $6 per ton.

There are usually about ten field rivets for every ton of structural steel, and these, at 10 cents each, make the cost of field riveting about $1.00 per ton. Field rivets driven under favorable circumstances with the structural work on skids or on the ground, will not cost more than 5 to 8 cents apiece, while those driven with the parts erected in position and the workmen standing on scaffolding or staging, may cost from 15 to 20 cents each. Bolts are usually as good as rivets for field connection and are more economical.

A pier shed in New York City, 56 feet wide and 545 feet long, was erected in nine working days by fifty men, working eight hours per day. The building was covered with corrugated iron, contained 350 tons of steel, and trusses were spaced 20 feet apart.

Another similar pier shed in New York was erected by a crew of ten men who averaged four trusses per day including all bracing.

COST OF ESTIMATING AND TIME REQUIRED.

The time occupied in making an approximate estimate of any ordinary structure need not exceed a few minutes, as weights can be taken from curves or figured from formulæ.

In taking off quantities and figuring the weight of steel cage construction, a man can estimate about 300 tons per day. Therefore, if a proposed new building contains 1,500 tons of steel, it can be taken off and estimated by one man in five days, or several men in proportionately less time.

The estimating of mill buildings and light construction requires more time. An engineer, who is continuously employed on building work, will probably estimate from 10,000 to 15,000 tons of steel per year, and secure from 10 to 20% of this in contracts. A good estimator would then obtain contracts for 1,000 to 3,000 tons of steel per year. A man regularly occupied in this work, would probably average four to five estimates per week, and the cost of these, including show drawings, would be from $10 to $15 each.

TENDERS.

After adding all the items that affect the final cost, including 2 to 3 per cent for contingencies, the contractor will add whatever profit he considers the work worth, and submit his tender. He should state very clearly what is or is not included in his price, so there will be no misunderstanding. If the estimate is on plans, which have been submitted to him, it will probably be a benefit for the contractor to make one or more alternate prices or reductions for proposed changes from the plans, or he may submit a different plan and a price thereon. In any case, the proposal must state that the price is based on plans and specifications, so there can be no misunderstanding.

Tenders should be written in the following forms. The first is for a steel mill building erected complete, while the second is a proposal on a building for export, and the price given is for material only, not including ocean freight or erection.

PROPOSAL FOR A STEEL MILL BUILDING ERECTED IN THE UNITED STATES.

Chicago, Ill., January 1, 1910.

The Wright Air Ship Company,
Chicago Ill.

Gentlemen:—We propose to supply all labor and furnish, deliver and erect at the site, all material necessary to complete a building for the Wright Air Ship Company, according to plans and specifications, for the sum of .... dollars. This proposal includes all structural steel work, corrugated iron, gutters, conductors, flashing, louvres, doors and windows, painted two coats, but does not include either ground floor or foundations.

(Signed) The Mill Construction Company,
John Jones, Secretary.

PROPOSAL FOR MATERIAL IN MILL BUILDING FOR EXPORT.

Chicago, Ill., January 1, 1910.

The Oriental Shipping Company,
Hong Kong, China.

Gentlemen:—We propose to furnish and deliver F. O. B. cars on the wharf at New York city, all steel structural work, corrugated iron, gutters, down spouts, louvres, flashing, wire netting, doors, windows, and glass, together with all necessary nails, rivets, bolts, etc., for erection, in a building for the Oriental Shipping Company, Hong Kong, China, for the sum of

.... dollars, according to the accompanying drawing. This quotation does not include ocean freight, erection or the cost of ground floor, foundations, partitions, or any material except that stated. The shipment will contain .... pieces, having a shipping weight of .... tons and occupy .... cubic feet in the vessel.

(Signed) The American Structural Company,
William Brown, President.

PREPARATION OF ESTIMATE FOR DRAFTING ROOM.

When a contract is secured, the design should be carefully reviewed , all dimensions verified, directions made distinct and clear, and the design plainly illustrated. After several days, places may be found where improvements can be made or the work cheapened. The picture drawing should be made to correspond with the revised strain sheets.

All notes or instructions should be written and accompany the estimate, as some requirements can be more easily described than illustrated. Instructions about shipping, when material will be needed, and which parts first, whom to see or correspond with to secure further information, color of paint and number of coats, etc., should be all noted in writing. The contract may not include all items in the estimate and it should be clearly stated what it covers. When all data and papers in connection with the work have been collected, they should be blue printed for the drafting office, and the originals kept on file for record. Some shops give to the drafting office prints of only such sheets as are needed, reserving weights of steel and cost pages.

CHAPTER XLIII.

APPROXIMATE ESTIMATING PRICES.

Materials—Delivered.			
Cement, Portland, Pacific Coast, per bbl.............$	2.20	to $	2.50
Cement, Portland, East, per bbl	1.35	to	1.75
Cement, Rosendale, per bbl	.80	to	1.00
Cement, Non-staining, per bbl	3.00	to	3.50
Lime, per bu	.20	to	.25
Sand, per cu. yd	1.00	to	1.50
Gravel, per cu. yd	1.00	to	1.25
Crushed limestone, per cu. yd	.75	to	1.25
Crushed granite, per cu. yd	3.00	to	3.50
Stone sill, 8×12 ins., per lineal ft			1.25
Stone sill, 5×12 ins., per lineal ft			.80
Stone sill, 4× 8 ins., per lineal ft			.45
Stone sill, 5× 8 ins., per lineal ft			.60
Stone sill, 4×10 ins., per lineal ft			.60
Stone steps, 7×14 ins., per lineal ft			.90
Brick, common, per M	6.00	to	10.00
Brick, face, per M	25.00	to	30.00
Brick, molded, per M	40.00	to	50.00
Brick, enameled, per M	70.00	to	80.00
Masonry—In place.			
Excavating, general, per cu. yd	.25	to	.50
Excavating, trench, per cu. yd	.50	to	1.00
Excavating, under water, per cu. yd	3.00	to	4.00
Filling, per cu. yd	.25	to	.50
Rubble—Masonry, Rosendale Cement, per cu. yd	4.50	to	5.50
Rubble—Masonry, Portland Cement, per cu. yd	5.50	to	6.50
Bedford limestone, per cu. ft			1.60
Carthage limestone, per cu. ft			2.30
Kasota or Mankota stone, per cu. ft			2.80
Granite, per cu. ft			3.50
Bedford Ashlar, 4 to 8 ins. thick, per sq. ft			1.00
Blue stone pier caps, per cu. ft			2.00
Ground floors, 1 in. cement on 6 in. concrete, per sq. yd.			1.40
Ground floors, ½ in. cement on 4½ in. concrete, per sq. yd			1.25
Ground floors, asphalt on 6 in. concrete, per sq. yd	1.40	to	3.25
Ground floors, asphalt block, per sq. yd	2.00	to	2.50
Ground floors, wood block, per sq. yd	1.50	to	2.25
Ground floors, brick paving, per sq. yd			2.50
Concrete sidewalk, per sq. yd	1.80	to	2.40
Concrete sidewalk, surface finish only, per sq. yd	.60	to	.90
Upper floors, fireproof, including form, per sq. ft	.35	to	.45
Piling.			
Wood piling, in place, driven and cut, per lin. ft	.25	to	.35
Concrete piling, in place, per lin. ft			1.25
Sheet piling, in place, per M			40.00
Concrete—			
Concrete in place, large mass., natural cement, per cu. yd.............$	4.00	to $	5.00
Concrete in place, Portland cement, per cu. yd	5.00	to	7.00

Concrete, in wall with forms, per cu. yd.	6.00 to	8.00
Reinforced concrete, roof slabs, 15 ft. span, sq. ft.	.25 to	.30
Reinforced concrete, floor slabs, 8-10 ft. (conc., steel and forms), per sq. ft.	.30	.40
Cement floor surface finish, per sq. ft.		.07
Reinforced concrete, including steel, per cu. yd.	10.00 to	12.00
Reinforced concrete, including steel and forms, per cu. yd.	16.00 to	20.00
Reinforcing bars, plain, per ton		30.00
Reinforcing bars, patent, per ton		50.00
Forms for reinforced concrete, per sq. ft.	.05 to	.08
Reinforced girder and columns (conc., steel and forms), per lin. ft.		1.00
Reinforced columns, wound, per lin. ft.		1.70
Wood forms for reinforced beams and columns, per lin. ft.		.50
2-in. concrete roof slab on trussit, per sq. ft.	.15 to	.18
3-in. concrete roof slab on trussit, per, sq. ft.	.20 to	.22
No. 10 expanded metal, 4 in. mesh, per sq. ft.		.035
3-in. concrete roof slab and expanded metal, per sq. ft.		.15
3-in. concrete partition slabs and expanded metal, with ¾ channel, per sq. ft.		.17
Brickwork.		
Common, in lime mortar, per M		18.00
Common, in Rosendale cement, per M		19.00
Common, in Portland cement, per M		20.00
Face brick, per M		45.00
Moulded brick, per M		70.00
Enamel brick, per M		100.00
Carpentry and Mill Work.		
Windows and doors, complete with glass and finish, per sq. ft.		.50
Windows and doors, frames only, in place, per sq. ft.		.20
Sash, 1¾-in. thick, not glazed, per sq. ft.		.07
Sash, 2⅛-in. thick, not glazed, per sq. ft.		.14
Sash, glazed and painted, in place, per sq. ft.	.15 to	.25
Double floors on wood joist, per sq. ft.	.12 to	.16
Spruce lumber, in place, per M		25.00
H. P. joists, purlins, etc., in place, per M		30.00
H. P. matched flooring, in place, per M		35.00
Maple flooring, No. 1 factory, 1½x13/16 ins., per M	70.00 to	80.00
Lumber in cofferdams, per M		40.00
Board fence, per lin. ft.	.50 to	1.00
Stairs, 3 ft. wide, good finish, per step	2.50 to	3.00
Stairs, 3 ft. wide, rear, per step	1.50 to	2.00
Structural Steel.		
Steel truss and column framing, in place, per lb.		.04
Steel beams, in place, per lb.		.03
Plain Castings, per lb.		.02
Ornamental Iron.		
Mason treads, per sq. ft.		2.00
Elevator fronts, per sq. ft.	1.00 to	2.00
Iron stairs, 3 ft. wide, 5c. per pound, per step	8.00 to	9.00
Fire escape, 10c. per pound, per story		100.00
Metal clothes lockers, 18×20×72 ins., in place, each		8.00
Pipe railing, 1 line, per lin. ft.		.50
Pipe railing, 3 line, per lin. ft.		1.00
Railing, plain lattice, per lin. ft.	2.00 to	3.00
Railing, fancy lattice, per lin. ft.	4.00 to	5.00
Cast iron cols., plain, per lb.		.015
Cast iron cols., ornamental, per lb.		.03

Roofing.			
Slate on board (boards not included), per sq	7.00	to	13.00
Tin on board (boards not included), per sq	10.00	to	12.00
Gravel on board (boards not included), per sq	5.00	to	6.00
Composition on board (boards not included), per sq	2.00	to	5.00
Wood shingles on board (boards not included), per sq.	3.00	to	5.00
Corrugated iron on purlins, per sq	7.00	to	9.00
Metal tile, tin, per sq	8.00	to	10.00
Metal tile, lead coated, per sq	10.00	to	14.00
Sheet copper, per sq	35.00	to	40.00
Ornamental clay tiles, per sq	40.00	to	60.00
Spanish tile, per sq			22.00
Ludowici, per sq			16.00
Sheet Metal Work.			
Metal windows, without glass, hung, per sq ft			.55
Metal windows, without glass, trunnioned, per sq. ft.			.40
Metal windows, glazed, with polished wire glass, per sq. ft.			1.10
Metal windows, glazed, with ribbed or maize glass, per sq. ft.			.80
Ribbed or maize glass, any size, in place, per sq. ft.			.25
Double strength clear glass, per sq. ft	.07	to	.10
Richardson metal doors, per sq. ft			1.30
Rolling steel shutters, per sq. ft			.50
Corrugated iron doors and shutters, per sq. ft			.35
Metal louvres, fixed, per sq ft			.40
Metal louvres, hinged, per sq. ft			.60
Round ventilators, each	5.00	to	100.00
Corrugated iron, No. 26 galvanized, in place, per sq			6.50
Corrugated iron, No. 26, black, in place, per sq			4.50
Corrugated iron, No. 22, galvanized, in place, per sq			9.00
Corrugated iron, No. 22, black, in place, per sq			7.00
Corrugated iron, No. 20, black, in place, per sq			9.50
Corrugated iron, No. 18, black, in place, per sq			11.50
Galvanized cornice, in place, per sq. ft			.12
Copper cornice, 16 ounce, per sq. ft			.35
Lath and Plaster.			
Wood lath, in place, per sq. yd	.08	to	.12
Metal lath, in place, per sq. yd	.18	to	.20
Plaster, 3 coats, interior, per sq. yd	.20	to	.21
Plaster, 3 coats, on wood lath, interior, per sq. yd	.28	to	.33
Plaster, 2 coats, on metal lath, interior, per sq. yd			.40
Plaster, 3 coats, on metal lath, interior, per sq. yd			.50
Plaster, on Sacket board, per sq. yd	.30	to	.36
Exterior plaster, 2 coats, on brick wall, without lath, per sq. yd	.50	to	.60
Rough cast on 2 coats of plaster and metal lath for covering frame building, per sq. yd	.80	to	.90
Painting.			
Prepared paint, per gal	.60	to	1.50
Painting structural steel, per coat, per ton			1.00
Painting miscellaneous iron work, per ton			1.50
Surface painting, 1 coat, per sq. yd	.10	to	.12
Surface painting, 2 coats, per sq. yd	.18	to	.20
Surface painting, 3 coats, per sq. yd	.25	to	.28
Plumbing.			
Water closets, in place, with pipes and attachment, each			70.00
Slop sinks, in place, with pipes and attachment, each			60.00
Lavatories, in place, with pipes			50.00
Marble toilet room partitions, per sq. ft			1.25
Marble toilet bases, countersunk, per sq. ft			1.85

CHAPTER XLIII.

THE DRAFTING OFFICE.

The office is the principal workshop. No part of industrial plants shows greater progress than the office and drafting rooms. Twenty years ago many offices were only a few dingy and ill-lighted rooms partitioned off from the shop, the air loaded with gas and fumes, the floors uneven and the ceilings festooned with cobwebs.

The modern office should contain everything necessary for the

Fig. 638.

convenience and comfort of its occupants, in order that they may give their best service. These features should exist in an equal or greater degree than in the shops, because office men or brain workers with less physical exercise are usually of a more nervous temperament. As the office produces no dust or dirt, there is no reason why its interior arrangements cannot be made both convenient and attractive. It must be light, well ventilated and have arrangements for heating in winter and cooling in summer.

LOCATION.

In large works it is customary to locate the drafting office on the upper floors of the executive building, because this office is constantly in communication with the management. The whole office building should be centrally located and convenient to the shops, and the sketches in Chapter I show it as the group center, with shops around it. The drafting office and the templet shop are so often in consultation that many plants have these two departments in the same building, the former occupying the second floor of the templet building. The arrangement is not entirely satisfactory, however, for the templet shop is noisy, often dusty, and contains dry combustible lumber, which exposes the office contents to serious fire risk. The more recent practice is to house all records and drawings in a fireproof building, using one or two lower floors for executive offices and upper floors for drafting rooms. These several story buildings should have elevators and stairs, the elevator taking passengers up and the stairs being used in coming down.

There is a noticeable tendency towards moving large drafting offices from the city to the suburbs, but this is more applicable to city offices which have no shop connection than for shop offices. It has the advantage of lessening the rent, while employees have better light and air, and because of rural surroundings, can do better work. At the suburban office, draftsmen can spend the noon hour out in the sunshine, by the water or among the trees, rather than on the hot and dusty pavements in the foul city atmosphere. The drafting offices of several architectural firms have been moved each summer to the seashore, in the belief that the workers will not only be benefited, but will also do more and better work.

THE BUILDING.

A fireproof building is the only kind suitable for housing valuable drawings. It should be fireproof in order that drawings in use can safely be left at the draftsmen's tables instead of being placed every night in a vault. The drawings and records are so valuable, that a fire loss can never be covered. In addition to the building being fireproof, it should contain one or more record

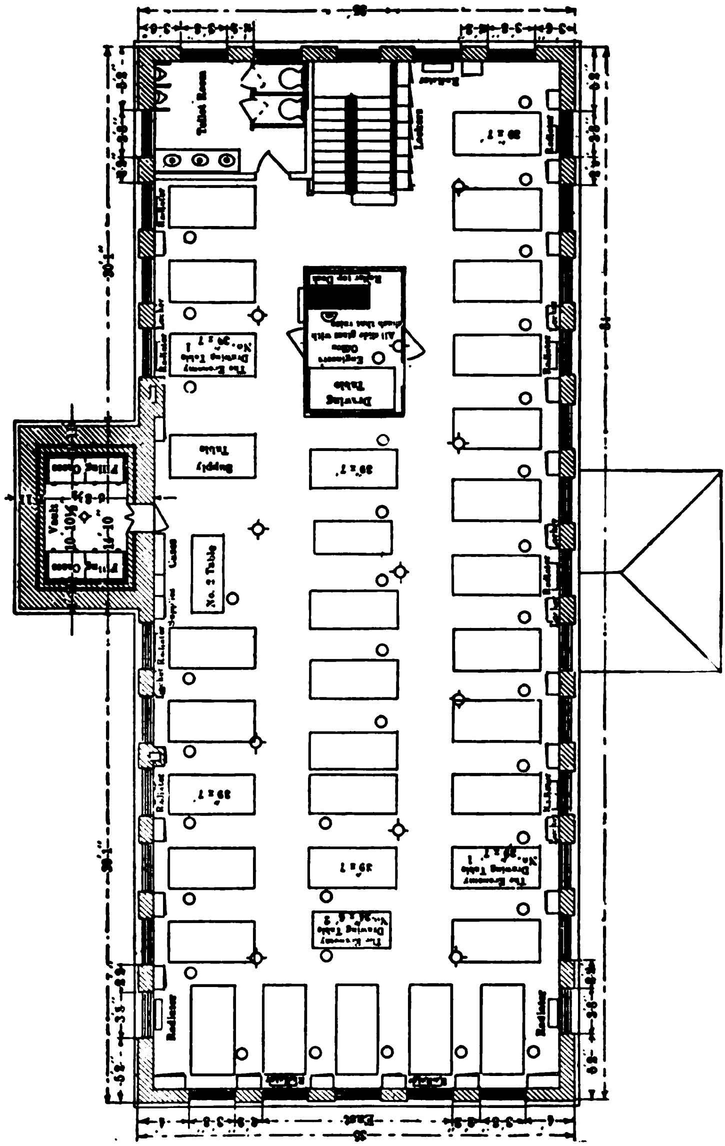


Fig. 634.

rooms built like vaults, with the least amount of combustible material, for storing drawings no longer in regular use.

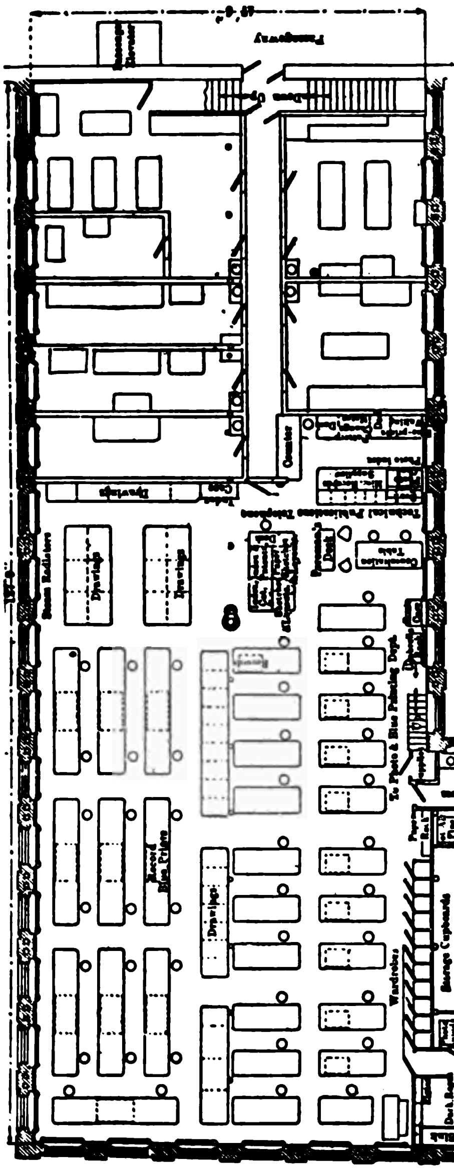
As far as constructive features are concerned, an office building is similar to those used for light manufacturing. There is no reason why work in an office cannot be done as well or better on several floors as on a single floor. On the other hand, the building with several floors has better air and light, and costs less for the required floor area. The subject of relative economy of buildings with one or more stories has been discussed in Chapter IV. It has been shown that the greatest economy for light floor loads results from using buildings of not less than three or four stories, for above the first story there is no further expense for roof or ground, the only extra expense being for the floor and enclosing walls.

WELFARE FEATURES.

Nearly all large factory offices are making provision in some way for the comforts and needs of the workers. In structural offices it is customary to find a room devoted to library purposes, where technical and trade journals pertaining to the business are on file. This feature, while very agreeable to the employees, is not charitable, for the owners are benefited in giving the workmen opportunities to learn from the trade journals the latest and best working methods. These rooms are supplied with technical books pertaining to structural engineering, so all may become proficient. Arrangements are made for taking books and magazines out over night, by leaving a card with some one who has charge of the room.

A dining room is another provision, where meals are served for a small sum, usually not much over cost price. Some works have their own dining room on the top floor of the office building, but this is a mistake, for many men remain in the building from morning till night. It is better to have the dining room in a separate building at a distance from the office, so all will get out in the open air at the noon hour. The exercise in the open air is beneficial and gives a change of thought and outlook. Service buildings of this kind are shown in Fig. 2. A ball ground is another common provision. The game takes thought away from work, and gives the men clearer brains for the afternoon's duties.

The Toledo office of the American Bridge Company, shown in Figs. 633 and 634, is located on the outskirts of the city, in a district free from smoke and dust, with a lawn around the building,



Floor Area	Sq. ft.
Drafting Room	4129
Engineering Depts.	2142
Room for Photographing Mach'ry	475
Photographing & Blue-Printing Dept.	640
Total	7386

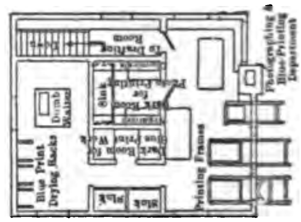


Fig. 635.

and two tennis courts in the rear. The basement contains kitchen, dining room, bicycle rooms and general toilet.

The best place for a printing room is in the upper story, or on the roof, where direct sunlight is always available. Besides the general printing room, there should be a dark room for making sensitive paper and for photo developing. The modern printing room is equipped with both sunlight frames and electric printing machines. The light from electric machines is so much more uniform than the varying sunlight, that many offices prefer to use it exclusively. With these machines, there is no need for estimating the degree of light, as it is uniform, and the same kind of paper will always print in the same length of time. When printing by sunlight, especially on cloudy or partly cloudy days, the clouds must be carefully watched, so the print will have the right amount of light.

Photography is an important part of an office equipment, for all important buildings made, should be photographed, and some shops are using photo reproduction for drawings, especially those for field or erection use. The cost of photo reproduction exceeds ordinary blue printing by only 15 to 20 per cent, and the advantage from the smaller drawings is great.

The type printing machine may be kept either in the printing room or in the general drawing office. It is used for placing titles, or any other wording that is repeated on several drawings.

The printing room of the Brown-Sharpe Company is shown in Fig. 635. There should be heating coils and drying racks over dripping trays lined with zinc.

THE FILE AND RECORD ROOM.

While the entire office building should be fireproof, so drawings can safely be left on the draftsmen's tables, there should be storage vaults for complete drawings which are used only for occasional reference. These record rooms should be as nearly fireproof as possible, with tile floors and sheet metal filing drawers. Some offices insist on placing all drawings every night in the safe or vault, causing a daily loss of time in waiting for them. In these offices it is common for fifty men or more to lose ten to fifteen minutes twice a day in collecting drawings for the vault, and waiting their turn to be served. Drawings that are in daily use or in course of making, should be kept at draftsmen's tables, and the vault used only for those drawings which are completed. The record room should be in charge of one person who is responsible for the safe keeping of records. There should be a complete card index in the drafting room adjoining the vault, so drawings can be easily found. When drawings are delivered, a receipt card should be left until they are returned.

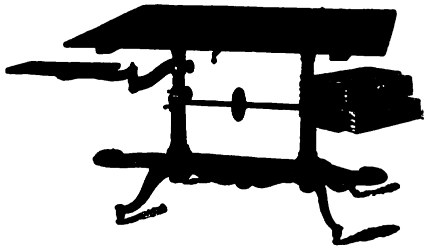


Fig. 636.

There should also be small drawers for filing photo plates and films, each one being placed inside an envelope, with a blue print of the plate pasted on the outside, in order that the picture can be seen without removing the original.

A common fault with record rooms is that they are too small for handling and sorting drawings. They should be large and spacious, and have a counter or table for holding tracings before

Fig. 637.

filing. The drawers in the record room should be 26 by 38 inches, with hinged lids at the front to hold the drawings down.

THE SUPPLY ROOM.

The store room for stationery and supplies should be convenient to the drafting office, and need contain only enough supplies for immediate use, being replenished occasionally from the general store. A few drawers or a locker press in the drafting room may be sufficient.

INSIDE ARRANGEMENT.

The interior of the office should be so furnished and arranged that accurate drawings can be made with the least interruption and the greatest ease. It should have a solid floor, free from vibration, and a wearing surface of pine or maple. The principal space will be used for drafting tables, placed around the wall, with the left end adjoining the windows. They should stand crosswise and not facing the wall, for then light is better, and the work of various men is separated. Tables should be spaced not less than four feet apart, so the men will have plenty of room for free movement. Down the center of the room should be a line of drawer cases with drawers on both sides for drawings that are in use. The tops of these tables are convenient for sorting and spreading plans. Drawers should have double handles and a metal holder on each for a card label. There are many kinds of drawing tables, most of them

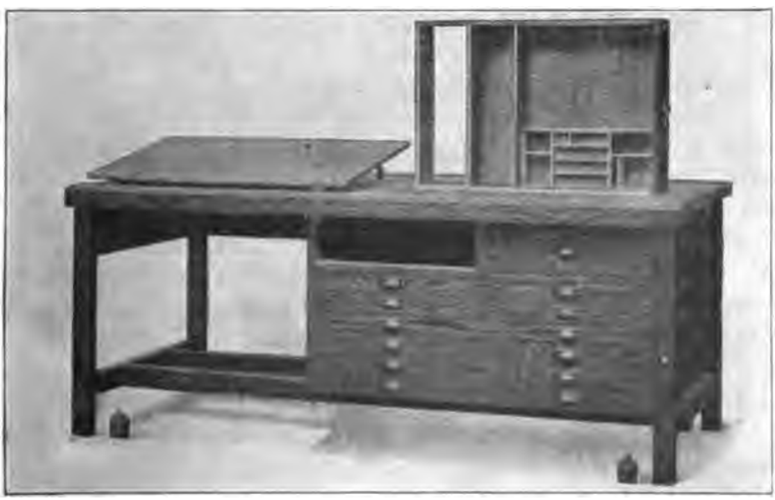


Fig. 638.

existing because of patent royalties which their originators receive. No table is more convenient than one 3 feet wide, 6 feet long and 3 feet 6 inches high with adjustable hinged leaf on the right end, which can be made of pine in any carpenter shop. There should be a tier of three drawers 6 by 15 inches at the right end, and three large drawers at the center 28 by 40 inches wide and 3 inches deep. The office should have an assortment of inclined raising blocks of different heights, for elevating the drawing board to a convenient position. In addition to these, the tables may have extension legs, to be used or removed to suit. Other kinds of tables are shown in Figs. 636 to 640. Figure 641 shows the interior of an office where the table tops are hinged and can be raised or lowered as desired. These vertical drawing boards are not satisfactory, for

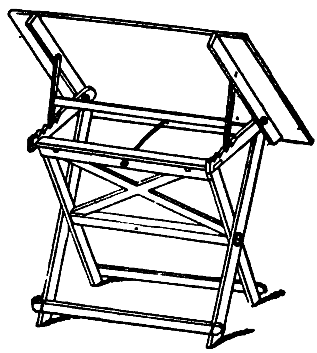


Fig. 639.

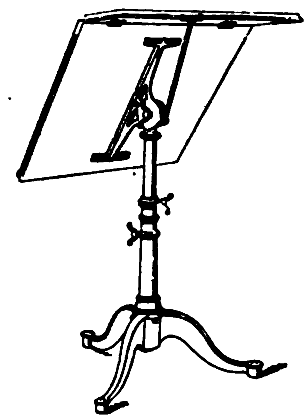


Fig. 640.

articles will not remain on them. The only sloping part should be the drawing board, and not the table top, for a level table is needed for books and papers. Adjustable drawing tables soon become unsteady and the absence of drawers is a detriment. Each table should have a revolving high stool, with circular foot rests, mounted on rubber tips, and a low chair for occasional use. The regular drawing boards should be not less than 30 $\times$ 48 inches, but there should be a few larger ones, 36 $\times$ 60 inches, for occasional special work, and some smaller ones, 18 $\times$ 24, for studies. Drawing boards should be $1\frac{1}{8}$ inches thick or more, and they may be lightened by grooving out the backs, and stiffened by two mortised cross bars. They must receive neither oil nor varnish. It is convenient to have a light gas pipe frame in front of each table, from which to suspend general or reference drawings, as shown in Fig. 641. The upper rail should have sliding spring clips or fasteners to grip the drawings. On the wall adjoining the tables there should be individual book cases with locks, as shown in Fig. 634, and near the entrance a clothes room with separate lockers for each occupant. These will add greatly to the neatness of the room.

Yellow or other colored drawing paper is less tiresome to the eyes than white, and is therefore preferred. Colored paper is sold in rolls, and one or two of these may be mounted on rollers in the drafting office and paper cut off in lengths as needed. White paper is sold in sheets and may be kept in drawers. Roll paper is satis-

Fig. 641.

factory for ordinary structural drawings, but as it warps and will not lie flat on the board, is unsuitable for fine work. For small scale drawings with much detail, strong white sheets which will stand erasing are preferable. The paper sheets of ordinary structural work are kept only until the work is erected or completed, when they are of no further use and may be destroyed. Tracings only are retained.

It was formerly the practice in some offices to place wood partitions about 7 feet in height between the tables, making separate stalls or compartments. This prevented attention being turned to the work of others and made more wall space on which to hang up drawings; but the partitions obstruct light and permit those to shirk who are inclined to idleness, so preference is now to have the entire office clear of partitions which prevent the men from being seen from every part of the room. For this reason, stair, elevator shafts or vaults that are needed near the center of the drafting room should be built out from the main building, leaving the main room rectangular in shape and allowing each table to be seen, as shown in Fig. 642.

The office superintendent should have a private room either at one end or near the middle of the main floor, with continuous glass around the sides above the wainscot. The glass allows him to see the entire office, and forms no obstruction to sight. It may be located at one end, as shown in Fig. 642, with a second stairway to the floor below. Where there is only one stairway, the superintendent's room is more convenient near the center of the drafting room, adjacent to the stairs and elevator.

There should be speaking tube and dumb waiter to the blue print room and a private telephone system connecting all departments and the shops. The order department is in close touch with the drafting office, and an order room may be made at one end, as shown in Fig. 642. In this department all material is ordered that is required for the building, much of it being copied from the bills on the drawings. A valuable addition to the drafting room is a catalogue case with a classified card index, and each catalogue numbered. The case should be locked, and when books are taken, a memoranda card should be left with the name of the borrower, and date taken. Sweet's indexed catalogue contains a summary of many others, but there is much information in the originals too bulky to be contained in it.

The drafting office should have a system of loose-leaf scrap books for clippings pertaining to the business. It is customary for manufacturing companies to receive duplicate copies of trade journals, and one set may be used for clippings. An hour or two should be set apart by the engineer or chief draftsman for reveiwing these journals, and the work of marking, clipping and arranging in loose-leaf books can be done by a clerk. After the journals are reviewed in the drafting office, they should be passed on to another department for further clippings valuable to them. There should also be loose-leaf books with views of recent plants or buildings.

NATURAL LIGHTING.

Ribbed glass in the upper sash will better diffuse light throughout the room than plain glass, but the lower sash should have heavy clear glass with adjustable lower blinds raising from the bottom. In upper stories, one or two box skylights are desirable with adjustable shades, but they must be carefully made to prevent water from driving in during heavy storms and destroying the drawings.

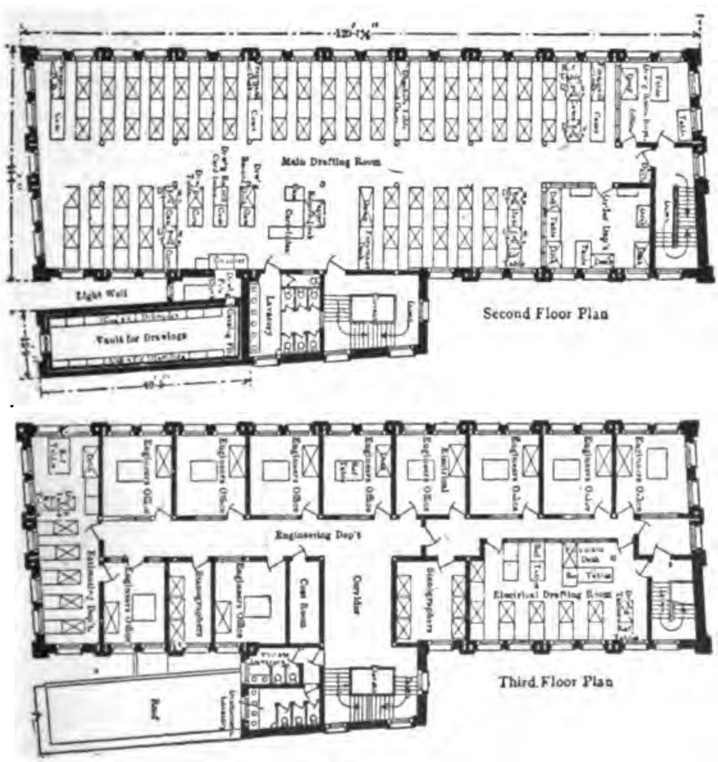


Fig. 642.

Leakage at night may do serious damage before being discovered. Skylights are good only for general lighting, as shadows are cast by the body on the drawing board. Light should come from the left, and is best when tables are arranged with their ends adjoining the windows. The amount of light is doubled when the interior walls and ceiling is white or a light color. There should be a wainscot of dark color about 5 feet above the floor, but the remainder of the walls and ceiling may be colored light blue or green, which will not soil as quickly as white and is not so tiresome to the eyes. The furniture and wood work should preferably be finished in natural wood, oiled and varnished. The general effect will be better than when a dark stain or paint is used.

Fig. 643.

ARTIFICIAL LIGHTING.

The drafting room must be well lighted, for effective work is impossible without it. The best kind of artificial lighting results from a combination of arc and incandescent lamps. Figure 645, taken at night, shows an arrangement of lamp shades throwing the light to the ceiling, from which it is reflected uniformly to the floor. In addition to the ceiling lights, there should be individual ones at the tables with green shades, either suspended by cords or held by adjustable arms or brackets, so light can be concentrated at any place.

HEATING AND VENTILATING.

If heating coils are used beneath the windows, the degree of heat should not be so great that air will be excessively warm near the radiators and chilly in the middle of the room. Improper heating is frequently the cause of colds and sickness and can be avoided. When warm air from a heating chamber is blown into the office, it may be passed through a washing vapor, and only clean air supplied. This is a great advantage when offices are located in a smoky district, adjoining the works. Impure air and smoke in the office is not only injurious to the occupants, but it soils and damages the drawings and other contents of the building. The process of washing, therefore, supplies clean air at all times, warmed in winter and cooled in summer. If ventilation is insufficient, it may be improved by a few ceiling fans, at small expense, as shown in Figs. 644 and 645.

LAVATORIES AND PLUMBING.

Toilet rooms should be placed on each floor, with one bowl for every ten or twelve occupants. Where less provision is made, there will be loss of time at certain hours of the day. There must also be washbowls in the toilet room and several individual ones in the drafting room. Cooled and filtered drinking water may be piped through the building from a center filter, or it may be supplied from separate cooling tanks in the various rooms.

CHAPTER XLIV.

ORGANIZATION OF DRAFTING OFFICE.

The drafting offices of many large structural plants are an important part of their organization. In them designs are originated and details perfected. Drafting office practice has a double interest to the designer of mill buildings, for not only is the engineer interested in the organization and management of the office in which he himself is engaged, but he is also interested in making office buildings for other industrial plants.

Fig. 644.

The engineering department of a structural company engaged in the design and manufacture of steel mill and industrial buildings is generally divided into two principal parts, (1) the designing and estimating, and (2) the drafting and detailing departments. A description of the usual methods followed in the designing and estimating department is given in another chapter, and the drafting office practice only is discussed here. As the drafting department contains from four to five times as many men as are needed in estimating, there is need for economy and uniform working methods.

Drawings are the principal medium by which knowledge of a design is conveyed from one man or set of men to another. The art of drawing has been likened to a language, and those who understand it best are best able to express their thoughts by drawings and to read and learn the thoughts so expressed.

It is assumed here that designs and general plans are already made, and the drafting department is called upon to elaborate these designs and make working drawings. The purpose of details is to supply the workmen in the shop with such information as they will need, and to answer all their inquiries. The draftsman should remember that while he may have the data by which to verify dimensions or clearances, the workmen in the shop have no such data and must make the pieces exactly as they are shown, without perhaps even knowing their location in the building, or to what other pieces they connect. He should therefore make a very careful study of two questions: (1) what information should be given to the shop, and (2) how that information can best be given.

The economic organization and management of drafting offices, where the office force is engaged in designing and detailing steel mill buildings, is important, because nearly all such buildings have their particular needs and require special plans. It is very seldom that a set of plans made for one building is suitable for reproduction. The great proportion of manufacturing done at structural shops is special work, and this requires the services of a large number of skilled workmen. Draftsmen are well-paid workmen, and the expense of these offices is high. There is, therefore, need for careful organization to get the best results for the least money.

Making drawings for structural steel work is important, because of the value of steel and the time required in procuring it. A building contractor in making timber trusses does not need elaborate details, showing the exact position of holes for nails and bolts, for these holes can be bored after the timbers are assembled, and spikes or nails driven where required. If a mistake is made in boring these holes, the loss incurred is not great and no long delay would follow, for well stocked lumber yards are everywhere and new timber could be bought at a day's notice. In steel construction the conditions are different. Boring holes in metal is not economical, and the various parts composing a truss are cut and punched before being assembled. With timber trusses, if a piece is found too long, it can easily be shortened with a hand saw without sending it back to the shop or to a shearing machine. With steel framing, it is economical to have all the parts cut to their correct length and shape and all holes punched in their exact position before the parts are assembled. When the various pieces for a wooden building are shipped to the site, if mistakes are discovered, columns or purlins found too long, it will take but a few minutes to cut them off and

Fig. 645.

remedy the error, but if similar mistakes are discovered in parts of a steel building, the pieces would need shipping back to the works, causing several days' delay, or it might be possible to cut off the surplus length with sledge hammers and cold chisels; in either case to remedy the error is expensive.

Accuracy is therefore the chief essential in a structural drafting room. It has been conclusively proven that money spent in making clear and neat drawings that can be read without difficulty, and in checking and verifying them, is saved many times before the work is completed.

Draftsmen should make a practice of frequently visiting the shops and studying and examining their practices. They should be as familiar with these methods as are the shop men themselves. Draftsmen will find it greatly to their benefit to converse freely with the workmen and particularly with the department foremen, who are usually pleased to give information. There is no better way for a draftsman to become conversant with shop methods.

Jealousy and rivalry are often the cause of scant courtesy between various departments. It is better for the proprietors and stockholders, and also for the men themselves, that friendly relations be maintained, for there will then be better coöperation with correspondingly better results. It is the custom in some organizations which have numerous departments to have frequent evening meetings of the department managers to arrange the work for the best interests of all; this brings the various departments to work in unison with less misunderstanding and fewer losses.

Draftsmen as a class are accustomed to moving about freely from one plant to another in order to broaden their knowledge and experience. The subdivision of labor, even in drafting offices, which keeps one man or set of men continuously at one kind of work, is largely responsible for this frequent moving. The monotony of constant indoor work of the same kind makes even the expense and trouble of moving a pleasure for the change secured. Changes are so frequent in structural drafting offices and new men so often employed that large companies issue illustrated pamphlets, setting forth in detail their methods of making drawings and doing work. These pamphlets in many cases are quite elaborate and are either printed in type or bound in blue print form. They show the shop and office practice, and draftsmen must familiarize themselves with these methods and incorporate them in their work. Many shops that formerly left minor details to the templet makers are now having these details figured on the drawings, and this makes extra work in the drafting room.

Any set of rules drawn for the guidance of draftsmen will need modification to adapt it to a particular shop, for tools, appliances and practice greatly vary. The directions given here are therefore intended merely as a general guide and will not necessarily be suitable for all plants.

ORGANIZATION.

The degree of organization needed in a drafting office depends upon the number of men employed. If there are not over six or eight, little or no organization is needed, excepting to fix the office hours and appoint a leader. The effect of consolidation is, however, tending to collect forces into greater numbers, and most structural works now have large drafting offices. It is common to find structural shops using from fifty to one hundred draftsmen, and then organization is needed.

Both engineering and executive ability are required. It was formerly the practice to select one man as the leader, and to depend on him, not only to employ men and manage the office, but also to act as detail engineer. It is now realized that these two kinds of service cannot be expected in any great degree from the same man, for if he becomes absorbed in making economical designs he will probably neglect executive duties. The present practice, therefore, in many of the largest works is to have two heads for the drafting department, one an executive or superintendent, and the other an engineer or chief draftsman.

Under these heads the office should be divided into parties, each containing four to eight men, who will work unitedly on the drawings for separate buildings, but will not interfere with other parties. They should be assembled at tables adjoining each other, and one man, known as "squad foreman," selected as a leader for each party, who will have charge of the work.

The parties will contain men with various degrees of skill, two or three being competent to work independently in laying out and designing details, while the rest, known as tracers, may be less experienced, giving their time chiefly to actually making the finished drawings.

There must also be checkers for verifying drawings after they are finished, generally one of these men for each party. The checkers should be assembled by themselves for ease in consultation, so their work will be done uniformly. They should work under the direction of the chief draftsman and not in any of the squads, to insure greater freedom in making changes where desirable or necessary.

There is usually some machine drawing in a structural drafting office, in connection with shop cranes or other mechanical appliances, and in an office of fifty draftsmen there should be one or two mechanical draftsmen, and all drawings for the machine shop should be made by them. In an office of this size there should also be one or two experienced in architectural work, for, while mill and factory buildings are not usually works of architecture, it is desirable to make them look as attractive as possible. The services of these men may also be needed in the designing and estimating department, in tendering for large building contracts containing architectural design, either on the exterior, or interior design for offices.

It may be necessary to make complete architectural drawings when tendering for work, and contracts are sometimes secured conditional on the steel contractor supplying free of charge the complete drawings for the building. At other times when tendering for attractive work it may greatly add to the chances of getting it if the proposal is accompanied by a water color perspective of the building. In all such work the services of architectural draftsmen will be of great value. The extra expense of these drawings is small in comparison to the prospective profits.

The blue printing and photographic departments will need the services of two or three men with separate rooms, and large offices should have one man whose duty it is to take charge of and file all drawings and other records. There should also be two or three boys for messenger service.

In an office of fifty men, not including the printing department, messengers and filing clerk, there will be—

1 Head Draftsman,
3 Mechanical Draftsmen,
1 Architectural Draftsman,
5 Checkers,
5 Drafting Squads with 8 men each.

If the shop contracts for structural work other than mill and factory buildings, it is better to divide the office into two departments, giving all the mill buildings to one department, and other structural work, such as that for office buildings, warehouses, business blocks, etc., to the other. If these departments are large enough to warrant it, there should be a head draftsman appointed for each.

SUBDIVISION OF LABOR.

It is economical for all work of the same kind to be done as far as possible by the same men. These men benefit by experience, and mistakes are not repeated. Perhaps the greatest benefit that is derived from the subdivision of labor is that the various shops become accustomed to receiving drawings made by the same lot of men, and the shop man and draftsmen learn to better understand each others' methods. The shop men become familiar with the drawings and know where to look for information, because of the uniformity of their methods. Subdivision of labor is the source of great economy in production, though it becomes tiresome to the workmen, who get little variety or change. The draftsmen tire of one continuous kind of work, and are often obliged to change from one office to another to relieve the monotony, but notwithstanding this, most large offices retain the system. It is practiced to such a degree in some works that men are kept continuously working on drawings of the same kind. One draftsman will make drawings of building columns, another of roof trusses, another will make bracing drawings, etc., each becoming so accustomed to his particular work that it is made easily, uniformly and with the least number of mistakes. The system has proved so economical that shops adhere to it, even though men leave and new ones must be employed. Draftsmen generally prefer to work in small offices, for subdivision of labor is then impractical and the duties of the men are more varied. It is quite common for men in a large office to be employed for a year or more making drawings of the same kind, and they will be so busily engaged that they may not have time to become familiar with the design as a whole.

THE CHIEF ENGINEER.

The chief engineer of a plant usually gives his principal attention to the designs and estimates, and his work is referred to at greater length in the chapter on "Estimating."

OFFICE SUPERINTENDENT.

The duties of the office superintendent are to employ and discharge men and see that work in the office is being carried on with the greatest economy. He must see that men are employed on work to which they are best suited, judge of their capabilities and see that office hours are enforced and employees giving good service. He should keep account of the cost of drawings made by different squads, and for different kinds of building. The superintendent should see that the office is working in harmony with the estimating department and with the shops, and should have a system of order blanks for the various departments to issue on each other. These written orders and receipts should be given when drawings are received and delivered. He must also have an office timekeeper, who will tabulate the time spent by every man on each particular contract, as well as noting any days that the men are absent. These time records are important in computing the cost of drawings for various buildings. The rating of office employees will be fixed by the superintendent and he will arrange vacations.

HEAD DRAFTSMAN.

The head draftsman must receive from the estimating and contracting department all available data, stress sheets, specifications, etc., relating to each building contract. When the office contains several squads, it is better that he give his time to supervision. He must keep careful record showing when all orders were received, when drawings were started, when completed, and the date when any or all drawings were sent to the shops, that he may know on short notice what progress has been made on any particular contract. It is customary to have a great many building contracts under way at the same time, and without a detailed record it would be difficult to make quick progress reports. A convenient record book for this purpose is one which can be carried in the pocket, with pages ruled in columns, allowing one column for each kind of information, with one horizontal line for each job. It is possible to tabulate a large amount of information in this way in a very compact space. When this is kept up to date, the head draftsman can report at once the progress made on drawings for each building. To avoid misunderstanding the head draftsman should give his orders only to the checkers and squad foremen, and not to the members of the squads. While his duties are principally in connection with the drawings, he should be a good manager and leader, so there will be no friction between the men under his direction. Contracts may be secured which have detail drawings, and these details must be examined to see where they need changing to suit shop practice. It is frequently easier to have such details redrawn than to change several sets of blue prints. All contracts received in the drafting office will be given a number, and the head draftsman must see that data papers come to him in duplicate, one set for his own record and the other for the squad foreman. All instructions must be written. The head draftsman must consult with squad foremen and checkers, with the officers of the company, with the contracting department, and with the shop foreman.

SQUAD FOREMAN.

The squad foreman will receive from the head draftsman all papers and data relating to the buildings for which his party is to make the drawings. As he may have several buildings under way at the same time, he must keep sepafate files for the papers relating to each. Spring clips are convenient for this purpose, when the files are not too large, and these may be hung on the wall convenient to the tables. For a large number of papers ordinary letter files are convenient. He must keep a record of the time when all papers are received, when drawings are completed, the number of drawings made for each building, and amount of time spent by men on different ones. This will enable him to keep account of the work under his direction. Rivalry between the squads will often result in a greater amount of work being done. Verbal instructions must be written, with the date when they were received, and placed in their proper file. Drawings and papers of every description must be dated; this is very important, as claims often depend upon the dates when material was ordered or work completed. An experienced draftsman should make from 30 to 40 square feet of finished drawings per week, including making corrections after they are checked; a beginner will make not more than half that amount. Drawings for ordinary mill buildings, including the design for details, order bills and shop lists, should not cost more than $1 per square foot.

The squad foreman must be an engineer, able to design all details and check the general design as it comes from the estimating department. He must make the general sketches from which material is ordered, and either order the material or check the list as written down by the others. If time will permit, he should check the stress sheets, for it is sometimes economical to change certain sizes to suit better details. Squads should be assembled by themselves, so work can be carried on with the least amount of traveling about the office. The squad foreman should give his chief attention to seeing that details are properly designed and drawings made economically. If he is unable to design all the details himself, he must see that they are properly designed by others, or when not employed in supervision, must himself be a worker. The cost of details made by experienced designers may be from 20 to 50 per cent less than those made by less experienced men, chiefly because of the less amount of metal used. It is therefore very important to have this work properly done by draftsmen who understand detail design.

Where a building is large or complicated it is convenient to have the general drawings traced, and provide each man who is working on the drawings with blue prints. Blue prints of the general drawing should also be sent to the works with the first lot of details, in order that the shop men may have an intelligent idea of what they are making.

Loose leaf books are preferable to others. When calculations are completed they can be filed away with other papers and the books used again.

The squad foreman must know the capabilities of the men and what work he can safely entrust to them. He must see that no parts or details be shown or ordered more than once.

CHAPTER LXV.

DRAFTING OFFICE PRACTICE.*

PRELIMINARY SKETCHES.

The first duty of the squad foreman after receiving orders to make detail drawings for a building is to prepare preliminary sketches complete enough for ordering material. If it is known that the required stock is in the company's yard in long lengths, it is then necessary to write an order with only approximate lengths, so it may be reserved for this particular building. This is done only when the work must be completed in a time which is insufficient to have special material delivered from the mill in the lengths needed. If long stock from the yard must be cut, the purchaser must generally pay a higher price than when time will permit the right lengths to be ordered from the mill. In the former case there will be waste in the ends that are cut, for a portion of which the purchaser must pay. Some of the cuttings can be used for details, but as the method involves waste it is better to order in exact lengths when time will allow. Some designers prefer to use two different scales for preliminary sketches, a small one for the general outline and a larger one for the joint details. A uniform small scale of one-half inch per foot has the advantage over the above method in that many proportions can be fixed by the experienced eye which cannot as well be done when different ones are used. Only enough drawing need be done on preliminary sketches to determine the lengths and sizes of materials. Joint plates must have the number and position of rivets shown to scale. The rivets are first located, spacing them not less than three diameters of the rivet apart, and then around the rivets the outline of a plate is drawn which will contain them. The size and allowable shearing and bearing pressures on rivets are given in any of the mill handbooks. For heavy work with large stresses the center lines of pieces must intersect at points, but members with small stresses, the joints of which have surplus strength, may be assembled at the panel points to produce the most compact and neat arrangement,

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* H. G. Tyrrell, Engineering News, March 23, 1905.

without regard to center lines. When the sketches are started right the work will advance smoothly, but if commenced wrong there is likely to be confusion until it is finished. Single pieces like purlins may be ordered directly from line diagrams, allowing clearance at the joints. A stiffer building results when purlin splices are staggered than when joints are all at the same panels.

ORDERING MATERIAL.

In ordering material, a schedule should be made for one piece, and the total number of pieces given. Parts like trusses, symmetrical about the center, should be scheduled by listing the material in one-half the truss, giving the number of half trusses.

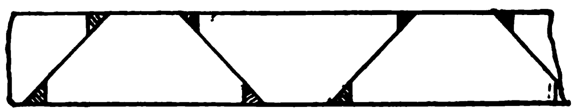

Fig. 646.

There is less chance for error in this way than when the total number of pieces is written at first. After the schedule has been made for all the pieces it should be recopied, writing all material of the same form and size together and separating soft from medium steel. It is better for this purpose to have blank forms with two columns for lengths—one for finished lengths and another for lengths in which material is ordered, which may contain only a small excess for trimming, or may be in long pieces.

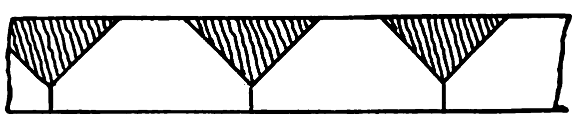

Fig. 647.

Beams, channels and tees are ordered by weight per foot, and all other shapes by width and thickness. Weight and thickness should not both be given, or confusion will follow. Short pieces should be ordered in long lengths not exceeding 40 to 50 feet for large angles or 30 feet for smaller ones which might bend when handling. Plates should not generally be ordered longer than 20 feet, for greater lengths are difficult to handle and can be raised only on a stiff frame or lifting piece. Irregular shaped connection plates should be ordered in multiple lengths with edges alternating, as shown in Fig. 646. Widths of plates should always be given in inches. If ends of pieces are to be milled, the material should be ordered one-fourth inch long for each end so finished. An extra charge is made by the mill if beams and channels are required in lengths with less variation than $\frac{3}{8}$ inch either way. Therefore, for ordinary work, beams and channels should be ordered $\frac{1}{2}$ inch shorter than the panel lengths. In ordering rods or eye bars requiring heads, allowance should be made for the extra length needed in forming them. The mills which make eye bars give the extra length required for forging heads in their machines. If plates are to be heated and bent, some allowance should be made for trimming the plate afterwards, as it may not bend exactly to the line. Long plates which must be straight on the edges, such as girder covers, are called Universal Mill and must be so marked on the order. Turned pins are ordered $\frac{1}{16}$ inch larger than the finished size, but small bracing or cotter pins are usually made of cold rolled shafting and ordered in exact size. Corrugated iron is made in even lengths from 4 to 8 feet. In ordering matched lumber over one inch in thickness, from one-fifth to one-sixth should be added for the tongues. Beams, channels or angle purlins that require only a small amount of shop work, perhaps no more than punching, should be shipped directly from the mill to the building site, thereby saving freight.

MASONRY PLAN.

After the preliminary sketches have been made and the material order written, the ground plan should be drawn so the foundations can be built to suit the prospective building. Unless the steel contract includes the foundation, which is rarely the case, it will be necessary to show only enough on the plan to enable the owner or local builder to make them fit the steel. The location of walls and piers should be shown, and a detail drawn for one pier indicating the exact position of the anchor bolts in reference to its center. If the walls have steel columns, a detail should be drawn with a general scale of $\frac{1}{4}$ or $\frac{1}{8}$ inch per foot, with other details to a larger scale. The general dimensions must all be given. A copy of this should be sent to the owner or local builder. If the steel contract includes the foundations, a complete plan should be drawn with all details thereon.

LAYING OUT WORK.

If the design is simple, the preliminary sketches used in ordering material may be a sufficient guide for the detailers, but when buildings are complicated, further general drawings are needed. It is important to start correctly, for it is easier to redraw an entire sheet than to make the corrections on a drawing that was wrongly laid out. It is easier to lay out simple work directly on the cloth, using pencil as little as possible, than to draw on paper and then trace. In many cases lines can be drawn at once in ink with a great saving in time. More difficult work requiring much study must be drawn and figured first on paper, for too many changes and erasures would be needed if this kind of work were put directly on cloth. The connections are the first to be detailed when starting a layout, and these parts may be indicated in red ink on the detail drawing for the purpose of showing clearances. After connections are detailed the balance of the member can be elaborated. If the process were reversed and the connections left until the last, it would then be found that many minor details which could just as well have been made in some other way, interfere with the joints and must be changed. Purlins should be located to suit standard lengths of sheathing, allowing a 4-inch lap for corrugated iron on the sides of buildings and 6-inch lap on the roof. Widths of roof monitors should be made to suit some even length of sheet from 4 to 8 feet.

It must be remembered in laying out, that the maximum sizes accepted by the railroad companies for shipping are widths up to 8 feet, heights up to 10 feet, and lengths for ordinary cars of 30 to 40 feet. In special cases, long girders may be shipped on two cars with a spacer car between them. In this way girders of over 100 feet in length may be loaded. It simplifies calculations to assume rivet values in round numbers, making gussets thick enough so the bearing value of rivets in the plate will at least equal the shearing value of the rivet. It is close enough to assume working values of rivets $\frac{5}{8}$, $\frac{3}{4}$ and $\frac{7}{8}$ inch diameter as 2,000, 3,000 and 4,000 pounds, respectively. The results are quite as good with much less labor as when values are assumed in exact units. Stiff members must be used wherever possible. The practice of using flat bars for the tension members of roof trusses is wrong, for they do not hold their shape when handled, and when once bent are seldom straightened. Work should be laid out so shop rivets can be used in preference to field rivets or bolts. Shop rivets costing 2 cents each, would cost 5 cents if field riveted under favorable circumstances. In wide angles with two or more rows of rivets in each leg, it is better to place the rivets in the two legs opposite each other, rather than make any effort at staggering, the inner row in one leg being opposite the outer row of the other. This will prevent interference when driving and save much time that would be consumed in figuring exact stagger. Moreover, there is no section area saved by alternating in angles having two or more rows in each leg. The method of placing rivets opposite each other has the advantage of preventing the rivets from interfering with outstanding legs of stiffening angles, as happens when the rivets in one flange stagger with those in the other flange. If there is only one row of rivets in each flange, it will then be better to alternate the rivets, for placing them opposite cuts out too great an area from the angles. When rivets alternate, the stagger should, for appearance sake, be exact.

Wherever possible, rivets should be symmetrical about a center line, for half templets may then be used with a proportionate saving in expense. Bracing should be stiff, as rods sag and rattle

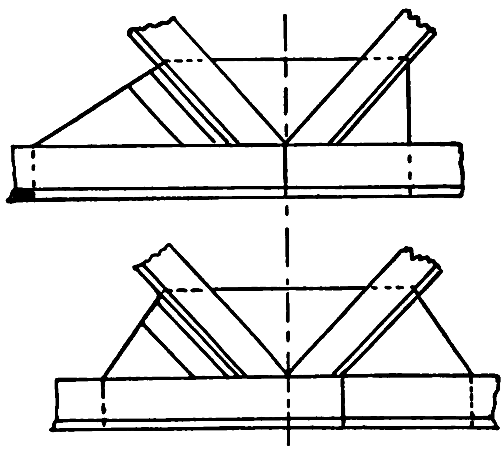

Fig. 648.

Fig. 649.

when loose. Simple angles may be used for roof purlins in lengths up to 15 feet, but from 15 to 20 feet they should be trussed, preferably with a light angle. Purlins should be bolted to the trusses and fastened through clips, rather than directly to the rafters. An essential in designing details is to make the joints stiff and have the whole frame well braced and rigid. If more than three rivets are used in the end of a piece, it is better to use lock angles and fasten the members by both legs. One size of rivets, especially for field joints, is preferable to several. It is better to increase the dimensions of a few members than to use several rivet sizes, requiring material to be moved about to different punching machines. When rivets resist direct stress, as those at truss joints, it is economical to use larger ones because fewer will then be needed, but when they are merely stitch rivets for holding parts together, it is better to use smaller ones. Stitch rivets have very little stress upon them and small ones are easier to drive. The work should be designed so there will be the least number of hand driven rivets. Joints should be made so that they can be bolted up during erection and made secure in the shortest possible time. Trusses 40 feet in length or less should usually be shipped loose, with only the connections and detail parts shop riveted to the members. The minimum freight charge for an entire car is for a weight of 30,000 pounds. The partial carload rate is higher per pound, but the weight to be shipped may be so small that a net saving will result by sending it loose.

Joint plates such as those used in trusses should, wherever possible, be made symmetrical, and this can generally be done by using a little care in locating the splice. Fig. 648 shows a common way of detailing joint plates by splicing the truss chord at the panel point, but by moving the splice slightly to the right, as shown in Fig. 649, a symmetrical plate results which has a much better appearance. Pin plates must have enough rivets to safely transmit the pressure on them from the pin into the chord section through shearing on the pin plate rivets. The thickness of plates must be great enough so the safe bearing pressure on pins will not be exceeded. Roof purlins at the gables must be either bolted to a continuous angle at the wall or have separate anchors or hooks holding them to the brickwork. When the purlins overhang the ends of the building, there should be a fascia or finish angle covering the purlin ends and the unprotected edge of the corrugated iron. At the eave, for both brick and corrugated iron walls, there should be a strut joining the tops of the columns. When bays exceed 15 feet in length, there should be rods $\frac{3}{8}$ or $\frac{1}{2}$ inch in diameter between the purlins to prevent them from sagging. Members composed of two channels should have the flanges turned out to allow the rivets to be machine driven, for if turned in, it may be difficult to insert the arm of a machine. Hand riveting is more expensive and not as satisfactory as power driving. Struts composed of two angles placed back to back should be united by stitch rivets from 3 to 4 feet apart. Roof trusses should be cambered not less than 2 inches in every 100 feet, and the amount of camber should be marked on the drawing at every panel point. Standard size sheets will, on an average, require from two to three days for laying out and making ready for tracing.

TRACING DRAWINGS.

The finished drawing is the final result of the engineering and drafting departments, and it is therefore important that it be neatly and carefully made. Some offices still use the services of beginners for tracing, while others prefer a higher grade of men for this work, the latter being the better plan. It is folly for experienced engineers to spend valuable time in perfecting designs and carefully laying out working drawings, and then permit beginners to trace these drawings so poorly that much of their meaning is lost. It is better to have the men who made the drawings trace their own work, and use assistants only for putting on printing and figures. It is preferable to detail pieces in the position which they will occupy in the building, columns being vertical, girders horizontal, etc. The top view of a piece should be placed above it in its natural position and the bottom view below the elevation, but top and bottom views should not be combined in one, as it is confusing. It is better to spend more time in drawing separate views than to take chances on causing errors. Center and dimension lines should be fine black, of uniform thickness, but full enough for printing. Red ink should never be used on tracings excepting for connections and for checking marks. It shows only faintly on blue prints and not plain enough for the principal drawing. Lines showing the picture of a piece should be solid but not so heavy that clearness in detail is lost. When drawings are copied by the photograph process, lines must be heavier than is permissible for blue printing, because in photo reproduction the thickness of lines is reduced in proportion to the reduction of the drawing. The style of lettering should be small block, inclined for greater ease in making at a slight angle to the vertical. The letters should be about $\frac{1}{8}$ inch high and made with a fairly coarse pen. In writing letters and figures, care must be taken to make them open, so adjoining lines will not run together and form blots. Letters indicating assembling and shipping marks should be larger and more pronounced, and from $\frac{3}{16}$ to $\frac{1}{4}$ inch high.

In the upper left hand corner there should be a small diagram of the whole building frame drawn in fine black lines, with the particular part detailed on that sheet emphasized in heavy black. This diagram allows the eye to see at once without reading the title of the drawing, the location of the piece detailed. Where there is doubt about details, notes on the drawing will often add clearness, but should not be made to take the place of drawings. Some offices make a practice of so burdening drawings with notes that it is difficult to know the actual detail from some other piece which is not shown but described. It is clearer to make a new drawing, showing the other piece, than to try reading it from notes on a piece which it resembles. Doubt about the makeup of a piece can be removed by showing a cross section. Sections at one end of members are one of the best means of making drawings plain, and should be freely used. Cloth and paper are cheaper than time spent in deciphering obscure details, and extra sketches should always be added where needed. Particulars in reference to reaming, painting, size of holes, distinction between bolts and rivets, or other information which cannot easily be shown, should be described by notes.

Only three or four standard sizes of sheets should be used, the regular one being 24 by 36 inches. Other convenient sizes are 18 by 24, and 12 by 18 inches, or one-half and one-fourth the regular sheets. Each sheet should have a fine border line about one inch from the trimming edge. This gives the drawing a finished appearance and shows, when printed, that no parts are missing. These lines should not be heavy, for they would then detract attention from the essential part. If there are many sheets to be joined they should be lettered, and a diagram put on one sheet showing the method of assembling them. It is convenient to make casting drawings not larger than 12 by 18 inches, and to place prints of them in a loose leaf book for future reference. The loose leaf file allows parts to be arranged in subjects, and when castings are needed, the draftsman should see whether drawings previously made for other contracts can be used again, thereby saving the expense of new drawings and patterns. This casting book should be kept in the drafting office, where it may be consulted freely without loss of time.

On the lower right hand corner of each sheet should be placed the title of the drawing, name of the manufacturing or engineering company, contract number, sheet number, total number of sheets in the set, date, and name or initials of the men who made and checked the drawing. These data will appear more uniform when put on with rubber stamps, but as india ink cannot be used with stamps, the letters on the tracing cloth must be blackened with drawing ink. A title as described above is shown in Fig. 650. The contract number, by which the work is known, rather than by the name, should be printed in large figures so it will at once be evident. Most large drafting offices have small printing presses for putting on titles or notes which are repeated on several sheets. The printing is more quickly done with a machine and looks better than hand work. Several sheets may be printed at one time, when the drawings are completed. When pieces are right and left, it is understood that the one shown is the right hand piece, and the other one is the left hand. The words right and left have no reference to the right and left sides of the building, but simply denote that the pieces are in pairs. It is frequently possible to avoid making rights and left by simply countersinking or driving a few more rivets, or making some other minor change, which may be unnecessary excepting for this purpose. The extra expense is warranted, for it may avoid serious errors during erection. It is a common mistake in erection to put right hand pieces where left hand ones belong, and this may often be avoided by a little addi-

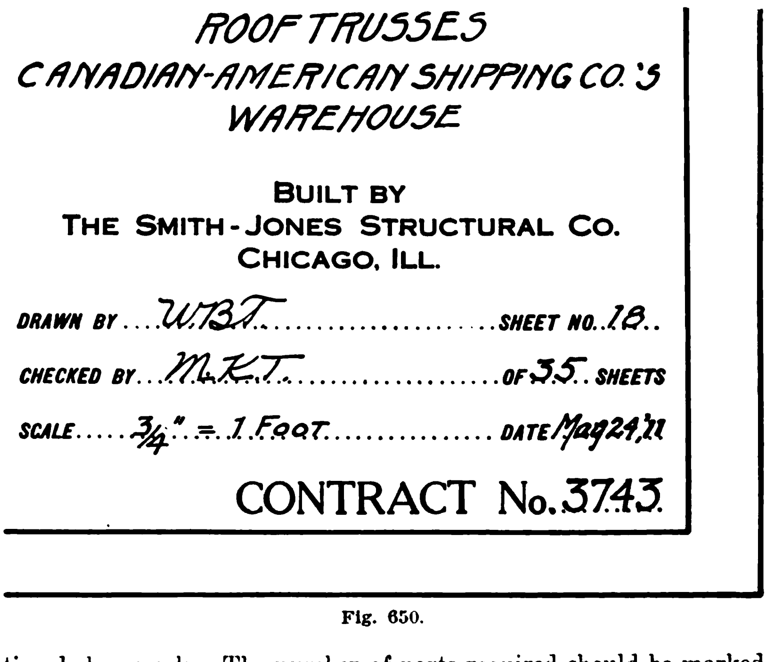

Fig. 650.

tional shop work. The number of parts required should be marked below each piece in letters about $\frac{3}{16}$ inch high. In giving dimensions, the draftsman should consider what ones he would need, were he the shop work man about to make the piece, and then give these dimensions and no more. Tracings should be made on the dull side of the cloth, and if the ink will not run smoothly, the cloth should be rubbed well with powdered chalk and then wiped clean with a soft cloth. Each drawing should be complete in itself, and reference from one sheet to another should not be necessary. As drawings are the final product of the drafting office and expensive, blue prints should be made from them and the original tracings filed. Changes on cloth must be made with soft ink erasers, and never with a knife or sharp instrument. Fractions should be written with horizontal rather than with oblique lines, to avoid any possibility of confusing such fractions as 13/16 with $1\frac{3}{16}$. Section views should be hatched or blackened, and when several blackened parts join each other, white lines or spaces must be left between them. Holes for field bolts and rivets should be blackened. Sheets should be numbered in the order in which material is required at the building, the foundation plan being Number 1, column Number 2, etc. Many dimensions on complicated trusses may be omitted, for such trusses will be laid out on the templet shop floor, and the position of rivets will be determined from the layout rather than from the drawings. Details for different shops should be kept on separate sheets, forgings on a sheet for the forge shop, machine parts on another sheet for the machine shop, etc. Standard beam and channel framing as given in mill handbooks should be used wherever possible. Clevises, turnbuckles, forkeyes, loop rods, pins, washers, etc., should be shown on standard blanks printed on strong linen paper, thin enough for blue printing and strong enough for erasures. Blank forms are also used for the different kinds of framed beams and channels. These blanks are either letter or cap size, 8 by 10 or 8 by 13 inches, and they are a great saving in time, as it is necessary only to write in the figures without any drawing. An extra blank may be used for miscellaneous sketches to be filled in free hand. Some of these forms are shown in Figs. 242 and 243.

MARKING DRAWINGS.

There are two kinds of marks used on shop drawings, assembly and erection marks. The former are wholly for the use of men in the assembly shop, and it is preferable to have them written on the templet shop blue prints with yellow pencil, and the prints passed on to the assembly shop. Assembly marks are sometimes written on the tracings, and similar parts should then be similarly indicated. Truss members would be T1, T2, T3, etc., gusset plates G1, G2, G3, etc., angle clips C1, C2, C3, etc. Only pieces that are exact duplicates should be stamped the same. The shipping marks of individual pieces serve also for assembly and all parts that are shipped separately, must have a different erection mark. Letters R and L refer to pieces which are right and left and should be written after the regular signs.

CHECKING.

There should be one checker for each squad. When drawings have been carefully made by men who understand their work, little will be needed. The principal trouble in checking is in overhauling work done by inexperienced men.

The several checkers in an office should be assembled by themselves, so they may compare notes with each other and work more uniformly. They should work under the direction of the head draftsman rather than in the squads, for they will then have greater liberty in making changes if such are desirable. Some offices have the false idea that money is saved by employing low priced draftsmen, whereas records made by the writer show that drawings by inexperienced men cost more than twice as much in actual wages as those made by experienced men who know their business and are better paid. To this difference must be added the extra cost of checking poor drawings, and the additional cost of working from them in the shop. It has been conclusively proven that money spent in making drawings that are neat, plain and accurate is saved many times over before the work is completed. Especially is this true in reference to checking. If the joints are complicated it is better to make a separate layout showing all rivets, to a size which can be safely scaled. Nothing must be assumed in checking, but everything investigated. It is especially important that field connections be correctly drawn, as errors discovered during erection cause greater expense than if found before the pieces have left the shop. The holes in pieces for field connections must correspond and be the same size. Sections must be compared with the stress sheets to see that the correct ones are used. A drawing should never be checked by the man that made it. After figures have been verified they should be marked with a lot of red ink, for red will print but faintly and will not rub off when the drawing is being cleaned. Corrections should be marked with a blue pencil, and new figures placed far enough away from the old ones so they will not be erased. The blue pencil marks will not print, are plainly seen, and easily cleaned off.

The following points should be considered when verifying drawings and they should be checked as to—

(1) Size of material compared with stress sheet.
(2) Size of holes for connecting parts.

(3) Number of field rivets at joints.
(4) Reaming or drilling of field connections.
(5) Number of main pieces required.
(6) Right or left of shipping pieces.
(7) Center lengths.
(8) Milling of ends if needed.
(9) Bevels for mitered joints.
(10) Need of countersinking.
(11) Insertion or driving of field rivets or bolts.

A checking list of building parts such as given in Chapter XL should be reviewed to see that all matters have received attention, and all needed parts called for on the shipping list.

CORRECTING DRAWINGS.

In order to have a drawing checked or verified, two persons must agree upon all of its details and particulars. It must, therefore, be an absolute rule that no changes shall be made until the maker and the checker have agreed. Some shops permit checkers to make changes on plans without having the changes sanctioned by the maker, but such drawings are really not checked at all, and are little better than when reviewed only by the men who made them. Blue pencil marks must be left on the tracings and not removed until the checker has again examined them, for if they are erased he will have no means of knowing whether the corrections have been made or not. When tracings have been altered and changes approved by the checker, the drawings should be cleaned with wool or waste saturated with gasoline or benzine, which should be kept in an automatic self-sealing metal bottle.

CHANGING SHOP PRINTS.

When changes are needed on drawings, prints of which have gone into the shop, the prints must either be collected and returned to the office for correction, or a draftsman must go through the shops and make the alteration on the prints with ink, marking each one with the date when changes were made. The tracings must be similarly changed and dated, and immediately corrected when discovered, inquiry being made to find if any work has been done on the parts affected.

LISTING.

There must be a bill of material for each separate shipping piece in order to know what parts to bring into the assembling shop. This bill should list the largest pieces first, with detail parts later. There must be two columns for lengths, one for the finished length, and the other for the length in which the material was ordered. If ordered in long lengths, it may contain only a small excess for trimming or milling. Where assembly marks are given, there should be a separate column for these in the bill. It is convenient to write the bill of material on the drawing, though some shops prefer to use small separate forms. There must also be a set of rivet and bolt lists, showing in detail the size and length of bolts and rivets for all joints, with marks showing parts which they connect. These lists should have one column for the grip and another for the total length beneath the heads. After they are completed, a summary of rivets and bolts should be made and written on a separate summary sheet. As there is usually some loss, and the lengths listed are not always used where they belong, there should be about 20 per cent more bolts and rivets shipped than are actually needed, the ones not used being returned.

A shipping list should be made, giving the marks of all the separate pieces with the size and a brief description. On this should be written all the structural steel members, corrugated iron, flashing, gutters, lumber, conductors, bolts and rivets, tools, spikes, railings, doors, windows, shutters, and all other articles needed to completely erect the building. It is very important that all pieces be placed on the shipping list, as express charges are high on additional parts which may have been forgotten. Lists should not be made until after the drawings are completed, for changes on them may seriously affect the lists or require them to be made over. Truss sections can be most easily identified by small free-hand sketches with extreme dimensions. Lateral plates projecting from the side of trusses or girders should be sent loose, as they are liable to be broken if shipped in place. Loose fillers should be avoided and should be tack riveted.

COPYING LISTS.

Lists are more quickly copied when written with ink made for printograph blocks than when blue printed. A dozen copies can be made on one of these blocks in five minutes, which might require an hour to print.

ERECTION DRAWINGS.

The erection drawing is a skeleton outline on which is indicated the shipping marks of separate pieces, length and position of corrugated iron, flashing, gutters, and all other parts going into the building. Bars and rods are described by their size and length, while pins are stamped with a mark on their ends. All general dimensions must be given, and expansion joints, if any, must be shown. Directions must also be given for the final painting, color, number of coats, etc. On this sheet there should also be a table of all the drawings and their titles. As erection labor is done under unfavorable circumstances and field errors are expensive, care should be taken to have the erection drawings as complete as possible. If it is discovered during erection that some pieces have been made too long, these may have to be sent back to the shop, and perhaps delay the work several days, awaiting their return. The cost of erection often varies from 20 to 30 per cent, depending upon the quality of the drawings, accuracy of shop work and other conditions. The plan should show the direction of column webs, the way channels turn, and all other information that the erection men will need. Field riveting of trusses when required, is cheapest when done on the ground, for if rivets are driven with the truss erected in position, the cost may increase from five cents to twenty-five cents per rivet, owing to the need of temporary staging. No staging is required when pieces are bolted in position.

FILING DRAWINGS AND LISTS.

Drawings should be laid out flat in drawers and not rolled, for after being rolled they are difficult to handle. Lists may be kept in ordinary letter files in the order of contract numbers. Some shops make a practice of filing drawings of similar buildings in drawers by themselves, but it is better to have contract numbers consecutive. Other shops number all drawings in numerical order, instead of marking each separate set of drawings upward from Number 1. The drawers in which they are filed should be about 30 by 40 inches inside, so occasional ones of a larger size than 24 by 36 can be included.

COPYING DRAWINGS.

The method almost exclusively used for copying drawings is blue printing. White prints are made by first making Van Dyke negatives, but they require twice the time and the resulting prints are no better than blue prints for ordinary use. White prints are used principally when it is desired to call attention to drawings of unusual importance. Drawings which are continuously used in the shop may be mounted on stiff cardboard and varnished. These will not soil so quickly and dust and oil may be removed with a cloth. There will usually be from twelve to fifteen sets of prints required, distributed as follows: Six for the shops, one for the inspector, two for approval, and two or three sets for the owners' files.

Fig. 651.

PHOTO REPRODUCTION.

There has been but little progress in the methods of copying drawings since the advent of blue printing. Photographic reproduction is occasionally used, but not as extensively as its merits deserve. The reason this method is not more generally used is no doubt its extra cost, but this is small when compared to the total cost and benefit gained by smaller sheets, especially for field use. Large sheets are awkward to handle anywhere, but during erection it is often impossible to open large drawings unless on a table or under the protection of a shed or office. Small size drawings, 8 by 10 inches, or even twice as large, can be conveniently handled, but standard size sheets, 24 by 36, can be consulted only where a table is available. The cost of photographic reproduction is from 15 to 20 per cent more than the cost of blue printing, but this is hardly a consideration when compared to its advantages. Drawings of standard size can easily be reduced to 8 by 12 inches by the photographic process, when the lines are heavy and carefully made. On a building contract amounting to $200,000 the extra cost of photo reproduction of drawings would not exceed about $300.

CHAPTER XLVI.

COST OF STRUCTURAL WORK SHOP-DRAWINGS.

There are two methods of estimating the cost of shop drawings for structural steel work, one of which is a valuable check on the other. The first is to estimate carefully the probable number of sheets that will be needed and to multiply this number by the cost per sheet, and the other method is to estimate by the usual cost of drawings per ton of steel work. The former method is the better one.

Ordinary structural work shop drawings, 24 by 36 inches in size, cost on an average $14 to $15 per sheet, including making, checking and correcting the drawings, checking estimates and stress sheets, designing details, machine work or mechanical appliances, and ordering material. This cost does not include making general designs, stress sheets or estimates, which is done in the estimating department. Multiplying the total number of needed drawings by $15, will therefore give the total estimated cost. In using this method, the number of sheets must be carefully counted in liberal numbers, for extra ones are often needed. Drawings made by experienced and better paid men may cost as low as $8 to $10 per sheet, while those made by lower priced and less experienced men or beginners may cost twice as much. A drawing that is carefully laid out at the beginning and completed by a competent workman, needs very little checking and will be more quickly made. It would seem, therefore, that an office should have no beginners, but it is necessary to have men in training to replace others who may leave.

The second method of estimating the cost of drawings is to figure them at a certain price per ton of steel work, which is obtained from actual office records for buildings of various kinds. These prices are as follows:

TABLE LXXI.

COST OF SHOP DRAWINGS.

	Per ton.
Steel cage office buildings, entire steel frame	$1.50
Steel cage office buildings, interior steel frame only	1.25

*H. G. Tyrrell, Iron Age, July 11, 1901.

Steel cage office buildings, interior steel frame, cast iron cols	.70
Steel cage office buildings, floor framing only	.85
Roof trusses only, on walls	1.25
Roof trusses and columns	2.50
Entire mill buildings	2.60
Bins and hoppers	2.50
Tipples, mining head-frames	$4.00 to 6.00
Hip and valley roofs, for fine residences or monumental bldgs,	$6.00 to 8.00

By this method the total cost of drawings may be estimated by multiplying the estimated number of tons of steel work by the cost per ton, as given in the above table.

Detail shop drawings will cost less when general details have previously been made by another engineer, but if engineers' plans have no dimensions, and these must be found from general and architectural drawings, there is then little or no saving from them.

Detail drawings made by working from an architect's general plans without a structural engineer's steel plans, will cost about 30 per cent more than given in the table above.

The making of drawings is 70 per cent of the total cost, checking and correcting them, 18 per cent, and general office expense, including service of head draftsman, rent, light, heat, stationery, insurance and janitor service, 12 per cent.

Generally speaking, experienced draftsmen should make from 30 to 40 square feet of finished drawings per week, including making corrections after they are checked, while a beginner may not make over half that amount. Drawings for ordinary mill buildings, including the design of details, order bills and shop lists, cost not more than $1 per square foot.

The above costs are taken from the author's private records in a drafting office employing forty men, with a squad system, and covering a period of 40 weeks, in which time 1,693 drawings were made for 515 different contracts. The wages paid were as follows:

1 Head draftsman, $180 per month	$180
5 Squad foremen, $125 per month	625
2 Checkers, $125 per month	250
3 Checkers, $100 per month	300
3 Draftsmen, $100 per month	300
2 Draftsmen, $90 per month	180
3 Draftsmen, $80 per month	240
6 Draftsmen, $75 per month	450
6 Draftsmen, $60 per month	360
6 Draftsmen, $50 per month	300
1 Draftsman, $40 per month	40
Total per month	$3,225

The actual amount of money paid in 40 weeks for 1,693 shop drawings after deducting time that men were absent on vacations, amounted to:

Making drawings	$16,465	or	70% of total
Checking drawings	4,390	or	18% of total
General expense	2,960	or	12% of total
	$23,815	or	100% of total

In addition to the above, 114 sheets of standard office drawings, 8 by 13 inches, were made, costing $1,100.

The 1,693 standard sheets of shop drawings, 24 by 36 inches in size, with a total cost of $23,815, had therefore an average cost of $14 per sheet. The item of general expense includes the wages of head draftsman, office boy, cloth, paper, stationery, heat, light, rent, insurance and janitor service.

CHAPTER XLVII.

DIRECTIONS FOR EXPORTING STEEL BUILDINGS.

America's export business is an important part of its entire trade. This business grew to large proportions in the decade preceding 1900 and it is still increasing. Steel bridges and buildings have been exported to Japan, China, Egypt, India, South America and various islands of the ocean, and the entire commercial world will probably soon look to America to supply much of its manufactured goods. American export business was slow in starting, but when foreign countries discovered the attractive prices and deliveries that were made, the continuance of the trade was assured. One of the reasons for the delay was the absence of price lists in American catalogues. A few enterprising companies have for several years issued attractive albums showing special buildings made by them, but none of them, prior to 1900, issued standard designs with advertised prices and discounts from which foreign buyers could select or order without delay. Price lists of this kind have long been issued by European firms, and buyers in foreign countries found it more convenient to order from them, rather than wait several months in getting American quotations by mail. Two or three months' time would easily be consumed in correspondence, and cable messages costing from 30 to 80 cents per word were too expensive.

Among common forms of buildings exported to other countries may be mentioned sugar houses, rice mills, warehouses, railroad stations, saw mills, barracks, hospitals, hay shelters and dwellings. There is also a large amount of structural work in monumental buildings. The palace of the Emperor of Japan, recently built, which was made proof against fire and earthquake, contained a large amount of American steel.

EUROPEAN AND AMERICAN PRACTICE COMPARED.

It is surprising that Europe so long monopolized the world's export trade in steel buildings, for European designs are not usually as economical as those made in America. Some expensive features ordinarily found in building designs from European shops will be mentioned.

It is customary to find queen trusses or other forms used with long members in compression, rather than in tension, and this adds greatly to the weight. The bottom chords are frequently raised at the center two or three feet above the ends, either for better appearance or for extra head room, and this adds to the chord stresses and corresponding sections. The web members are shortened, but the saving in the web does not equal the extra weight in the chords, and it is doubtful if the practice gives any more pleasing appearance than horizontal chords, while it has the disadvantage of requiring the bottom lateral plates to be bent, thus adding expense. The European method of making the roof curved on top, instead of a straight pitched roof, is also more expensive.

Large roofs are often erected at the works where they are made, to see that the parts will go correctly together. American shops take no such expensive precautions, for their methods are accurate enough without it, as shop and drafting office work in harmony from drawings that have been carefully verified.

Many of their details are also more expensive than in America. It is common in European designs to find such details as clevises, pins, forkeyes, gibs and cotters, etc., instead of cheaper bolted joints. Special cast iron joint blocks, truss shoes, gutter heads, etc., are common features, and while the cast iron is not expensive in itself, the use of special patterns will make the cost excessive, unless there are a large number of pieces of the same kind. The practice of using heavy T irons for rafters is common in Europe, but the cost of cutting T irons and making connections to them is higher than the cost of double angles which are more easily sheared, and gusset plates between the angles make symmetrical joints. The European practice of using truss pins for connections instead of bolts and rivets is an expensive one, its only merit being the greater ease of erection.

SUITABILITY OF STEEL BUILDINGS FOR EXPORT.

A large proportion of the steel buildings exported from America are sent to warm countries. The reason for this is evident, because buildings for warmer climates need no heating, and wall and roof covering of corrugated iron is sufficient.

Business is more secure when carried on in fireproof buildings than when exposed to fire risk. Steel buildings need no insurance, but the saving by their use is not for insurance alone. The money received by a manufacturing company for a fire loss rarely, if ever, repays them for the real loss incurred, for the stoppage of business and the delay in finishing contracts are frequently more serious than the fire itself and cannot be covered by insurance. Buildings for heavy manufacturing require the service of shop cranes, which are an economic necessity to meet competition. The supports and framing of these cranes should be made of steel, for heavy joints in wood are difficult to make and are apt to work loose, thus causing the traveling cranes to bind on the tracks.

Steel buildings are preferred in foreign countries as well as at home, because the cost of repairs and insurance on wooden buildings will more than pay the interest on extra money spent for permanent ones.

DESIGN OF EXPORT BUILDINGS.

Buildings for export to tropical or semi-tropical countries usually contain features not found on similar ones in the United States. As they require no heating, corrugated iron covering for wall and roof are suitable for buildings of low or medium cost, but they must be well ventilated, for if not, the direct rays of the sun on the metal makes the interior excessively hot. Buildings for cold countries where artificial heating in winter is needed, must have non-conducting walls. The buildings must in any case be weather-proof, strong, with good light and ventilation, and the location of columns and other parts of framing studied, so there will be no interference with machinery or other contents. The cooling and ventilating of buildings in warm climates is quite as important as heating them in colder regions. It is therefore the practice of the writer to provide large ventilation area in the roof, and to use swinging side shutters with continuous open ventilation from one to two feet in width, beneath the eaves. These openings should be covered with a heavy grade of galvanized wire with ¼-inch mesh, which will admit a continuous current of air but exclude animals, birds and insects. Another feature suitable for iron buildings in warm countries is the wide, overhanging eave, to protect the sides of the building from the sun. These eave projections may vary from 4 to 8 feet, depending upon the height of side walls. Figs. 33 and 34 show market buildings designed in this way, and the wide eaves not only protect the sides of the building from the sun, but serve also as a shelter above the sidewalks where people congregate around market stalls. The overhanging eave is indispensable for dwellings, for the metal covering exposed to the sun would be intolerably warm were it not for the sunshade verandas and free air circulation between the upper ceiling and the roof.

Another method of preventing building interiors from becoming excessively warm in tropical countries is to line the walls with some kind of non-conductor, such as asbestos board. When put up with tight joints, this lining will prevent heat radiating in the building and at the same time does not add inflammable material or expose the building to risk from fire.

Thatched roofs produce a cooler interior than those covered with corrugated iron, and thatch matting is, therefore, often preferred. Heat will not penetrate through the thatch and radiate

Fig. 652.

from the under side as it will with iron. This kind of roof is popular for small dwellings in the hot region of southern California, as shown in Fig. 652.

The suitability of other native building material should also be considered. In some southern countries, walls made of stucco or plaster are less expensive than metal sheathing, as local products can be secured at small expense and workmen are accustomed to using it. A market building with stucco walls is shown in Fig. 32.

Buildings must be so designed that their parts can be conveniently stored on shipboard and easily erected by labor in the foreign country.

The cost of those erected in other lands is greater than in America, owing to the extra ocean freight or other transportation and the additional handling caused thereby. It is therefore economical when using corrugated iron for walls and roof, to have all such metal galvanized. The extra expense of the galvanizing will be small in comparison to the total expense and the benefit obtained by the use of non-rusting sheathing. An asbestos covered metal described on page 284 is also suitable for export buildings.

SUGGESTIONS FOR FOREIGN PURCHASERS.

Foreign buyers find it to their advantage in asking for prices on steel buildings to make only such requirements and specifications as are absolutely essential for their needs. It is economical to leave details to the builders, for shops can manufacture cheaper when following their own methods than in filling special requirements of the buyers which may not be important. It is generally cheaper, therefore, for the buyer to permit American shops to furnish their own plans rather than to manufacture from plans submitted. Many details, such as doors, windows, ventilator shutters, louvres, etc., are as effective in one style as in another, and can be made by manufacturers according to their own practice at a much less cost than if required to follow a special plan. The buyer should, therefore, state only essentials which must be followed, special floors, loading, location of machines, etc. The ground floor and foundations should be supplied by local builders, unless they contain steel framing, as those who are on the ground and familiar with local conditions can do the work cheaper than others at a distance.

SUGGESTIONS FOR EXPORTERS.

The total cost of a building to a purchaser in a foreign country is divided into five items, as follows:

(1) Cost of all material on board cars at the manufacturer's shops.
(2) Railroad freight from the manufacturer's shops to seaport and delivering same on wharf beside the vessel.
(3) Cost of ocean freight, including loading the material into the vessel and unloading it again at its destination.
(4) Cost of freight or hauling in the foreign country.
(5) Cost of erection at the site.

Quotations on steel buildings for export are made by American manufacturers in either of two ways: (1) on the material, delivered beside the vessel at seaboard, together with the weight, number of pieces and cubic contents of the shipment; (2) price delivered complete to the purchaser at the site, including freight and ocean charge.

There are several companies in New York which devote their attention to export business, including not only steel buildings, but various other American products, such as machinery, track material, etc., and these companies get prices from American shops and buy their supplies from the lowest bidders. They are well informed in reference to ocean freight rates and transportation charges in foreign countries, and are able to make quotations on the material delivered in other countries at the site. These companies have arrangements whereby their correspondence is carried on in the language of the purchaser, and this feature is an advantage to them in securing business. The buyers may be unable to correspond in English and may not understand quotations in dollars and cents, and it may be very attractive to them to receive letters and prices in their own language.

Other companies which are not prepared to carry on correspondence in foreign languages and are not familiar with ocean or foreign freight charges, prefer to make quotations on material delivered on the wharf at American seaboard, giving the necessary data in reference to space required, number of pieces and tonnage, so freight charges can be computed. The latter method has several advantages. The purchaser may secure as low freight quotations as the exporting company, and by ordering the freight himself would save the profit of the middleman. Another benefit from making quotations at seaboard only, is that the risk in connection with ocean and foreign freights is not assumed by the American manufacturer, for if he includes these freights in his prices, he will add a percentage for the risk incurred. The purchaser may save this charge by assuming the freight risk himself.

Ocean freight charges depend upon three factors, (1) the weight of the shipment, (2) the number of pieces that must be handled, (3) the cubic contents which the material will occupy in the ship. It is necessary, therefore, in giving prices at seaboard, to furnish the buyer with weight, number of pieces and cubic contents, in order that he may obtain the freight charges.

The shipping weight is ascertained in the usual way by weighing the cars after they are loaded.

The number of pieces should be a minimum, for the charges increase with the number. It is economical to fasten small pieces together in bundles of as large size as can be conveniently handled, uniting them with wire through the rivet holes to avoid their falling out. Rivets, bolts, washers and other small parts must be shipped in kegs or boxes, keeping different sizes and lengths separate, and each box must be plainly marked. Bags for nails, spikes or bolts are unsatisfactory, for they tear and expose the contents to the water, causing them to rust. Corrugated iron must be shipped in bundles tied together with wire, all the various lengths and thicknesses being bundled by themselves, and the gage and length marked on each. Glass or other fragile articles must be packed in excelsior or straw, and carefully boxed. Ocean freight receives rough handling, and shippers must use great care that no pieces are injured. Records from American ports show that the most carefully packed and crated export shipments come from manufacturers of agricultural implements, and others should use the same care. The shipper should be liberal in estimating the number of pieces, as the estimated number is often exceeded.

The cubic contents of a shipment is computed by estimating the space occupied by the riveted sections when piled together to the best advantage. The maximum dimensions for single cars are widths up to 8 feet, heights of 10 feet and lengths 30 to 40 feet. Riveted sections may be piled above each other on the cars to a height of 10 feet. Small parts, such as kegs, boxes, separate gusset plates and the like, can be placed in the open spaces between the riveted sections, and it is necessary to measure only the space occupied by the larger pieces. In piling riveted sections upon each other, strips of wood or pieces of plank must be inserted between the steel sections to prevent their damaging each other, and in measuring the cubic contents on the cars, allowance must be made for these packing strips. The cubic contents of the various car loads may then be measured, and their sum will be the space required in the vessel.

The shipper should inquire as to the maximum size and length of pieces that the vessel will accept, or that can be loaded through the hatchways. Some ships will not take material longer than 40 feet and greater lengths require splicing.

MARKING PIECES.

The manufacturer must furnish the purchaser with erection drawings so clearly made and plainly marked that the building can be easily erected by unskilled labor. The manufacturer may be obliged to send an experienced foreman to superintend the erection of large orders, but small shipments will not require this expense. The erection drawings should show the mark of every piece, the size and length of field bolts or rivets, position of washers, splice plates, etc. Erection drawings for export buildings must be made so clear that ordinary mechanics can understand them. It may occasionally be necessary to mark the erection plans in both feet and meters, so either system of notation can be used, but there will seldom be need for other than the English language on the drawings, for in nearly all countries English speaking foremen can be employed. Where there is doubt in reference to the language, the drawings can first be worded in English and the corresponding wording of the foreign country added.

Marking should be the same as for domestic work, and when a number of pieces of the same mark are shipped in bundles, that of the separate pieces will then be the shipping mark of the whole crate. Each piece, box, bundle or keg must have its own individual shipping mark.

When steel buildings are consigned to districts in foreign countries which are not accessible by rail or regular highways, material for the buildings is sometimes transported on mules, and the separate pieces must then not exceed about 8 feet in length nor 250 pounds in weight. Each animal is loaded with two equal pieces, the combined weight of which must not exceed 500 pounds. This method of transportation is used for conveying material to mining districts in mountain regions before railroads or highways have been built. Roof purlins may be shipped in 8 foot lengths by making them continuous over the trusses and splicing approximately at the points of contra flexure. A set of buildings of this kind was designed by the writer for export to a mining camp in the Andes mountains.

DIRECTIONS TO FOREIGN PURCHASERS IN COMPARING PLANS.

In comparing various designs that he has received for a mill building, the purchaser should carefully note what items are included in the bids. Some manufacturers, in order to make their prices low, show the building complete in all its parts on the drawing, but their prices include only the steel structural work and metal sheathing, charging extra for miscellaneous items such as doors, windows, shutters, etc. Corrugated iron must be compared by weight rather than by gage, as there are several metal gages, and confusion might occur.

A design with excessive strength in some parts, but lacking in others, is very little better than one which is lacking in strength throughout. Weight added where not needed is a detriment, for the buyer must pay freight on the useless weight. In comparing competitive plans, the purchaser may find that some drawings are made to an exaggerated scale, various parts and members being shown heavy with neither size nor weights marked thereon. This effort to give a design the appearance of strength on the drawing is deceptive and misleading, and the merit of the building must not be judged by the appearance of an elaborate drawing made to an exaggerated scale with sizes omitted. Many manufacturers who would not dare to erect a bridge of doubtful strength are willing to design and put up buildings which are stressed under maximum loads up to or beyond their elastic limit, the chief requirement being that they are well braced. The loads on buildings which have no traveling cranes are mostly static, and maximum wind loads occur very seldom. Manufacturers therefore often specify sizes for export buildings which are dangerously weak, knowing that the buyers are far away, and even if the work is unsatisfactory, there will be little probability of complaint.

Steel frames, such as those used for the temporary buildings for various expositions, are ordinarily proportioned with high unit stresses from 20,000 to 25,000 pounds per square inch. The expedient for temporary buildings is permissible, but cannot be sanctioned for permanent ones. Unfortunately, however, too many buildings supposed to be permanent, are no better than others which are known to be temporary.

It is the practice of some structural shops, after securing a building contract, to put designs and plans through what they call the "reduction process." The plans are again submitted to the designer or to some engineer, whose duty it is to revise them and cut out weight or expense any place that safety will allow. Every pound is omitted that is not absolutely required to make the building stand until erected and paid for. Pieces must, of course, have sufficient strength to prevent their bending or breaking during shipping and erection. Between this method of making extremely light designs, and the European method of making excessively heavy ones, there is a mean where the building is strong enough for its maximum loads, and yet not wasteful. Generally speaking, designs submitted by European firms for steel mill buildings in foreign countries are from 20 to 25 per cent more expensive than designs from shops in the United States. This percentage is approximate only, and taken from the writer's records when bidding on this class of work.

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