MILL BUILDING CONSTRUCTION

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CHAPTER I.

LOADS.

Mill buildings differ so greatly in character and purpose that it is impossible to formulate tables of dead weights which will suit all cases. The use to which the building is to be put, its location, the character of the roof covering, the presence or absence of cranes, etc., all affect the dead weight, and generally each case must be considered individually. For most purposes of design the loads may be divided into: (1) roof loads; (2) floor loads; (3) crane loads; (4) snow and wind loads, and (5) miscellaneous loads.

ROOF LOADS.—For making rough estimates the diagram of weights of roof trusses given in Fig. 1 will prove useful. These weights have been figured separately and do not quite agree with any of the published formulas. From this diagram, the table (Table I.) giving the weights of roof coverings and the table (Table III.) of wind and snow loads, the total weight to be carried is found. Were it possible to realize in actual practice the small sections required, the weight of trusses would be directly proportional to the load carried. Iron purlins weigh from 2 lbs. to 4 lbs. per square foot of ground covered, according to the spacing of the trusses. Good practice in the United States requires that roofs in northern latitudes shall be figured for at least 40 lbs. per square foot of roof surface.

FLOOR LOADS.—The Building Law of New York City requires that floors shall be proportioned to carry the following minimum loads per square foot: Office buildings, 100 lbs.; public halls, 120 lbs.; stores, factories, warehouses, etc., 150 lbs.; floors carrying heavy machinery, 250 lbs. to 400 lbs. In every case the floor must be strong enough to carry its maximum load. Mr. C. J. H. Woodbury, in his book on "The Fire Protection of Mills," gives a table of weights per square foot of floor of various kinds of merchandise, which is reprinted herewith (Table I.) and which will be found valuable in determining loads on floors.

CRANE LOADS.—For small traveling cranes of one or two tons capacity it is safe to consider the total weight of one end of the crane and its load as twice the capacity of the crane. For cranes of larger capacities Table II. gives the maximum weight which will come on two carrying wheels at one end of the crane when the fully loaded trolley is at that end. The corresponding figures for the other end would be somewhat smaller, but not enough so to affect materially the construction of the building. From the figures in Table II. the strength of traveling crane runway girders and columns may be calculated.

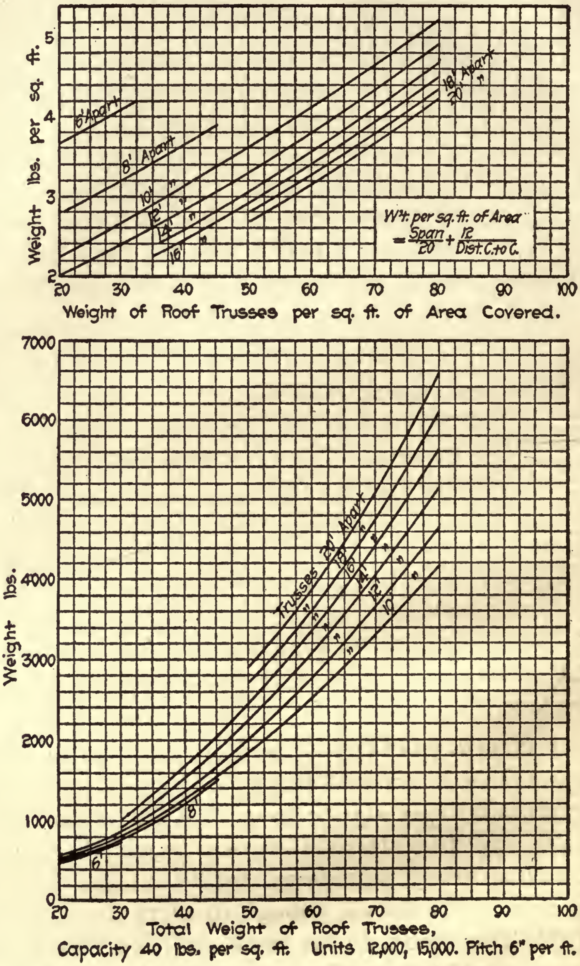


Fig. 1. Diagrams Showing Weights of Roof Trusses.

The strains due to the presence of jib cranes vary so greatly in number, character and intensity in different cases, that they do not admit of any general tabular statement. They must, however, be carefully figured in each case and fully provided for in the design. The principal strains produced will be in the lower chord bracing of the roof trusses, and the bending strains in the supporting columns.

SNOW AND WIND LOADS.—The pressure exerted by wind on roofs is in every case normal to the plane of the roof surface.

The amount of wind pressure usually assumed in proportioning framed structures is 30 lbs. per square foot on a vertical surface, which corresponds to a velocity of from 70 to 80 miles per hour. This velocity includes all storms except tornadoes, which cannot be provided for. Table III. gives the normal pressures on roof surfaces of different slopes for a pressure of 30 lbs. per square foot on a vertical surface.

Snow loads of from 10 lbs. to 20 lbs. per square foot of horizontal projection of the roof should be provided for. There are records of snow and ice deposits weighing 40 lbs. per square foot having formed on roofs in northern latitudes, but this is a very exceptional occurrence. When the roof has a pitch of 45° or more, snow load need not be considered. In New England latitudes, for roofs of ordinary pitch, it will be sufficient to assume 30 lbs. per square foot of roof surface for snow and wind loads combined. The maximum strains from wind and jib crane loads will so seldom occur together in the horizontal bracing that a combination need not be provided for. If they should occur at the same time, once in a year or so, the factor of safety will enable the metal to withstand the strain without injury.

The overturning effect of wind acting on the building as a whole and tending to revolve it about the bases of the leeward columns need be considered only in the case of tall narrow buildings. Wind acting on the sides of a building will necessitate the use of knee braces running from the columns to the bottom chords of the roof trusses, and the strains in these braces will be considerable. These strains will produce bending strains in the columns which must be provided for.

MISCELLANEOUS LOADS.—In special cases there will be other loads to provide for besides the more common roof, floor, crane, snow and wind loads just considered. The bottom chords of roof trusses are frequently employed to carry shafting, steam pipes, trolleys, etc. It is sometimes convenient also to have the roof trusses sufficiently strong to permit of a block and tackle being attached at any point to handle goods. The roof may require a ventilator and when it does this extra weight must be added to the roof loads. Columns in exposed places where they are liable to shocks from vehicles or merchandise should be made stronger than those built into brick walls.

SUMMARY OF LOADS.—The total roof loads per square foot of roof, including weights of trusses for spans under 75 ft., is about as follows for different constructions of roofing:

Style of Construction.	Lbs. per sq. ft.
Corrugated iron, unboarded	8
" " on boards	11
Slate on laths	13
" " 1¼-in. boards	16
Tar and gravel	12
Shingles on laths	10
Tile	20-30

When any of these roofs are plastered below the rafters 10 lbs. per square foot should be added to the loads given. For spans greater than 75 ft. a weight of 4 lbs. per square foot should be added to the weights given. For snow and wind loads combined add for northern latitudes 30 lbs. per square foot to the loads given.

The weight of steel in the sides and roofs of mill buildings, without cranes, is from 4 lbs. to 6 lbs. per square foot of exposed surface for the frame only. Corrugated iron sheathing weighs from 1 lb. to 2 lbs. per square foot. These weights, with steel at 5 cts. per lb., make the cost of steel buildings from 25 cts. to 40 cts. per square foot of exposed surface. A rough approximate rule for calculating the extra weight of steel required in columns and girders when traveling cranes are used is as follows: Add 100 lbs. of steel per lineal foot of building for every five tons of crane capacity. This would give for a 5-ton crane an addition of 100 lbs. per lineal foot and for a 20-ton crane an addition of 400 lbs. per lineal foot.

METHODS OF CALCULATION.—Methods of calculation will not be touched upon in this book, since they may be found in any text-book upon the subject. Briefly enumerated, the cases to be considered in determining strains are the following:

(1) Strains in roof trusses and columns from permanent dead loads.

(2) Roof trusses on walls, strains from wind normal to the surface.

(3) Wind on side of building and roof, strains in trusses, columns and knee braces; (a) columns hinged at the base; (b) columns fixed at the base.

Partial loading can never cause maximum srains in the parts of a Fink truss as they may in other forms of roof trusses.

TABLE I.—Showing Weights of Merchandise as Given by C. J. H. Woodbury in his Book on "Fire Protection of Mills."

Wool in bales	17 to 29	lbs. per cu. ft.
Woolen goods	16 to 22	" " "
Baled cotton	20 to 40	" " "
Cotton goods	16 to 40	" " "
Rags in bales	15 to 36	" " "
Strawboard, newspaper and manilla	33 to 44	" " "
Calendered and super-calendered book	50 to 70	" " "
Writing and wrapping paper	70 to 90	" " "
Wheat	39 to 44	" " "
Flour	40	" " "
Corn	31	" " "
Corn meal	37	" " "
Oats	27	" " "
Baled hay	57	" " "
Compressed hay and straw	19 to 30	" " "
Bleaching powder	31	" " "
Soda ash	62	" " "
Indigo	43	" " "
Cutch	45	" " "
Sumac	39	" " "
Caustic soda	88	" " "
Starch	23	" " "
Alum	33	" " "
Extract logwood	70	" " "
Lime	50	" " "
Cement, American	59	" " "
Cement, English	73	" " "
Plaster	53	" " "
Rosin	48	" " "
Lard oil	34	" " "
Rope	42	" " "
Tin	278	" " "
Glass	60	" " "
Crockery	40	" " "
Leather in bales	16 to 23	" " "
Sugar	42	" " "
Cheese	30	" " "

TABLE II.—Showing Maximum Weight in Pounds Which Will Come on End Wheels of Traveling Crane When the Fully-Loaded Trolley is at the Same End.

Capacity.	Span of crane in feet.							
in tons.	25	30	35	40	45	50	55	60
5	31,700	32,870	33,800	34,900	35,900	37,200	38,600	40,300
10	45,100	46,000	47,400	48,900	50,200	51,600	53,200	55,700
20	72,100	74,100	75,800	77,600	79,400	82,000	83,900	86,100
30	103,800	108,200	110,000	112,600	115,200	117,700	120,400	122,800
50	152,300	158,100	162,200	167,500	171,600	175,600	178,600	182,400

TABLE III.—Giving the Normal Pressures from Wind on Roofs of Different Slopes for a Wind Pressure of 30 lbs. per Square Foot Against a Vertical Plane.

Angle.	Pressure.	Angle.	Pressure.	Angle.	Pressure.
5	3.9	25	16.9	45	27.1
10	7.2	30	19.9	50	28.6
15	10.5	35	22.6	55	29.7
20	13.7	40	25.1	60	30.0

CHAPTER II.

GENERAL DESIGN.

In every case the use to which a building is to be put will in a great measure determine the character of its general structural features. A building may or may not require to be heated in winter; it may or may not need to be well lighted, and it may require a heavy or a light construction. With these general facts in mind we are in position to consider the questions of general design.

GENERAL CONSIDERATIONS.—In determining the size of an iron building, in case the ground room is unlimited, it is well to locate first the machinery to the best advantage to turn out products at the minimum cost, and afterwards to decide on the size and shape of the building to suit the machinery. If, however, the amount of ground is limited, this cannot be done, as the building will cover only the limits of the lot. It is well also to consider whether or not the proposed building is to be a permanent one. If for temporary purpose, unit strains may be taken high and the first cost of construction cut down to the very lowest limit. If, however, the building is to be permanent, this is not desirable, as it is frequently found that heavier loads and greater strength is required than at first anticipated. It is the practice of the writer, after making his original design, to go over the plans a second time and rearrange and omit all unnecessary pieces, at the same time adding bracing where it may be found necessary. Stiffness in the whole construction should be one of the principal ends. There are more steel buildings throughout the country going to ruin on account of insufficient bracing than perhaps from any other cause. Steel will easily stand being strained nearly up to the elastic limit without serious injury, but lack of stiffness is liable, not only to destroy the frame itself, but the covering and glass, at the same time cause shafting to get out of line, and traveling cranes to bind and run untrue. It is frequently the intention in constructing a building to plan for future extension at one or both ends. Provision can well be made for this by placing regular trusses at the ends and putting in temporary posts up to the height of the bottom chord to support the end purlins. Then when extension is desired the end covering can be removed and these posts taken out to be used again in the new end.

WALLS.—The wall construction most commonly employed in mill buildings is: Solid brick walls; iron columns with brick curtain walls, or iron columns and purlins covered with corrugated iron. Concrete filling between steel columns has occasionally been employed for side walls, but it is somewhat more expensive than brick filling on account of the temporary timber-work required to keep it in place while hardening and also because a light permanent iron frame is necessary to hold the windows in position. Of the forms of construction named, corrugated iron is the cheapest and most easily renewed, but it cannot be used for buildings which are to be heated. Machine shops, electric light stations, and similar buildings must have solid walls, and if the height is not great or if the loads are not excessive, brick walls will be the cheapest construction. Brick walls make a rigid construction suited to withstand the action of cranes and heavy machinery. In case the walls are required to be very thick under trusses, the most economical construction will be iron columns with curtain walls. This construction is usually less rigid than solid brick walls, and it is consequently not so serviceable for buildings having heavy traveling cranes. In special cases, where sand and gravel are plentiful, and where bricks are expensive, a concrete filling between the wall columns is less expensive than brick, and is in every way just as serviceable. Where columns with curtain walls are employed, the tops of the columns should be connected by steel struts to keep them in position. Columns with bracing between them in a vertical plane make as stiff a construction as can be secured, and consequently are well suited for heavy cranes and machinery.

Fig. 2.

The form and section of column employed varies greatly. For light loads four angles latticed together, as shown by Fig. 2, is a construction frequently used, and the column must be given sufficient width to take the bending strains from the knee braces. If brick-work is to be built into the columns, their width must be made to suit the size of the brick. It may sometimes be desirable to have one or more large bays or wide panels in the walls, in which case the ends of the roof trusses coming over these bays must be supported on side or wall girders attached to the columns on each side of the bay.

ROOF TRUSSES.—The Fink truss is the type most commonly used in the United States for the roofs of small buildings. It is economical because most of its members are in tension and the struts are short. Fig. 3 is the form of Fink truss commonly used for spans of from 30 ft. to 40 ft.; Fig. 4, the form used for spans of from 40 ft. to 55 ft.; Fig. 5, the form used for spans of from 55 ft. to 85 ft.; and Fig. 6, the forms used for spans of from 85 ft. to 100 ft. If the slope of the roof is small, some form of English truss will be preferable to the Fink truss, because it gives better intersection angles. If the roof is hipped it is necessary to have vertical members to which to fasten the hip rafters. Figs. 7 and 8, respectively, show a Queen truss and a Fink truss of the same span and pitch, and both with vertical posts. It will be observed that the longest vertical strut in the Queen truss is avoided in the Fink truss.

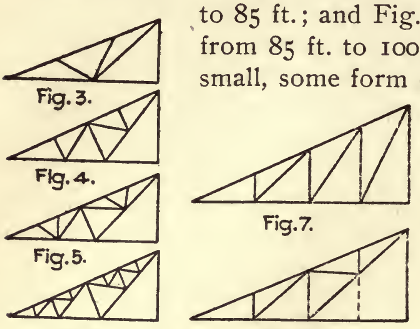


Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.

Figs. 3 to 8. Diagrams of Common Forms of Roof Trusses.

For small spans up to say 30 ft., sheets of corrugated iron may be curved and provided with a single tie-rod across the bottom to form an arched roof. This construction can often be used to advantage for ventilator roofs.

The allowable slope or pitch of roofs depends upon the kind of covering or roofing employed. The allowable slopes for some of the more common roof coverings are shown in Table IV. It is more economical to employ horizontal bottom chords for roof trusses, or at least to keep the cumber down to an inch or two, since it avoids any bending of the bottom chord laterals. A truss whose bottom chord has a rise of two or three feet, however, presents a better appearance. The neutral axes of all chord members should intersect in a common point at each intersection. Flat iron should not be used in roof trusses, except for connection plates, as it lacks the necessary stiffness. Steel is a superior material to timber for roof trusses, because it is lighter, stronger and more durable.

SPACING OF TRUSSES.—For the least weight of purlins the distance between supports must be a minimum, and since the weight of trusses is directly proportioned to the load upon them, the least total weight of trusses and purlins will be when the trusses are placed close together. This reasoning assumes that it is possible to realize practically the small sections required for the truss members, which it is plainly impossible to do. Experience shows that the most economical distance between centers of trusses for small spans up to say 50 ft., is from 10 ft. to 16 ft.; for spans exceeding 50 ft. it should be from one-fourth to one-eighth of the span, depending upon the nature of the roof covering and purlins.

For plank laid directly on rafters spacing should not exceed 8 ft. for 2-in. plank and 10 ft. for 3-in. plank.

JACK RAFTERS.—Jack rafters need not ordinarily be used in mill buildings. When, however, the distance between trusses exceeds 20 ft., it will be more economical of material to run a few heavy purlins from truss to truss to carry one or more jack rafters which in turn support the small purlins upon which the roof covering rests. This construction was used in most of the buildings for the Columbian Exposition at Chicago and in many of the roofs for large train sheds which have recently been constructed.

ROOF COVERINGS.—A great variety of roof coverings are available to the engineer. In selecting a roof covering the principal things to be considered are the cost and the necessity or not of having it fire-proof Figures of slopes required for various ordinary kinds of roof coverings are given in Table IV. It should be remembered that the material requiring the greatest slope will require the largest amount of covering.

TABLE IV.—Showing Least Pitch of Roof Required for Various Kinds of Roof Coverings.

Wood shingles on plank	least pitch =	1/4	span.
Slate, large	“ “ =	1/5	“
“ ordinary	“ “ =	1/4	“
“ in cement	“ “ =	1/6	“
Steel roll roofing	“ “ =	1/12	“
Rubber	“ “ =	1/12	“
Asbestos	“ “ =	1/12	“
Asphalt	“ “ =	1/12	“
Corrugated iron laid in cement	“ “ =	1/8	“
“ “ not laid in cement	“ “ =	1/4	“
Tar and gravel		flat	
Tin or terne plates		“	

The building laws of the principal cities specify the conditions under which fire-proof roof coverings shall be used and also state what coverings are to be classed as fire-proof. Where this matter is not specified, the engineer must decide whether or not the risk warrants the use of fire-proof roofing, keeping in mind always that the cost of insurance on fire-proof buildings is less than for buildings which do not come within this classification. When the risk is inconsiderable a covering of some of the best brands of roofing paper makes in every respect a first-class roof, since this material is cheap, is easily applied, will last for years, and does not transmit cold as do metal or slate. Metal roofing is soon destroyed in buildings where corrosive gases accumulate. If warm air comes in contact with the underside of the roof the covering should be laid on boards or have some kind of anti-condensation lining. Figures showing the comparative costs of different kinds of roof coverings are given in Table IX.

TRUSS CONNECTIONS.—The choice between the use of bolts or of pins for truss connections is determined in each case by the relative cost of manufacture and erection. Generally for small trusses bolted connections are very much the cheaper, but for trusses of long span, where erection may be difficult or expensive, pin connections can be employed to greater advantage.

RAFTERS.—The most common form of rafter is one made up of two angles arranged as shown by Fig. 9, and having gusset plates between the adjacent flanges at the panel point connections. If the load is uniformly distributed, this form of rafter should have a continuous web riveted between the angles to resist the bending strain, instead of the separate gusset plates at connections only. When the loads are concentrated at the panel points they should be located as nearly as possible directly over the sub-struts.

Fig. 9.

BOTTOM CHORDS.—For all ordinary cases the bottom chords of roof trusses may be made of two angles placed back to back. If, however, it is desired to have stiff chords to which weights can be safely attached at any point, two channels riveted back to back should be used. When jib cranes are used there should be a horizontal bracing between the roof trusses in the plane of the bottom chords.

PURLINS.—Angles, channels, Z-bars and I-beams are all used for purlins. Angles, channels and Z-bars are fastened to the rafters by angle clips, Fig. 10, but I-beams are usually bolted directly to the rafter. An angle trussed with a tension rod and center strut is a form of purlin sometimes employed, but ordinarily simple shapes without trussing are preferable, since too much trussing and bracing injures the appearance of the roof and adds to the

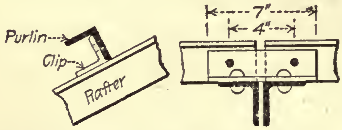


Fig. 10. Clip Connection Between Purlin and Rafter.

cost of manufacture. It is more economical to use simple shapes even at the expense of increasing the weights slightly than it is to introduce trussing. When the distance between rafters is more than about 15 ft. a line of ⅜-in. rods should be run from the ridge through the purlins to prevent them from sagging in the plane of the rafters. At the gable walls a single angle may be built into the masonry and the purlins attached to it by clips as they would be attached to a rafter.

The best way of placing angle purlins on a sloping roof is as shown in the sketch, Fig. 10a. In this position it has a greater vertical moment of resistance than if the roof leg were placed in a reverse position, as in Fig 10b. To rivet the overlapping ends of the corrugated iron on both sides of the angle purlin, as shown in the sketch, Fig. 10c, and securing the covering to the angle by means of a bent iron, passing around the purlin, makes altogether a very much tighter piece of work than for a single clinch nail to be driven through the sheathing and bent around one leg of the purlin. In order to protect the overhanging corrugated iron at the eave from being battered and getting out of shape it is desirable to extend the upper chord angles of the trusses out far enough to receive an outside purlin placed as nearly as possible at the edge of the sheathing. This overhang need not be greater than 12 or 15 ins., and if a slightly better appearance is desired a molded sheet metal cornice may be used.

Fig.10a.

Fig.10b.

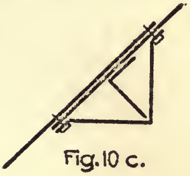


Fig.10 c.

UNIT STRESSES.—For dead and for live load stresses a factor of safety of four is sufficient. For greater combinations such as dead, live, wind and crane loads combined, a factor of safety of three should be used. The temporary buildings for the Columbian Exposition at Chicago were proportioned for unit tensile strains of from 20,000 ℔s. to 25,000 ℔s. per square inch of section.

LIGHTING AND VENTILATION.—A very efficient method of lighting mill buildings is to make the entire upper halves of the side walls of windows with the sash bolted to the framing. In buildings which do not require heating in cold weather, such as forge shops and boiler houses, the lower halves of the side walls may be made of wood panels which can be easily removed to allow a free circulation of air and to give clear space for the handling of material. Windows in the sides of monitor roofs admit light to the upper part of the building only; they throw very little light to the floor. Translucent wire cloth may be used for skylights, but it collects dust and smoke and becomes soft in warm weather. In cases where the movement of heavy cranes and the jar of steam hammers and running machinery cause sufficient vibration to break glass skylights, the translucent wire cloth may be used to advantage, but it must be frequently cleaned. Continuous monitor roofs with open sides are usually sufficient to ensure ventilation. In forge shops or other buildings where there is considerable gas and smoke the monitor roof may be rendered much more efficient as a ventilator by placing a line of shutters about 2 ft. high in the side walls at their bottoms. When these shutters are opened an upward draft is secured through them and the open sides of the monitor roof.

A good common rule for the amount of windows required in the side of a building is to make the window area one-fifth of the walls, or say one-tenth of the total floor area. In place of removable wooden panels for the sides, corrugated iron doors may sometimes be used to advantage. These are built to fill the whole panel and are counter weighted. They can be easily opened, but on account of the counter weights and rigging for hanging them, the cost is considerably more than that of wooden panels. If sash is used in the side monitor for the purpose of securing light, then this monitor should be wide, say one-fourth the whole width of the building, in order to allow light to reach the floor. This arrangement of wide monitor, however, does not secure so good ventilation. The upper part of the roof holds a considerable amount of dead air. To overcome this a second smaller monitor may be placed along the ridge with louvres or shutters on the sides. This arrangement will secure both a light interior and good ventilation.

ESTIMATING THE COST.—It has already been stated that the weight of steel frames for mills and similar buildings is from 4 lbs. to 6 lbs. per sq. ft. of exposed wall and roof surface; also that provision for traveling crane adds a weight of about 100 lbs. per lin. ft. of building for every five tons capacity of crane. Other material, such as brick wall, roofing, doors, windows and floors, is very easily figured out in square feet. Hence, with the aid of the following table of prices, the approximate cost of the whole building can be very quickly estimated.

TABLE OF APPROXIMATE PRICES.

Common brick work	25 to 35c. per cu. ft.
Rubble masonry	$5 to $7 per cu. yd.
Concrete	$6 to $8 per cu. yd.
Cut Stone pier caps	$2 per cu. ft.
Piles in place	25 cts. per lin. ft.
Earth excavation	50 cts. per cu. yd.
Steel truss and column frame in place	4 cts. per lb.
Steel beams, in place	3 “ “ “
Plain casting	2 “ “ “
Corrugated iron No. 22, in place, black	7 cts. per sq. ft.
“ “ “ “ galvanized	9 “ “ “
Flashing, galvanized	15 “ “ “
Spruce lumber, in place on floor or roof	$25 per M.
H. P. matched, in place	$35 “
H. P. joist and purlins, on floor or roof	$30 “
Door frames and doors	50 cts. per sq. ft.
Window frames and windows	50 “ “ “
Sash, glazed and painted	15 to 25 “ “ “
Gutter and conductor	25 cts. per lin. ft.
Stairs, 3 ft. wide, wood	$3 per step.
Stairs, 3 ft. wide, iron	$8 per step.
Rolling steel shutters	50 cts. per sq. ft.
Louvres, fixed	50 “ “ “
Louvres, moving	75 “ “ “
Corrugated iron doors and shutters	35 “ “ “
Wire netting, galvanized	20 “ “ “
Skylight, ¼-in. thick glass	25 “ “ “
Skylight, translucent fabric	15 “ “ “
Pipe railing	50 cts. per. lin. ft.
Round ventilators	$5 to $10 each.
Metal cornice	10 to 25 cts. per lin. ft.
Slate roof, not including boards	$7 to $12 per sq. of 10 × 10 ft.
Slag and gravel roof, not includ’g boards	$5 “ $7 “ “ “
Prep’r’d comp’sit’n roof, n’t incl’d’g b’ds	$2 “ $5 “ “ “
Wood shingle roof, not including boards	$3 “ $5 “ “ “
Tin plate roof, not including boards	$10 “ $12 “ “ “
Corrugated iron roof	$ 7 “ $9 “ “ “

Roughly speaking, the cost of one-story iron buildings, complete, is, for sheds and storage houses, 40 to 60 cts. per sq. ft. of ground, and for such buildings as machine shops, foundries, electric light plants, that are provided with traveling cranes, the cost is from 60 to 90 cts. per sq. ft. of ground covered.

CHAPTER III.

DESIGN OF STRUCTURAL DETAILS.

FOUNDATIONS AND ANCHORAGE.—The subject of foundation construction is such an extensive one that it is impossible to consider it exhaustively within the limits assigned to this book. It will be evident to all, however, that the design of foundations for the great majority of shop buildings is not a difficult problem, since the site selected for them will usually be in a location free from water and treacherous soils.

For the outside lines of columns either a continuous foundation wall, if the columns are close together, or, individual piers, if the columns are widely separated, may be employed. In either case the foundations must have ample area to distribute the loads over a sufficient area of foundation bed to ensure safety from settlement. The bearing power of different soils is given in Table V.

If the building is large and any doubt exists as to the nature and quality of the foundation soil, soundings should be made and the bearing power tested by placing weights on a small known area. The bottom of the walls should always be carried to a sufficient depth to make certain that the original bed soil is reached. A few layers of wet sand or gravel placed in the bottom of the excavation, filling it from side to side, and thoroughly rammed will help to distribute the pressure evenly. The wall or piers should have two good footing courses and the projection of each course beyond the one immediately above should be so small that the lower footing will not be cracked by the bending strain from the load above. Each column should rest on a cut stone cap except where the load is so small that the foot of the column may rest directly on the regular masonry without danger of crushing. The usual safe load for

TABLE V.—Showing Supporting Power of Various Foundation Soils in Tons per Square Foot.

Bedrock (hardest)	200
" (poor)	5 to 30
Dry clay in thick beds	4
Soft clay	1
Gravel and sand well cemented	8
Compact sand	4
Clean and dry sand	2
Quicksand and soft soils	½

stone is 250 lbs. per sq. in. and for brick is 125 lbs. per sq. in. In the opinion of the writer hard brick or concrete are superior to stone for small foundations on account of their better bond.

For very light loads a wooden box may be set in the ground and filled with concrete, the column base resting directly on the concrete or on a thin layer of cement mortar covering the top of the concrete. In special cases of heavy loads on soft soil a grillage of concrete and I-beams or of concrete and railway rails will enable the load to be distributed over the requisite area with a saving over masonry.

Where there is a tendency toward overturning, the column bases should be anchor-bolted to the foundation masonry. Generally the anchor bolts should extend through the masonry and be fastened on the underside. These bolts are set in position by means of wooden templates and the masonry is built up around them. In some cases a small plug anchor set in the capstone, with sulphur or lead, will provide sufficient anchorage.

It is the practice of the writer in designing wall columns for buildings to consider the same rigidly fixed at the base, provided there is sufficient load on the column to hold it down. In some cases even though the load may be considerable, if the post is small there is still a liability to pin ended action.

GROUND FLOOR CONSTRUCTION.

CONCRETE FLOORS.—In the construction of floors as in other parts of the building the requirements of each case will determine the design and construction to be adapted. A very solid floor is made as follows: The soil is excavated to a depth of about 18 ins. and leveled up. Upon the bottom of this excavation is placed a 6-in. layer of broken stone which is thoroughly rammed and then covered with a layer of concrete 8 ins. thick. After the concrete has set it is covered with a wearing surface of cement 4 ins. thick. A combination of asphalt, Portland cement and sand makes a good wearing surface. Fig 11 shows a section of this floor.

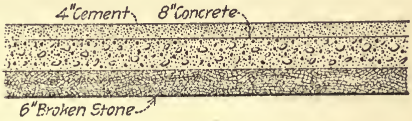


Fig. 11. Concrete Ground Floor Construction.

ASPHALT FLOORS.—Asphalt floors are becoming very popular where small cost is not the chief consideration. Rock asphalt is limestone impregnated with from 8% to 17% of bitumen. It is found in many localities, but the principal workable deposits are at Limmer in Germany, Neuchatel in Switzerland, and at Seyssel in France. Less well-known deposits exist at Ragusa in Sicily, near Santa Barbara in California, and in Kentucky, Colorado, Utah and New Mexico. For shipping the rock is usually made into asphalt mastic in the following manner: The rock is ground into powder and heated in kettles with 8% of Trinidad asphaltum added to prevent burning. The mixture is heated to a temperature of 350° and kept at that temperature for about five hours, being constantly stirred the whole time. The next step of the process is to mold the mixture into blocks weighing from 50 lbs. to 60 lbs. each. These blocks as purchased in the market always have the name of the mine from which they come plainly stamped on them. When marketed the mastic should contain 14% of bitumen and 86% of carbonate of lime.

To prepare the mastic for flooring it is mixed with Trinidad asphalt and sand in the following proportions: Mastic blocks, broken, 60 lbs.; Trinidad asphalt, 4 lbs.; fine gravel and sand, 36 lbs. This mixture is heated for about five hours at 400° F., and is constantly stirred during the heating. At the termination of this heating the material is taken out of the kettles and spread.

Fig. 12.

Asphalt Floor with Concrete Foundation.

For a mill floor the asphalt should be spread 1 in. thick on a foundation of concrete or on boards. The concrete foundation should be 3 ins. or 4 ins. thick, and if boards are used they should be covered with a layer of sheathing paper before the asphalt is placed. Fig. 12 is a section of asphalt floor having a concrete foundation and Fig. 13 is a similar section with a foundation of wood.

Any composition of coal tar becomes useless in a short time on account of the evaporation of the tar which causes the material to disintegrate and crumble away. Felt saturated with coal tar becomes brittle and finally useless. The oils of asphalt, however, are not volatile at any natural temperature, and hence properly prepared asphalt flooring composition remains absolutely unchanged during years of exposure to the air and sunlight. Other important advantages of asphalt for flooring are that it is impervious to water and is so elastic that cracks do not develop. An asphalt floor has no joints to accumulate dirt and can be easily and thoroughly cleaned. It is pleasant to walk on, not tiring the feet as do stone

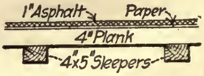


Fig. 13.

Asphalt Floor with Wood Foundation.

blocks or flagging. It is not worn away by traffic as are stone blocks, but is simply compressed. Asphalt flooring costs 16 cts. per square foot when laid 1-in. thick, the cost running higher or lower according to the location and size of the floor.

There are many imitations of asphalt made of coal tar and crushed limestone which it is almost impossible to distinguish from the genuine article, but none of these imitations has the properties of asphalt. These imitation asphalts will all crack and crumble after a few years' service.

Asphalt is softened and finally destroyed by oil and it cannot, therefore, be recommended for floors subjected to oil drippings from machinery and materials.

WOOD FLOORS.—A first-class wood floor is made as follows: Excavate the soil to a depth of 18 ins. and place a thoroughly rammed layer of concrete 8 ins. thick on the bottom. After this layer of concrete has set place 6x6-in. sleepers of pine or spruce 3 ft. apart c. to c. and fill between them and flush with their tops with a second layer of concrete. For a wearing surface lay a flooring of 3-in. plank spiked to the sleepers. Fig. 14 is a section of floor of this construction. This floor construction is heavy and solid and will carry ordinary machinery without special machine foundations.

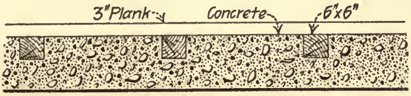


Fig. 14. Heavy Timber and Concrete Floor.

A much lighter and cheaper wood floor may be constructed by embedding 3-in. plank or half-round sleepers in a layer of 6 ins. or 8 ins. of cinders and spiking to them a flooring of 3-in. plank (Fig. 15). When this construction of floor is used all machines must be provided with special foundations. Wood block pavement on a concrete foundation is a form of shop floor which has been considerably used, but the writer cannot recommend this construction.

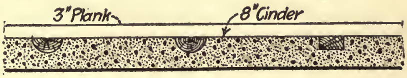


Fig. 15. Light Timber and Concrete Floor.

FLOOR FOR CAR SHEDS.—Car sheds for electric railways require a special floor construction because of the pits beneath the tracks for the use of the inspectors and cleaners. These pits are from 4 ft. to 5 ft. deep. A common construction is to build brick piers nearty to the height of the floor level which carry timber sills, to which the floor planking is spiked.

Where wood floors are employed the preservation of the timber from decay is an important consideration. The best authorities on the question recommend the application of a coating of lime ½-in. thick around the sills and on the bottoms of the floor planks. This protection should give the floor a life of 50 years. Mixing coal tar with the concrete makes a good preservative, or the concrete may be covered with tar wherever the floor timbers come in contact with it. Coating the sills and the underside of the planking with rosin is another excellent means of preventing decay.

UPPER FLOOR CONSTRUCTION.

STEEL TROUGH FLOORS.—There is probably no more substantial a construction for floors above the ground floor than the riveted steel trough construction known as the Lindsay floor. With this construction the floor boards may be laid directly on the metal or they may be spiked to small timber sills embedded flush in a concrete or cinder filling carried by the troughs, as shown by Fig. 16. The "Hand Books" published by most of the rolling mills give the safe load per square foot of trough flooring for various spans.

CORRUGATED IRON AND BRICK ARCH FLOORS.—A cheaper construction of iron floor than the steel trough consists of corrugated iron arches sprung between I-beams and filled above with concrete in which the timber sills are bedded and planked over, as shown by Fig. 17. This floor has no spring. Corrugated iron sheets of No. 18 B. W. G., having a span of 6 ft. and a rise of 10 ins., have in actual tests sustained a load of 1,000 ℔s. per square foot. Brick or terra cotta arches filled above with concrete is a floor construction which has been much used, but besides being heavy and expensive, this construction cannot be recommended for floors which are subjected to vibration from heavy running machinery. Fig. 18 is a section of brick arch floor.

STEEL GIRDER AND TIMBER FLOORS.—A floor construction which has been extensively employed consists of a timber flooring carried by metal beams or girders. Fig. 19 shows one form of this construction, which consists of steel I-beams spaced 3 ft. or 4 ft. apart and capped with timbers to which a flooring of 3-in. or 4-in. plank is spiked. Another form of this construction is shown by Fig. 20, which consists of built up steel girders capped with plank and carrying timber joists to which the plank flooring is spiked. In this construction the girders are spaced from 10 ft. to 15 ft. apart. Another form of I-beam and timber floor construction which is not much used in this country but which is a very efficient construction for heavy loads is shown by Fig. 21. The I-beam joists are spaced the proper distance apart, which should be not more than 3 ft. or 4 ft., so that the depth of the wooden flooring may be kept at the minimum, and on them planks are set close together on edge and firmly spiked together. The top of this planking is then covered with a ½-in. coating of fine sand mortar and a wearing surface of matched boards is laid on top of it.

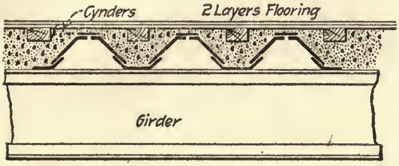


Fig. 16.

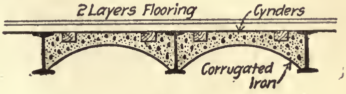


Fig. 17.

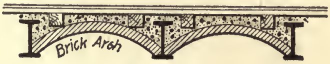


Fig. 18.

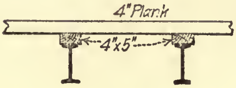


Fig. 19.

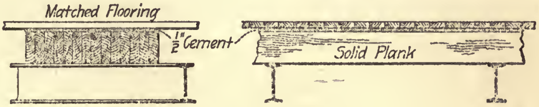


Fig. 21.

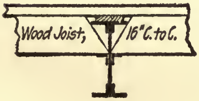


Fig. 20.

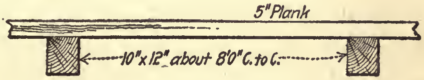


Fig. 22.

Figs. 16 to 22. Typical Upper Floor Constructions.

SLOW BURNING WOOD FLOORS.—A form of floor construction known as "slow burning construction" is shown by Fig. 22. The principle of this construction, which is entirely of wood, is to concentrate the timber into the fewest number of large pieces so that a minimum surface will be exposed to the attack of flames. The construction consists simply of widely spaced heavy timber joists covered with a flooring of heavy planks.

ROOF COVERINGS

GENERAL CONSIDERATIONS.—The importance of having an absolutely weather-proof roof for shop buildings is evident without argument. The kind of roof covering employed determines in a large measure the possible pitch or slope of the roof. A roof with a steep slope sheds rain and snow more efficiently than one which is more nearly flat, but it has the disadvantage of a greater area and consequently of being heavier and also of presenting a larger surface to wind pressure. All metal roofs are lightning-proof and because of their smooth surfaces are more easily kept clean by the wind and rain and the rainwater from them is likely to be more pure than that off a shingle or gravel roof. With these brief general remarks attention will be turned to the various forms of roof coverings.

SLATE ROOFING.—Roofing slates are usually from ⅛-in. to ¼-in. thick and of various sizes. The minimum slope of roof recommended for slate covering is one with a 6-in. pitch. If the pitch is less than this water is likely to be driven through the joints in beating rains. If, however, the joints are laid in cement, the pitch may be decreased to 4 ins. or 5 ins. to the foot. Cement joints are advantageous in any case since they prevent the slates from breaking and make the building warmer in winter and cooler in summer. A few courses of slate, with cement joints, are always advisable at the eaves and ridges and around chimneys. If the roof is exposed to the action of the corrosive gases, as is the case in chemical works, cement joints are imperative because any kind of nails will be destroyed after a time.

Slate when well laid have a longer life probably than any other form of roof covering; they will last for 50 years or more. Slate make a fire-proof roof covering, but they will crack when exposed to heat and also if they are walked upon. Hard slate of a shiny appearance are the best; those that absorb water will be destroyed by frost. Slate may be laid on boards, on lath or directly on iron purlins. When laid on wood they are held in place by two nails, one in each upper corner. When laid on iron purlins they are held in place by copper wire. For roofs of small pitch a lining of roofing felt will help to make the roof watertight.

The cost of nails for slate roofing varies with the market, but the following table is a fair average:

3d. galvanized slate nails, per keg	$5.50
4d. " " "	5.00
3d. tinned " "	5.75
4d. " " "	5.25
3d. or 4d. polished steel wire nails, per keg	4.00
Copper nails, per lb	.20

Slaters' felt in rolls of six squares costs $1.25 per roll; two-ply tar roofing felt costs $1 per square, and three-ply $1.25 per square. Slaters' cement in 25-℔. kegs costs 10 cts. per pound.

Shorter slates must be used for the first course at the eaves and the final course at the peak. To give the first course at the eaves the same inclination or slope that the succeeding courses will have, a thin lath must be laid under the slate at the edge of the eaves. A lap of 3 ins. is the amount usually allowed and it should not be decreased. Slate does not make a cheap roof covering, because it is heavy and requires a stronger framing to carry it, and because the steep pitch required makes the area to be covered large. At present the Brownville and Monson slates of Maine and the Peach Bottom slate of Pennsylvania are the best and also the most expensive.

The weight of slate per cubic foot is 174 ℔s., hence the weight per square foot of different thicknesses of roofing slate is as follows:

Thickness.	Weight, lbs. per sq. ft.	Thickness.	Weight, lbs. per sq. ft.
1/8-in.	1.81	3/8-in.	5.43
3/16-in.	2.71	1/2-in.	7.25
1/4-in.	3.62		

An experienced roofer will lay about two (10 ft. x 10 ft.) squares per day of ten hours. The price of the best slate on board cars at the quarries is from $5 to $7 per square, according to size and color. Red slate costs from $10 to $12 per square, and ordinary slate, black, purple, or of mixed colors, cost from $2 to $4 per square. These prices include punching and countersinking the nail holes. Table VI. gives the number of slate per square, using 3-in. lap for various sizes of slate.

TABLE VI.—Showing Number of Roofing Slate of Different Sizes and 3-in. Lap Required per Square of 10 × 10 ft.

Size, ins.	No. in each square laid.	Size, ins.	No. in each square laid.	Size, ins.	No. in each square laid.
6 × 12	533	9 × 16	247	11 × 22	138
7 × 12	457	10 × 16	222	12 × 22	126
8 × 12	400	9 × 18	214	12 × 24	115
7 × 14	374	10 × 18	192	13 × 24	106
8 × 14	327	10 × 20	170	14 × 24	98
9 × 14	291	11 × 20	154		
8 × 16	277	12 × 20	142		

ASPHALT ROOFING.—Asphalt roofing for flat roofs is applied as follows: (1) One or two layers of felt paper; (2) a coating of asphalt roofing cement; (3) a layer of roofing felt; (4) a final coating of asphalt cement into which is rolled clean sand and fine gravel. For pitched or sloping roofs the layers of roofing felt already cemented together by the first coating of asphalt cement are sold in rolls about 36 ins. wide. This covering is laid in courses with the edges overlapping about 2 ins. and fastened with the nails and tin washers. When laid the roofing is covered with the final coating of asphalt cement and gravel. A canvas bottom layer may be used in place of the first layer of paper. This form of covering, with the top covering and gravel complete and ready for laying is sold for $3.50 per square of 10x10 ft.

The principal advantage of any kind of asphalt roof covering is that it is perfectly water-proof, and after being laid it does not crack or peel off like tar and does not run at any natural temperature. When graveled over it makes a practically fire-proof roofing. Finally, it is easily applied by unskilled workmen.

SLAG AND GRAVEL ROOFING.—Slag is preferable to gravel for these roofs because of its lighter weight. The construction of both slag roofing and gravel roofing is as follows: (1) Three layers of felt paper are fastened to the roof; (2) a coating of tar is applied to the top layer of felt; (3) two layers of felt paper are laid on the tar; (4) a covering of tar is applied to the top layer of the second course of felt using about eight gallons of tar per 10x10 ft. square, and the slag or gravel is rolled into the tar. This form of roof covering should last from 10 to 20 years. It is fire-proof, needs no paint and refracts the heat. It is noiseless and is not affected by gas, acids, etc. Finally, it is a comparatively cheap covering, costing 50% less than tin.

CORRUGATED IRON ROOFING.—Corrugated iron is made from sheet iron of standard gages by stamping, one corrugation being stamped at a time. As there are no sharp joints to be made there is no advantage in using sheet steel. The corrugated sheets are made in lengths increasing in dimensions by even feet from 5 ft. to 10 ft., inclusive, and of such width that they lay 2 ft. even on the roof. The sizes of corrugations made in the United States are 5 ins., 2½ ins., 1¼ ins., ⅝-in., and 3-16-in. c. to c. of corrugations. The 2½-in. corrugation is the size most commonly used. Table VII. gives the costs and weights of both black and galvanized iron for Birmingham Wire Gage and the new American Standard Gage adopted by Congress in 1893.

TABLE VII.—Showing Cost and Weight per 10 × 10 ft. Square of Painted and Galvanized Corrugated Iron.

	Birmingham.				American.			
	Painted.		Galvanized.		Painted.		Galvanized.	
Gage.	Wt.lbs. per sq.	Price per sq.	Wt.lbs. per sq.	Price per sq.	Wt.lbs. per sq.	Price per sq.	Wt.lbs. per sq.	Price per sq.
28....	....	....	87	....	69	$2.90	86	$4.90
27....	72	$3.00	94	$5.40	77	3.10	93	$5.30
26....	81	3.20	101	5.60	84	3.30	99	5.50
24....	98	3.80	114	5.80	111	4.15	127	6.40
22....	123	4.60	141	6.80	138	4.90	154	7.40
20....	153	5.40	188	8.40	165	5.80	182	....
18....	214	7.20	221	11.60	220	7.40	236	....
16....	283	9.60	287	15.20	....	8.60	....	....

The prices given in Table VII. are for small lots; for car load lots the prices will be about 10% less. This table also refers to 5-in. 2½-in., and 3-16-in. corrugations; for 1¼-in. and ⅝-in. corrugations, 5% should be added to the weights and prices given. If painted with asphalt or graphite instead of iron oxide, the cost will be 25 cts. more per 10x10 ft. square. Wire nails cost 10 cts. per square; galvanized nails cost 15 cts. per square and cleats and bolts cost 25 cts. per square. The price of curved sheets is 20% more than that of straight sheets.

Fig. 23.

Fig. 24.

The sheets of corrugated iron should be laid with a lap of 4 ins., as shown by Fig. 23, when used for covering side walls, and with a lap of 6 ins., as shown by Fig. 24, when used for roof covering. When laid on wood sheathing corrugated iron covering is lined with water-proof paper and fastened with 6d. nails, using about 25 nails per sheet. When laid on iron purlins for boiler houses or anywhere that water is likely to collect on the underside of the corrugated sheets, a lining of the following composition may be employed: (1) Wire netting tightly stretched over the purlins; (2) asbestos paper; (3) tar paper; (4) asbestos paper; (5) tar paper; and (6) the corrugated iron roof covering. When corrugated iron is laid over iron purlins it may be fastened to them by clinch nails bent around the purlins, as shown by Fig. 25, or by cleats of ¾-in. hoop iron 2½ ins. long riveted or bolted to the sheets and to the purlins. Generally, however, cleats of this form are used especially with channel or Z-bar purlins. The clinch nails or cleats should be placed about 5 ins. or 6 ins. apart and care should be taken to connect them always to the tops of the corrugations, as shown by Fig. 25. The following table shows the size of clinch nails to be used with different sizes of angle purlins and also the number of nails to the pound in each instance:

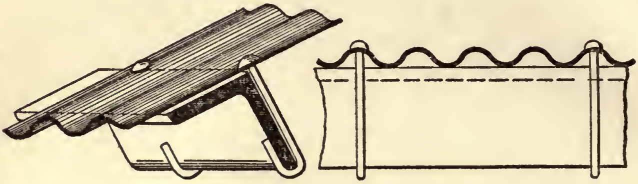


Fig. 25. Clinch Nail Fastening for Corrugated Iron Roofing.

Purlin angle	2 × 2 ins.	2½ × 3 ins.	3½ × 3½ ins.	4 × 4½ ins.
Length of nail	4 ins.	5 ins.	6 ins.	7 ins.
No. of nails per lb.	48	38	33	27

Corrugated iron of No. 27 and No. 28 gage is too thin to support any weight above and must be laid over sheathing. For other gages the purlin spacing should be as follows:

Thickness, B. W. G.	Spacing c. to c., ft.	ins.	Thickness, B. W. G.	Spacing c. to c., ft.	ins.
No. 26	2	0	No. 20	4	0
" 24	2	6	" 18	5	0
" 22	3	0	" 16	6	0

The advantage of galvanized over black corrugated iron is that it requires painting less frequently. Galvanized corrugated iron seldom needs to be painted within five or six years after erection. When painting becomes desirable, it is always necessary to remove the zinc by applying with a brush the following wash: Chloride of copper, one part; nitrate of copper, one part; and salammoniac, one part, dissolved in 64 parts of water, with one part hydrochloric acid added to the solution. This solution will burn the metal black ready to receive paint in about 24 hours. Black corrugated iron should be painted upon leaving the shop and about every two years thereafter.

Corrugated iron is not recommended for roofs having a slope of less than 3 ins. in 12 ins., and if it is used for flatter roofs all the joints should be laid in elastic cement. Cement joints can be used to advantage for roofs of any pitch since they ensure a much tighter covering. When corrugated iron is used for siding where it is liable to receive shocks, a heavy gage should be employed. The siding should not touch the ground as contact with the earth hastens its corrosion.

SHEET STEEL ROOFING.—Sheet steel is a cheap roof covering; it is light and water tight and as it comes in large sheets it can be rapidly applied; it is suitable for roofs of any pitch, is lightning proof and has a low insurance rate. Sheet copper, sheet lead and sheet zinc have been used for roofing in special cases, but they are much more expensive than sheet steel.

Sheet steel roofing is annealed Bessemer steel of the best quality; a sample piece may be hammered into all kinds of shapes without cracking. Sheet iron is unsuitable for roofing since it is liable to break when bent and hammered to a flat joint. Sheet steel roofing should not be laid over tar paper or on wood containing acids, and it should have a coat of paint on top. Steel roofing sheets are made 96x28 ins. in size and will cover an area 93½x24 ins. They must be laid over lath or sheathing, and if warm air comes into contact with the undersides of the sheets they should be protected by an anti-condensation lining of the construction used for corrugated iron roofing previously described, or by a lining of asbestos paper.

The weight of sheet steel roofing of the construction just described is about 80 lbs. per 10x10 ft. square. At present prices the cost per square of No. 27 B. W. G. sheet steel painted red is $3.50, and of galvanized sheet steel is $5.90. These prices are for small lots; for car load lots the cost will be about 10% less. Graphite paint costs 25 cts. more per square than iron oxide paint. Table VIII. shows the weight per square foot of painted and galvanized steel roofing sheets of different gages. Roughly speaking, galvanized sheets weigh about 20 lbs. per 10x10 ft. square more than black or painted sheets.

TABLE VIII.—Showing Weight in Lbs. per Square Foot of Steel Roofing Sheets of Different Gages.

		Gage.						
Gage.		27	26	24	22	20	18	16
B. W. G.	Black	.64	.72	.88	1.12	1.40	1.97	2.60
B. W. G.	Galvanized	.88	.94	1.06	1.31	1.75	2.06	2.69
U. S. Standard,	Black	.68	.75	1.0	1.25	1.50	2.00	2.50
U. S. Standard,	Galvanized	.84	.90	1.16	1.41	1.66	2.16	2.66

CRIMPED ROOFING.—Crimped roofing is laid directly on wood rafters or over sheathing, the latter construction being preferable, and is probably the least expensive metal roof covering available. It should have a pitch of at least 2 ins. to the foot. Crimped roofing weighs 83 lbs. per 10x10 ft. square painted, and its present cost for No. 27 B. W. G. is $3.10 per square painted and $5.50 per square galvanized. For car load lots 10% should be deducted from the above prices.

STEEL ROLL ROOFING.—Steel roll roofing differs from steel sheet roofing by having the sheets of 8 ft. and 10 ft. length joined at the factory into a continuous piece some 50 ft. long. As the side joints must be made after the material is laid out on the roof this roofing is more suitable to roofs of small pitch, say 1 in. to the foot, than to steeper roofs. Steel roll roofing is easily handled and the cost of shipping is less than in the case of steel sheets which have to be boxed. Parrafined felt packing should be inserted in the joints. If desired the manufacturers will make steel roll roofing in any length required up to 150 ft. to suit the length of roof to be covered. This roofing weighs about 85 lbs. per 10x10 ft. square, and in sheets of No. 27 B. W. G. it costs $3.50 per square painted, and $5.90 per square galvanized. Steel roll roofing requires no ridge capping since the strips or rolls are continuous over the ridge. Generally the manufacturers of any kind of steel roofing having folded joints provide special tools for laying it.

TIN AND TERNE PLATE ROOFING.—Tin and terne plate roofing are generally used only for flat roofs or roofs with a small pitch. The plates come in 14x20-in. and 28x20-in. sizes, and well laid plates of good quality should last 30 years. It is very important to the life of the covering that its joints should be well soldered and that there should be no travel on the roof. Tin and terne plates may be laid on sheathing or over old shingles. If the roof is quite flat all joints should be soldered, but when laid on sloping roofs the side joints may be folded and the cross or horizontal joints soldered. Some roofers lock all joints and fill the horizontal seams with lead. The sheets are fastened to the roof by cleats; if the side joints are soldered the cleats should be soldered in the joints. For sloping roofs it is often convenient to have a number of sheets jointed in the shop into strips of the right length to reach from the eaves to the ridge. After laying the plates should be painted with two coats of paint and they should be repainted about every two years afterward. To reduce the noise, tin or terne sheet roofing may be laid on a lining of tar paper.

The old method of preparing tin or terne plates was to immerse the sheet of iron or steel in a bath of tin or lead, a coating of which adhered to the plates when they were removed. The modern method of manufacture is to pass the sheets between rolls which are immersed in a bath of tin or lead, and thus by adjusting the rolls to secure a coating as thin or as thick as may be desired. The cost of the finished plate depends largely upon the thickness of the coating. Plates coated with lead are called ternes and are somewhat cheaper and less durable than tin plates. Terne plates are more generally used for roofing than tin plates. The best plates are made from charcoal iron, but Bessemer steel is also used. The thickness of sheets commonly employed are known as I C and I X, and correspond to No. 30 and No. 28 B. W. G., respectively.

METAL SHINGLE ROOFING.—Metal shingles are made either of tin or terne plate or of sheet steel painted. They possess the regular advantages of metal roofing, being fire and lightning proof, of light weight and not being easily cracked or detached. Like shingles of any kind they cannot be laid on flat roofs. They are manufactured in a great variety of sizes and forms to fit different kinds of sloping roof, are durable and present a fine appearance. Metal shingle roofing weighs from 90 lbs. to 110 lbs. per 10x10 ft. square.

RUBBER ROOFING.—Rubber roofing is made of felt paper soaked in a preparation of rubber and then rolled. It is put up in rolls 32 ins. wide and is laid lengthwise of the roof and fastened either with strips running up and down the roof about 2 ft. apart or with nails and tin washers. After being laid the roofing is coated with two coats of slate paint, the upper coat of which is sanded. Rubber roofing is very cheap and is especially suitable for temporary roofs or for sheds where an expensive covering is not required. When painted it does not take fire easily, and it can be laid on roofs having a pitch as flat as 2 ins. to the foot. It does not make a hot upper story as some other coverings do. The slate paint does not contain tar and so will not crack or peel off, and it is very elastic. The color is chocolate brown. As usually laid the layers are lapped about 2 ins. The cost of rubber roofing complete as described, including nails, painting and sanding, runs from about $2.50 to $3.75 per 10x10 ft. square, according to the thickness of the felt paper used.

ASBESTOS ROOFING.—Asbestos roofing is made of canvass coated on both sides with a water-proof composition and lined on the bottom with Manilla paper and on the top with asbestos felt. It is laid in horizontal courses and fastened with nails and tin washers, and afterwards it is coated with asbestos paint. Asbestos roofing weights complete as described about 85 lbs. per 10x10 ft. square and costs about $4.50 per square. The covering requires occasional repainting, the paint costing from 40 cts. to 50 cts. per gallon and one gallon covering about 100 sq. ft. Asbestos cement for stopping leaks and calking around chimneys costs from 5 cts. to 10 cts. per pound. Asbestos building felt in rolls 36 ins. wide weighing about 70 lbs. per roll costs about 12 cts. per pound. This paper runs 6 lbs., 10 lbs., and 14 lbs. in weight for thin medium and thick paper, respectively. Another paper made from long fibered asbestos costs about 15 cts. per pound.

WOOD SHINGLE ROOFING.—According to Kidder's "Architects' Pocket book":

> "The average width of a shingle is 4 ins. Hence when shingles are laid 4 ins. to the weather, each shingle averages 16 sq. ins., and 900 will cover a square. If laid 4½ ins. to the weather, 800 will cover a square; if laid 5 ins. to the weather, 650 will cover a square; and if laid 6 ins. to the weather, 600 will cover a square. This is for common gable roofs. In hip roofs where the shingles are cut more or less to fit the roof, add 5%. A carpenter will carry up and lay on the roof from 1,500 to 2,000 per day, or two and a half squares of plain roofing; 1,000 shingles laid 4 ins. to the weather will require 5 lbs. of shingle nails."

When cost will permit and the roof is not steep shingles should be laid in ¾-in. of mortar, as the lime prevents decay. The life of shingles is greatly increased if they are dipped in paint before being laid.

COMPARATIVE COST.—The comparative approximate cost per square of 10x10 ft. of the several kinds of roof covering which have been described is given by Table IX.

TABLE IX.—Giving Comparative Approximate Cost per 10 × 10 ft. Square of Different Roof Coverings.

Slate on iron purlins	$2.00	to	$7.00	per sq.
Metal tile, tin	8.50	“	9.75	“
“ “ steel, lead-coated	10.75	“	13.75	“
Rubber roofing	2.00	“	3.75	“
Felt and gravel	6.50			“
Ornamental tile	40.00	“	60.00	per M.
Tile shingles	21.00	“	35.00	“
Charcoal tin plates, I.C., 14 × 20 ins.	6.00	“	6.50	per box of 112.
“ “ I.C., 20 × 28 “	12.00	“	13.00	“ “
“ “ I.X., 14 × 20 “	7.50	“	8.50	“ “
“ “ I.X., 20 × 28 “	15.00	“	17.00	“ “
Coke plates, tin, I.C., 14 × 20 ins.	5.50			“ “
“ “ “ I.C., 20 × 28 “	11.50	“	12.00	“ “
“ “ “ I.X., 14 × 20 “	7.50			“ “
Charcoal plate, terne, I.C., 14 × 20 ins.	5.50			“ “
“ “ “ I.C., 20 × 28 “	10.75	“	11.00	“ “
“ “ “ I.X., 14 × 20 “	6.40			“ “
“ “ “ I.X., 20 × 28 “	12.80			“ “

MISCELLANEOUS STRUCTURAL DETAILS.

WALL ANCHORAGES OF ROOF TRUSSES.—There are several methods of anchoring roof trusses to the side walls of buildings. Fig. 26 shows the standard anchorage in which the lower chord of the truss is connected by bolts to the projecting end of a plate built into the wall masonry. Fig. 27 shows an anchorage consisting of bolts set into the wall and attached to a washer plate at their bottoms. Fig. 28 shows a similar anchorage with the washer plate omitted and the bolts held in the masonry by cement. Fig. 29 shows a method of attaching the truss to the side of the wall. As shown by the drawing, the anchor bolts pass through the wall against the outside of which their heads secure a bearing by means of a washer plate. The area of this washer plate in square inches should equal eight times the tension on the bolts in tons. It is important also that the end of the truss should fit tight to the wall, shims being used if necessary to ensure such a fit. The following table shows the diameter of bolt to be used for walls of different thicknesses; the washer plate area in square inches to be allowed for each bolt, and the holding value of the bolt in tons:

Diam., ins.	8-in. wall, tons.	12-in. wall, tons.	16-in. wall, tons.	20-in. wall, tons.	Area of plate, sq. ins.
⅝....	0.5	0.7	...	...	18
¾....	0.6	0.9	1.0	...	26
⅞....	0.7	1.05	1.4	...	36
1.....	0.8	1.2	1.6	1.77	46

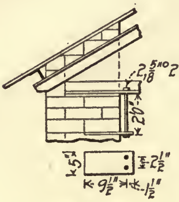


Fig. 26.

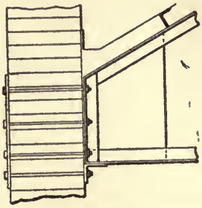


Fig. 29.

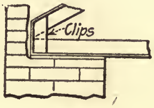


Fig. 30.

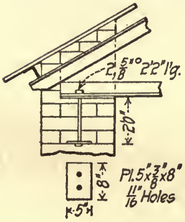


Fig. 27.

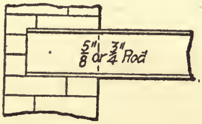


Fig. 31.

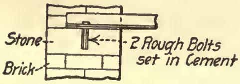


Fig. 28.

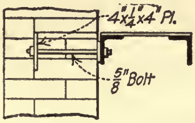


Fig. 32.

Figs. 26 to 32. Typical Wall Anchorages for Roof Trusses.

When it is inexpedient to pass the anchor bolts through the wall, as shown by Fig. 29, the anchorage is accomplished by inserting expansion bolts into the wall. The following table shows the holding power of expansion bolts of different sizes:

Diam.,	Holding power in tons for lengths of				
ins.	4 ins.	6 ins.	8 ins.	10 ins.	12 ins.
⅝....	0.24	0.36	0.46	0.52	...
¾....	0.28	0.42	0.56	0.70	0.84
⅞....	...	0.47	0.65	0.81	0.99
1.....	...	0.57	0.75	0.93	1.12

Fig. 30 shows the end of the truss built into the wall, the angle clips serving as anchors. Fig. 31 shows the method of anchoring a beam built into the wall; the length of the rod should equal the width of the beam flange plus 6 ins. Fig. 32 shows the manner of anchoring channel beam wall struts. The anchor bolts should be spaced about 3 ft. apart. If the struts are to be anchored to a wall already built the bolts should be run through the wall with washers on the outside, or expansion bolts may be used.

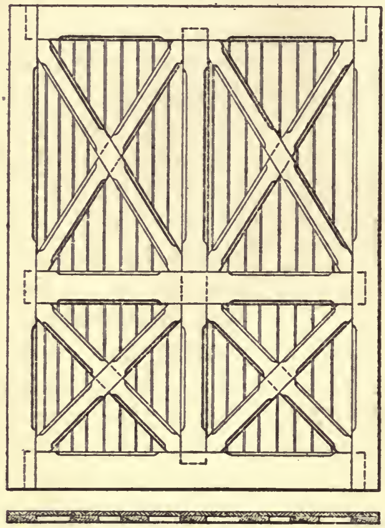
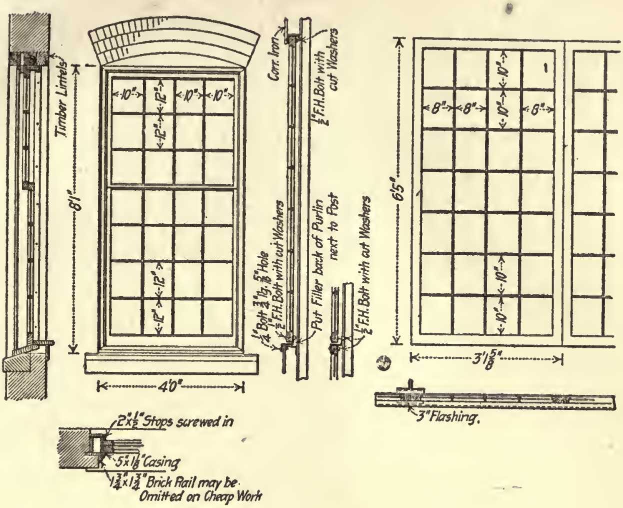


Fig. 33. Construction for Narrow Doors.

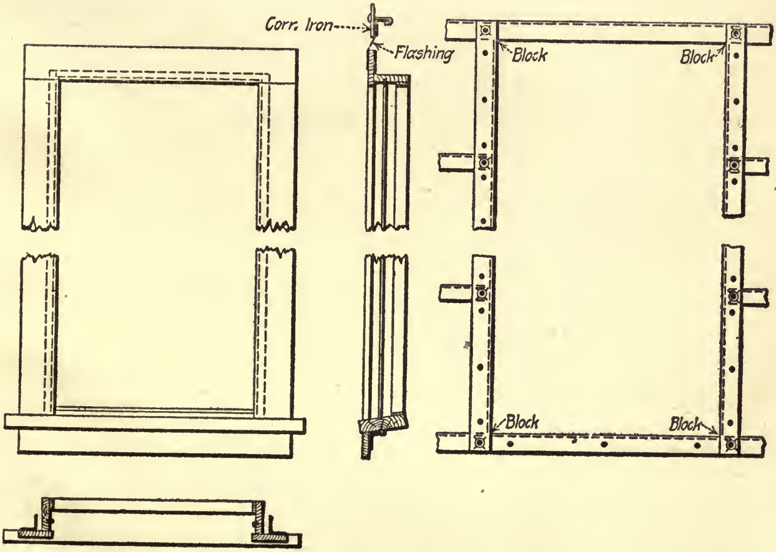
DOORS AND WINDOWS.—Narrow doors may be made without center styles and wide doors should have two or more spaced from 3 ft. to 6 ft. apart. The rails and styles should be halved together, and they and the diagonals also should have a ⅛-in. chamfer; the sheathings should be screwed on. Fig. 33 shows a door of the construction described. Tables X. and XI. give the proper sizes of material and hardware for doors of different sizes.

TABLE X.—Showing Proper Sizes of Material for Doors up to 14 × 20 ft. in Size.

Size of Doors. In ft.	Styles. Ins.	Rails. Top. Ins.	Rails. Center. Ins.	Rails. Bottom. Ins.	Diags. Ins.	Sheath. Ins.
5 × 8 or less........	4 × 1¼	4 × 1¼	4 × 1¼	6 × 1¼	4 × 1¼	4 × ⅞
5 × 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



Figs. 34 and 35.



Fig, 36.

Figs. 34 to 36. Details for Side Window in Brick and Iron Frame Walls.

TABLE XI.—Showing Dimensions of Hinges and Appurtenances for Doors of Different Sizes.

Stanley Works Heavy Hinges.

	Plain		Galvanized.		Screws.		
Size of doors. Ft.	Strap. Ins.	T. Ins.	Strap. Ins.	T. Ins.	Door. Ins.	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. “ “				“	“	½
Over 5 × 12...	36-in. “ “				“	“	½

Fig. 34 shows the details for a side window in a brick wall. Using 10x12-in. glass, these windows are usually made with from 24 to 40 lights or panes. The sizes of wall openings required for windows with from 24 to 40 10x12-in. lights, are as follows:

No. of lights.	Size of opening.
24	4 × 7 ft.
28	4 × 8 ft. 1 in.
32	4 × 9 ft. 1 in.
40	4 ft. 10 ins. × 9 ft. 1 in.

Figs. 35 and 36 shows details of window construction in the side wall of an iron frame building covered with corrugated iron.

VENTILATORS.—Ridge ventilators may be in the form of a monitor roof or they may be round ventilators placed at intervals (Fig. 37). The area of ventilators required per 100 sq. ft. of floor surface for shop buildings of various kinds is given in square feet by the following table:

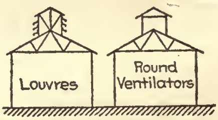


Fig. 37.

Height, in ft., above ground.	20	30	40	50	
Machine shop, sq. ft......	⅞	¾	⅝	½	Round vents.
Mills, sq. ft..............	7	6	5	4	Louvre vents.
Forge shop, sq. ft........	9	8	7	6	Louvre or open vents.

The areas given in this table are net areas and when louvres are used 60% should be added to allow for the obstruction of the opening by the slats. The areas in square feet of round ventilators of different diameter are as follows:

Diameter, ins....	12	18	24	36	38	42	48
Area, sq. ft................	0.8	1.8	3.1	4.9	7.1	9.6	12.6

Details of a monitor roof ventilator with louvres are shown by Fig. 38. Fig. 39 shows details of a monitor roof ventilator with hinged flat iron shutters. These details are for a shutter 8 ft. long. Ordinarily, shutters should be made 6, 7, 8, 9 or 10 ft. long, but intermediate lengths may be used if necessary. The width of the shutters should be the same for all lengths. The shutters may be either

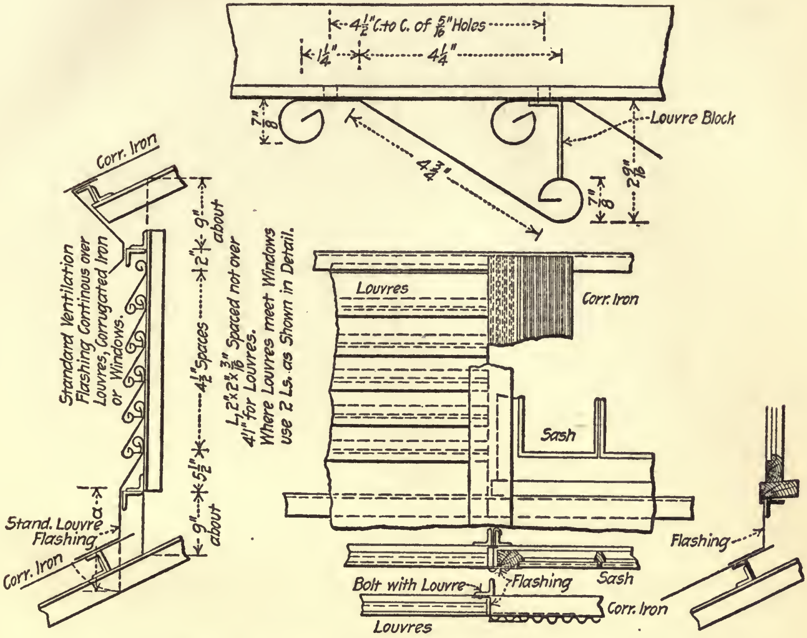


Fig. 38. Monitor Roof Ventilator with Louvres.

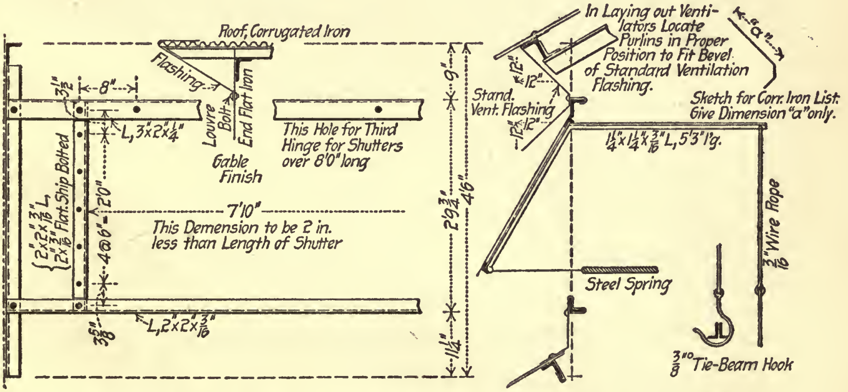


Fig. 39. Monitor Roof Ventilators with Hinged Flat Iron Shutters.

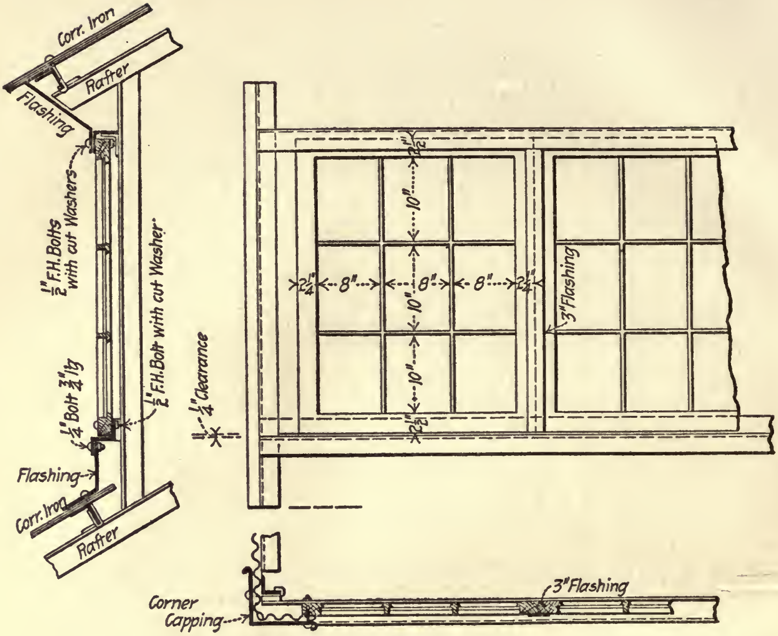


Fig. 40. Montior Roof Ventilator with Fixed Sash.

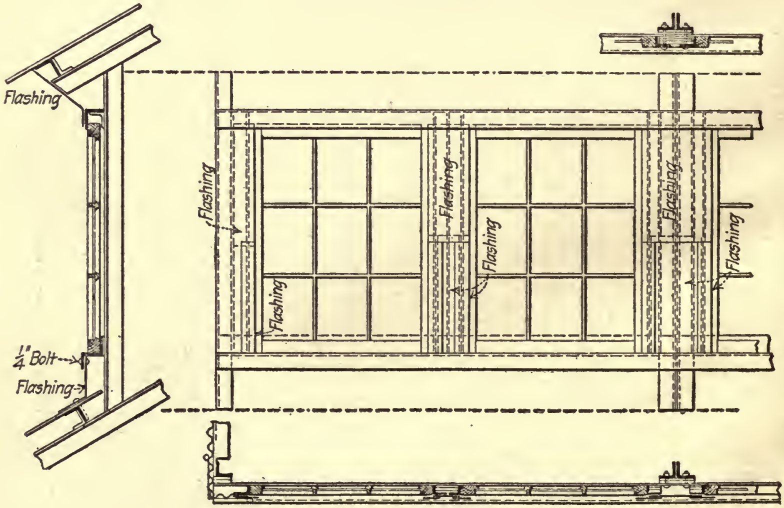
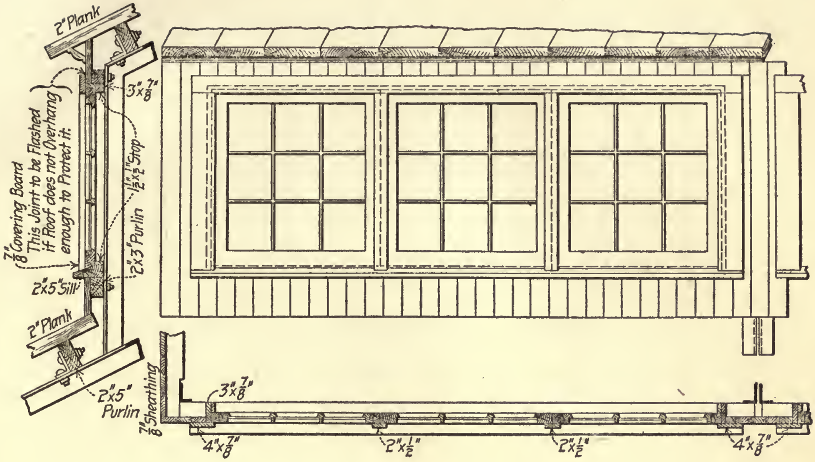
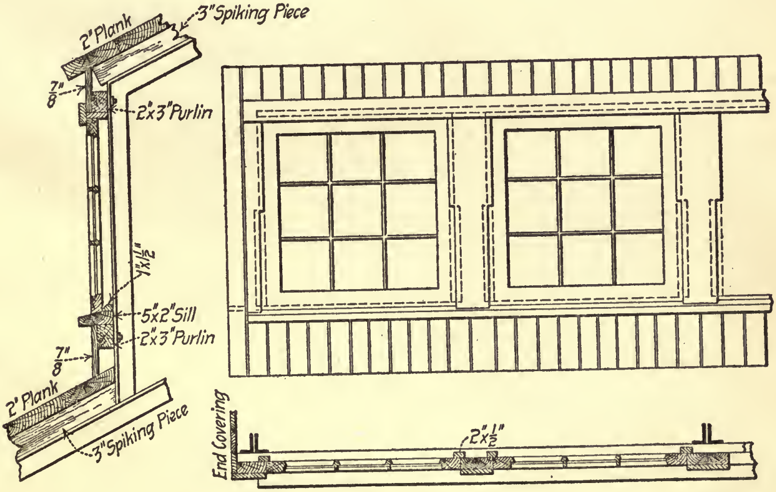


Fig. 41. Monitor Roof Ventilator with Movable Sash.

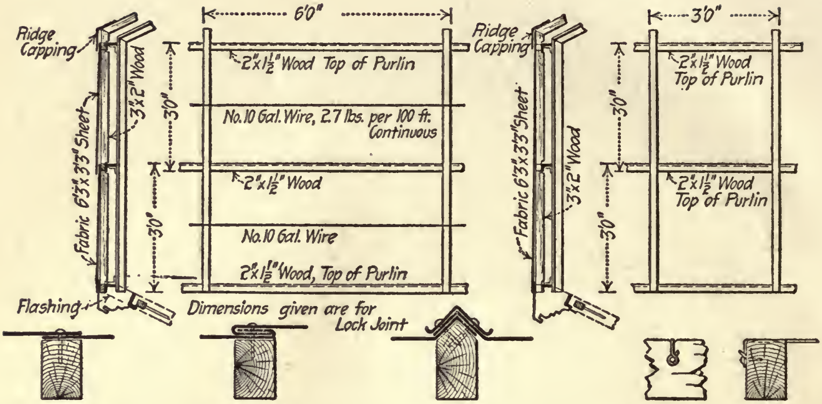


Fig, 42.



Fig, 43.

Figs. 42 and 43. Monitor Roof Ventilators with All-Wood Framing.



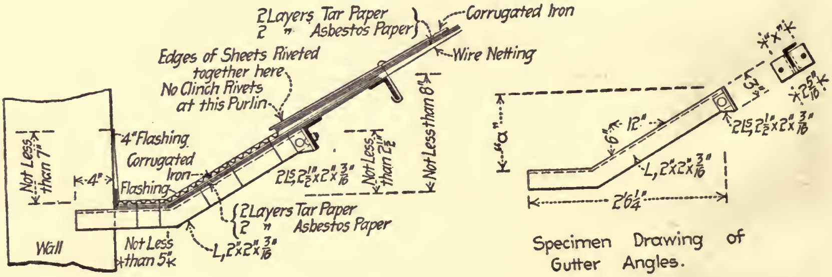
Detail of Lap Joint.

Detail of Lock Joint.

Detail of Capped Joint.

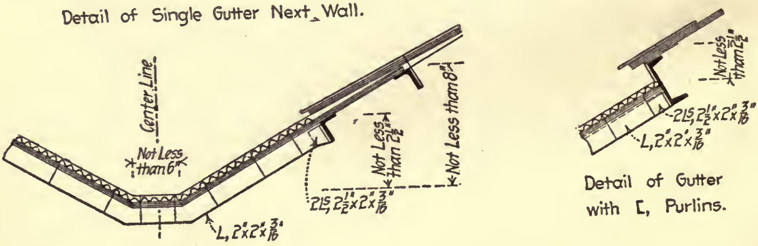
Method for Fastning Ends of Wire.

Fig. 44. Monitor Roof Skylight of Translucent Fabric.



Detail of Single Gutter Next Wall.

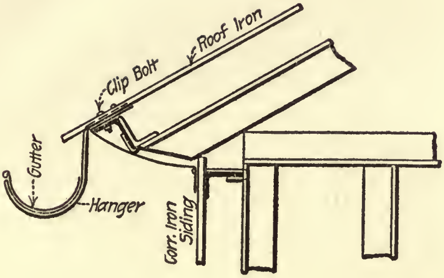
Specimen Drawing of Gutter Angles.



Detail of Double or Valley Gutter.

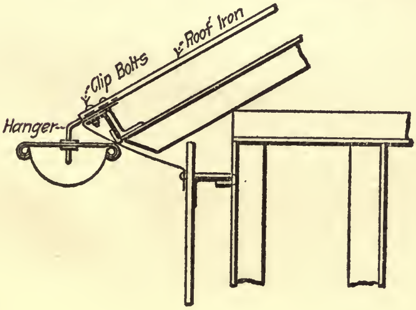
Detail of Gutter with [, Purlins.

Fig. 45. Single and Double Gutters.

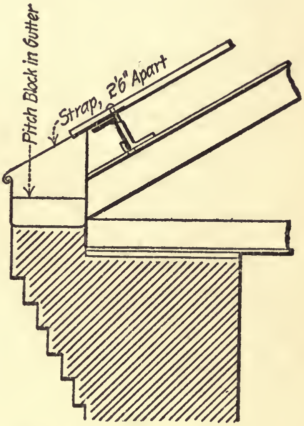


For Hanging Gutters, Punch $\frac{5}{16}$" Holes in Purlin to take Hangers.
Out Edge of Gutter must not Extend above Roof plane prolonged.

Hanging Gutter
Berger's Patent Adjustable Hanger.



Hanging Gutters "D.B."
Adjustable Strap Hanger.



Details of Box Gutter.

Fig. 46. Types of Fixed and Hanging Gutters.

of black iron or galvanizd iron. If galvanized iron is used all covering and flashing for the ventilator roof, sides and ends, and all bolts, clips, clinch rivets or other fastenings, any part of which shows on the outside of the covering or finishing, should also be galvanized.

Fig. 40 shows a monitor roof ventilator with fixed sash and all iron framing, and Fig. 41 shows a similar construction with movable sash. Figs. 42 and 43 show monitor roof ventilators with fixed and swing sash, respectively, all wood framing. Fig. 44 shows a skylight on roof of monitor made of translucent fabric. It should be noted that the roofing sheets run lengthwise of the building and are 6 ft. 3 ins. x 3 ft. 3 ins. in size. This size of sheet should be used whenever possible, although sheets may be readily cut to smaller sizes. The width of the lap should be 2 ins. and both edges should be securely fastened. For fastening the fabric wire nails 1¼-in. long, or 3d nails, should be used; the amount required being 1¼ lbs. per 100 ft. of seam. Lap joints or lock joints can be used for all seams, but capped joints can be used only for seams running in the direction of the roof slope.

GUTTERS AND DOWN SPOUTS.—The sizes of gutters and down spouts and their distance apart for roofs with ¼ pitch and of different spans are shown by the following table:

½ roof span, ft.	10	20	30	40	50	60	70	80
Size of gutter, ins.	5	5	6	6	7	7	8	8
Size of down spouts, ins.	3	3	4	4	5	5	6	6
Spacing of down spouts, ft.	50	50	50	50	40	40	40	40

The slope of gutters should be at least 1 ft. in 50 ft. When the length of the roof overruns the spacing more than 10 ft. an extra down spout should be put on.

Fig. 45 shows details of single and double gutters with both angle and channel purlin connections, and Fig. 46 shows different forms of hanging and box gutters. Regarding hanging gutters it may be noted that ordinarily gutters should slope 1 in. in 15 ft. A 6-in. gutter takes a 4-in. leader and will drain about 3,000 sq. ft. of horizontal surface. A 4-in. gutter will take a 3-in. leader and will drain about 1,700 sq. ft. of horizontal surface. Hangers for hanging gutters should be spaced about 2 ft. 6 ins. apart.