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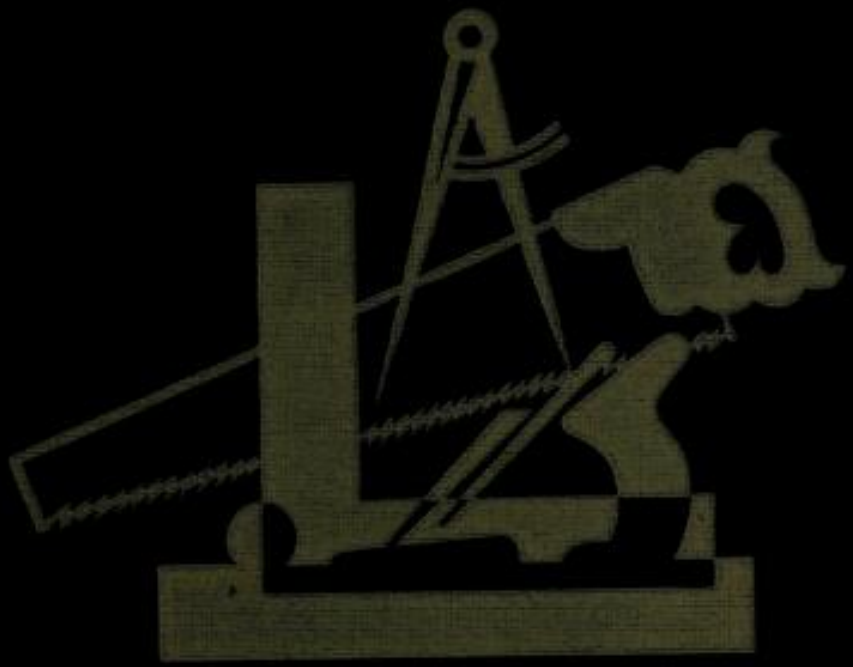

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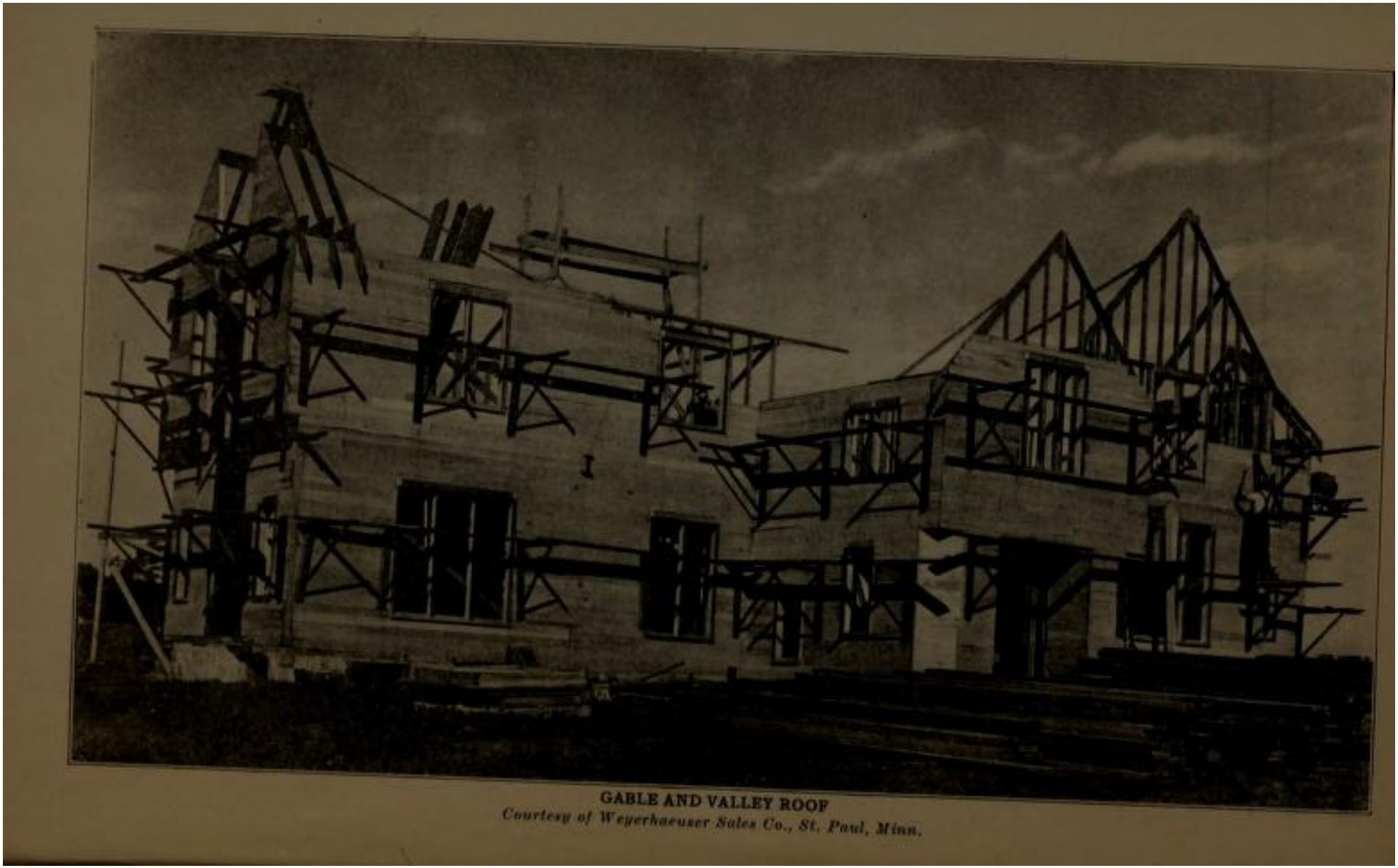

GABLE AND VALLEY ROOF

Courtesy of Weyerhaeuser Sales Co., St. Paul, Minn.

CARPENTRY

A Practical Treatise on Simple Building Construction, Including Framing, Roof Construction, General Carpentry Work, Exterior and Interior Finish of Buildings, Building Forms and Working Drawings

By Gilbert Townsend, S.B.

Member of Royal Architectural Institute of Canada
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Architects and Engineers, Montreal, Canada

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REVISED EDITION

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INTRODUCTION

IN THE very nature of things the present-day carpenter is not the same sort of a workman as his brother of twenty-five years ago, but if anyone imagines for a moment that he is a disappearing species that person should inspect some building operations in his own locality in order to correct this impression.

With all the strides which have been made in steel and concrete construction, and in the face of the developments in mill work and in the manufacture of special building material, no method has ever been devised for dispensing with the services of the skilled worker in wood. His knowledge of lumber and of its behavior under varying conditions; his ability to perform rapidly and in workmanlike manner the many details connected with the frame, the roof, the walls, and the exterior and interior finish; and his technical knowledge of the simpler elements of construction make him an efficient workman, and give him the ability to rise to higher things.

It is with the idea of satisfying a real demand for a practical work on Carpentry and Joinery which shall cover in every detail the many problems the present-day workman and contractor must meet and solve, that this volume has been published. It is especially adapted for purposes of self-instruction and home study. The utmost care has been used to make the treatment appeal to the technically trained expert as well as to the beginner and the self-taught practical man.

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DIAGONAL LAYING OF ROUGH FLOORING MEANS GREATER STRUCTURAL STRENGTH AND IS A STANDARD PRACTICE AMONG CARPENTERS

Courtesy of American Builder

CARPENTRY

PART I

INTRODUCTION

The carpenter has always been a worker in wood and probably will always be so, unless we are so foolish as to neglect the newer art of Forestry to such an extent that in the course of time we have no wood wherein to work and with which to build and decorate our habitations. The building and the decoration of houses and other structures has always been the special contribution of the carpenter to the general welfare of the community, and this feature has distinguished him from other woodworkers such as furniture builders, shipbuilders, coopers, and makers of various implements. But whereas the carpenter formerly did all the work connected with the building or decoration of the structure, he now performs only a small part of it. At one time he was called upon to prepare the rough lumber for framing, erect the building, make the doors and windows together with their frames, and then make and put in place all the outside and inside finish, even including the furniture. In these days, however, factories are doing a great deal of this work, such as the manufacture of doors and window sash, interior finish, furniture, etc., and the lumber which was formerly prepared by hand is now sawed, cut, planed, molded, and even sandpapered by machinery, leaving for carpenters the preparation of the framing of buildings not large enough to be built of brick, stone, steel, or concrete, and the putting in place at the building of the exterior and interior finish which has previously been made ready so far as possible at the factory. The old-time joiner has given way to the modern cabinet maker or the factory woodworker, and his plane, saw, and chisel have been replaced by electrically-driven machinery of the planing mill and the door factory. Nevertheless, the principles upon which the art of carpentry is based have not changed, and we still use the

formulas, and profit by the wisdom which has come down to us from our fathers.

The carpenter has always found at hand his material provided by Nature, needing only to be cut down and shaped to suit his purposes. It is easily worked, beautiful in texture, and capable of being treated with paints, oils, and varnishes in such a way as to preserve it and at the same time give it a pleasing appearance. So suitable is wood for purposes of interior decoration that now when other materials such as sheet metal are substituted for it on account of their greater durability or their superiority as fire resistants, great pains are often taken to make these materials look like wood by the skillful use of paints and varnishes, and such good results have been obtained along this line, and the grain of the various kinds of wood has been so closely imitated, that one not accustomed to woodwork in a business way can hardly distinguish the real wood from the imitation.

A knowledge of the characteristics of this material which plays so important a part in our lives and which is so plentiful, especially in the more recently settled parts of the earth, is sure to prove of advantage to all, and such knowledge is an absolute necessity to the carpenter, architect, or other user of wood.

Unlike many of the other materials used in building, wood has life and has come into existence by a process known as growth, and these two facts have a very important bearing on the use of wood in construction, as they affect both its physical characteristics and its action after it has been put in place in a building. In order, therefore, to be able to make use of wood intelligently, it is necessary to know something about its mode of life, its method of growth, and the way in which it will act after it has been cut away from the tree, killed, so far as it is possible to kill it, by seasoning or drying, and then setting up in place. All woods are not the same in these respects; in fact, no two kinds of wood are exactly the same in structure, nor will they behave in the same way even under the same conditions, and this makes it necessary to select them very carefully for various purposes and for use in various places.

While it is true that no two kinds of wood are exactly the same in structure, they still have some things in common. For example, all wood is a vegetable product, and all wood is built up in the same

general way out of a very great number of individual parts called cells, or fibers, which are like so many tiny pockets filled with a fluid substance. The size, shape, and arrangement of these little cells is different in different kinds of wood, and this accounts for the differences in appearance, texture, and durability. Wood is largely composed of carbon, which accounts for the readiness with which it takes fire and the heat which it gives off when burned. There is also a considerable quantity of water, the exact amount depending upon whether the wood is seasoned or is still green, and even seasoned wood, if it is left lying about in a damp place, will absorb more or less moisture from the atmosphere.

There are two words which are used to describe the wood used for building purposes, namely, *timber* and *lumber*. Timber is the name which can properly be applied to any wood which is suitable for structural uses, when the material is in its natural state, before it has been cut down and prepared for the market. Lumber is the word which should be used to describe the timber after it has been cut down and sawed up into pieces ready for use. In practice, the word *timber* is often used to designate the larger beams of a structure although these beams are ready for use. We will first consider the timber in its natural condition, study its manner of growth, the different classes of trees, the defects which are to be found in this material and their causes, the way in which timber is converted into lumber, and pass on to the consideration of the various kinds of timber.

TIMBER IN ITS NATURAL STATE

CLASSES OF TREES

There are in general four kinds of trees from which lumber suitable for structural purposes may be obtained, which differ from each other in their manner of growth and in the details of their structure, as well as their adaptability to building work, but of these only two, the so-called broad-leaved trees and the needle-leaved trees, yield lumber used in any great quantity for building. The other two, palms and bamboos, are suitable for structural work but for one reason or another have not been extensively utilized as yet except in the immediate neighborhood of the places where they grow. In the woodworking trade, the broad-leaved trees and the needle-leaved trees are referred to as hardwoods and softwoods. The hard-

woods come from the broad-leaved trees, and the softwoods come from the needle-leaved trees. However, this terminology can sometimes be confusing, because no definite degree of physical hardness divides the hardwoods and softwoods. Basswood, which is classified as a hardwood, is actually much softer than yellow pine, which is classified as a softwood but is rather hard. There are other cases similar to this, but, in general, the oaks and maples and other hardwoods are hard both in name and character, and the white pines, spruces, and other softwoods are soft both in name and character.

Manner of Growth. There is a marked difference between the four classes of trees mentioned above in regard to their manner of growth. The palms and bamboos are somewhat similar and are known as endogenous trees, differing from the broad-leaved trees and the conifers which are known as exogenous trees. The endogens, to which family also belong cornstalks and certain kinds of grasses, increase from the inside and do not usually have a covering of bark. The wood is soft in the center of the trunk and becomes hard toward the outside. The soft interior of the stem sometimes is found to be missing entirely, leaving a hollow sort of tube, but this is true of the bamboos only, the palms being solid. The wood of these trees is composed of a multitude of cells or pockets like that of the exogenous trees, but the end of a log which has been cut does not show the rings which we see at the end of a log cut from a broad-leaved tree or a conifer, Fig. 1. Instead we see a series of dots of a darker color than the general surface, the difference being due to the different ways in which the two kinds of trees grow.

Fig. 1. Log Section of Conifer Showing Age Rings

The exogenous trees, to which class belong the broad-leaved trees and the conifers, increase from year to year both in height and in size of trunk. The increase in height and in the length of the branches is the result of a sort of extension process which takes place at the ends of all the small offshoots as well as at the extreme end of the main trunk of the tree. A bud is first formed at each of these places and speedily develops into a small twig, at first quite

soft and with a covering of thin skin. In the course of time the skin gets harder and darker in color and the woody tissue inside gets firmer, while the extension process continues to take place at the end. Thus the branch or trunk of the tree becomes each year a little longer but any particular point on the branch remains in the same position with relation to the ground or to the parent trunk or branch. While the lengthening process is going on, another and a different kind of growth is taking place. The fluid known as sap is continually passing up and down between the roots of the tree and the leaves, and each year a new layer of wood is formed on the outside of the trunk and branches underneath the bark. Thus a cross section of the trunk of an exogenous tree presents a series of rings beginning at the center, where there is a small, whitish substance called pith, and extending to the outside where there is a covering of bark. In Fig. 1, *A* is the pith, *B* is the woody part of the tree, and *C* is the bark. The arrangement of the wood in concentric rings is due to the fact that it was formed gradually, one layer being added each year, and for this reason the rings or layers are called annual rings. It is interesting to note that the age of the tree may usually be determined with a fair degree of accuracy by counting the number of layers which appear on the cross section. The width of the annual rings varies from one-fiftieth of an inch to one-eighth of an inch according to the character of the tree and the position of the ring with relation to the center. In general, it may be said that the widest rings are to be found nearest the center or pith and that they grow regularly narrower as they approach the outside or bark. They are also wider at the bottom of the tree than at the top. The rings are very seldom circular or regular in form, but follow the contour of the tree trunk.

The wood nearest to the center of the tree where the pith is located is considerably harder and denser, as well as darker in color, than that which is on the outside nearer the bark. This wood is called heartwood to distinguish it from the other and softer wood which is called sapwood. The reason why the heartwood is harder and denser than the sapwood is that it is older and has been compressed more and more each year as the tree has increased in size, so that the pores have gradually become filled up. The sapwood is soft and of a lighter color than the heartwood showing that it has

been more recently formed. The time required to transform the wood from sapwood to heartwood varies from nine to thirty-five years, according to the nature of the tree, and those trees which perform this hardening in the shortest time usually yield the most durable timber. It is not certainly known whether the change from sapwood to heartwood takes place ring by ring and year by year or whether sections of the trunk consisting of a number of rings change at the same time, but it is probable that the latter process is what really takes place, indeed there seems to be evidence to show that not even the whole of each ring changes at one time, but that part of a ring may remain sapwood after the remainder has become heartwood.

In addition to the annual rings, there are to be seen on the cross section of any log other lines which run from the center toward the bark at right angles to the annual rings. These are called medullary rays. Usually they do not extend to the bark, but alternate with others which start at the bark and run in toward the center but are lost before they reach the pith. This is shown at *E* and *F* in the figure. The medullary rays are much more pronounced and the structure of the wood is much more complicated in the broad-leaved trees than in the conifers, the structure of which is comparatively simple with most of the fibers running up and down in the direction of the growth of the tree. Thus, the wood of the pines and other conifers splits very much more easily than that of the oaks, chestnuts, and other broad-leaved trees.

Medullary rays are sometimes called pith rays and are caused by fibers or bundles of fibers which run at right angles to the others. It is the pith rays which appear as smooth, shiny spots or blotches in woods which have been quarter sawed. This will be explained later when dealing with the conversion of timber from its natural state into planks and other shapes ready for the market.

Details of Wood Structure. If a piece of wood were to be examined carefully under a microscope it would be seen that it was a composite substance, made up of a great number of very small fibers, and that these fibers were not solid but were so many little tubes or cells arranged together in a more or less complicated manner according to the kind of wood. Thus a piece cut from one of the needle-leaved trees would be seen to be much more simple and regular

in arrangement than a piece cut from one of the broad-leaved trees. Both kinds of wood are composed of bundles of these fibers or tubes running parallel to the stem of the tree which are crossed by other fibers running at right angles to the first ones and binding the whole together. The cross fibers are much more numerous in the wood of the broad-leaved trees than in that of the conifers, and it is these fibers which appear on the cross section of a log as pith rays. There are also to be seen through the microscope a few resin ducts and other special fibers scattered through the wood. It is said that in pine more than 15,000 fibers occur on a square inch of section so that each one is very small and they can not be distinguished without the aid of a powerful microscope. The general arrangement is shown in Fig. 2, in which *AA* are the fibers parallel to the trunk of the tree and *BB* are the cross fibers. It will be noticed in this figure that the more numerous the cross fibers, the more thoroughly the wood will be tied together, and the harder and tougher it will be; also that it will split much more readily if there are a few cross fibers than it will if there are many. Thus the most important characteristics of timber are directly dependent on the structure of the wood.

Fig. 2. Diagram of Pine Wood Fibers Magnified

Grain. The arrangement of the fibers which go to make up a piece of timber give to it certain characteristics which are described as different conditions of the "grain" of the wood, the word "grain" being used as a substitute for the word fiber. Thus "across the grain," means at right angles to the general direction of the fibers; "along the grain," means parallel to the direction of the fibers. In like manner woods are said to be "fine grained," "coarse grained," "cross grained," or "straight grained," these terms being used to indicate the relation of the fibers to each other and to the general direction of the growth of the tree. The wood is said to be fine grained when the annual rings are relatively narrow so as to show a large number of fine lines on a cross section of the log, and it is said to be coarse grained when the rings are wider so as to show a smaller number of coarser lines on the cross section of the log. Woods which are fine grained are generally harder and denser than those

which are coarse grained and they can be made to take a high polish, while with the others, as a rule, this is not possible. Fine-grained woods are also said to be close grained. When the fibers are straight and parallel to the direction of the trunk of the tree, the wood is said to be straight grained, but if they are twisted so as to be spiral in form, not growing straight but following around the trunk of the tree, the wood is said to be cross grained. In Fig. 3 are shown three pieces of timber of which *A* is *absolutely cross grained*, *B* is *partially cross grained*, and *C* is *straight grained*. As examples, it may be mentioned that hemlock is coarse grained and usually cross grained, while white pine is close grained, although soft, and is usually straight grained. Most of the hard woods are fine grained.

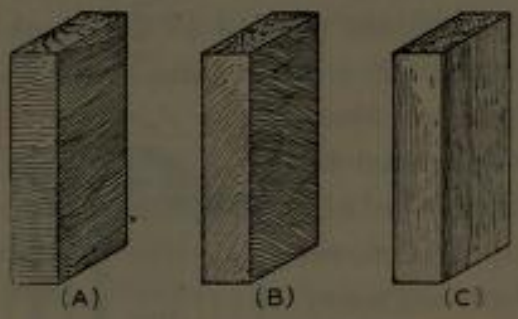


Fig. 3. Blocks Showing Cross Grained, Partially Cross Grained, and Straight Grained Wood

Defects in Wood. The fact that timber is not a manufactured material like iron or cement but is a natural product which has been formed by years of growth in the open where it has been all the while exposed to various adverse conditions of wind and weather, make it peculiarly liable to defects of different kinds, most of which can not be corrected and which render much of it unsuitable for use in construction. Moreover timber is not homogeneous like iron and steel products, in other words, it can not be safely assumed that several pieces of timber, even if they are cut from the same log, will have similar characteristics or will act in nearly the same way under the same conditions. Each piece of timber must be judged by itself and must be subjected to a very careful inspection if it is to be used in an important position with satisfactory results. Such inspection will often reveal some hidden weakness or blemish which is sufficient to warrant the rejection of the piece as not good enough for the particular purpose for which it is intended, and such weaknesses or blemishes are known as defects.

Most of the defects which render timber unsuitable for building purposes are due to irregularities in the growth of the tree from which the timber has been taken. These defects are known by

various names as "heartshakes," "windshakes," "starshakes," and "knots." Other defects are due to deterioration of the timber after it has been in place for some time or even before the tree has been felled, among which are "dry rot" and "wet rot." The defects of the first class are defects of structure; those of the second class are defects of the material itself. It may also be said that the defects of the first class are permanent and are definitely defined, being caused by outside forces or conditions, thus the timber affected can be cut out and discarded leaving the rest of the piece perfectly sound and good, as the defect does not influence the timber near to it and does not spread. On the other hand the defects of the second class are in the nature of a disease which spreads from one part of a piece of timber to another and can even be carried from one piece of timber to another by contact.

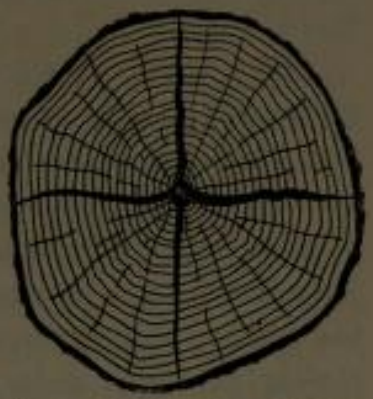


Fig. 4. Section of Log Showing Heartshake

Heartshake. As indicated by the name, heartshake is a defect which shows itself at the heart of the tree in the center of the trunk. The appearance of a cross section of a log affected by heartshake is shown in Fig. 4. There is first a small cavity at the center caused by decay, and flaws or cracks extend from this cavity outward toward the bark. The heartshake is most often found in those trees which are old, rather than in young, vigorous saplings; it is especially to be feared in hemlock timber.

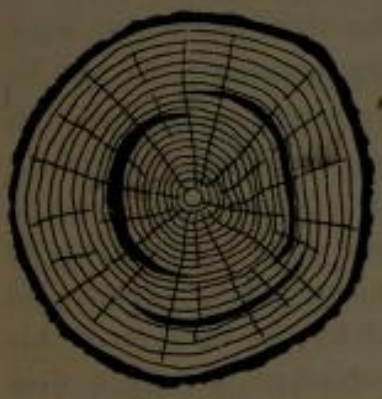


Fig. 5. Section of Log Showing Windshake

Windshake. The defect known as a windshake is so-called on account of the belief that it is caused by the racking and wrenching to which the growing tree is subjected by high winds. It is also claimed that it is produced by the expansion of the sapwood which causes a separation of the annual rings from each other, thus leaving a hollow space in the body of the trunk and following around between two

of the annual rings. Fig. 5 shows the appearance of a windshake on the cross section of a log, and this appearance has given rise to the term *cupshake* which is sometimes used instead of *windshake*. The hollow space may extend for a considerable distance up the trunk of the tree. Windshakes are very frequently found in pine timber.

Starshake. A starshake is not readily distinguished from a heartshake, as the appearance of a log of wood affected by one is very similar to that of a log affected by the other, but the difference between the two is that while the center of a log affected by a heartshake is decayed so as to leave a large round cavity at this point, a log affected by a starshake shows no such decay at the center, but the cracks forming the star extend right across the cross section of the log, becoming wider as they approach the center and narrowing down to nothing near the bark, while all of the wood has the appearance of being sound.

Dry Rot. The defects which have been mentioned above are all of such a kind that they can be readily detected in the lumber before it has been put in position in a structure, and, therefore, the use of the lumber so affected may be avoided, but dry rot, while it is probably the most common and the most dangerous defect of them all, may start and spread rapidly in lumber which appears to be absolutely sound when it is put in place. Dry rot is a disease which fastens itself upon the wood and spreads from one part of it to another, causing it to lose its strength and cohesive power and even to decay altogether. It may be readily seen that this process can lead to most serious results when it takes place in lumber which is depended upon to carry heavy loads. Large beams and posts have been known to fail and thereby cause considerable damage solely because of dry rot, and others have been so weakened by the ravages of this disease that they have yielded when subjected to slight fires which would have had very little effect upon them if they had been sound.

The lumber in which dry rot is most to be feared is that which is kept alternately wet and dry, while that which is always either entirely submerged in water or absolutely dry appears to be able to last indefinitely without a sign of the disease. For this reason wood

piles should always be cut off below the water level. Decay takes place very rapidly when the wood is in a confined position where the gases can not escape. The ends of beams buried in brickwork and the ends of posts fitting into iron caps and bases are examples of such cases, and special precautions should be taken to allow the air to circulate freely around such woodwork wherever this is possible. Woodwork which is in contact with wet or damp materials, such as wet concrete or masonry in which the mortar has not dried out thoroughly, is peculiarly liable to dry rot. Wood flooring laid on top of newly-placed concrete slabs and immediately covered with some other substance has been known to rot very quickly. It is also noticeable that this form of decay seems to be hastened by warmth and is more common in the southern climates than in the northern. It may be prevented by introducing into the lumber certain salts such as the salts of mercury, also by heating the wood to a temperature above 150° F. and keeping it at that temperature. As precautionary measures, all wood should be thoroughly seasoned before being painted, as good ventilation as possible should be provided for it, and it should be kept from contact with anything from which it can absorb moisture. Posts should have a hole about one and one-half inches in diameter bored through them from end to end, and other holes near each end bored through them crosswise, so as to provide for the free circulation of air in the interior of the post.

Wet Rot. There is another form of decay which affects wood in a manner somewhat similar to dry rot, but which takes place in the growing tree. It is known as "wet rot" and is caused by the wood becoming saturated with water which it may absorb from a swamp or bog. Wet rot may be readily communicated from one piece of wood to another by contact so that it is apt to spread rapidly.

Knots. Knots are more or less common in all lumber and consist of small pieces of dead wood which occupy a place in the body of the log with sound wood all around them. These bits of dead wood have no connection with the living wood about them, so that in the course of time they work loose, and when the log is sawed up into boards the pieces of dead wood fall out leaving round or irregular-shaped holes. Knots are formed at the juncture of the

main tree trunk with branches or limbs, while such branches are still young and green. At such points the fibers of the main trunk, near the place where the branch comes in, do not follow straight along up the trunk, but are turned aside so as to follow along the branch as shown in Fig. 6. Frequently such a branch is broken off near the trunk of the tree when it is still young, while the tree itself continues to grow and the trunk increases in size until the end of the branch which was left buried in the main trunk is entirely covered up. Meanwhile the end of the branch dies and a knot is formed. The presence of a limited number of knots will not harm a piece of lumber which is subjected to a compressive stress so long as they remain in place and do not drop out, but they very greatly weaken a piece subjected to a tension stress or used as a beam. Knots always spoil the appearance of woodwork which is to be polished.

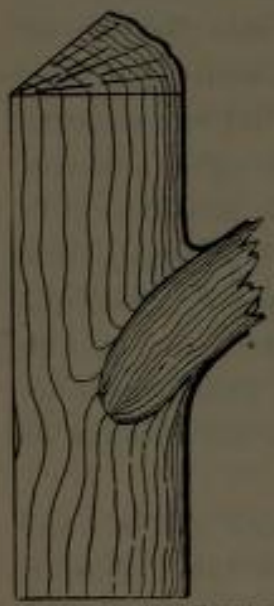


Fig. 6. Section Showing Formation of a Knot

The defects heretofore considered result from the natural growth of the tree and are not attributable to the handling of the timber after it has been cut, but there are several classes of defects which are caused by the seasoning of the lumber and which have little or nothing to do with the growth of the tree. Among these are the actions known as "warping" and "checking."

Warping. This is the result of the evaporation or drying out of the water which is held in the cell walls of the wood in its natural state, and the shrinkage which naturally follows. If wood were perfectly regular in structure, so that the shrinkage could be the same in every part, there would be no warping, but wood is made up of a large number of fibers, the walls of which are of different thicknesses in different parts of the tree or log, so that in drying one part shrinks much more than another. Since the wood fibers are in close contact with each other and interlaced, thus making the piece of wood rigid, one part cannot shrink or swell without changing the shape of the whole piece, because the piece as a whole must adjust itself to the new conditions; consequently the timber warps.

In Fig. 7, if the fibers in the lower portion of the piece near the face *CDG* happen to have, on the average, thicker walls than those in the upper portion, near the face *ABFE*, the lower part will shrink more than the upper part. The distance *CD*, originally equal to the distance *AB*, becomes smaller and the shape of the whole piece changes as shown in Fig. 8.

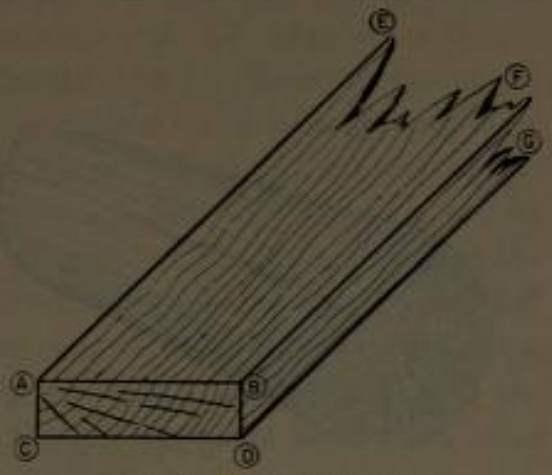


Fig. 7. Straight Board

The only way in which warping can be prevented is to have the lumber thoroughly dried out before it is used, as after it is once thoroughly seasoned it will not warp unless it is allowed to absorb more moisture. All wood which is to be used for fine work, where any warping after it is in place will spoil the appearance of the entire job, must be so seasoned, either in the open air or in a specially prepared kiln.

The wood of the conifers which is very regular in its structure shrinks more evenly and warps less than does the wood of the broad-leaved trees with its more complex and irregular structure. Sapwood, also, as a rule shrinks more than does heartwood.

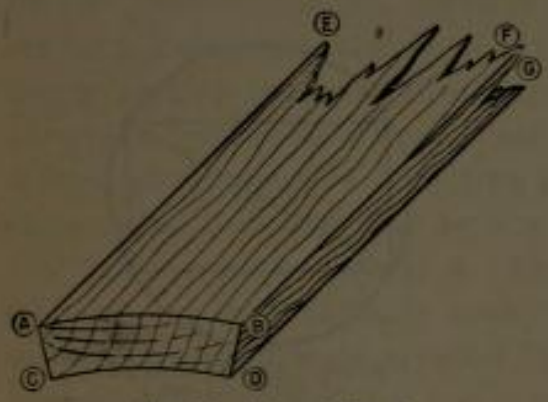


Fig. 8. Warped Board

Checks. Another defect which is caused by the drying out of the timber and the consequent shrinkage of the cell walls is what is known as checking. In any log of wood there is always opportunity for shrinkage in two directions, along the radial lines following the direction of the medullary rays, and around the circumference of the log following the direction of the annual rings. If the wood shrinks in both directions at the same rate, the result will be only a decrease in the volume of the log, but if it shrinks more rapidly

around the circumference of the log than along the radial lines, the log must develop cracks around the outside as shown in Fig. 9. Such cracks are called checks. In lumber which has been prepared

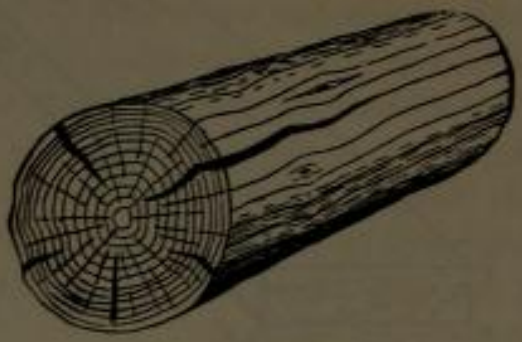


Fig. 9. Log Showing Checks

Fig. 10. Finished Lumber Showing Checks

for the market they show themselves in the form of cracks which extend along the faces of solid squared timbers and boards, seriously impairing their strength. Fig. 10 shows checks as they would appear in a square post or column.

Conversion of Timber into Lumber. Lumber may be found in lumber yards in certain shapes ready for use, having been cut from the logs and relieved of their outside covering of bark. The cutting up of the logs is done in the mills by machinery and there are various methods in use for transforming the logs into boards, planks, and

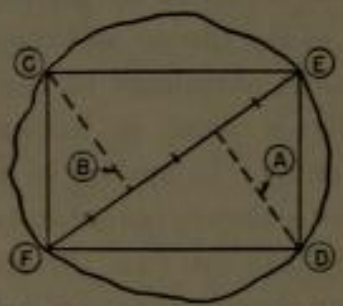


Fig. 11. Economical Method of Cutting Logs

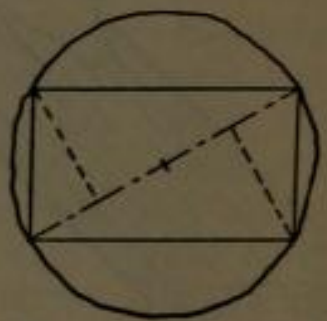


Fig. 12. Another Method of Cutting Logs

heavy timbers. The method of cutting the log determines the appearance of the wood when finished and also affects it in other ways.

If the log is to be squared off so as to form only one heavy beam or post, a good rule to follow is to divide the diameter into three

equal parts and then to draw perpendiculars to this diameter at the division points one on each side of the center, as shown at *A* and *B* in Fig. 11. The points *C* and *D* in which these perpendiculars to the diameter cut the circumference of the log, together with the points *E* and *F* in which the diameter cuts the circumference of the log, will be the four corners of the timber. The lines joining these points will give an outline of the timber, which will be rectangular and will be found to be the largest and best timber which can be cut from the log. Another good rule is to divide the diameter of the log into four equal parts and to proceed in the same way as described above, using the outside quarter points from which to draw the perpendiculars as shown in Fig. 12. This method will give the outlines of a stiffer beam than the one described above, but there will be more waste from the log and the beam will not be on the whole as strong as the other.

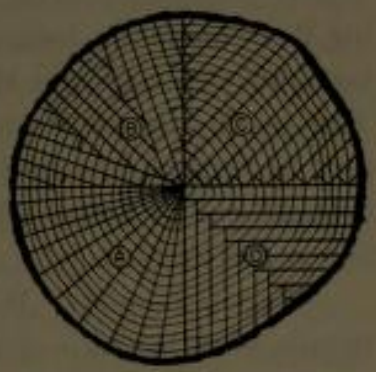


Fig. 13. Method of Cutting Planks from a Log

In Fig. 13 are shown several different methods of cutting planks from a log. First it is divided into quarters, and the planks are cut out as shown in the figure, there being four ways in which the work may be done. All of the four methods shown may be said to give what is called quarter-sawed lumber since the log is first cut into quarters, but that shown at *A* is the best. All of the planks are cut radiating from the center of the log and there will be no splitting or warping, but the method is very expensive, as all of the planks have to be squared up afterward and there is much waste as a result. A fairly good method is that shown at *B* where the planks are nearly along radial lines and may be much more easily and cheaply cut out than can those shown at *A*. The method shown at *C* is a common one and leads to fairly good results, although only the plank nearest the center is on a radial line. It is practically as good a method as that shown at *B* and is much more simple. The method shown at D is not so good as the others, as planks cut out in this way are very liable to warp and twist. If the silver grain, caused by cutting of the medullary rays is desired, the planks must be cut as shown at *A*, *B*, or *C*.

Planks are sometimes simply sliced from the log as shown in Fig. 14, without first dividing it into quarters, but this is the worst possible way of cutting them, as the natural tendency of the timber to shrink causes the planks to curl up as shown in Fig. 15. It is almost impossible to flatten them out again, and they can not be used in that condition.

Fig. 14. Method of Slicing a Log

There is another method of cutting up a log which has been introduced more recently than the others, and which is known as the "rotary cut." It consists in placing the log on a movable carriage which keeps it whirling rapidly about its longitudinal axis, at the same time bringing it up against a long stationary knife which catches the log and peels off strips around the circumference of any desired thickness. This method is used extensively in the preparation of wood to be used as veneers, and in the case of many kinds of wood the figure is brought out to better advantage in this way than is possible with any other method.

Waney Lumber. When a log of wood has been sawed up into boards, each board is apt to have along the edge a strip of the bark which was originally on the outside of the log, and the edges will not be square with the face of the board, owing to the cylindrical shape of the log. Such boards should be squared up by having the rough edges to which the bark adheres trimmed off. But sometimes the bark alone is stripped off, leaving the boards with the edges not square with the face. Such boards are said to be waney, and very often specifications state that no waney lumber shall be employed on the work. The pieces which are cut off when waney boards are trimmed in order to square them up are called "edging" and are used to make laths.

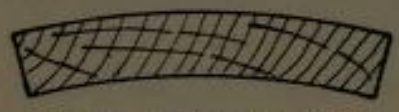


Fig. 15. Slicing Logs Gives Warped Lumber

Slabs. The pieces known as slabs are those which are left over after a log has been sawed up into boards. In cross section they are of the shape of a half moon, and are covered with bark. They are useless except for laths or fuel.

VARIETIES OF TIMBER

Although there are a great many different kinds of trees growing in different parts of the world, only a comparatively small number of them yield wood which is used to any great extent in building work. These differ very much among themselves, each variety possessing certain characteristics which render it especially suitable for use in one part of a building, while the same peculiarities of growth or of texture may make it unfit for use in another.

For use in places where the lumber must be partly buried in the ground a wood is required which will be able to withstand the deteriorating effects of contact with the earth, and for this purpose chestnut, white cedar, cypress, redwood, or locust may be used.

For light framing is needed a cheap, light wood, as free as possible from structural defects, such as knots and shakes, and one which can be readily obtained in fairly long, straight pieces. Spruce, yellow pine, white pine, and hemlock all satisfy these requirements fairly well, spruce being perhaps a little better than the others, and more popular.

For heavy framing, such as trusses, girders, and posts, a timber is needed which is strong, and which can be obtained in large, long pieces. Georgia pine, Oregon pine, and white oak may all be used for such work, and also Norway pine and Canadian red pine. White oak is the timber which was always used for framing in the old days, but is too expensive to be used with profit for such work now. The timber most commonly used today is the Georgia pine.

A wood which can be easily worked and which will also be able to withstand the deteriorating effects of the weather is in demand for the outside finish. White pine is usually selected for this purpose, although cypress and redwood are also suitable and are used to some extent. The same woods are used for shingles, clapboards, and siding, with the addition of cedar and spruce for shingles, and Oregon pine and spruce for siding.

For the interior finish is chosen a wood which will give a pleasing appearance when finished and which will take a high polish, while for floors, hardness, and resistance to wear are the additional requirements. For floors, oak, hard pine, maple, and birch are good, while for the remainder of the interior finish white pine, cypress, and red-

wood for painting, or any of the hard woods such as ash, cherry, oak, walnut, or mahogany, may be selected.

Some of the more important varieties of timber used in Carpentry will now be mentioned, and a brief description of each variety will be given in order to convey an idea of their characteristics and the part of the world from which they come.

Soft Woods. Needle-leaved trees (conifers) are to be found mostly in the North, where they form great forests from which are taken the large quantities of timber of this kind used every year. The wood is very popular for use in rough building construction or for finished work which is to be painted, as it is very regular in structure and consequently easy to work; it can be obtained in large, long, straight pieces, and is light and strong. The demand for woods of this kind is considerably in excess of the demand for the harder woods. The trees are mostly but not all evergreen, and bear needles instead of leaves, together with the cones, from which they are called conifers.

Cedar. The wood known as cedar has long been used in construction, as is illustrated by the references in the Bible to the "Cedars of Lebanon" from which the Temple of Solomon was constructed. The wood in use at the present day called cedar is, of course, not of exactly the same species as was that used in the famous temple, but it is of the same family and possesses the same general characteristics. There are two kinds, the red cedar, and the white cedar, which differ from each other principally in color, the white cedar being grayish brown, while the red cedar is reddish brown.

There are several different kinds of white cedar in use, of which one is known as the canoe cedar. The wood is not very strong, but is light and soft, possessing considerable stiffness and a fine texture. In color it is as mentioned above, grayish brown, the sapwood being, however, of a lighter color than the heartwood. It seasons quickly, is remarkably durable, and does not shrink or check to any great extent. The wood is used in building construction, principally for shingles, for which purpose its durability in exposed positions makes it especially valuable. It is also used for posts and ties.

The trees are usually scattered among others of different kinds, forming occasionally, however, forests of considerable size. They are

to be found all through the northern part of the United States and in Canada, also on the Pacific Coast in California, Oregon, and Washington. They also grow to some extent in the southern states. Some of the trees are of small or medium size, while others are very large, especially the canoe cedar of the Northwest.

In addition to the white cedars, there are the red cedars, which are similar to the white cedars but differ from them slightly in the color of the wood, which is reddish brown instead of grayish brown. The red cedars are also of somewhat finer texture than the white cedars. Red cedar is used but little in building construction, but is used extensively in cabinet work for chests and closets which this wood is supposed to render proof against moths. The wood is also used for the making of lead pencils and for cigar boxes, large quantities of timber being used for these purposes every year.

Cedar trees are sometimes subject to a disease similar to wet rot, which attacks the growing tree. This disease does not, however, render them unfit for use in every case, as the disease often disappears as soon as the tree has been cut down, and trees have been known to yield timber which has endured for long periods, although the living tree itself was diseased.

Redwood. There is a wood which greatly resembles good red cedar and which is found only in the State of California. One species of this tree grows to an enormous size and is famous on this account, but this is not the one which yields the lumber used for building purposes, which is known as the common redwood. The wood is used for cheap interior finish and for shingles, also for use in heavy construction, thus serving nearly the same purposes as does hard pine in the eastern states. Redwood is light, and not very strong, but on the other hand, it is remarkably durable, resisting fire to a considerable extent. It is easy to work and will take a polish so that it is valuable for inside finish, and some of the wood has a wavy grain which adds greatly to its finished appearance. This wood is known as "curly" redwood. In color the heartwood is red, but the sapwood is nearly white, with the wood between them varying in color and averaging a rich reddish brown. The grain is usually straight and the wood is solid and dense in structure but the grain is more or less coarse in appearance.

Cypress. This is a wood which is somewhat similar to white cedar in appearance, and which grows in quantities only in the southern states, where it may be seen in great swamps with the roots very often partially exposed. Although there are a great many varieties, they are similar in their general characteristics, differing only in quality. "Gulf Cypress," growing near the Gulf of Mexico, is the best. "Bald Cypress" is a name which has been applied to these trees on account of the fact that they show no leaves in winter and this gives them a peculiar appearance. When the wood is dark in color it is called "Black Cypress," and in some localities yellow and red cypress are spoken of. The growing trees are often affected by a disease which leaves the wood full of small holes which look as though they might have been made by driving pegs into the wood and then withdrawing them. Cypress wood affected in this way is called "peggy."

Hemlock. There are two varieties of hemlock, one found in the northern states, from Maine to Minnesota, and along the Alleghenies southward to Georgia and Alabama, while the other is found in the west from Washington to California and eastward to Montana. The eastern tree is smaller than the western and its wood is lighter, softer, and generally inferior. The trees are evergreen and bear cones, with flat, blunt needles, and they usually grow alone or in small groups in the midst of forests of other trees.

The timber is of a light, reddish-gray color, fairly durable, but shrinks and checks badly, and is coarse, brittle, and usually cross grained. It is hard to work but will hold nails very well. The wood is sometimes used for cheap framing, and has been used for cheap interior finish, but it is so liable to imperfections, such as windshakes and starshakes, that it is not the best wood to use for these purposes, although the increasing cost of the better woods will no doubt force it into more general use. Hemlock is most frequently used for rough boarding and sheathing.

Spruce. Another evergreen and cone-bearing tree which furnishes great quantities of lumber to the market every year is the spruce. There are three kinds of spruce, *white*, *black*, and *red*, of which the white spruce and the red spruce are the varieties commonly found on the market. The white spruce is scattered throughout all of the northern states, along the streams and lakes, the largest

varieties being found in Montana. The black spruce is found in Canada and in some of the northern states. It is distinguished from the other varieties by its leaves and bark only, the foliage being much darker in color than that of the white spruce, while the cones remain in place for several years, a much longer time than do those of the white spruce. The red spruce is sometimes known as Newfoundland red pine and is found in the northeastern part of North America. It is used very extensively in northern New England where it serves as a substitute for soft pine, and large quantities of it are used up every year for pulp wood.

The leaves of the spruce are single and have sharp points at the ends. They are short and four-sided and are arranged on the stem so as to point in all directions. The cones hang downward, while those of the fir trees point upward.

Spruce trees have many natural enemies and numbers of the trees are destroyed before they reach the market. Large quantities of fallen tree trunks are to be found in the forests, blown down by the wind alone during heavy wind storms, or so weakened by the ravages of insects that they have fallen from their own weight. There is a beetle which attacks these trees especially, and which causes great damage, while very often the same trees are attacked by various kinds of fungous growths.

Spruce timber is of a light color, very nearly white except the heartwood which has a reddish tinge. It is very dense and compact in structure and straight grained. The wood is light and soft, fairly strong for a soft wood, but not very durable when exposed. It is very resonant and is frequently used for sounding boards on this account. It can not be obtained in large sizes, but it is considered by many to be the best framing timber available, except the pines.

Pine. This is the timber which has been used in building construction to a greater extent than any other except perhaps oak. It is peculiarly fitted for the purpose as it has grown in great abundance all over the United States and possesses all of the most desirable characteristics of a good building material, being strong, but at the same time light in weight and easily worked, elastic, and very durable. The tree is almost always a large one with branches starting at a considerable distance from the ground. It has a smooth, straight trunk, evergreen, needle-shaped leaves, of varying length, and cones.

There are two distinct classes of pines used in building work, the soft and the hard pines, both of which are found in large quantities. The softer varieties are used for outside finish of all sorts, and the harder varieties for heavy framing and for flooring. The ease with which the soft-pine lumber can be cut and shipped to the market, makes it the most popular wood in use at the present time. It is of uniform texture and nails without splitting, seasons very well, and does not shrink so much as the harder pines, will take paint and is very durable. The wood is white in color, straight grained, and has few knots. The hard pines furnish the strongest timber in use for building, with the exception of oak, which is now almost too expensive to be used for heavy framing. The pieces can be obtained in large sizes and great lengths and the wood is very hard, heavy, and durable, at the same time being tough. In color it is yellow or orange, the sapwood being of lighter color than the heartwood.

There are many different kinds of pines, which are recognized in different parts of the country under various names, but there are five general classes into which the species is commonly divided, though the same timber may be called by different names in two different localities, as will be seen.

(1) The term "hard pine" is used to designate any pine which is not white pine, a classification which is very general, though it is often seen in works on Carpentry and in specifications.

(2) "White pine," "soft pine," and "pumpkin pine," are terms which are used in the eastern states for the timber from the white-pine tree, while on the Pacific Coast the same terms refer to the wood of the sugar pine.

(3) The name "yellow pine," when used in the northeastern part of the country, applies almost always to the pitch pine or to one of the southern pines, but in the West it refers to the bull pine.

(4) "Georgia pine" or "longleaf yellow pine," is a term used to distinguish the southern hard pine which grows in the coast region from North Carolina to Texas, and which furnishes the strongest pine lumber on the market.

(5) "Pitch pine" may refer to any of the southern pines, or to pitch pine proper, which is found along the coast from New York to Georgia and among the mountains of Kentucky.

Of the soft pines there are two kinds, the white pine and the sugar pine, the latter being a western tree found in Oregon and California, while the former is found in all the northern states from Maine to Minnesota. There is also a smaller species of white pine found along the Rocky Mountain slopes from Montana to New Mexico.

There are ten different varieties of *hard pine,* of which, however, only five are of practical importance in the building industry. These are the "long-leaf southern pine," the "short-leaf southern pine," the "yellow pine," the "loblolly pine," and the "Norway pine."

The long-leaf pine, also known as the "Georgia pine" and the "long straw pine," is a large tree which forms extensive forests in the coast region from North Carolina to Texas. It yields very hard, strong timber, which can be obtained in long, straight pieces of very large size.

The loblolly pine is also a large tree but has more sapwood than the long-leaf pine, and is coarser, lighter, and softer. It is the common lumber pine from Virginia to South Carolina, and is found as well in Texas and Arkansas. It is known also by the names of "slash pine," "old field pine," "rosemary pine," "sap pine," and "short straw pine," and in the West as "Texas pine."

The short-leaf pine is much like the loblolly pine and is the chief lumber tree of Missouri and Arkansas. It is also found in North Carolina and Texas.

The Norway pine is a northern tree found in Canada and the northern states. It never forms forests, but is scattered among other trees, and forms small groves. The wood is fine grained and of a white color but is largely sapwood and is not durable.

Fir. The fir tree yields timber very similar to spruce, and is often mixed in with spruce in the market. There are two kinds of fir trees, the western fir tree and the eastern fir tree, the first being known as the silver fir and the other as the balsam fir. All of the firs are evergreen, and bear cones which stand erect instead of hanging down. The wood is soft and not strong, being of a much coarser quality than ordinary spruce. It can be used in building work only for the roughest work in the case of the eastern fir, while the western fir is used more extensively but is not as good as spruce.

Douglas Fir. There is another very useful wood which is ex-

tensively employed in building construction, especially on the Pacific Coast where the tree from which this lumber is obtained is found growing in forests in several states, particularly in Washington, Oregon and Colorado, and also in Canada. It is known under various names in different parts of the country such as "Oregon Pine," "Douglas Fir," "Oregon Fir," "Douglas Spruce," "Red Fir," "Red Pine," "Washington Fir," "British Columbia Pine," and "British Columbia Fir." The name which is most generally used by the best authorities when speaking of this wood is "Douglas Fir," but Botanists tell us that the tree is not really a pine tree nor a fir tree but is more like a hemlock.

The wood has many of the valuable properties of Long-Leaf Southern Pine and is used in a similar way. It is strong enough so that it may safely be employed for structural timbers and, as the tree grows to a tremendous size and a great height, the lumber can be obtained in very large sizes and in long pieces. It is also used for cheap flooring and for interior finish, as well as for framing lumber.

Tamarack. This is a wood which is very much like spruce in structure, but is hard and very strong, resembling hard pine in this respect. The tree grows in the northern part of the United States and Canada, both in the East and in the West, and also in Europe. Its true name is larch, but it has come to be known as tamarack, tamarack pine, and hackmatack. In the East the tree grows in wet places called tamarack swamps, but the tree in the West and in Europe thrives best in dryer soil, and grows more quickly under these conditions than in a swamp. The wood is used mostly for long straight timbers such as posts, poles, and quite extensively for piles. It has also been used a great deal for railroad ties. It is supposed to be very durable, and is well suited for use as ties or as piles, but it can not always be obtained now. It has never been used to any extent as sawn lumber, because the demand for the trunks for use as posts and poles has been so great that it did not pay to saw them up.

Hard Woods. *Ash.* Ash is a hardwood which is occasionally employed for interior finishing in public buildings, such as school houses, churches, and so forth, and also in the cheaper classes of dwelling houses. It is one of the cheapest of hard woods, and is used when it is desired to have a hard-wood finish and when the more expensive kinds of hard wood, such as oak, can not be afforded. The

wood is somewhat like oak in texture and appearance, the difference being that ash is coarser, and the pith rays do not show. It is strong, straight grained, and tough, comparatively easy to work, elastic, and fairly durable. It shrinks moderately, seasons with little injury, and will take a good polish. The trees do not grow together in forests, but are scattered. They grow rapidly, and attain only medium height. Of the six different species found in the United States, only two, the "white ash," and the "black ash," are used extensively in building work. The first is most common in the basin of the Ohio River, but is also found in the North from Maine to Minnesota, and in the South, in Texas. The black ash is found from Maine to Minnesota, and southward to Virginia and Arkansas. There is very little difference between the two species. The black ash is also known as the "hoop ash," and the "ground ash."

Beech. This wood is not used to any great extent in carpentry except in Europe, but is made up into tool handles, shoe lasts, and so forth, and is also used in wagon making and shipbuilding. The tree grows freely in the eastern part of the United States and Canada and also in Europe. There are a number of different species and the tree is sometimes called by other names such as "ironwood," and "horn-beam." The wood is used for building work in the United States only occasionally for inside finish and is not a popular wood. It is heavy, hard, and strong. In color it is light brown, or white. It shrinks and checks during the process of drying out, and is not durable when placed in contact with the ground. It works fairly well, stands well, and will take a good polish.

Birch. Birch is a very handsome wood of a brown or red color and with a satiny luster. There are two kinds, the red birch and the white birch, but they are both taken from the same kind of tree, the difference being that the red birch consists of more and older heartwood, while the white birch is the sapwood or the younger heartwood. The trees are of medium size and form large forests. They are found throughout the eastern part of the United States and Canada, and in the extreme north. The distinguishing feature of the tree is the bark, which is famous because of its beauty and its usefulness for a number of purposes. This bark is white in color with long dashes of a darker color running around the tree trunk in a horizontal direction. It is water-tight and pliable, which made it useful to the Indians for the

covering of their canoes. It was also used in ancient times, before the manufacture of paper, as a material to write upon. The bark has been used for a number of other purposes. The wood is used quite extensively for inside finish and floors, and to imitate cherry, mahogany, and walnut, as it has a grain which is very similar to the grain of these woods. It takes a good polish and works easily, but it is not durable when exposed to the weather.

Butternut. Butternut is really a branch of the family of walnuts, and differs from them only slightly. The wood is used to some extent for inside finish, and is cheaper than most of the other hard woods. It is light, but not strong, and is fairly soft. In color it is light brown. The trees, of medium size, are found in the eastern states from Maine to Georgia.

Cherry. Cherry is a wood which is frequently used as a finishing wood for the interior of dwellings and of cars and steamers, but, owing to the fact that it can be obtained only in narrow boards, it is most suitable for molded work, and work which is much cut up. The wood is heavy, hard, strong, and of fine texture. The heartwood is of a reddish brown color, while the sapwood is yellowish white. It is very handsome and takes a good polish, works easily, and stands well. It shrinks considerably, however, in drying. The timber is cut from the wild black cherry tree, not from the cultivated cherry tree. This tree is of medium size, and is found scattered among the other broad-leaved trees along the western slopes of the Alleghenies, and as far west as Texas. The fruit of the wild cherry is of a dark purple color, about the size of a large pea. When ripe it tastes slightly bitter. The bark of the tree also tastes bitter. Cherry is often stained to resemble mahogany, and sometimes birch is stained to resemble cherry.

Chestnut. The grain of chestnut somewhat resembles oak but it is much softer and coarser in texture and does not show the medullary rays which form the distinguishing feature of oak. Chestnut is used for cabinet work, for interior finishing, and sometimes for heavy construction. It is light, fairly soft, but not strong. The wood has a rather coarse texture, works easily and stands well, but shrinks and checks in drying. It is very durable and can be safely used in exposed positions. The tree grows in the region of the Alleghenies, from Maine to Michigan, and southward to Alabama. The

wood is dark brown in color, with the sapwood a little lighter.

Elm. There are five species of elm trees in the United States, scattered throughout the eastern and central states. The trees are usually large and of rapid growth, and do not form forests. The timber is hard and tough, frequently cross-grained, hard to work, and shrinks and checks in drying. The wood has not been used very extensively in building, but has a beautiful figured grain, can take a high polish, and is well adapted to staining. The texture is coarse to fine, and the color is brown with shades of gray and red.

Gum. The wood of the gum tree has been used extensively for cabinet work, furniture, and interior finish. It is of fine texture and handsome appearance, heavy, fairly soft, yet strong. Its color is reddish brown. The wood warps and checks badly, is not durable when exposed, and is hard to work. It has a close grain, and some pieces are so regular that they have been stained to imitate black walnut and used as veneers for the manufacture of furniture and cabinet work. The species of gum tree, which yields timber of use in carpentry, is known as the sweet gum. It is of medium size, with a straight trunk. The trees do not form forests, though they are quite abundant east of the Mississippi River. The leaves have five lobes which are long and pointed, thus giving them a starlike appearance. The bark is very rough, and its resemblance in appearance to the skin of an alligator has caused the wood to be called "Alligator Wood" in some localities.

Maple. Almost all of the maple used in building work comes from the hard sugar maple, which is most abundant in the region of the Great Lakes, but which is also found from Maine to Minnesota and southward to Florida. The trees are of medium to large size and form quite considerable forests. They are so abundant in Canada that the maple is the national tree, and the national emblem is a maple leaf. The wood when finished presents a very pleasing appearance, and ranks as one of the best of the hard woods in this respect. It is heavy and strong, of fine texture, and often has a fine wavy grain which gives the effect known as "curly." Other defects which add to the beauty of the grain occur in what is called "blister" and "bird's-eye" maple. These defects are the result of twisting of the fibers which make up the woody structure of the tree, and the maples seem to show them more frequently than any of the other

trees, though they sometimes are to be found in birch and various other woods. The color of the sapwood is a creamy white while the heartwood is tinged with brown. The lumber shrinks moderately, stands well, is easy to work, and is tough, but not very durable when subjected to exposure. The finished wood takes an excellent polish. It is most commonly employed for floors, and in other positions where a good wearing surface is required, as well as for ceiling and paneling, and other interior finish.

Oak. This is a wood which has probably been used more than any other kind in all classes of structures. In ancient times it was about the only wood in use both for the building of houses and for shipbuilding. Since the softer woods have become popular and oak has become somewhat less easy to get, its use has diminished to some extent, but it is still one of the most useful of woods. The trees grow freely all over the northern parts of Europe and America, extending as far south as the Equator, and have been particularly plentiful in the British Isles. There are about twenty different kinds of oaks to be found in various parts of the United States and Canada, but there are three distinctly different species, which are sold separately. These are the "white oak," the "red oak," and the "live oak." The red oak is usually more porous, less durable, and of coarser texture than the white oak or the live oak. The trees are of medium size and form a large proportion of all the broad-leaved forests. Live oak was once very extensively used, but has become scarce and is now expensive. Both the red oak and the white oak are used for inside finishing, but they are liable to shrink and crack and must, therefore, be thoroughly seasoned. They are of slightly different color, the white oak having a straw color while the red oak has a reddish tinge, so that they can not be used together where the work is to be finished by polishing. Oak is always best if quarter-sawed and it then shows what is known as the "silver grain." This is the result of the cutting of the medullary rays, and appears on the finished wood as a succession of splashes or blotches which are of lighter color than the rest of the wood and which glisten in the light.

Poplar. This wood is also known in the market as "white wood," "tulip wood," and sometimes as "basswood." The poplar, the whitewood or tulip tree, and the basswood are, however, three distinct kinds of trees, but the wood of each so nearly resembles that

of the others as to be indistinguishable in the market and so it is sold under any one of these various names. The lumber yielded by the tulip tree and known commercially as whitewood is the best. This tree is a native of North America and grows freely all over the United States and Canada. There are a number of different varieties growing in various parts of the country. It is sometimes called "yellow poplar." The poplar or cottonwood is most common in the region of the Ohio basin, and grows in the western desert regions along the water courses. The tree is a large one and usually grows in small groups, not forming extensive forests. The basswood tree, also known as the linden, grows all over the eastern part of the United States and Canada, and in the middle west. The wood of all these trees is light, soft, free from knots, and of fine texture. In color it is white, or yellowish white, and frequently has a satiny luster. It can be so finished as to retain its natural appearance, but it is often stained to imitate some of the more costly woods, such as cherry. It is used extensively for cheap inside finish and fittings, such as shelving, and sometimes for doors, but it warps badly if it is not thoroughly seasoned, and will not stand exposure.

Sycamore. Sycamore is frequently used for finishing, and is a very handsome wood. It is heavy, hard, strong, of coarse texture, and is usually cross grained. It is hard to work, and shrinks, warps, and checks considerably. The tree is of large size and rapid growth, found in all parts of the eastern United States, and is most common along the Ohio and Mississippi rivers.

Walnut. There are a number of different kinds of walnut trees, of which only one or two, however, yield timber which is suitable for use in building construction. The best known trees are the "English walnut," the "black walnut," the "white walnut" or "butternut," and the "Circassian walnut." The English walnut grows in Europe, and is not very popular as a finishing wood, while it is too expensive to be used for rough lumber. Formerly great quantities of it were used in the manufacture of gun stocks, so much so as to create a demand for the entire supply. The black walnut is a native of North America, and until about sixty years ago it was used very extensively in the United States for interior finish and furniture, taking the place of oak which had previously been used for these purposes. Then mahogany took the place of the walnut and for a long time was

considered the most desirable wood. During recent years, however, walnut has again become popular, and is now very extensively used. It is a heavy hard wood of coarse texture and of a rich dark-brown color. Very handsome pieces having a beautiful figure may be selected for veneers for furniture and cabinet work. Although the wood shrinks somewhat in drying, it works easily, stands well, and will take a good polish. The tree is large and of rapid growth. It was formerly very abundant in the Allegheny region, and was found from New England to Texas and from Michigan to Florida. White walnut, or butternut, is somewhat like black walnut wood, but is of a lighter color and is not so pleasing when finished. Circassian walnut is beautifully figured, and is sometimes used for piano cases, and costly cabinet work, but it is very scarce and very expensive.

Laurel. The tree of this name which is most extensively used in building work is the California laurel, which grows on the Pacific Coast and is seldom seen used in the eastern part of the country. The wood is hard, heavy, and strong, light brown in color, and of close grain. The sapwood is considerably lighter in color than the heartwood. The wood takes a very good polish and is quite generally used on the Pacific Coast for cabinet work and interior finishing.

Osage Orange. This is a southern wood, growing in the Gulf States and seldom seen in the North. The tree is of medium size, bears fruit somewhat resembling an orange, and is protected by large thorns. The wood ranges in color from bright yellow or orange to brown and is hard and strong, though at the same time very flexible. It is very durable in damp places, and in positions where it comes in contact with the earth. The wood shrinks somewhat, and checks, but will take a good polish, and it is, therefore, used to some extent for interior finish, but its principal use is for poles and posts, piles, ties, etc.

Locust. The locust is a tree which yields wood valuable in construction on account of its great durability in exposed positions. The eastern tree is called the black locust, while the tree in the western states is known as the mesquite. There is a slight difference between the two trees, but they belong to the same family. The wood is hard, heavy, and strong, reddish brown in color, and close-grained. It was largely used in the past for long wood pegs called tree-nails and is now used wherever great durability is required.

Holly. This wood is very highly prized for use in inlaid work, both on account of its beautiful even grain, and on account of its clear white color. The American tree grows in all the eastern states where it attains to medium size. It is characterized by its evergreen foliage and its red berries. The wood is cream white in color, and moderately strong. It is easily worked, but is not durable and can not be exposed.

Imported Timber. Besides the woods which grow in the United States, a number of others are brought in from foreign lands for use in the best grade of public buildings and private residences. The most popular of these are the mahogany, rosewood, satinwood, French burl, and Circassian walnut.

Mahogany. True mahogany comes from Cuba and Mexico and formerly was obtained also from Santo Domingo and Honduras. These woods are now much more difficult to obtain and are more expensive than they formerly were.

Other kinds of mahogany are obtained from Africa and India. The mahogany most generally used today is the African. A sort of mahogany has also been brought from the Philippine Islands but is not used to a great extent.

Mahogany, however, is not now so popular as it once was. The wood is generally imported in the rough log and cut up by the purchasers as it is required. It is easy to work, will take an excellent polish, and stays in place very well if it is properly seasoned. The color varies from very light to deep red, which becomes darker and richer with age. There is also what is called white mahogany, which is golden yellow in color. The wood is very costly and can only be used for the best work. Generally mahogany is used in the form of veneers.

Satinwood comes from both the East and the West Indies. It is hard and strong and very durable, but brittle and hard to work. It is so costly as not to be used for anything but the finest cabinet work, for which it is valued on account of its color, which is very light yellow, and its satiny luster. It takes a very good polish.

French burl comes from Persia, and *Circassian walnut* from near the Black Sea. Both of these woods are very expensive and can be used on that account only in veneers and only for the best furniture and trim work.

GENERAL CHARACTERISTICS OF TIMBER

In speaking of wood we are accustomed to use certain words to express our idea of its mechanical properties, or of its probable behavior under certain conditions. Thus we say that a wood is hard, or tough, or brittle, or flexible, and frequently we use these terms without having a clear understanding of just what they mean. A very brief discussion of some of these properties or characteristics of lumber will now be given in order that we may see what peculiarities of structure or of growth cause them.

Hardness. If a block of wood is struck with a hammer when lying on a bench, the hammer-head will make an impression or dent in the wood, which will be deeper or shallower according as the wood is soft or hard. A wood is said to be very hard when it requires a pressure of about 3,000 pounds per square inch to make an impression one-twentieth of an inch deep. A hard wood requires only about 2,500 pounds to produce the same effect. Fairly hard wood will be indented by a pressure of 1,500 pounds, and soft woods require even less. Maple, oak, elm, and hickory are very hard; ash, cherry, birch, and walnut are hard; the best qualities of pine and spruce are fairly hard, and hemlock, poplar, redwood, and butternut are soft.

Toughness. "Toughness" is a word which is often used in relation to timber, and implies both strength and pliability, such as is found in the wood of the elm and the hickory. Such timber will withstand the effect of jars and shocks which would cause other woods like pine to be shattered.

Flexibility. Timber is said to be flexible when it bends before breaking instead of breaking off short, or, in other words, a flexible wood is the opposite of one which is brittle. The harder woods, taken from the broad-leaved trees, are usually more flexible than the softer woods, taken from the cone-bearing trees. The wood of the main tree trunk is more flexible than that of the limbs and branches, and moist timber is more flexible than dry wood. Hickory is one of the most flexible woods.

Cleavage. Most woods split very easily along the grain, especially when the arrangement of the fibers is simple, as in the conifers. In splitting with an axe, the axe-head acts as a wedge and forces the fibers apart, so that usually the split runs along some distance ahead of the axe. Hard woods do not split so easily as do soft woods, and

seasoned wood not so easily as green wood, while all timber splits most easily along radial lines.

Seasoning. If a tree were to be cut down and the timber sawed up into boards, planks and scantlings, and if then this lumber were to be at once fitted and nailed together to form part of a building or dressed and screwed, or glued together to form a piece of furniture or interior finish, the result would be far from satisfactory because each piece of lumber used would contain a large quantity of moisture which in time would dry out and as the moisture dried out each piece of lumber would change in size. It would become shorter and thinner and narrower than it was originally, and since the pieces were carefully cut to size and fitted together to suit their original dimensions, it would be found after a while that they did not any longer fit together at all and the work would be ruined. Moreover, any other work or finish such as plaster which might have been applied over such a frame would be found to be full of cracks caused by the change in size and shape of the pieces of which the frame underneath the finish was made.

Wood of this kind which has just come from the tree is called "green" lumber and the large amount of moisture which it contains must be removed from it in some way before it is fit for use. If the moisture were not removed from the wood and the wood thoroughly dried, it would decay.

When such timber or lumber is exposed to the air, the moisture in it dries out very quickly at first, especially near the surface, and then what moisture is left dries out much more slowly and there is a certain amount which will not dry out naturally until after many years, if at all. This is the reason why lumber for some purposes must be dried out, or seasoned, by artificial means in a kiln and is said to be "kiln-dried." It also explains why lumber for some purposes, such as ordinary framing in buildings, can be used before it is entirely seasoned, provided that the larger part of the moisture has had a chance to evaporate and the rest of the seasoning may be allowed to take place while the partially completed frame work is standing exposed to the air and the sun, more especially if the building is started in the spring as most buildings are.

It would be too expensive to season the lumber for such framing work in a kiln, and so it is almost never done, but instead the

lumber is piled up in a lumber yard and allowed to stay there exposed to the drying effect of the air until it is in such a condition that it can safely be used. Of course, the longer the lumber stays piled in the yard the better it is, but very often it is impossible for the ordinary builder to buy lumber which has been standing in the yard more than a few months at the time when he must have it to start his work. For this reason, most of the lumber used for ordinary buildings is not properly seasoned when it is used and cracks appear in the finished work on this account. Large users of lumber who appreciate the advantage of having it well seasoned and who can afford to buy it and keep it for some time often have their own private lumber yards and allow the lumber to remain there for seasoning several years before using it. Even then the wood is not fit for fine furniture and must be kiln-dried.

The lumber in the yards is not simply piled up one piece on top of another, because if this were done the air would never reach some parts of the pile. Neither should the pile of lumber be started directly on the ground where it would be exposed to dampness. Instead, blocking composed of sound timber or of concrete should be laid on the ground to a height of about 2 feet and a layer of the lumber to be seasoned should be laid crosswise on top of the blocking. Then pieces of scantling 1 inch or more thick should be laid at intervals across the first layer of lumber and another layer of lumber laid on top of them but not touching the first layer. Then some more 1-inch thick scantlings laid on top of them and then another layer of lumber and so on to the top of the pile, which, if carefully built, may be 30 or 40 feet high or even more, with open air spaces all through the pile so that air can freely circulate around each piece. See Fig. 16.

On the very top of the pile are placed some thicker scantlings, maybe 3 inches thick, laid crosswise of the lumber, to provide a good open space and above them are laid boards to form a sort of roof overhanging the lumber pile on all sides and sloping slightly to one end so as to shed water.

It is of great importance that the timbers used for blocking up the lumber piles from the ground, and the scantlings used for separating the layers of lumber in the pile, should be free from dry rot, so not to spread the disease to the lumber in the pile.

Lumber seasoned in the open air in the manner above described may be said to be well seasoned when only 15 per cent of moisture by weight is left in it, which means that about $\frac{1}{7}$ part of the weight of any particular piece of the lumber is the weight of the moisture still remaining in it after the seasoning process. This may be tested by weighing a small piece carefully and then drying it out

Fig. 16. This Illustration Shows an Alley in the Drying Yard of One of the Manufacturing Plants of the Weyerhaeuser Group
Courtesy of Weyerhaeuser Forest Products

thoroughly in an ordinary oven and then weighing it again afterward. If the second weight is about $\frac{6}{7}$ of the first weight, then the moisture which has been dried out in the oven must have been about $\frac{1}{7}$ of the original weight or nearly 15 per cent.

For many purposes, such as furniture and interior finish, lumber cannot be properly seasoned by natural means in the open air but must be placed in a shed which can be heated by means of steam pipes or otherwise, and kept at a temperature of about 160° F.

Such a shed is called a "kiln" and must, of course, be weather tight but must also have some means provided for ventilation.

The lumber must be piled as described for natural seasoning but, if possible, with even larger open spaces between the layers of material so as to allow the heated air to circulate very freely throughout the pile. See Fig. 17.

Fig. 17. The Modern Kiln Drying Equipment at One of the Mills of the Weyerhaeuser Group—a Battery of Dry Kilns and in the Foreground the Kiln Cars "Stacked" Ready for the Kilns

Courtesy of Weyerhaeuser Forest Products

Usually tracks are placed in the floor of the kiln building and the lumber is piled onto flat open trucks outside. When the trucks are loaded, they are pushed into the kiln.

Hardwoods cannot be placed in the kiln as soon as they come from the saw, because if this were done the outside surfaces of each piece would dry out too quickly while the core remained moist, with the result that checks would form. This condition is called "case hardening" and can be avoided by allowing the hardwood to remain

piled in the open air for four or five months before being placed in the kiln, and after that seven or eight days in the kiln will be enough to properly season lumber 1 inch thick. Thicker lumber will, of course, require a longer time in the kiln according to its thickness.

Sometimes hard wood lumber is subjected to steam in a kiln to prevent case hardening instead of being piled in the open air and this treatment seems to be successful, but is costly.

Soft woods may be placed in a kiln as soon as they are sawed from the log and require only about one-half as long to season as do the hardwoods.

Lumber may be accepted as thoroughly seasoned when it contains only about 12 per cent or ⅛ part of moisture by weight, but it must be remembered that if the stuff is left lying around in a damp place it will soon absorb enough moisture from the air to destroy all the value of the kiln drying.

Commercial Sizes. Lumber which is supposed to have been properly seasoned is kept in stock by dealers in the various cities and towns. This lumber is usually furnished in certain standard sizes and is classified, according to the size of the pieces, into from three to five different types each of which includes lumber of certain standard sizes.

What is known as "dimension" stuff, as it comes from the saws, is 2 inches thick and from 4 to 12 inches wide. The narrower sticks are often called "scantlings" and the wider ones "planks."

"Timbers" are from 4 to 8 inches thick and from 6 to 10 inches wide.

"Common Boards" are 1 inch thick and from 4 to 12 inches wide.

These are the three standard types of rough lumber, and the nominal sizes, but when either the sides or the edges are smoothed up or "dressed" about ⅛ inch is taken off from each side of the thinnest pieces and from ⅜ to ½ inch is taken off from the sides or edges of the thickest pieces. This smoothing process is often called "surfacing" and the letters "D" for "dressed" or "S" for "surfaced" are used to show how many sides or edges of a piece are to be dressed or surfaced. Thus D.1.S. or S.1.S. means dressed or surfaced on one side and D.1.E. or S.1.E. means dressed or surfaced on one edge. S.4.S. means surfaced on all four sides or edges while S.1.S.1.E. means surfaced on one side and one edge.

STANDARD SIZES OF LUMBER

Conforming with the recommendations of the Lumber Industry as set forth in Simplified Practice Recommendations No. 16 published by the United States Department of Commerce

Type of Lumber	Nominal Size		Actual Size S4S At Comm. Dry Shp. Wt.	
	Thickness	Width	Thickness	Width
Dimension	2 in.	4 in.	1⅝ in.	3⅝ in.
	2 in.	6 in.	1⅝ in.	5⅝ in.
	2 in.	8 in.	1⅝ in.	7½ in.
	2 in.	10 in.	1⅝ in.	9½ in.
	2 in.	12 in.	1⅝ in.	11½ in.
Timbers	4 in.	6 in.	3⅝ in.	5½ in.
	4 in.	8 in.	3⅝ in.	7½ in.
	4 in.	10 in.	3⅝ in.	9½ in.
	6 in.	6 in.	5½ in.	5½ in.
	6 in.	8 in.	5½ in.	7½ in.
	6 in.	10 in.	5½ in.	9½ in.
	8 in.	8 in.	7½ in.	7½ in.
	8 in.	10 in.	7½ in.	9½ in.
Common Boards	1 in.	4 in.	25/32 in.	3⅝ in.
	1 in.	6 in.	25/32 in.	5⅝ in.
	1 in.	8 in.	25/32 in.	7½ in.
	1 in.	10 in.	25/32 in.	9½ in.
	1 in.	12 in.	25/32 in.	11½ in.
Shiplap Boards	1 in.	4 in.	25/32 in.	3⅛ in. face
	1 in.	6 in.	25/32 in.	5⅛ in. face
	1 in.	8 in.	25/32 in.	7⅛ in. face
	1 in.	10 in.	25/32 in.	9⅛ in. face
	1 in.	12 in.	25/32 in.	11⅛ in. face
Tongued and Grooved Boards	1 in.	4 in.	25/32 in.	3¼ in. face
	1 in.	6 in.	25/32 in.	5¼ in. face
	1 in.	8 in.	25/32 in.	7¼ in. face
	1 in.	10 in.	25/32 in.	9¼ in. face
	1 in.	12 in.	25/32 in.	11¼ in. face

FIGURE 18

Fig. 18 shows the standard thicknesses and widths which the different pieces should have after they are surfaced on all four sides or edges, in accordance with the recommendations of the U. S. Department of Commerce.

It will be seen that two more types of boards are mentioned, namely, "Shiplap Boards" and "Tongued and Grooved Boards." Shiplap boards have their edges cut or "rabbeted" so as to fit together as shown in Fig. 19, while the others have their edges treated as shown in Fig. 20 with a groove in one edge and a tongue on the other edge so that any two boards will fit tightly together. This stuff is sometimes spoken of as "matched" boarding.

Fig. 19. Shiplap

Where the width is given in Fig. 18 as "3⅛-inch face" or "11½-inch face" it means the width is measured from one joint to another after three or more pieces have been fitted together. Sometimes boards have tongues and grooves, or are "matched," at the ends as well as at the edges. The object of having the edges of boards ship-lapped or matched together is to prevent an open joint between any two boards after they have taken their usual shrinkage.

Fig. 20. Tongued-and-Grooved

CARPENTERS' TOOLS

Steel Square. It is not only important that the workman should know the character and usefulness of the various materials, but it is also essential that he should be familiar with the steel square, which is the universal tool used to lay out the material. Figs. 21 and 22 show one side of one of the common squares in general use. The three parts are distinguished by special names, the tongue, the blade, and the heel. The longer and wider arm is the blade, the shorter and narrower arm is the tongue, and the point where the two arms meet is called the heel.

The Standard Steel Square has a blade 24 inches long and 2 inches wide, and a tongue from 14 to 18 inches long and 1½ inches wide. The blade is at right angles to the tongue. On the face of the square is always stamped the manufacturer's name and number.

Saws. Another very important and much used tool, wherever wood working is done, is the saw, and so much depends upon its careful manipulation and intelligent use that it will not be out of place to devote a few pages to a consideration of the different kinds

of saws and their respective possibilities, as well as to their care and the way in which they should be chosen.

There are in general two kinds of saws, which differ from each other in the arrangement of the teeth, and which are intended, one for cutting wood in the direction of the grain, and the other for cutting wood at right angles to the grain. In order to cut the wood in the direction of the grain it is not necessary to cut through very many of the fibers, as the cut is, in general, parallel to them, but it is necessary rather to force the fibers apart without tearing them. Of course it is impossible to cut the wood without tearing the fibers to some extent, but this is the best way to make clear the difference in principle between the two kinds of saws, and an understanding of this difference is necessary in order to appreciate their construction and the proper care of them. The cutting of the wood across the grain, on the other hand, requires a tool made especially with a view to cutting through the fibers as quickly and as easily as possible. Besides these two there are various other special saws designed for a particular kind of work, such as the cutting out of key holes, the cutting of dovetails, the cutting of miters, and other operations required in joiners' or carpenters' work.

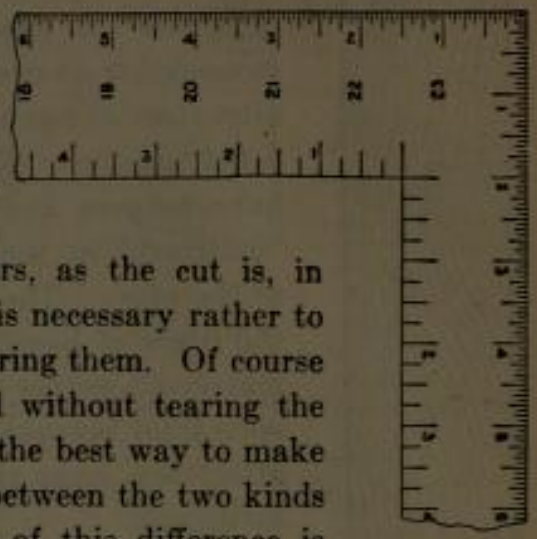


Fig. 21.
Steel Square

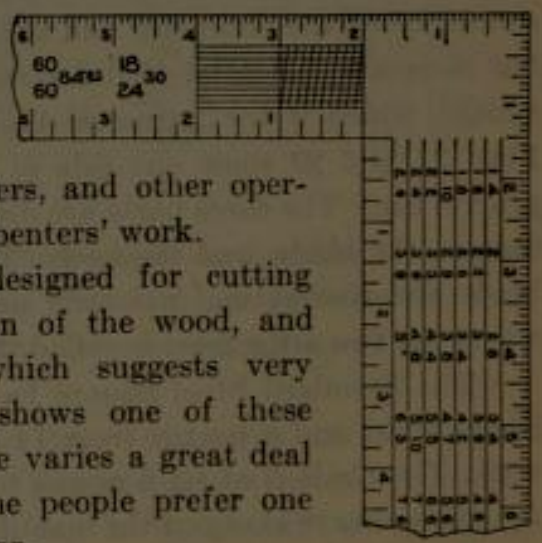


Fig. 22.
Steel Square

Rip Saw. This saw is designed for cutting along the direction of the grain of the wood, and from this comes its name, which suggests very clearly its purpose. Fig. 23 shows one of these saws, but the shape of the blade varies a great deal with different makers, and some people prefer one shape while others prefer another.

The distinguishing feature is the shape and arrangement of the teeth, which are shown in detail in Fig. 24. There are always a certain number of teeth to the inch length of the saw.

In this kind of a saw, the number is usually four or five, and it will be noticed that one side of the tooth is vertical while the other slopes. The vertical side of the tooth is always toward the front or point of the saw, while the sloping side is always toward the handle. The amount of slope to be given to the teeth of a saw is a matter of

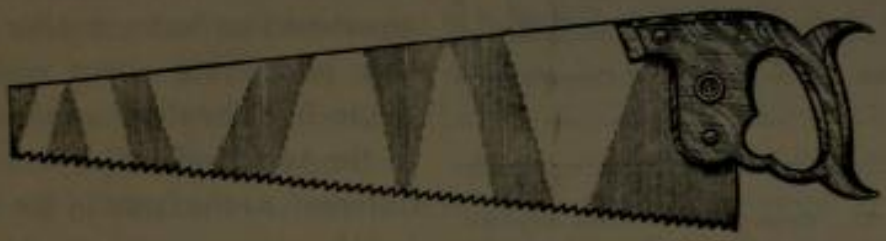


Fig. 23. Side View of Rip Saw

opinion and can be regulated when the saw is sharpened, or "filed," but the slope should always be a flat one in this kind of a saw, that is, it should make an angle of less than forty-five degrees with the horizontal, or with the line of the back of the saw.

Fig. 24. Slope of Teeth in Rip Saw

It is held by some that the teeth of a rip saw should be straight on the front edge, that is, that they should have the edge at right angles with the side of the blade, while others maintain that the edge of the tooth should be cut across obliquely, so as to be at an angle of about eighty-five degrees with the side of the blade. A saw may be filed either way, according to the opinion of the owner, the determining factor being usually the kind of wood to be cut and whether the grain is absolutely straight or more or less crooked. In the latter case the edges of the teeth should certainly have a slight bevel so as to give a cutting edge. The bevel should, however, be on alternate sides of adjacent teeth, that is, one tooth should be beveled toward the right and the next toward the left and so on. This arrangement helps to keep the saw straight while cutting, and prevents it from being forced over to one side or the other. Fig. 25 shows a view of the cutting edge of a rip saw, showing the way in which the teeth should be filed.

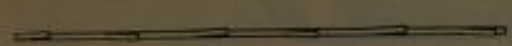


Fig. 25. Blade of Rip Saw Edge-On

Cross-Cut Saw. As has been already explained above, and as is clearly indicated by its name, this saw is intended for the cutting of wood across the grain at right angles to the direction of the fibers. It differs from the rip saw principally in the size and arrangement of the teeth, those of the cross-cut saw being smaller, usually numbering about eight to the inch. The shape of the teeth in the two kinds of saws is also different, as the front of the tooth in the cross-cut saw, instead of being straight as in the rip saw, is inclined backward at an angle of about 115 degrees, while the back of the tooth slopes at an angle of about 125 degrees. The slope of the teeth should be varied according to the hardness of the wood to be sawed, those given above being suitable for soft wood. The bevel on the front of the tooth should also be varied according to the hardness of the wood, so as to give a more or less sharp cutting edge. In the saw described above this bevel should be about sixty degrees, while for harder wood it should be as much as seventy-five degrees. In general, the harder the wood to be cut, the smaller should be the teeth of the saw. Fig. 26 shows a cross-cut saw with the slope of the teeth indicated, and Fig. 27 shows how the teeth should be filed. The cross-cut saw is also known as the "panel saw."

Fig. 26. Slope of Teeth of Cross-Cut Saw

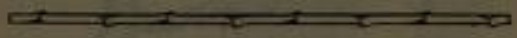


Fig. 27. Cross-Cut Saw, Blade Edge-On

Hand Saw. Rip saws and cross-cut saws are both referred to as hand saws. Hand saws are available with either a straight or a curved (skew) back. The straight edge, which may be used for drawing lines before sawing, is an advantage of the straight-back saw. The curved back of the skew-back saw reduces its weight and also results in reduced friction when the saw is in use.

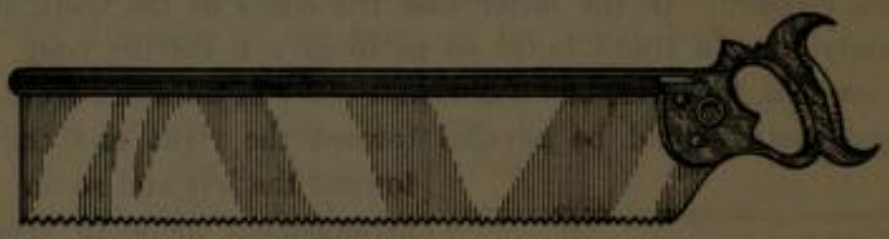


Fig. 28. Back Saw

Back Saw. Fig. 28 shows a saw which is known as a back saw, probably because of the extra piece on the back which limits the depth to which the saw will cut. It is also called a "tenon saw." There are a number of different kinds, varying in the width of the blade and in the length of the saw, and they are used for various special purposes, usually in miter boxes and for sawing bevels on moldings. Fig. 29 shows the arrangement of the teeth on a back saw. It will be seen that the front of the tooth is nearly straight, and that the slope of the back is very sharp, making the number of teeth to the inch more than in the rip or cross-cut saws.

Fig. 29. Slope of Teeth of Back Saw

Compass Saw. Fig. 30 shows a set of saw blades which are intended to be fastened in turn to the same handle and used for various purposes. The smallest of these can be used for cutting out small holes such as keyholes, and it is for this reason that such a saw is called a "keyhole saw." The teeth are in general similar to those of the back saw, but are usually smaller.

Great care must be exercised in the filing of a saw, to give it the proper "set" to enable it to do the work required of it, and this work is better left to an expert. Most carpenters, however, like to know how to file their own saws and to keep them in good condition. A great deal has been written on this subject both in books and in trade papers, but it is almost impossible to describe, in writing, the proper methods. It is a part of the carpenter's trade which must be learned by experiment and by watching the older workmen.

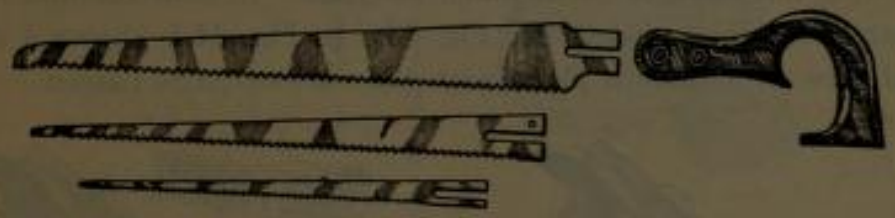


Fig. 30. Compass Saw with Detachable Blades

Planes. Timber comes from the mills rough from the saw, and before it can be used for any finished work it must be prepared to receive paint or other kinds of finish. This preparation consists in a smoothing or planing which can be carried to any extent, including

sandpapering or even polishing. The instruments used for the rougher part of this work are called planes, after which, if more smoothing is required, come scrapers and sandpaper. There are a great many different kinds of planes, but the principle of all of them is the same. They consist of a sharp blade, or knife, in the form of a chisel, which is held in a large block of wood or iron by means of clamps, so that the knife can be kept steady and guided easily. The knife projects at the bottom through a slot, and takes off a shaving which is larger or smaller according to the projection of the knife. For smoothing, the cutting edge of the knife must be absolutely straight and must be clamped into the block in such a way that the blade projection will be exactly the same all along the edge. Any imperfections in the edge of the knife will be repeated on the surface of the wood being planed. Fig. 31 shows a view of the wood bottom jack plane which was the predecessor of the present day all metal jack plane shown in Fig. 32.

Fig. 31. Wood-Bottom Jack Plane

Jack Planes. The jack plane is used for the rougher work to give the preliminary smoothing after the lumber comes from the mill. It is bigger and, as a rule, heavier than the finishing planes. The handle is necessary to push the plane forward, and it is usually necessary to bear down slightly on the forward end of the tool.

Smooth Planes. The smooth plane is usually much smaller than the jack plane, as it is not expected to take off so much material and there does not have to be so much leverage. In construction, it is similar to the jack plane. See Fig. 33. In Fig. 34 is shown a sectional view of a smooth plane with the various parts named.

Fig. 32. Jack Plane Used for Rough Work and Preliminary Smoothing

Fig. 33. Smooth Plane, Usually Smaller than the Jack Plane

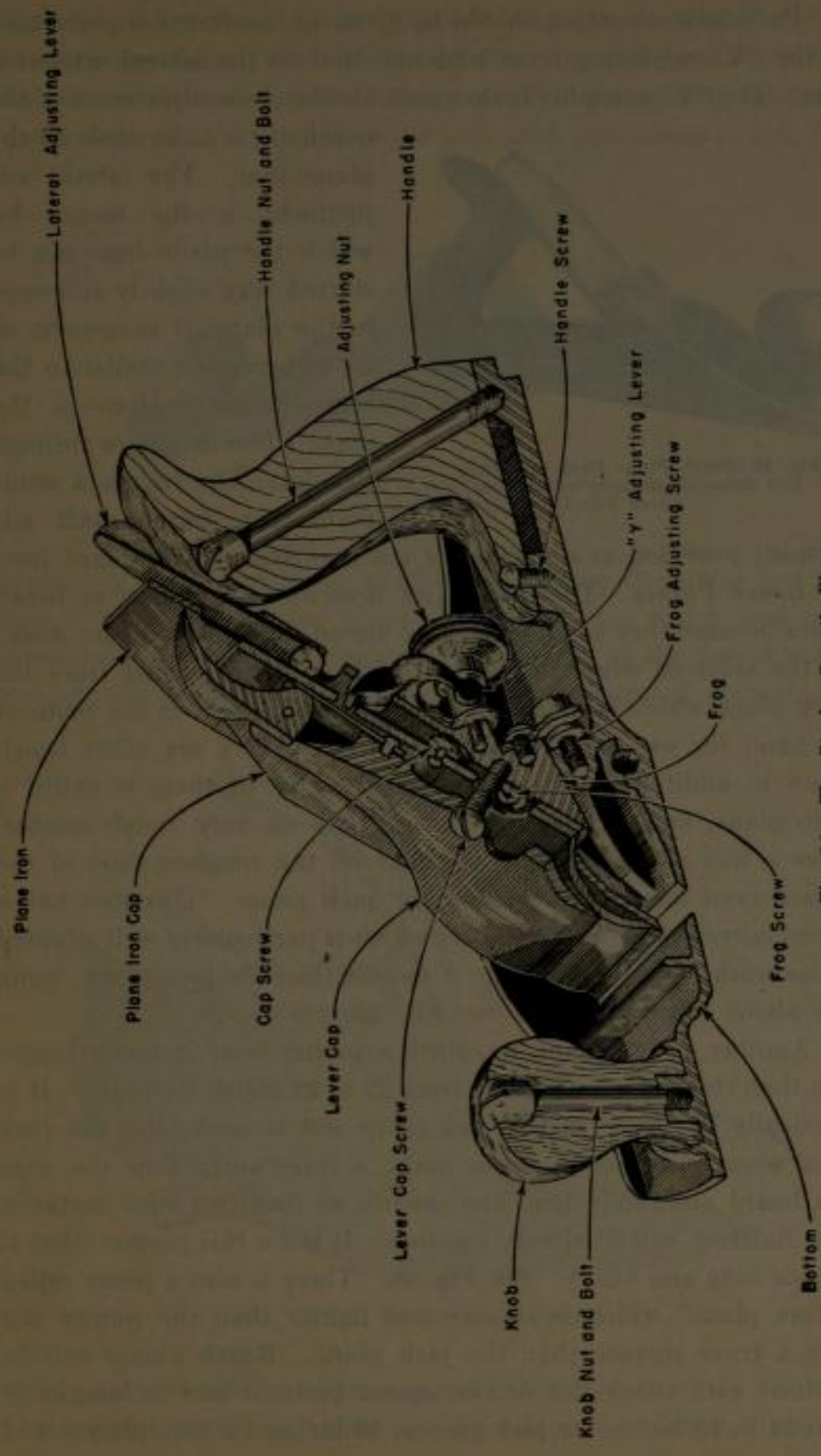


Fig. 34. The Stanley Smooth Plane

Particular attention should be given to the function performed by the "Y" adjusting lever and nut, and to the lateral adjusting lever. The "Y" assembly makes possible the close adjustment of the depth of cut to be made by the plane iron. The lateral adjustment is the means by which the plane iron can be shifted very slightly sideways in the plane, if necessary, so as to bring it parallel to the edge of the bottom of the plane where it passes through the slot. The frog is a semi-permanent, fore-and-aft adjustment provided as a means for the regulation of the plane iron.

Fig. 35. Scrub Plane Used to Hollow Out Trim Members or to Give an Adzed Effect

Bench Planes. The planes just described are known as bench planes because they are intended for use on the bench and for working the sides or edges of the material, as distinguished from the block plane which is much smaller and can be held in the palm of one hand for use on the end of a piece. There are other bench planes in addition to those mentioned. One of these is called a scrub plane, and is intended for use only on very rough lumber, where a tool is needed that will take off the roughest part of the surface even more quickly than the jack plane. This tool has a special curved plane iron or cutter which is particularly well adapted to this work. The scrub plane is shorter than the jack plane, being only about 10 inches long. See Fig. 35.

Another bench plane is called a jointer, and is much longer even than the jack plane, being from 22 to 24 inches in length. It is practically the same as the jack plane nut is used after the jack plane when it is necessary to make a large surface or the edge of a board absolutely true and smooth so that two such surfaces, when finished, will fit closely together. It is for this purpose that it is made long and heavy. See Fig. 36. There is also a plane called a "fore plane" which is shorter and lighter than the jointer but gives a truer surface than the jack plane. Bench planes can be obtained with either flat or corrugated bottoms and in lengths of from 14 to 15 inches for jack planes, 18 inches for fore planes, and

22 to 24 inches for jointers. Smooth planes are obtainable from 7 to 10 inches long. The widths vary from 1⅝ inches to 2⅜ inches, the shorter planes being the narrower. The old, wooden bottomed planes were much lighter than the iron ones, and easier to use, both

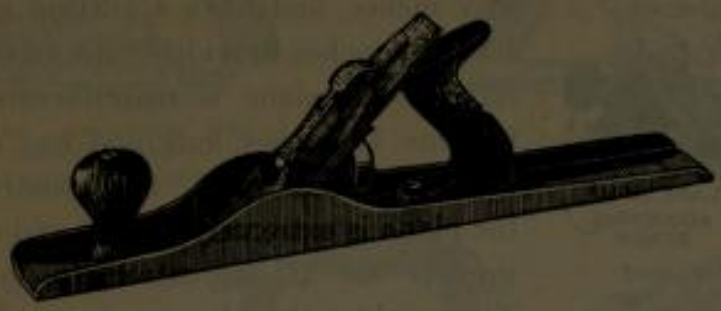


Fig. 36. Jointer Plane, Largest of the Carpenter's Planes, Is Intended for Use on the Workbench

because of the difference in weight and because there was less friction between the wooden plane and the surface which was being smoothed. To partially overcome the friction of the flat-bottomed iron planes, planes have been made with corrugated bottoms, the

Fig. 37. How to Use a Plane

corrugations consisting of grooves cut in the surface which will be in contact with the wood. This will allow some circulation of air and

will lessen the tendency for the iron to heat due to the friction. Fig. 38 shows a view of the bottom of such a plane.

Block Planes. The block planes are generally much smaller than bench planes and are made entirely of steel. They vary in length from 3½ to 7 inches, and have a cutting edge from 1 to 1⅝ inches in width. An exceptionally large block plane is manufactured which is some 14 inches long and has a cutting edge 2 inches wide. The construction of the plane is extremely heavy, and the plane iron is set at an extremely low angle. This enables the plane to be used to good advantage in cutting against the grain.

Fig. 37 A. Steel Block Plane Operated with One Hand

Special Planes. Another class of planes, called "rabbet planes," are made for the special purpose of cutting grooves, such as rabbets and dadoes, in wood. Some of these planes are called "dado planes," "filletster planes," and "double-side matching planes." This last one is especially adapted for tonguing and grooving, and is so made that it has two cutting edges on the bottom and the top of the plane, one edge carrying a narrow cutter to form the groove, while the other edge carries a special grooved cutter to form the

Fig. 38. Smoothing Plane
Courtesy of Sargent & Company

Fig. 39. Low Angle Block Plane
Courtesy of Sargent & Company

tongue. The plane may be turned over and the same size cut will be made on both tonguing and grooving so that the two will match perfectly.

Expensive combination planes are made which have many interchangeable parts so that one tool can be made to do a variety of different jobs for each of which a separate tool would otherwise be required, such as dadoing, rabbeting, tonguing and grooving, beading, slitting and sash cutting, and may be used as well for

cutting different mouldings on the edge of a piece of stuff. These planes are shown in Figs. 39, 40, 41, and 42.

Fig. 40. Adjustable Iron Rabbet Plane
Courtesy of Sargent & Company

Fig. 41. Adjustable Double Side Matching Plane
Courtesy of Sargent & Company

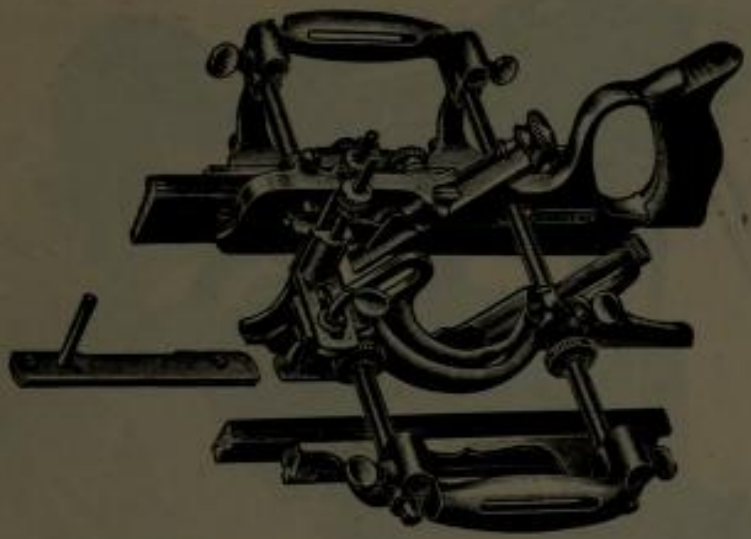


Fig. 42. Combination Moulding Plane
Courtesy of Sargent & Company

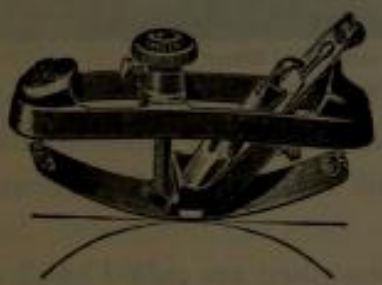


Fig. 43. Adjustable Iron Circular Plane
Courtesy of Sargent & Company

Fig. 44. Adjustable Iron Scraper Plane
Courtesy of Sargent & Company

There are planes known as "Circular Planes" made for working on curved surfaces. These planes have the bottom composed

of a flexible steel strip which may be adjusted by means of a screw to fit the surface corresponding to the arc of any required circle or a hollow of similar circular shape. These planes are about 10 inches long and 2 inches wide and can be used in places where it would be impossible to use a straight plane. See Fig. 43.

There are a variety of tools constructed in such a way as to hold the cutter securely in a nearly vertical or straight up-and-down position so that it scrapes the surface of the wood instead of cutting

Fig. 45. An All-Purpose Saw Adjustable to Many Angles
Courtesy of De Walt Products Corporation

it. These tools are called Scraper Planes and are intended for use after using the smooth plane to still further finish and smooth the wood. See Fig. 44.

Power Tools. All the tools thus described are called hand tools. That is, they are worked by hand and not by mechanical power such as electric or gasoline motors. In woodworking factories where power has been available, it has for a great many years been customary to use machine tools for sawing, smoothing, and shaping lumber. In recent years, it has become more and more common to have small portable machines and to set up small temporary woodworking

shops right at the location where the building is being constructed. This has probably come about because it is now so easy to get electric power to operate these machines almost anywhere, and also because of the development of the gasoline engine. Some of the machines are also made for operation by hand and foot power. Others can be worked by plugging into an ordinary lighting plug outlet. The machines most used in this way consist of portable sanders, portable drills, powered handsaws, and radjal saws. The most useful of all on a job is the machine usually called a "Universal" or "Variety" Woodworker which is a single piece of equipment operated by one motor or other single source of power and

Fig. 46. Standard Common Cut Nails
Cut, Casing and Flooring Nails

having attachments for doing all of the classes of work mentioned above. Some of these combine in one machine as many as fourteen different functions so that they are practically the equivalent of fourteen separate pieces of shop machinery. They are sometimes called "Combination Woodworkers."

Nails. In general, nails are of two kinds, namely, cut nails and wire nails, the difference between the two kinds being in the material and the method of manufacture. See Figs. 46 and 47.

Cut Nails. These nails, also formerly called plate nails, used to be stamped out of a flat iron plate, in alternate, slightly wedge-shaped pieces, and the head afterward formed on the large end of each piece. The cut nails are now made of much the same shape as the old iron nails but are cut from steel plate by a machine which also forms the head and are made in three classes, according to finish, and are called, respectively, "common," "casing," and "finish" nails. The nails known as "finishing nails," however, are far too rough for fine finished work. The length of the nail is regulated according to the "penny," which formerly had reference

to the weight, but which now is purely arbitrary. Thus a three penny nail is 1¼ inches long; four penny, 1½ inches; five penny, 1¾ inches; six penny, 2 inches; seven penny, 2¼ inches; eight penny, 2½ inches, nine penny, 2¾ inches; ten penny, 3 inches; twelve penny, 3¼ inches; sixteen penny, 3½ inches; twenty penny, 4 inches; thirty penny, 4½ inches; forty penny, 5 inches; fifty penny, 5½ inches; and sixty penny, 6 inches. The specifications which have just been given for cut nails also hold good for wire nails.

Wire Nails. Wire nails are rapidly replacing the cut nails in

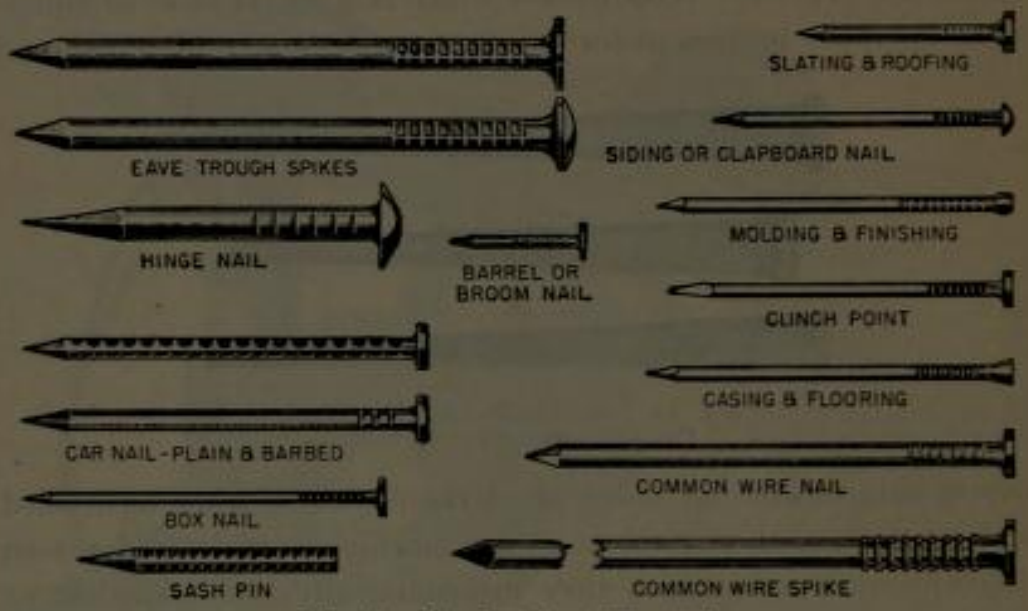


Fig. 47. Standard Steel Wire Nails

general use. They are now very nearly the same price and are very much stronger, so that they do not buckle up when driven into hard wood, and they are not nearly so liable to split the wood on account of their cylinder-shaped shaft, which is the same size throughout its entire length. They are made from wire, which is cut in lengths by machinery and pointed and headed. They can also be ribbed or barbed, if desired, which gives them a stronger hold on the wood. They are made with various kinds of heads, some being large and flat, so that the nail can be easily withdrawn, while others are very slightly larger than the shaft of the nail and can be made almost invisible in the finished work.

For framing, large nails should be used, from 4 to 6 inches in length. For the rougher exterior and interior finish, such as sheath-

ing and rough flooring, nails about 3 inches long are suitable, while for the finer inside finish smaller nails from 2½ inches down to 1½ inches should be used. Roofing should be put on with special galvanized or copper nails so as not to rust out.

Both cut nails and wire nails are made with a special finish called "blueing" or with a coating of cement applied while the nail is hot, both of which processes are supposed to increase the holding power of the nail. They can also be had galvanized by an electric process or hot-dipped-galvanized. There is an extra charge for nails treated in any of these ways.

The value of nails in holding two pieces of lumber together and in resisting a force which may tend to pull the pieces apart has been found by carefully conducted tests at several Universities to be much greater with some kinds of wood than with others, and depending also upon whether the nails are driven into the wood parallel to the grain or across the grain. It has been found that with both kinds of nails the holding power is greater when the nail is driven into the wood across the grain than it is when driven parallel to the grain, but that this difference is much greater with cut nails than it is with wire nails. Moreover, wire nails when driven into hard dense wood, such as Southern Pine or Douglas Fir, hold nearly twice as well as the same kind of nail driven into soft wood, such as White Pine, and if driven into White Oak the nails would hold nearly three times as well as when driven into Southern Pine or Douglas Fir. With cut nails this difference in holding power in different kinds of wood is similar, but the difference is not nearly so great. Cut nails are harder to start pulling out than wire nails, but after they are fairly well started they pull out quite easily, so that on the whole, the wire nails seem to hold just about as well as the cut nails. To properly hold a piece of lumber in place, the nails used should be of a length equal to three times the thickness of the lumber.

Screws. Screws are now used in building work to a much greater extent than was formerly the custom, largely on account of their decreased cost. They have the advantage over nails, as they do not split the wood, and they can be easily withdrawn when desired, without injuring the work materially. There are a great many different kinds of wood screws, which vary as to the shape of the

head, the size of the shaft, and the length. They are made in about the same lengths as those given above for nails, and with both round and flat heads. See Fig. 48.

Screws, however, are sold according to the length in inches and each length is made in a number of sizes, each size being designated by a number called the "gauge" of the screw, which corresponds to the diameter of the "shank" or the portion of the screw between the threads and the head. For instance, a No. 5 gauge screw is about ⅛ inch in diameter and a No. 15 gauge about ¼ inch, a No. 34 gauge

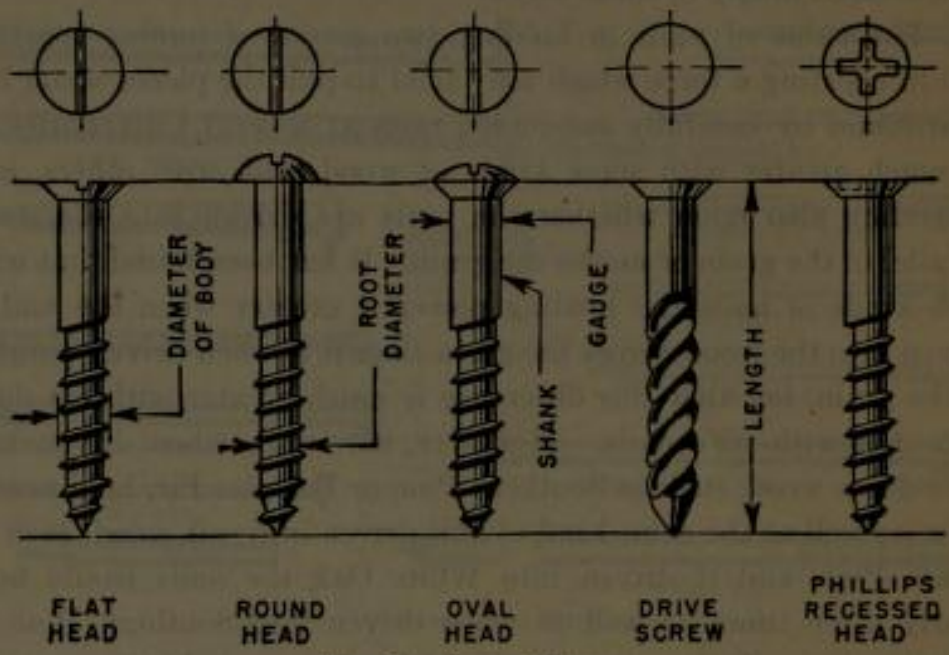


Fig. 48. Types of Screws

about ½ inch, and so on. If you know what diameter screw you need and want to find the approximate gauge, subtract $\frac{1}{16}$ inch from the diameter and multiply by 80 and the result will be the gauge. To find the approximate diameter from the gauge divide the gauge by 80 and then add $\frac{1}{16}$ inch.

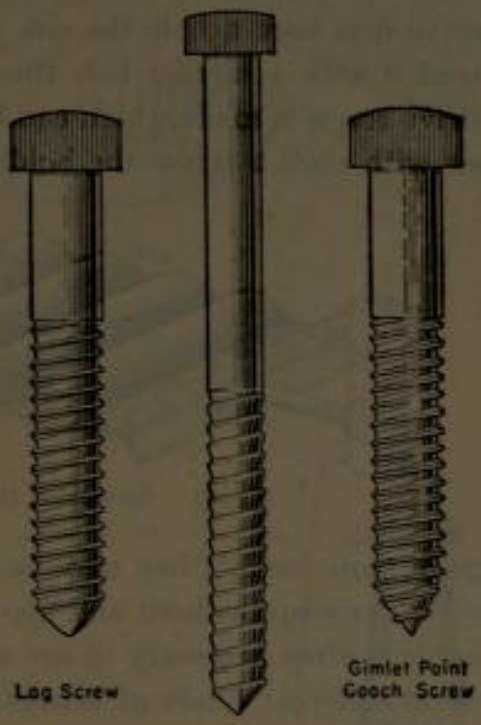
Screws can be had in steel, copper, bronze, and brass. They are also made with chromium or nickel or silver-plated finish to match finishing hardware. All screws are sold by the gross.

If an ordinary screw is driven into the wood as one would drive a nail and is then screwed up tight with a screw driver, the fibers of the wood will be so badly crushed that the screw will not hold the pieces securely together. For this reason, one should always

bore a hole in the wood before inserting the screw, the size of the hole being equal to the size of the threaded part of the screw without the threads. This is called the "core" of the screw. As the "shank" is larger in diameter than the core, it is necessary in hard wood to first bore a hole the size of the shank and as deep as the length of the shank and then take a smaller bit and continue the hole, making the deeper part equal to the diameter of the core. This is done so that the screw will not split the wood when it is driven home. There

Twist Drive Screw

Fig. 49.



Fetter Drive Screw

Fig. 50. Coach or Lag Screws

are special screws available which are so made that it is only necessary to bore one hole, even in hard wood, and other screws called "drive screws" are made with the threads so far apart and so shaped that the screws can be driven with a hammer.

Tests have shown that the holding power of screws is more than twice as great as that of nails of similar size, but that "drive" screws are only about two-thirds as good as ordinary screws. These tests also showed that it made little difference whether the screws were driven into the wood parallel to the grain or across the grain, and that the holding power is in proportion to the size of the screw.

Screws are made with square heads for heavier work so that they can be driven home with a wrench instead of a screw driver. These are called "Lag Screws" when they have a "cone" point and "Coach Screws" when they have a "gimlet" point. They can be had in lengths from 1½ inches up to 12 inches, and in diameters from ¼ inch to 1 inch. They are sold by the hundred and are designated by diameter and length in inches as "a ⅜ inch lag screw 3 inches long." At a little extra cost, they can be had with heads hexagonal instead of square. In using lag or coach screws, it is necessary to first bore a hole the size and depth of the shank and then extend it with a smaller hole the size of the core. A square-headed drive screw is made which can be used without boring these holes, but with such a screw the holding power is less. To make

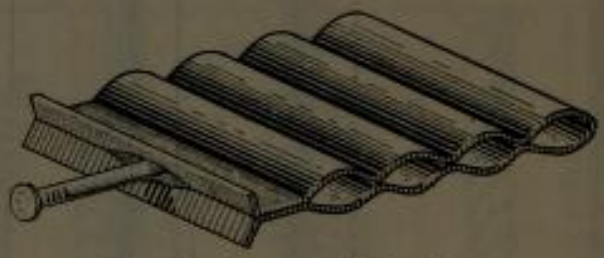


Fig. 51. Corrugated Metal Plug

screws go in more easily, they may be treated with a heavy lubricant, such as tar soap, without any appreciable loss of strength. In hard wood it is often necessary to use a lubricant. Figs. 49 and 50 show several different kinds of screws.

A condition is often met with where a wooden stringer or other member must be laid against a masonry wall and secured to the wall. Nails or screws are usually not satisfactory for this sort of work because, even if they could be driven into the joints of the masonry, they would soon work loose. Sometimes wooden bricks are built into the wall at intervals in place of the regular bricks so that nails can be driven into them, or even wooden strips or plugs are built into the mortar joints. On account of the natural shrinkage which takes place in the wooden bricks or plugs, they will in time work loose and so are not very satisfactory. It is possible to buy corrugated metal plugs like the one shown in Fig. 51 which can be built into the joints of a brick wall and into which a nail can be driven as shown. It is often found, however, that these plugs have been

forgotten when the wall was built or that they have been built in at the wrong places. When it is necessary to provide a nailing plug after the wall has been built, it is possible to buy a type of "spot ground" called a "Ped" which consists of a round wooden nailing block securely fastened into a circular metal frame in the form of a disk. The disk has a flange provided with eight holes which hold the

Fig. 52. A Ped

Fig. 54. Expansion Bolt

Fig. 55. Screw Anchor

plaster which keys through them when they are pressed against the masonry wall. To set such a wall "Ped" in place, a dab of quick setting plaster or cement is spread over the back surface of the ped and it is then pressed against the masonry wall until the plaster is squeezed out through the holes in the metal flange. In a short time the plaster sets hard and the plug is securely fastened in place. In nailing into these wall plugs, the nails should not be driven straight in through the entire thickness of the wood, as this would loosen the

peds, but instead the nails should be driven into the wood at an angle. This method of nailing is called "toe-nailing." Fig. 52 shows a Ped.

Another method employed is to use an "expansion bolt" such as the one illustrated in Fig. 54 or a "Screw Anchor" as shown in Fig. 55.

In using these bolts and screws, a hole is drilled in the masonry wall and the "shield" of the bolt or screw is inserted in the hole.

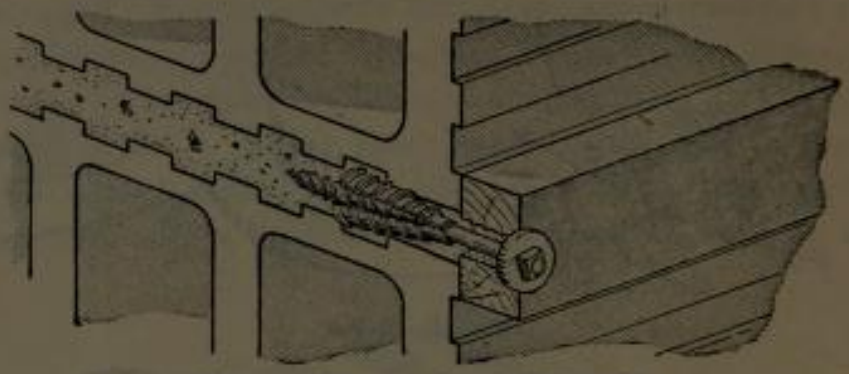


Fig. 56. Expansion Bolt in Hollow Tile Wall

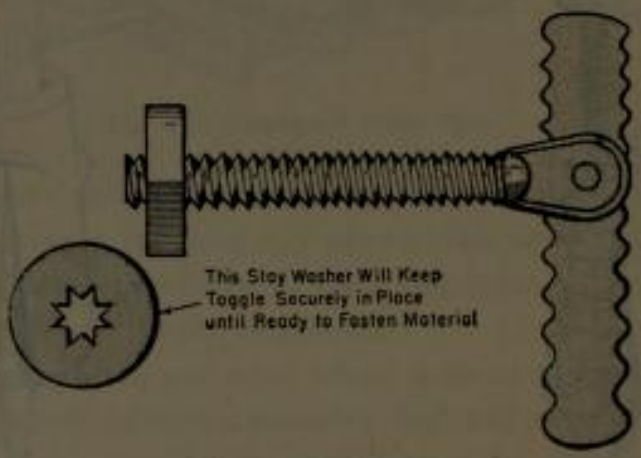


Fig. 57. Toggle Bolt

Then when the bolt or screw is driven through the wood stringer into the hole formed by the shield, this shield, which is split lengthwise, will expand until it becomes very tightly wedged into the hole in the masonry and will remain permanently tight. The bolt or screw can be easily removed when this becomes necessary. Fig. 56 shows an expansion bolt in place in a hollow tile wall.

Should it be required to fasten such a wood stringer to a masonry wall, which is built up out of a number of hollow blocks with comparatively thin masonry walls and with cavities behind, such as a

partition wall of hollow tile, then an expansion bolt cannot very well be used and it is customary to employ a device called a "toggle bolt," one of which is illustrated in Fig. 57. To use this bolt, a small hole is drilled in the wall going right through to the hollow space; then the loose swinging anchor on the end of the toggle bolt is swung around until it is parallel with the shaft of the bolt and both bolt and anchor are shoved through the hole until the swinging anchor is entirely in the hollow space. As soon as this is accomplished the anchor will swing around on its pivot and assume a position at right angles to the shaft of the bolt as shown in Fig. 57. The anchor

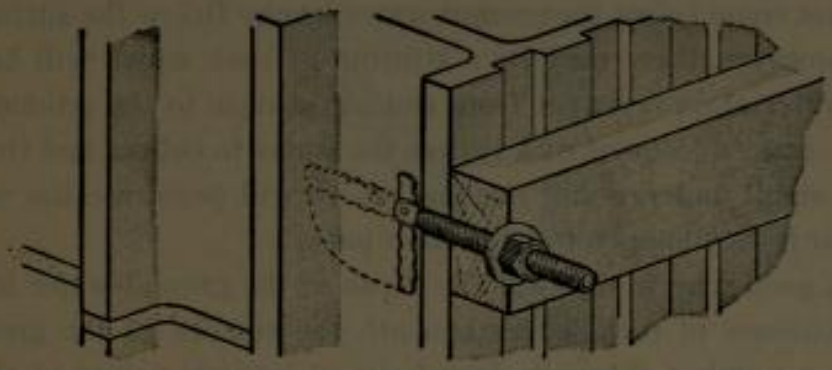


Fig. 58. Toggle Bolt Used in Hollow Tile Wall

then prevents the bolt from being withdrawn through the hole, and the nut at the outside end of the toggle bolt may be tightened up so as to hold the wooden stringer firmly against the wall, as shown in Fig. 58.

CONSTRUCTION

Having now considered the material and the most important of the tools with which the carpenter performs his work, we shall pass to a consideration of the work itself, and see how a building of wood construction is put together.

Ground Location. In undertaking the construction of any building, the first thing to do is to make a thoughtful examination of the piece of ground upon which the structure is to be placed. This is very important as the character of the soil upon which a dwelling is located will very largely determine its sanitary condition, and will influence to a great extent the health of the occupants.

Very often a difference of a few yards in the location of a building will be enough to cause the difference between a perfectly dry cellar and one which is constantly flooded with water. Water is, indeed, the one thing above all others which must be guarded against, since it is impossible to keep it out of a cellar which is sunk in damp ground, unless some elaborate system of waterproofing is employed.

Ground Water. Below the surface of the earth there is to be found what is known as "ground water." This stands always at a level, and is not met with so near the surface on a slight knoll or other elevation as in a depression. If possible, a house should be located on comparatively high land, so that the floor of the cellar does not come below the ground-water level. Below the surface of a hill, however, there may be a stratum of rock which will hold the rain water and prevent it from sinking at once to the ground-water level. Such a ledge of rock causes the water to collect and then flow off in small underground streams, which will penetrate the walls of a cellar if they happen to be in their path.

A good way to discover the depth of the ground-water level, or the existence of rock ledges beneath the surface of the ground, is to dig a number of small, deep holes at various points of the site. These should be carried below the proposed level of the cellar bottom. A suitable location for the building may thus be chosen.

If, however, it is not easy to make so thorough an examination of the site as this would allow, another method may be employed. This consists in the use of an instrument called an "auger," which is very much like an ordinary carpenter's auger or bit, though much larger. The auger generally used is about 2 inches in diameter. It is driven into the ground, and as it descends into the hole which it bores it brings to the surface small portions of all the different kinds of material through which it passes. This material may be preserved and examined at leisure. The character of the site may be determined in this way.

Staking Out. When the approximate position of the structure has been decided upon, the next step is to "stake it out," that is, the position of the corners of the building must be located and marked in some way, so that when the excavation is begun the workmen may know what are the exact boundaries of the cellar. This "staking out" should always be carefully attended to, no matter

how small the building may be. In works of importance it is best to have the work done by an engineer, but on small work it is customary for the contractor or the architect to attend to it. It is well to have at hand some instrument with which angles can be accurately measured, such as a transit; but the work can be done very satisfactorily with a tape measure and a "mason's square." This simple instrument is composed of three sticks of timber nailed together as shown in Fig. 59, to form a right-angled triangle. It is important that the tape used should be accurate, a steel tape being always preferable, and that the mason's square should give

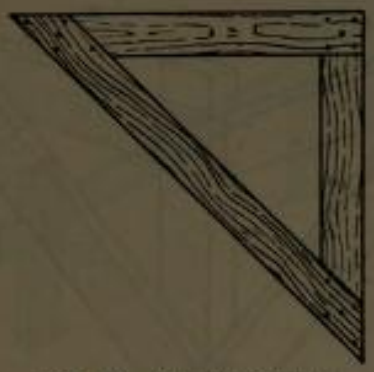


Fig. 59. Mason's Square

an exact right angle. A mistake in the staking out may cause endless trouble when the erection of the building itself is begun, and it is then too late to remedy it.

There are several different lines which must be located at some time during the construction, and they may as well be settled at the start. There are: The line of excavation, which is outside of all; the face of the basement wall, inside of the excavation line; and in the case of masonry building, the ashlar line, which indicates the outside of the brick or stone walls. In the case of a wood structure only the two outside lines need be located, and often only the line of the excavation is determined at the outset.

The first thing to do is to lay out upon the ground the main rectangle of the building plan, after which the secondary rectangles which indicate the position of ells, bay windows, etc., may be located.

The position of the corners of the building and of the excavation might be indicated by driving stakes into the ground exactly at these points as soon as they were located, but it would be found that as

soon as the excavation was made near these corners the stakes would necessarily be dislodged and no permanent mark would remain to indicate the proposed position of the corners, or the lines of the sides of the building. This would result in a great deal of confusion. To avoid this, it is customary not to use stakes to mark the position of the corners but instead to employ batter boards, and to locate them not exactly at the spots where the corners are to be, but some distance away from these points, so that they will be well outside of the line of the excavation and will not be dislodged

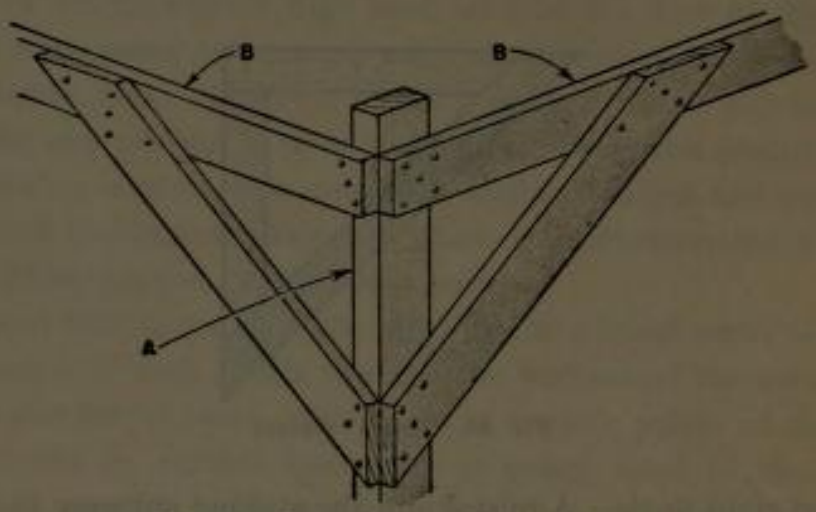


Fig. 60. Batter Board to Indicate Layout

when the hole is dug. One of these batter boards is shown in Fig. 60. It will be seen that it consists of a post *A*, which is set up near the proposed location of the corner of the building, together with two horizontal pieces *BB*, which extend outward for a short distance in directions parallel to the sides of the rectangle which will be formed by the walls of the building. The horizontal pieces may be braced securely as shown and the whole will be a permanent indication of the position of the corner. Notches may be cut in the top of the horizontal pieces to indicate the position of the various lines, and cords may then be stretched between the notches from batter board to batter board. These cords will give the exact location of the lines.

Another way to indicate the position of the lines is by driving small nails into the tops of the batter boards instead of cutting

notches in them, as nails may be withdrawn, while notches, when they are once cut, cannot easily be obliterated.

Batter boards should always be set up very securely so that they will not be displaced during building operations. If there is danger that the form of batter board shown in Fig. 60 may be overturned, because of the length of time during which it must be used, the form shown in Fig. 61 may be substituted. Two of these at right angles to each other must be placed at each corner and they are therefore, somewhat more costly than the ones first described, but for work of any importance they are well worth the extra trouble

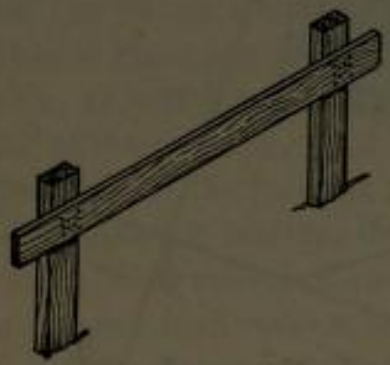


Fig. 61. Extra Strong Type of Batter Board

and expense on account of their greater permanence and accuracy. It is important that the batter boards of whatever type should be so constructed and set up that their tops will be practically level and the tops of all of them should be at the same level so that the lines stretched between them will be level. This can be accomplished by sighting along the top of a mason's long level.

In Fig. 65 the use of a mason's level for this purpose is illustrated and this figure also shows another type of batter board which may be used at the corner of an excavation and which can be constructed with the use of only three upright stakes instead of four as would be required with the type of batter board shown in Fig. 61.

Starting at any point on the lot where it is desired to place one corner of the building, as at *B*, Fig. 62, a stake should be driven firmly into the ground and the exact position of the corner of the building should then be indicated by a nail, *C*, driven into the top of the stake. The perpendicular distance from this stake and nail to the street line of the property can then be measured with the tape,

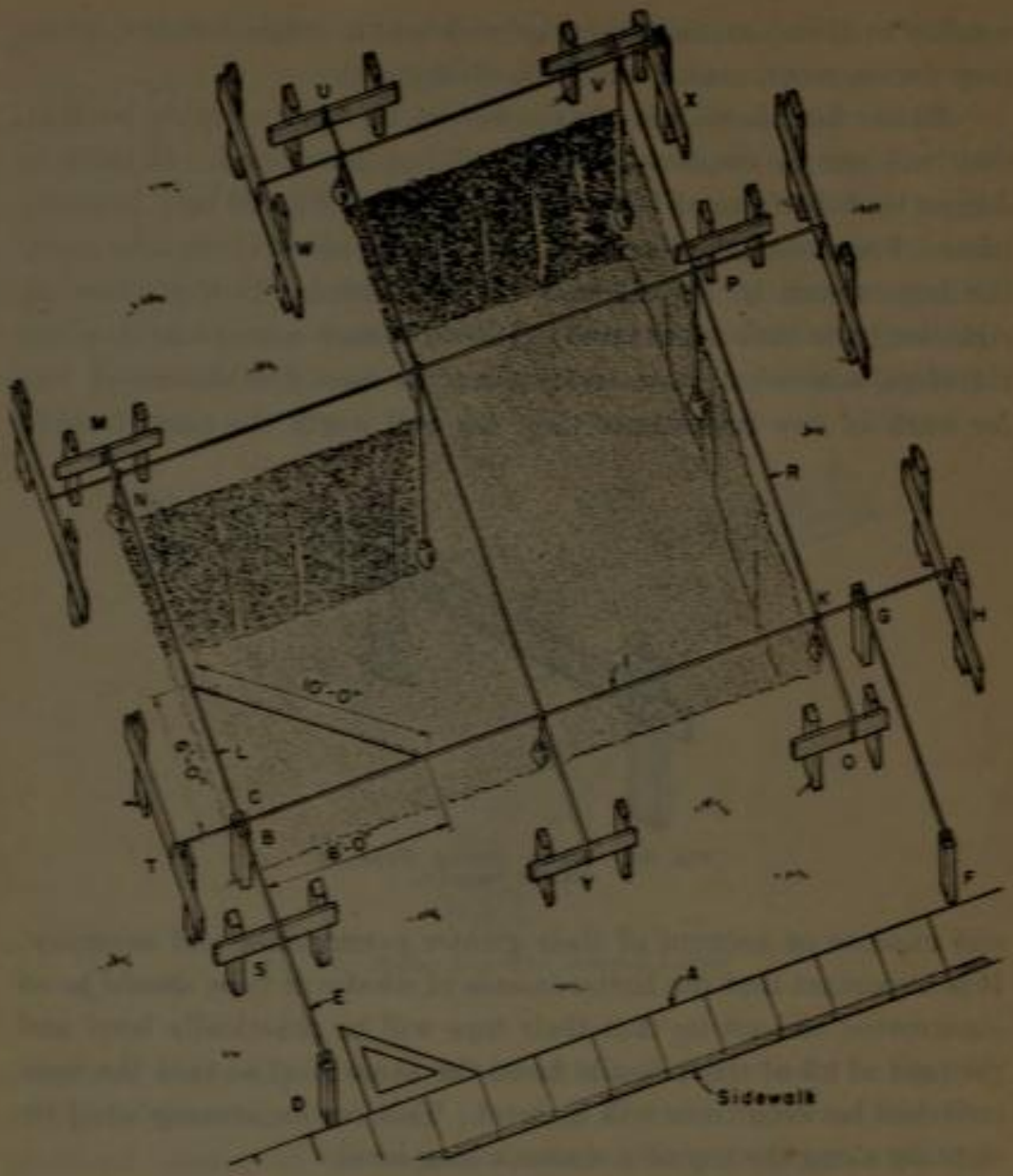


Fig. 62. Bird's-eye View of Method Used in Laying Out Excavation Limits

and a batter board, *H*, can be erected, located an equal distance from the street line and at a distance from the first stake somewhat greater than the length of that side of the building which is parallel to the street. If a line is now stretched between the stake, *B*, and the batter board, *H*, it can be adjusted until it is exactly parallel to the street and one end of it, at the first stake, will be exactly at one corner of the building. Suppose the length of the side or end of the building parallel to the street is to be 25 feet 4 inches from outside corner to outside corner. The batter board will have been

placed maybe 28 feet away from the first stake, and it will be possible to measure off with a steel tape on the cord or line which has been stretched between the stake and the batter board a distance of exactly 25 feet 4 inches. At this point, *K*, a piece of cord with a plumb bob at the end, may be tied tightly around the stretched cord or line so as to exactly mark the place, and this knot will be just at the second corner of the building. We have now a stretched cord or line parallel to the street line of the property and just in the position where we wish the outside of one wall of the building to be. One end of the line, at the nail, *C*, in the top of the first stake, indicates the exact position of one of the front corners of the building and a plumb bob, *K*, tied around the line 25 feet 4 inches from the nail in the top of the first stake marks the exact position of the other front corner. This is illustrated in Fig. 62, which is a bird's-eye view.

A is the street line of the property. *B* is the first stake driven into the ground at the corner of the building nearest the street. *C* is the nail in the top of the stake, *B*, marking the exact position of the corner. *D* is another stake at the street line and *E* is a cord stretched perpendicular to the street line from stake *B* to stake *D*. It is along this stretched cord, *E*, that the distance of the corner of the building, stake *B*, from the street line, stake *D*, is measured and the mason's square is used to make sure that this line is really at right angles to the street line. *F* is another stake at the street line which has been driven into the ground at a distance from stake *D* somewhat greater than 25 feet 4 inches, say, 27 feet, and *G* is a guide stake so located that its distance from stake *F*, measured at right angles to the street line, is exactly equal to the distance between stake *D* and stake *B*. *H* is the first batter board and *I* is the line stretched between the stake *B* at the corner of the building and this first batter board. At *K* is shown the knot and plumb bob marking the position of the second corner of the building.

We now want to locate by means of stretched cords or lines the location of the other sides of the building and the other two corners. We can take another line and tie the end of it onto the nail in the top of the first stake, *B*, and with the aid of the mason's square we can stretch this cord out perpendicular or at right angles to the street line of the property and at right angles to the stretched line, *I*, as shown at *L*, Fig. 62. Knowing the length of the side of the

building which will lie along the line L, at right angles to the street line, we can have erected a second batter board, M, somewhat more than this distance from the first stake, B, and we can adjust the line, L, until it is at right angles to the first stretched line, I.

At this point, it is necessary to emphasize the importance of having these lines stretched exactly at right angles to each other. If this is not found to be the case, the angle laid out is not an exact right angle, and, instead of a rectangle, we will have a parallelogram as shown in Fig. 63. This will not do at all and the inaccuracy must be corrected. In the absence of the instrument

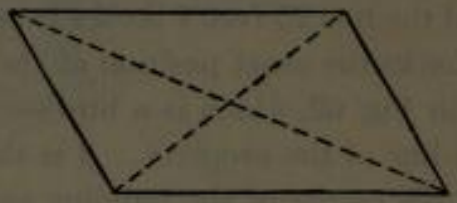


Fig. 63. Diagram Showing Wrong Ground Layout

called a transit, the accuracy of the right angle may be checked by the use of what is known as the "three-four-five" rule. This rule is based upon the fact that a triangle whose three sides are, respectively, 3, 4, and 5 feet long, is an exact right-angled triangle, the right angle being always the angle between the 3-foot and the 4-foot sides. This fact may be proven by applying the well-known theorem, which states that the length of the hypotenuse of a right-angled triangle is equal to the square root of the sum of the squares of the other two sides. The rule may be used as follows:

Lay off on one of the side lines already laid out on the ground any multiple of 3 feet, as 9 feet or 12 feet. On the other line, presumably at right angles to the first one, lay off the same multiple of 4 feet, as 12 feet or 16 feet. Now a straight line measured between the points so obtained, should have a length equal to the same multiple of 5 feet, as 15 feet or 20 feet. It is possible to lay out the right angle in the first place by this same method, using two flexible cords, respectively, 4 feet and 5 feet long. The end of the 4-foot cord should be fastened at the end of the side line of the building, and the end of the 5-foot cord should be fastened on this

same side line, 3 feet away from the corner. When the loose ends of both cords are held together, and the cords are both drawn taut, the point where the ends meet will be a point on the side line of the building perpendicular to the first side line. It is evident that this point must be just 4 feet from the corner, and that the distance between it and the point on the other side line, 3 feet from the corner, must be 5 feet.

Another method often employed is to use a wooden pole 5 feet or 10 feet long, in place of a cord, for the long side or hypotenuse of

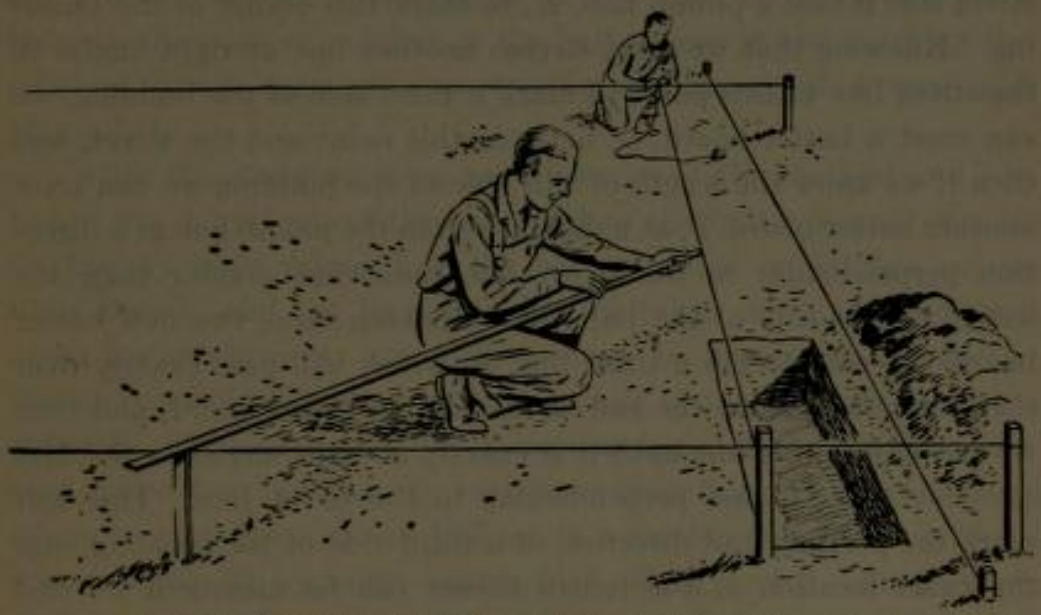


Fig. 64. The Illustration Shown Above Shows the Workman in the Foreground Using a Stick as the Hypotenuse of the Triangle and the Workman in the Background Adjusting the Line Either to the Right or Left to Form a Perfect Square Corner. This is the 3-4-5 Rule

the triangle. This pole would have notches cut in the two ends large enough and deep enough to fit over the cords and the distance 5 feet or 10 feet would be measured exactly between the notches. The pole is used as illustrated in Fig. 64, a stake being driven into the ground at the proper position, 4 feet or 8 feet from the corner stake, to support one end of the pole while the other end is held up by a workman while some one adjusts the stretched cord as shown in Fig. 64 until the angle between the two cords is in the correct position to make a true right angle of exactly 90 degrees.

Being certain that the second stretched line, *L*, Fig. 62, is really at right angles to the first one and thus perpendicular to the street

line of the property, we can measure out along this line the known length of the side of the building and locate another corner by means of a plumb bob and cord tied to the stretched line *L* in the same way as we located and marked the first corner. If no plumb bob is at hand, a small stone tied to the end of the cord will do. This is shown at *N*, Fig. 62.

We now have two sides and three corners of the proposed building laid out and marked by means of stretched lines and plumb bobs. At the far end of the line, *I*, stretched out parallel to the street line is tied a plumb bob, *K*, to mark this corner of the building. Knowing that we must stretch another line at right angles to the street line at this point to mark a third side of the building, we can erect a batter board, *O*, between this point and the street, and then if we know the length of this side of the building we can erect another batter board, *P*, at a distance from the plumb bob in a direction perpendicular to the street line somewhat greater than the length of this side of the building. Between these two new batter boards we can stretch a third line, *R*, which will pass exactly over the plumb bob, *K*, at the end of the first stretched line, *I*, and then we can adjust this line until it is exactly at right angles to the first stretched line, *I*, and perpendicular to the street line. This will mark the position and direction of a third side of the building, and the exact location of the fourth corner can be measured off and marked on this line by a plumb line tied to the stretched line as was done for the other corners. We now have all four corners marked and three sides of the building laid out by stretched lines. The fourth side can be laid out by erecting batter boards and stretching a fourth line over the plumb bobs marking the two rear corners of the building in the same way as described above for the third side.

We must not forget that the corner of the building at which we started is still marked only by the single stake, *B*, with a nail driven into the top of it at the exact position of the corner. This stake is just at the corner of the lines marking the position of the sides of the building and will be inside of the lines of the excavation so that it is sure to be dislodged when the excavation is made and this mark then will be lost. It is, therefore, necessary to erect two more batter boards, *S* and *T*, some 3 feet or so outside of the lines marking the

wall lines of the building and in such a position at right angles to each other that if the two stretched lines, *I* and *L*, at this corner are continued beyond the nail, *C*, in the top of the first stake, one towards the street line and the other parallel to the street line, they can be fastened to the two new batter boards, *S* and *T*, and will still pass directly over the nail, *C*, in the top of the stake, and cross each other exactly over this nail. After the position of these lines is clearly marked on the two new batter boards, *S* and *T*, the original stake *B* can be removed and the position of this corner of the building can still be found again at any time by stretching lines between the nails or notches in the batter boards and marking the point at which they cross each other by means of a cord and plumb bob.

After the stretched lines have been carefully checked and adjusted, the places where they are tied to the batter boards can be marked by nails driven into the batter boards or notches cut in these boards, and the lines can then be taken down and replaced again for reference at any time as may be necessary, the batter boards remaining in place until the walls of the building are constructed. Of course only the main rectangle of the building has been laid out so far, but any variations from this rectangle, such as ells or bay windows, can be laid out in a similar way. This is illustrated in Fig. 62, by batter boards *U*, *V*, *W*, *X*, and *Y*. Frequently, on large jobs, when the stretched lines are to be left in place for some time, wires are used instead of cords.

We now have marks on the batter boards from which lines may be stretched indicating the position of the outside faces of the walls of the building, but what we need most of all at first is some way of marking the position of the sides and corners of the proposed excavation for the basement or cellar and the lines of the outside of the concrete basement walls which may be some inches outside of the outside face of the walls of the building.

When the earth is of such a nature that the sides of the excavation can be cut down practically perpendicular, and will not cave in, the lines of the excavation can frequently be made the same as the lines of the outside faces of the basement walls and these lines are often also the same as the lines of the outside faces of the walls of the building. This is the condition illustrated in Fig. 62.

Sometimes the excavation is made about one foot larger all around than the dimensions of the actual building, that is, the sides of the excavation are about one foot outside of the side lines of the building. See Fig. 65.

This distance, then, can be measured off on the top of each batter board from the marks already made and other marks made at these points. Then lines stretched between the batter boards at the new marks will indicate the position of the sides and corners of

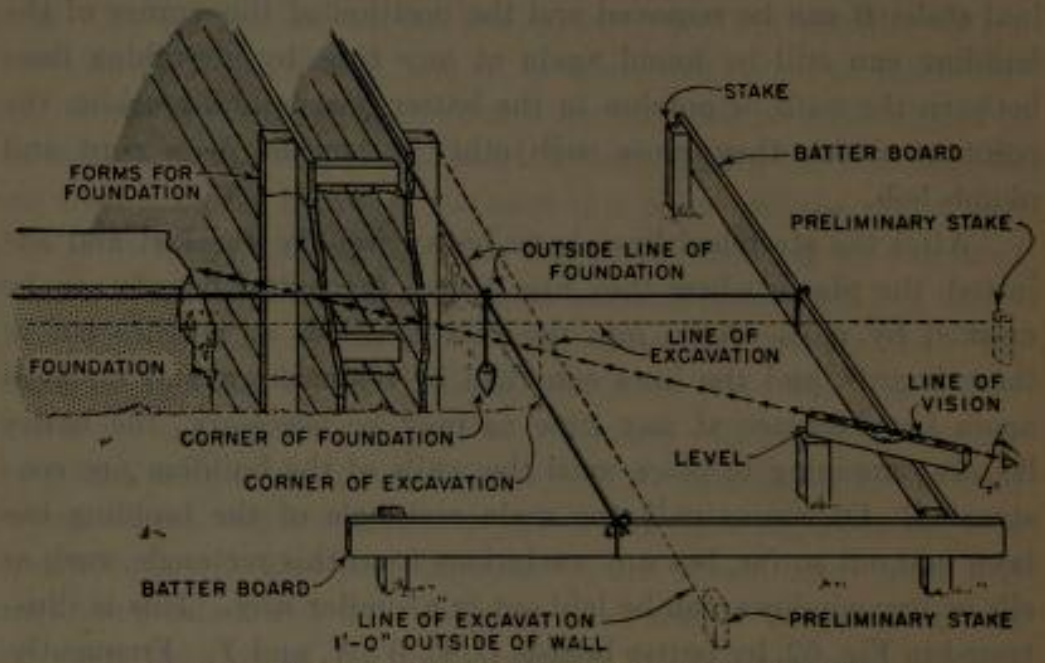


Fig. 65. Method of Staking and Laying Out Foundation Walls
Courtesy of National Lumber Manufacturers Association

the excavation. In the same way, the position of the outside of the foundation walls may be indicated. Some regular system should be used in making the marks on the batter boards as, for instance, always using nails to mark the lines of the excavation and notches to mark the lines of the foundation walls, and so on, or different kinds of nails can be used. This will make it less likely that a mistake may be made in stretching the lines.

Fig. 65 shows how the batter boards, if they have been carefully put up with the tops at the proper level, may be used later with the help of the mason's long level to layout the lines for the masonry or concrete foundation walls and to locate the tops of these walls. It also shows a portion of the wood forms for the concrete foundation walls.

DIAGONAL END-MATCHED SHEATHING
Courtesy of Weyerhaeuser Sales Co., St. Paul, Minn.

FRAMEWORK AND SHEATHING OF HOUSE IN PROCESS OF CONSTRUCTION

Courtesy of American Builder

CARPENTRY

PART II

FRAMING

After the building has been laid out, and the batter boards are in place, the next work which a carpenter is called upon to do is the framing. This consists in preparing a skeleton, as we may say, upon which a more or less ornamental covering is to be placed. Just as the skeleton is the most essential part of the human body, so is the frame the most essential part of a wood building; and upon the strength of this frame depends the strength and durability of the structure. When the carpenter comes to the work, he finds everything prepared for him; the cellar has been dug and the foundation walls and the underpinning have been built. It is his business to raise the framework on them. First is the wall, then the floors, and then the roof. Therefore, the subject may be subdivided, and considered under these three main headings. In connection with the walls we may consider the partitions as well as the outside walls, and in connection with the floors we may consider the stairs, while the roof may be taken as comprising the main roof and also subordinate roofs over verandas, balconies, and ells. This covers all the framing that will be found in a wood building, except special framing. (See page 271, Part III.) Whatever framing there is in a brick or stone building is similar to that in a wood building, with the slight differences which may be noted as we come to them.

JOINTS AND SPLICES IN CARPENTRY

Before beginning a description of the framing, it will be well to consider the methods employed in joining pieces of timber together. The number of different kinds of connections is really very small, and the principles upon which they are based may be mastered very quickly.

All connections between pieces of timber may be classified as joints or as splices. By a "splice" we mean a connection between two pieces which extend in the same direction, as shown in Fig. 66, and each one of which is merely a continuation of the other. The only reason for the existence of such a connection is the fact that sticks of timber can be obtained only in limited lengths and must, therefore, very often be pieced. By a "joint" we mean any connection between two pieces which come together at an angle, as shown in Fig. 67, and which are, therefore, not continuous. Such a connection may be required in a great many places, and especially at the corners of a building.

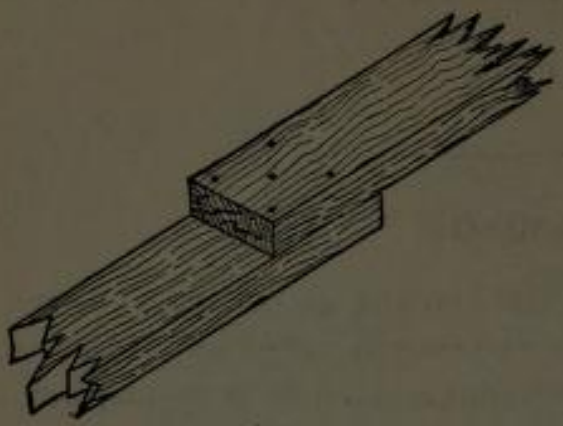


Fig. 66. Example of a Splice

Joints. The principal kinds of joints to be met with in carpentry are the "butt joint," the "mortise-and-tenon joint," the "gained joint," the "halved joint," the "tenon-and-tusk joint," and the "double-tenon joint."

Butt Joint. This is the most simple of all the joints, and is made by merely placing the two pieces together with the end of

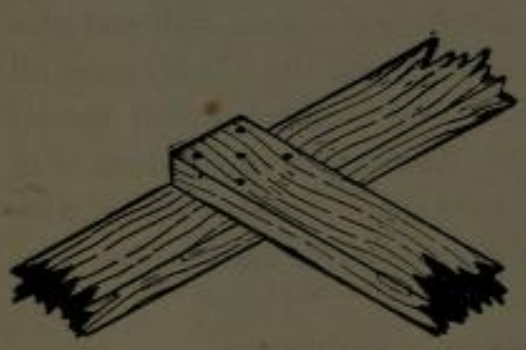


Fig. 67. Example of Plain Joint

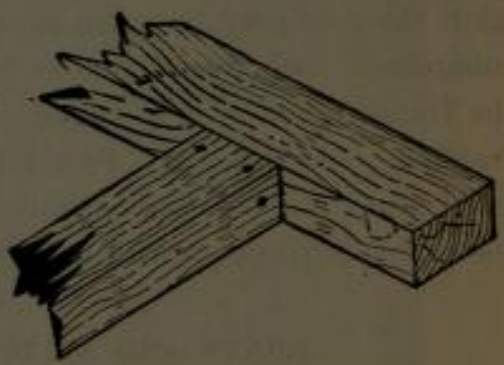


Fig. 68 Square Butt Joint

one piece against the side of the other and nailing them firmly to each other, after both have been trimmed square and true. Such a joint is shown in Fig. 68. The two pieces are perpendicular to each

other and neither piece is cut. The nails are driven diagonally through both pieces, an operation which is known as "toe-nailing" and are driven home, if necessary, with a nail set. This is called a "square" butt joint. Fig. 69 shows two pieces which are not perpendicular to each other. They are trimmed to fit closely together, and are then nailed in place. Such a joint is called an "oblique" butt joint. The butt joint does not make a strong connection between the pieces, and should not be used if much strength is required. It depends entirely upon the nails for its strength, and these are very likely to pull out.

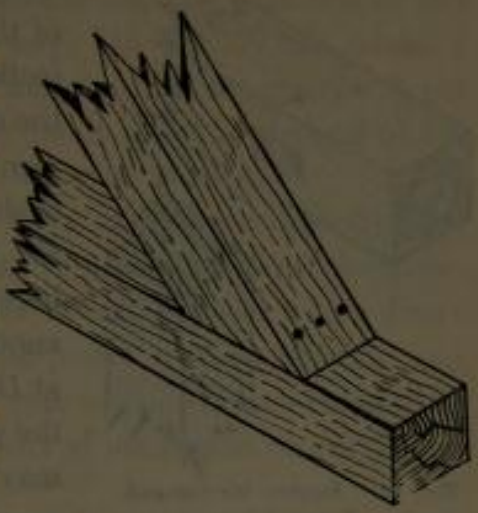


Fig. 69. Oblique Butt Joint

This form of joint is sometimes modified by cutting away a part of one of the pieces, so that the other may set down into it as shown in Fig. 70, the square joint at *A*, and the oblique joint at *B*.

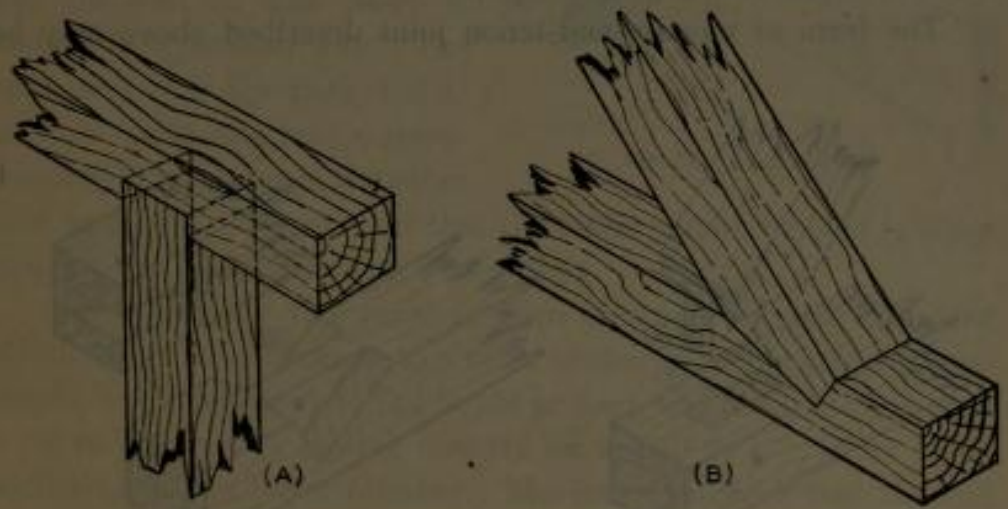


Fig. 70. Special Types of Square and Oblique Butt Joints

This gives much additional strength to the joint, especially in the case shown at *B*, where there may be a tendency for one piece to slide along the other.

Mortise-and-Tenon Joint. From the modified butt joint it is only a step to the "mortise-and-tenon" joint, which is formed by cutting a hole called a "mortise" in one of the pieces of timber, to receive a projection called a "tenon" which is cut on the end of the other piece. This arrangement is shown in Fig. 71. The mortise is shown at *A*, and the tenon is shown at *B*. It will be noticed that there is a hole bored through the tenon at *C*, and that another hole is bored in the mortised piece at *D*. These holes are so placed that when the pieces are joined together, a wood pin may be driven through both holes, thus preventing the tenon from being withdrawn from the mortise. The pin should always be inserted in a mortise-and-tenon joint. Ordinarily this pin is of hard wood, even when the pieces to be joined together are themselves of soft wood, and it may be of any desired size. Round pins from ¾ inch to ⅞ inch in diameter are ordinarily employed, although it may sometimes be found better to use a square pin.

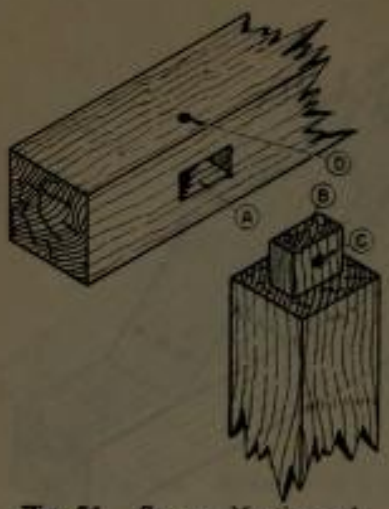


Fig. 71. Square Mortise-and-Tenon Joint

The form of mortise-and-tenon joint described above may be

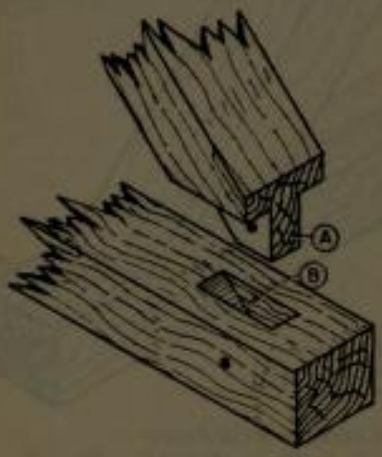


Fig. 72. Form of Bridge or Straddle Joint

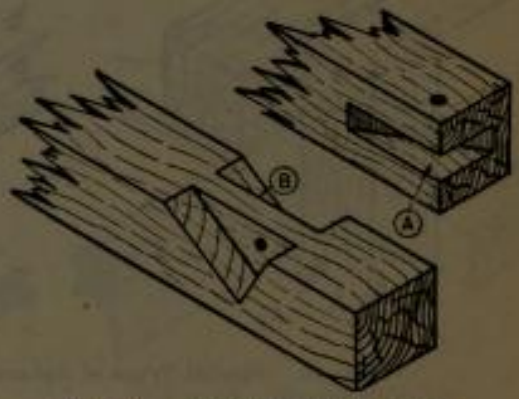


Fig. 73. Another Form of Bridge or Straddle Joint

used wherever the pieces are perpendicular to each other. When, however, the pieces are inclined to each other, a modification of the

above joint known as the "bridge" or "straddle" joint is employed. This joint is shown in Figs. 72 and 73. It is similar to the square mortise-and-tenon joint, having a similar mortise and tenon, but these are cut in a slightly different way. In Fig. 72 the tenon *A* is cut in the end of the inclined piece and fits into the mortise *B* cut in the other piece. In Fig. 73 the mortise *A* is cut in the end of the inclined piece and the tenon *B* is cut in the other piece.

Gained Joint. The joints which have so far been described are applicable only where the members are subjected to direct compression, as in the case of posts or braces, or in certain cases where direct tension is the only force acting on the pieces. When bending and shearing are to be expected, as in the case of floor beams connecting to sills or girders, a slightly different sort of joint must be employed.

One of the most common joints for such places is a modification of the mortise-and-tenon joint which is known as the "gained joint." An example of this form of connection is shown in Fig. 74, and it may be seen that the end of one piece is tenoned in a peculiar way. The tenon proper is the part *A-B-C* and this tenon sets into a corresponding mortise cut in the other piece as shown. It is evident that the tenon cannot be held in place by a pin, but it may be secured by nailing.

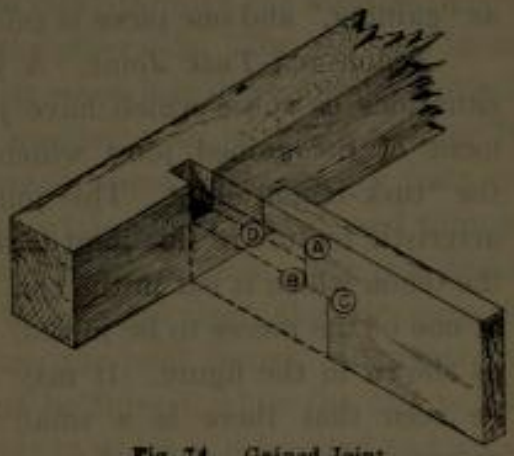


Fig. 74. Gained Joint

The reason for this peculiar form of tenon may be explained as follows: A floor beam, or any other timber, which is loaded transversely, has a tendency to fall to the ground, and must be supported at its ends either by resting directly on a wall or sill, or by being mortised into the latter member. Moreover, in order that the end of the piece resting on the support may not be crushed or broken, a certain amount of bearing surface must be available. This same bearing surface must be provided in every case no matter whether the timber rests directly on the top of the sill or is mortised into it. Of course the simplest connection is obtained by resting the transverse piece directly on top of the sill without cutting either

piece; but such a joint is not stiff and strong, and it is often necessary to bring the timbers flush with each other at the top or at the bottom. For this reason a mortised joint is used; and in order to obtain the required amount of bearing surface without cutting the piece too much, the form of tenon shown in Fig. 74 is employed. The available bearing area here is furnished by the surfaces *D-A* and *B-C* and it may easily be seen that this area is the same as would be available if the piece rested directly on top of the sill.

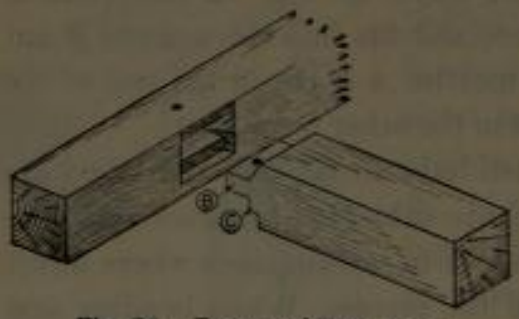


Fig. 75. Tenon-and-Tusk Joint

The operation of cutting such a tenon and mortise is known as "gaining," and one piece is said to be "gained" into the other.

Tenon-and-Tusk Joint. A joint in very common use in such situations as those which have just been mentioned is a development of the gained joint which is call the "tenon-and-tusk" or the "tusk-tenon" joint. This joint is shown in Fig. 75. The characteristic feature of this joint is to be found in the peculiar shape of the tenon which is cut in the end of one of the pieces to be joined, as shown in the figure. It may be seen that there is a small square tenon *B* cut in the extreme end of the piece, and that in addition to this there are other cuts *C* which constitute the "tusk." The bearing area is furnished partly by the under side of the tenon and partly by the under side of the tusk.

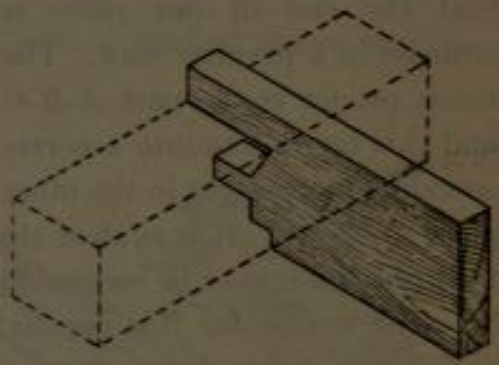


Fig. 76. Tenon-and-Tusk Joint with Specially Cut Tenon Piece

This joint makes a very good connection, and the cutting of the mortise does not weaken the piece of timber so much as does the mortise for a gained joint. It is especially applicable when it is desired to have the two pieces flush on top, although it may also be used in other positions. When the top of the tenoned piece must project above the top of the mortised piece, the tenon may be cut as shown in Fig. 76.

There are several ways of securing the tenon in place. The simplest is that shown in Fig. 77, where the pin *B* is passed through the tenon *A* and the mortised piece so as to hold the tenon securely in place. Another scheme is to cut the square tenon a little longer,

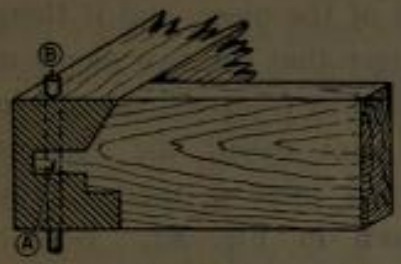


Fig. 77. Pinned Tenon-and-Tusk Joint

Fig. 78. Pegged Tenon-and-Tusk Joint

as shown in Fig. 78, so as to pass clear through the mortised piece, and to fasten it with a peg *B* on the other side. The peg may be cut slightly tapering, as shown, so that when it is driven in place it will draw the pieces together. Still another plan is shown in Fig. 79. Here a small hole is cut in the header some distance back from the tenon and a nut *C* is placed in it, while a bolt *B* is passed through a hole bored lengthwise in the header to receive it. The bolt passes through the nut, which may be screwed up tight, thus drawing the pieces closely together and making the joint secure. In tightening this up, it is the bolt which must be turned, while the nut is held stationary inside of the square hole in which it is inserted and which is just large enough to receive the nut and a wrench.

Fig. 79. Bolted Tenon-and-Tusk Joint

Double Tenon Joint. Fig. 80 shows a form of tenon joint called the "double tenon" joint, which is not very extensively used at the present time but which has some advantages. As may be readily seen, there are two small tenons *A* and *B* through which a pin may be passed if desired.

End-Lap Joint. A form of joint which may be used to connect two pieces which meet at a corner of a building is shown in Fig. 81.

This is known as the "end-lap" joint from the fact that both pieces are cut half way through and then placed together. The pieces are held in place by nails or spikes.

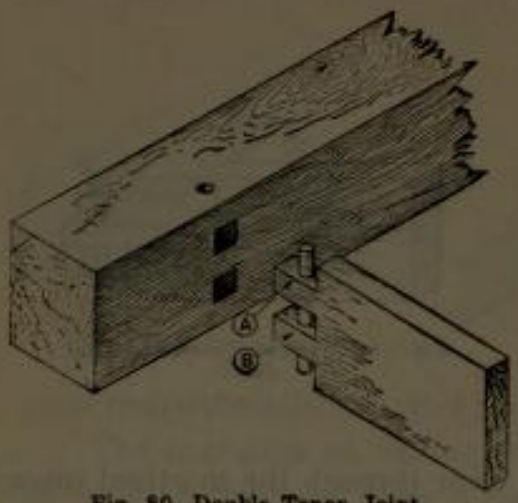


Fig. 80. Double Tenon Joint

If one piece meets the other near the center instead of at the end of the piece, and if there is danger that the two pieces may pull away from each other, a form of joint called the "dovetail" halved joint is used. This is shown in Fig. 82. Both the tenon and the mortise are cut in the shape of a fan, or dovetail, which prevents the two pieces from being pulled apart. This joint may also be cut as shown in Fig. 83, with the flare on only one side of the tenon, the other side being straight.

Splices. As already explained, a splice is merely a joint between two pieces of timber which extend in the same direction, and is sometimes necessary because one long piece cannot be conveniently or cheaply obtained. The only object in view, then, is to fasten the two pieces of timber together in such a way that the finished piece

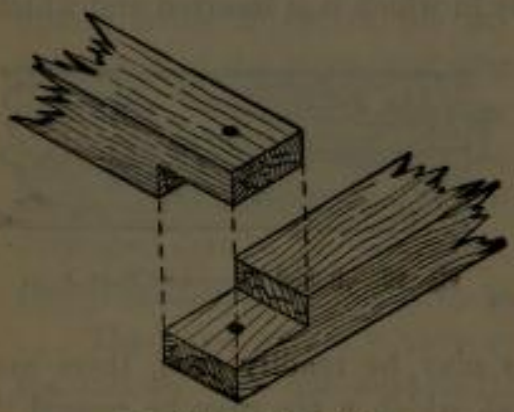


Fig. 81. End-Lap Joint

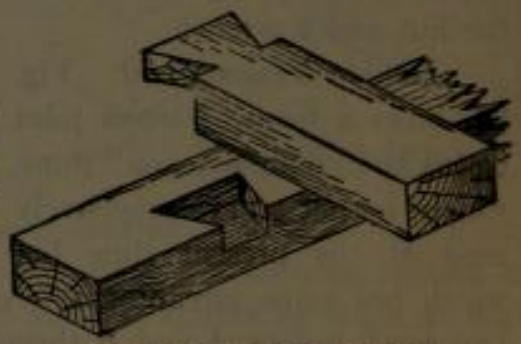


Fig. 82. Dovetail Halved Joint

will be in all respects equivalent to a single unbroken piece, and will satisfy all of the requirements of the unbroken piece. This is really the only measure of the efficiency of a splice.

There are three kinds of forces to which a piece may be subjected, namely: Compression, tension, and bending. A splice which would be very effective in a timber acted upon by one of these forces might be absolutely worthless in a piece which must resist one of the other forces. We have, therefore, three classes of splices, each designed to resist one of these three forces.

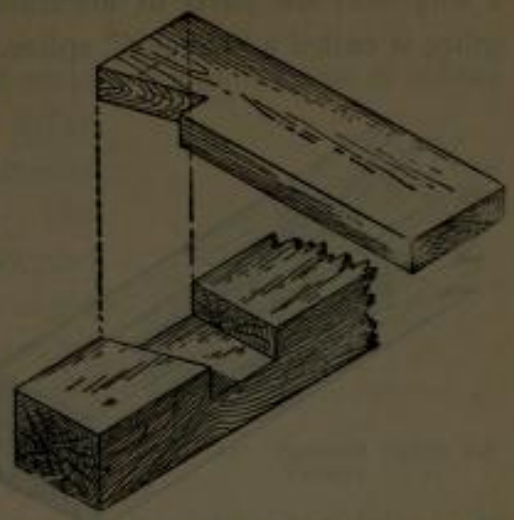


Fig. 83. Dovetail Halved Joint with One Flare

Splices for Compression. The simplest splices are those intended to resist compression alone, and of these the most simple is that shown in Fig. 84. This piece is said to be "fished"; the two parts are merely sawed off square and the ends placed together. A couple of short pieces *A-A*, called "fish plates," are nailed on opposite sides to keep the parts in line. In the splice shown in Fig. 84, the splicing pieces are of wood, and ordinary nails are used to fasten them in place, but in more important work thin iron plates are used, the thickness being varied to suit the conditions. They are held in place by means of bolts with washers and nuts.

Fig. 84. Fished Splice

If for any reason it is desired not to use plates of this kind, four small pieces called dowels may be used, as indicated in Fig. 85. These dowels may be set into the sides of the timbers to be spliced, so that they do not project at all beyond the faces of these pieces and a very neat job may thus be obtained.

It is but a step to pass from this simple splice to the "halved" splice shown in Fig. 86. It will be noticed that it is much like the halved joint described above, the only difference being that the pieces are continuous, instead of being perpendicular to each other. The nature of the splice will be easily understood from the figure without further

explanation. A modification of this which is somewhat more effective, is shown in Fig. 87. The cuts are here made on a bevel in such a way that the parts fit accurately when placed together, and the splice is called a "beveled" splice.

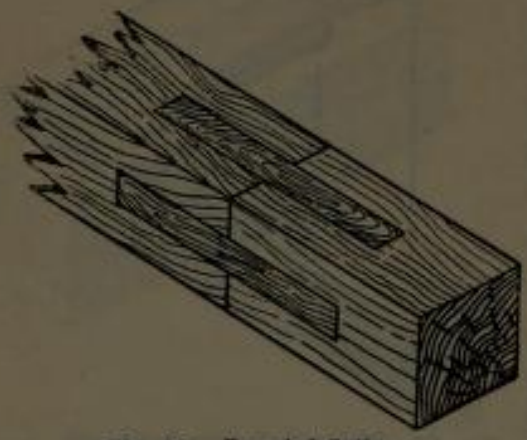


Fig. 85 Doweled Splice

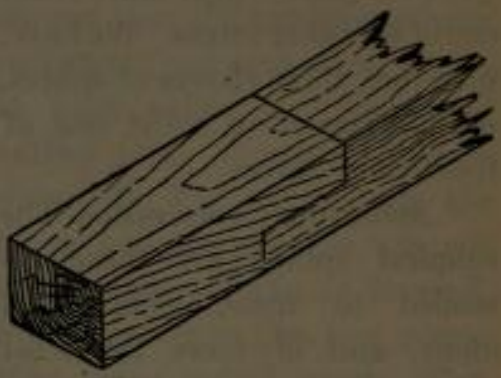


Fig. 86. Halved Splice

The halved splice is perhaps the best that can be used to resist direct compression, and when it is combined with fish plates and bolts, as shown in Fig. 88 it may be used in cases where some tension is to be expected. It will be noticed that in Fig. 88, the ends of the timbers are cut with a small additional tongue *A*, but this does not materially strengthen the splice and it adds considerably to the labor of forming it. In general it may be said that the simplest splice is the most effective.

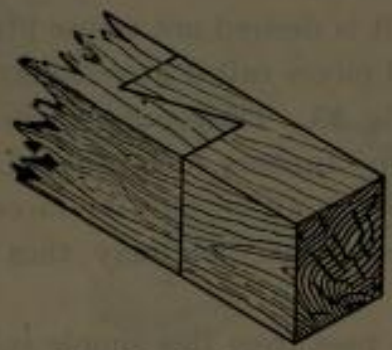


Fig. 87 Beveled Splice

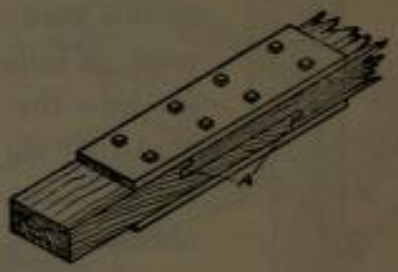


Fig. 88. Halved Splice with Fish Plates and Bolts

Whenever the pieces are cut to fit into one another, as they do in the halved and beveled splices, the splice is known as a "scarf" splice, and the operation of cutting and joining the parts is called

"scarfing." Scarf splices are used, as we have already seen, both alone and in combination with fish plates. The fished splice is always the stronger, but the splice where scarfing alone is resorted to has the neatest appearance.

Splices for Tension. There are several common forms of splices for resisting direct tension. These differ from each other mainly in the amount of labor involved in making them. The simplest of them is shown in Fig. 89, and it will be seen that it is only a slight modification of the halved splice used for resisting compression. It is evident that the pieces cannot pull apart in the direction of their length until the timber crushes along the face marked *A-B*, or shears along the dotted line *A-C*. By varying the dimensions of the splice it may be made suitable for any situation. The parts are held closely together by the light fish plate shown in the figure, which also incidentally adds something to the strength of the splice.

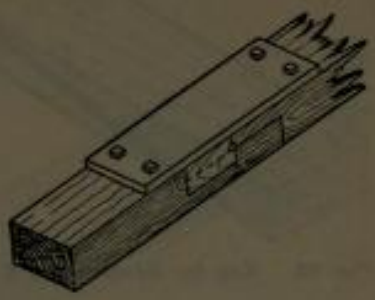


Fig. 89. Squared Splice for Tension

Instead of cutting the ends of the beams square, as shown in Fig. 89, they frequently are cut on a bevel as shown in Fig. 90, and a further modification may be introduced by inserting a small "key" of hard wood between for the pieces to pull against, Figs. 90 and 91. This key is usually made of oak and may be in two parts, as shown in Fig. 92, each part in the shape of a wedge, so that when they are driven into place, a tight joint may be obtained. The two wedge-shaped pieces may be driven in from opposite sides, the hole

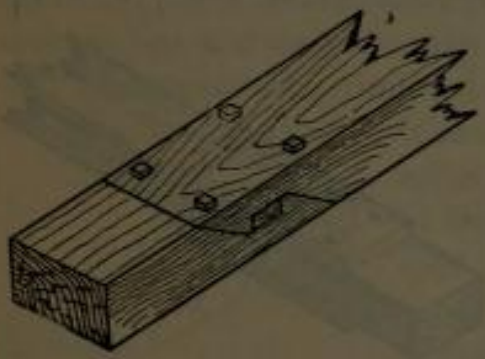


Fig. 90. Beveled Splice for Tension

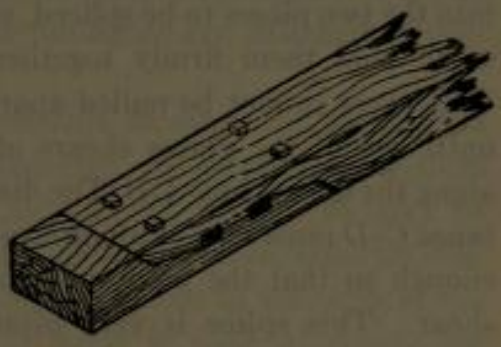


Fig. 91. Beveled and Keyed Splice for Tension

being a little smaller than the key. If the key is made much too large for the hole, however, a so-called "initial" stress is brought into the timbers, which uses up some of their strength even before any load is applied. This should be avoided.

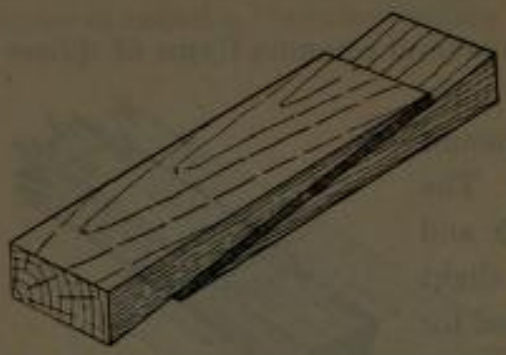


Fig. 92. Key for Beveled and Keyed Joint

If it is desired, two or more keys may be employed in a splice, the only limiting condition being that they must be placed far enough apart so the wood will not shear out along the dotted line shown in Fig. 91. Another feature of the splice here shown is the way in which the pieces are cut with two bevels on the end instead of one. One bevel starts at the edge of the key and is very gradual, the other starts at the extreme end of the piece and is rather steep and sharp. These bevels can be used only in joints which resist tension alone. If such a splice were subjected to compression, the beveled ends would slide on each other and push by each other very easily, except as they are prevented from so doing by the fish plates, if these are used.

Tension Splice with Fish Plates. The splices for tension which have so far been described have all been scarf joints, but there is a fished splice which is very commonly used for tension. This splice is shown in Fig. 93. The fish plates, in this case of wood, are cut into the two pieces to be spliced, so as to hold them firmly together. The pieces cannot be pulled apart until one of the plates shears off along the dotted line A-B. The distance C-D must also be made large enough so that the piece will not shear. This splice is very often used for the lower chords of the various forms of wood trusses, and it is considered one of the best that has been devised for resisting direct tension.

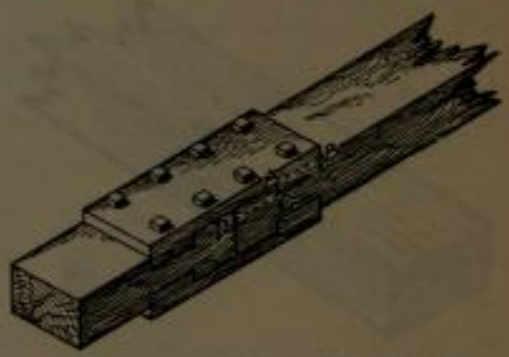


Fig. 93. Tension Splice with Fish Plates

Splices for Bending. It sometimes happens that a piece which

is subjected to a bending stress must be spliced, and in this case the splice must be formed to suit the existing conditions. It is well known that in a timber which is resisting a bending stress the upper part of the piece is in compression, and the tendency is for the fibers to crush, while the lower part of the piece is in tension, and the tendency is for the fibers to pull apart. To provide for this, a form of splice must be selected which combines the features of the tension and compression splices. Fig. 94 shows such a splice. The parts are scarfed together, as is the case with other splices described, but in this case the end of the top piece is cut off square to offer the greatest possible resistance to crushing, while the underneath piece is beveled on the end as there is no tendency for the timbers to crush.

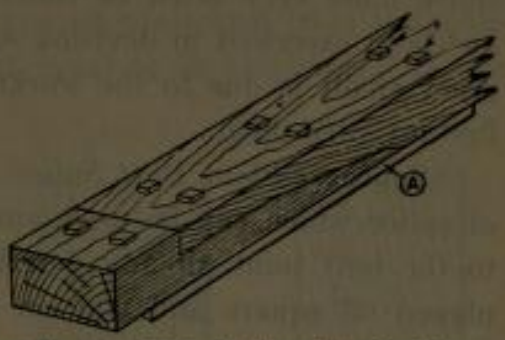


Fig. 94. Splice Designed for Bending Strains

We have already seen that in the lower part of the splice, there is a tendency for the parts to be pulled away from each other. In order to prevent this, a fish plate, *A*, is used, which must be heavy enough to take care of all the tension, since it is evident that the wood cannot take any of this. The plate must be securely bolted to both parts of the splice. There is no need of a fish plate on the top of the pieces because there is no tendency for the pieces to pull apart on top, and the bolts shown in the figure are sufficient to prevent them from being displaced.

In any case where it is not desirable to scarf the pieces in a splice subjected to bending, the form of butt joint shown in Fig. 95 may be used. The plates, either of wood or iron, are in this case bolted to the sides of the pieces. If wood is used, of course the plates must be made very much heavier than if iron is used. In either case they must be large enough to take care of all the bending stress, and a sufficient number of bolts must be used to fasten them securely to both parts of the splice.

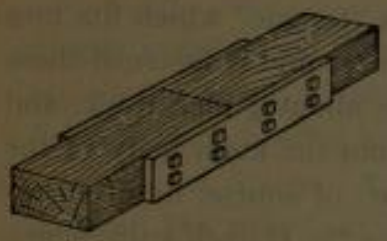


Fig. 95. Butt Joint with Plates

JOINTS AND SPLICES IN JOINERY

We have considered a few of the most important joints and splices used in the putting together of rough framing, and we will now take up some of the methods used in the joining together of finished work, where more care is necessary and where the joint or splice must very often be concealed from view. Much ingenuity has been exercised in devising some of these concealed joints, and great credit is due to the workmen, unfortunately unknown, who first invented them.

Splices. *Plain Butt Splice.* Fig. 96 shows the simplest kind of splice which can be used, similar in principle and construction to the butt joint already described. Here the pieces are simply planed off square and true on the ends and glued together with nothing but the glue to hold them. It is evidently not a very strong splice and should not be used where any tension or bending is likely to come at the point where the splice is made.

Splice with Spline. Fig. 97 shows a splice which is a slight advance over the simple butt splice. It is formed by ploughing the ends of the pieces to be spliced after they have been finished square and true, and inserting into the slot thus formed a third piece, which is called a "spline" or a "tongue." The spline is about 1 inch or less in width, and about $\frac{1}{8}$ or $\frac{3}{16}$ inch thick. Its length is regulated by the width of the pieces to be spliced together. As will be explained later, this form of connection is made use of in the construction of the better class of doors.

Tongued-and-Grooved Splice. This form of splice is somewhat similar to the splice with splines, the difference being that only one of the pieces is ploughed, and the other is rabbeted on both sides so as to leave a projecting portion called a "tongue" which fits into the groove formed by poughing the other piece and is fastened there securely with glue. The tongue should be about $\frac{3}{8}$ inch thick, and should project about the same distance from the main body of the piece. The groove in the other piece must, of course, be of corresponding dimensions. The figures given are for $1\frac{1}{8}$-inch stuff, which is the most common thickness of lumber used in cabinet work and interior finishing. For other thicknesses they should, of course, be varied. The tongued-and-grooved splice, Fig. 98, is used extensively in flooring.

Rabbeted Splice. In Fig. 99 is shown what is known as a "rabbeted splice." It is similar to the halved splice described before but depends upon glue or small nails for its strength. It must be much more carefully made than the rough halved splice. As will be seen each piece is rabbeted on one side so that when put together they fit into each other perfectly. The tongue should here be about one half of the thickness of the piece and its projection from the main body of the piece should be about equal to its thickness. If this

Fig. 96. Plain Butt Splice

Fig. 97. Splice with Spline

Fig. 98. Tongued-and-Grooved Splice

Fig. 99. Rabbeted Splice

tongue is made too thin and projects too much, it is liable to curl up, as the wood shrinks in drying, and make ugly ridges on the finished work besides leaving the splice open.

Filleted Splice. A form of splice which is little used in this country, but which can occasionally be worked to advantage, is the filleted splice which is shown in Fig. 100. It is made by rabbeting the two pieces to be spliced, as in the case of the rabbeted splice, but this time both on the same side, and a third piece called a "fillet," which is somewhat like the spline in the splice with a spline, is inserted

in the hollow space so as to join them together. This prevents any possibility of an open joint. The fillet is generally made somewhat less than one half the thickness of the pieces to be spliced, and is about 1 inch in width.

Battened Splice. A variation of the filleted splice, which is quite generally made use of where great strength is not required and it is only necessary to cover up the butt splice neatly, is what is called a "battened splice," Fig. 101. As will be seen this con-

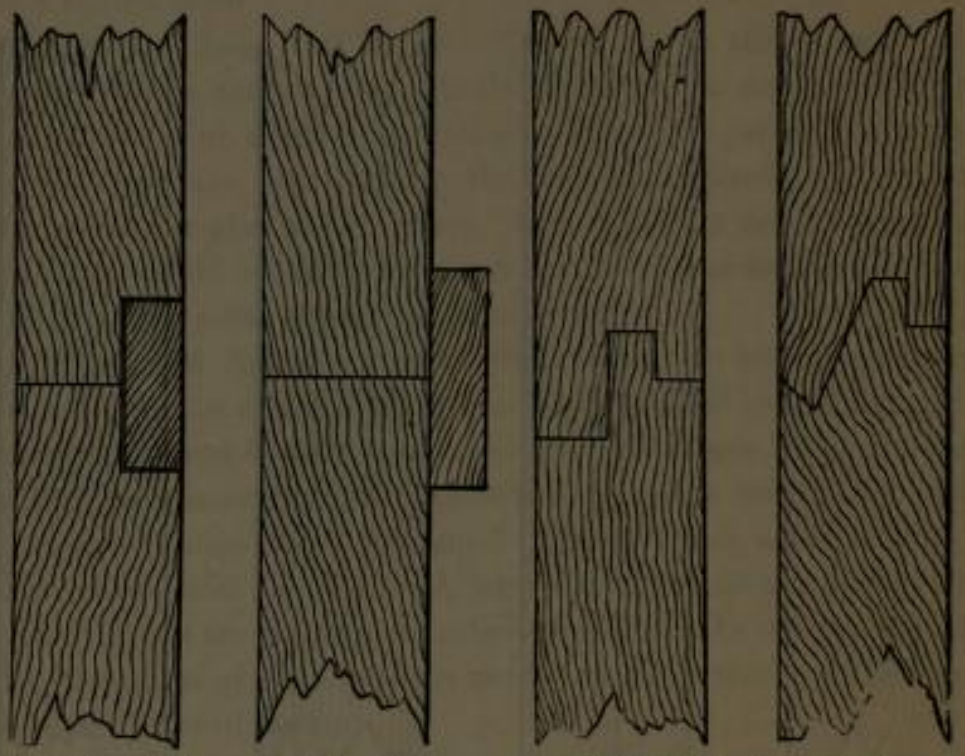


Fig. 100. Filleted Splice

Fig. 101. Battened Splice

Fig. 102. Tongued-Grooved-and-Rabbeted Splice

Fig. 103. Tongued Grooved-and-Splayed Splice

sists simply in covering the butt splice with a small piece called a "batten." The batten should be about the same size as that given above for the size of the fillet, but can be made large or small as desired.

Tongued-Grooved-and-Rabbeted Splice. A combination splice, which combines the advantages of the tongued-and-grooved and the rabbeted splices, is shown in Fig. 102. The groove is ploughed in the end of one piece and the tongue is left projecting on the end of the other piece while, in addition to this, one of the pieces is rabbeted

against the other. The tongue should be about $\frac{3}{8}$ inch thick and should project about the same amount from the end of the piece. One piece of the splice should be rabbeted against the other a distance of about $\frac{3}{8}$ inch. This splice is considerably stronger than the simple tongued-and-grooved splice, but it is a great deal harder to make and is more expensive as regards both material and labor.

Tongued-Grooved-and-Splayed Splice. Another variation of the tongued-and-grooved splice consists in the introduction of a splay on one side of the tongue and a corresponding splay on one side of the groove so that they fit into each other. Fig. 103 shows this arrangement. It makes a very neat form of splice and it looks well, but it is apt to be less strong than the simple tongued-and-grooved splice and much weaker than the tongued-grooved-and-rabbeted splice, though stronger than the simple rabbet. This is, of course, a very troublesome and expensive form of splice to make, and it is, in consequence, seldom used.

Joints. *Miters.* A miter is a joint between two pieces which come together at a corner at an angle of ninety degrees with each other. Strictly such a joint can be called a mitered joint only when each piece is beveled off so that each will come to a sharp edge at the corner. There are, however, a number of different methods of cutting the pieces so that they will come together in this way.

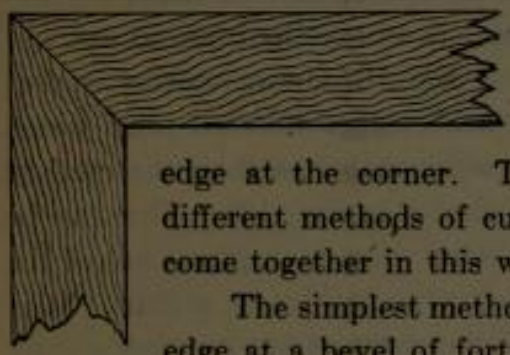


Fig. 104. Miter Joint

The simplest method is to cut off each piece along the edge at a bevel of forty-five degrees, so that when they are put together they will make an angle of ninety degrees with each other. This method is shown in Fig. 104. In practice, however, it is very difficult to make a perfect joint of this kind. The joint is very apt to open on the outside of the corner and leave an unsightly crack there, and great care must be exercised to see that the bevels are cut to exactly forty-five degrees, as the least variation will cause endless trouble.

Miter with Spline. A simple mitered joint may be made stronger by the introduction of a spline, which is inserted at the joint in a direction perpendicular to it. This is shown in Fig. 105. The spline

used in this way is also known as a "feather." It strengthens the joint very considerably, and a joint of this kind is a great improvement over the simple mitered joint. The spline or feather should be about $\frac{3}{4}$ inch wide and about $\frac{3}{8}$ inch thick. Its length, of course, varies with the width of the pieces which meet at the joint. Great care must be taken in ploughing out the grooves into which the spline fits, for if they are not exactly the same distance from the corner on each of the pieces the finished joint will not be neat and true.

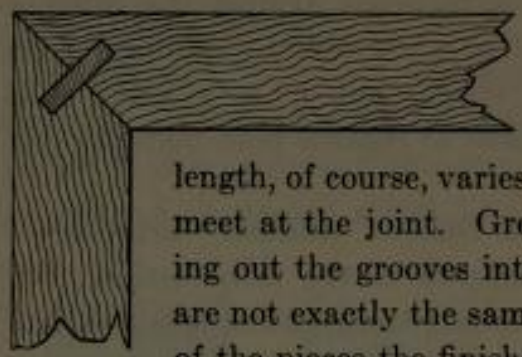


Fig. 105. Miter with Spline

Rabbeted Miter Joint. There are two or three variations of the simple mitered joint made by rabbeting one piece on the other at the corner, so that the miter goes only part way through each piece. One of these joints is shown in Fig. 106, in which only one of the pieces is rabbeted and the other piece has a simple miter. This form of joint can only be used when one piece is somewhat wider than the other, so that it can be rabbeted a little and still have a miter which will match the miter on the narrower piece. If both pieces are of the same width, this cannot be done. Wherever it is possible, however, this joint is an excellent one to use.

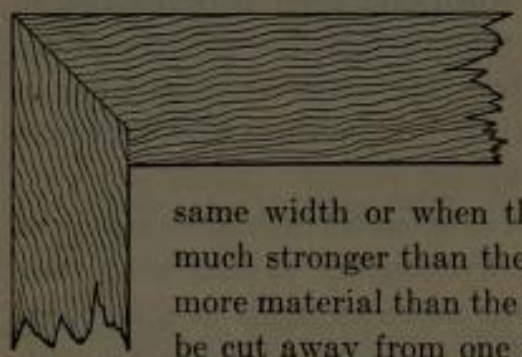


Fig. 106. Rabbeted Miter Joint

Fig. 107 shows another way of rabbeting a mitered joint which is much better than the method shown in Fig. 106. This can be done when both pieces are of the same width or when they are of different widths. It is much stronger than the other method but requires a little more material than the simple mitered joint, as some must be cut away from one piece to form the rabbet and thus much of the timber is wasted. Very often, however, it happens that this timber would have to be used in any case and, when this occurs, the waste need not be considered. The increased strength of the joint would seem to be worth much more than the small additional amount of material which is required.

Rabbeted-Mitered-and-Splined Joint. In Fig. 108 is shown a joint which is mitered and at the same time rabbeted and splined. In order

to accomplish this, one piece is cut at an angle of forty-five degrees and then rabbeted to the thickness of the other piece. The other piece is then cut with a miter to match that left on the first piece and also cut to match the rabbet. Both pieces are ploughed to take a spline, and thus a very strong joint is formed which combines the advantages of the mitered joint and the rabbeted or splined joints. The spline in this case should be about $\frac{3}{8}$ inch thick and about $1\frac{1}{8}$ inches wide and should, in all cases, be of hard wood.

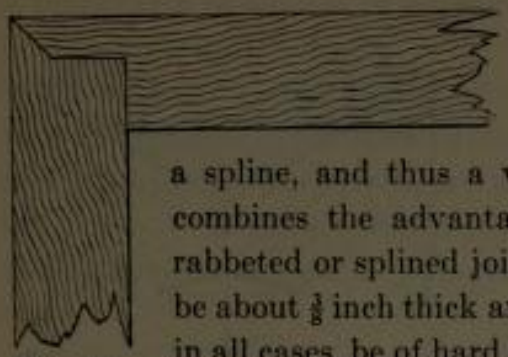


Fig. 107. Rabbeted Miter Joint

Joint Mitered and Keyed. Another way of strengthening a mitered joint is by inserting what are known as "keys" into the pieces on the outside of the joint. These keys are thin slices of hard wood which are placed in slots prepared to receive them and held in place by means of glue. As the glue fastens them securely to each of the pieces at the joint, they hold them firmly together and prevent the joint from opening. Fig. 109 shows a joint of this kind. The keys, of course, show on the outside of the joint, but they can be cut very thin and only the edge of them can be seen. The keys give a great amount of additional strength to the connection and are more effective than is a spline for preventing the joint from opening, as they come right out to the edge of both pieces and can be placed as near together as seems to be necessary. Sometimes, instead of being placed horizontally, or in a plane perpendicular to the edge of the joint, they are inclined as shown in Fig. 110. This arrangement strengthens the joint still more.

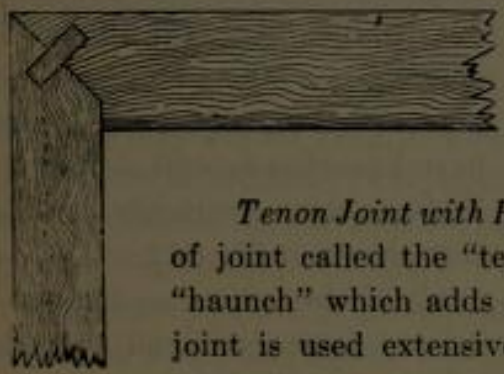


Fig. 108. Rabbeted Mitered-and-Splined Joint

Tenon Joint with Haunch. In Fig. 111 is shown a form of joint called the "tenon joint," with the addition of a "haunch" which adds considerably to its strength. This joint is used extensively in the making of doors. One of the pieces to be joined is rabbeted on each side to about one-third of its depth, leaving a projecting part called the "tenon" about one-third the thickness of the piece. This tenon is then rabbeted on either the top or the bottom, but instead of being cut entirely back to the body of the piece, the

rabbet is stopped a little short of this and a "haunch" is left. In Fig. 111, *A* is the tenon and *B* is the haunch. The other of the two

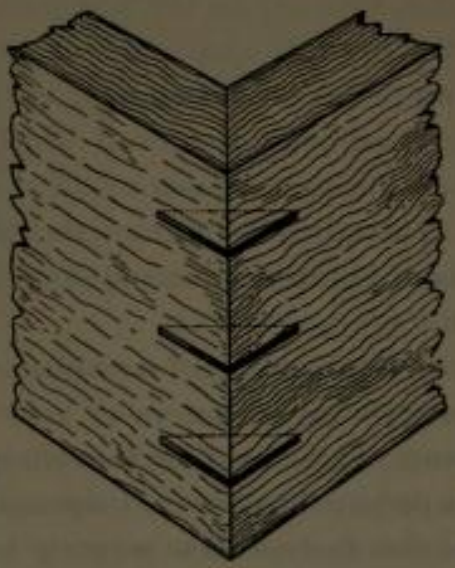


Fig. 109. Mitered Joint Keyed Square

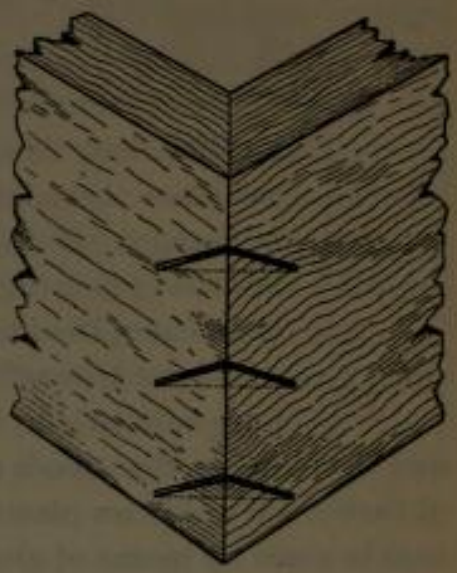


Fig. 110. Mitered Joint Keyed Diagonally

pieces which are to be joined is cut with mortises to receive the tenon and the haunch in the first piece. Fig. 111 shows the simplest form of simple tenon joint, but there are many variations of this, two of which are shown in Figs. 112 and 113. Fig. 112 shows a single tenon joint with two tenons, while Fig. 113 shows a double tenon joint which has four tenons. Both of these joints have haunches as well as tenons. The one most commonly used is that shown in Fig. 112.

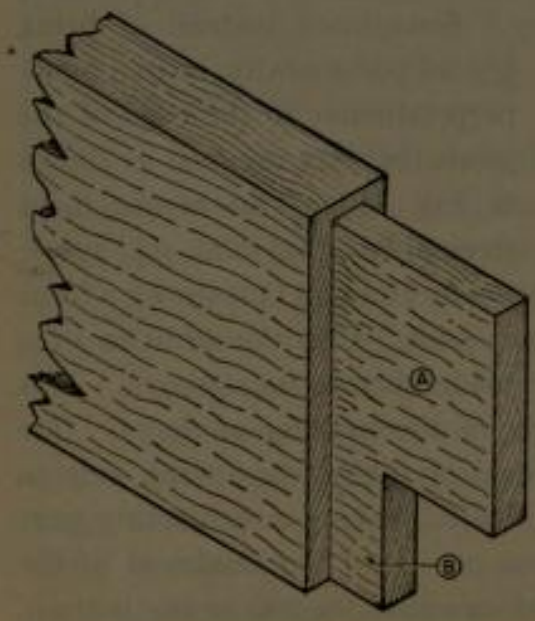


Fig. 111. Tenon Joint with Haunch

All of the splices so far considered have been end to end splices, that is, they have been those kinds which would be used in fastening pieces together at the ends. It often becomes necessary, however, to fasten pieces

together side by side. Any of the methods already described for splices will be applicable in such a case, but there are in addition a few others which are especially useful, two or three of which will now be described.

Dovetail Key. This method consists in the use of a strip of wood which is applied to the back of the several pieces to be held together and prevented from slipping by means of glue. The strip, however, is let into the pieces a little way in a special manner known as dovetailing, which prevents it from pulling out, and gives it an especially

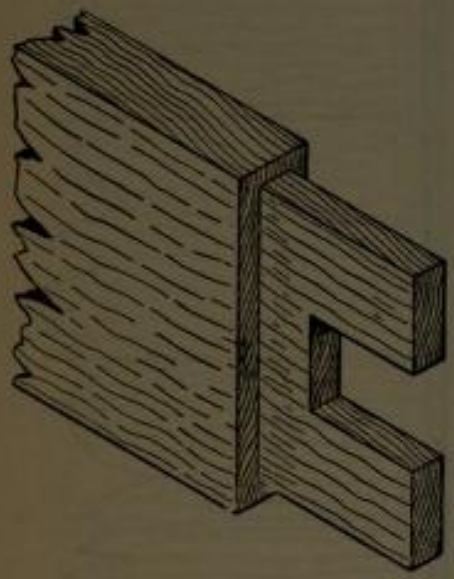


Fig. 112. Single Tenon Joint with Two Tenons

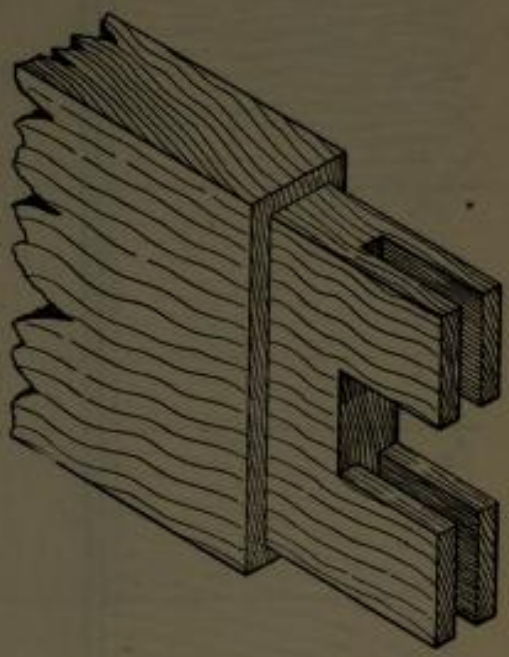


Fig. 113. Double Tenon Joint with Four Tenons

strong hold on them. Fig. 114 shows this arrangement both in elevation and in section. It is useful in making up large panels from narrow boards. In this method, only one of the pieces must be glued to the strip, the others being left free to move.

Another method of accomplishing this same result is by the use of a strip which sets against the back of the pieces to be joined, but is not let into them at all, Fig. 115. It is held in place by means of screws which go through slotted holes in the strip. This is in order that the pieces may have a chance to swell or shrink without bulging or splitting. It is usually customary to employ brass slots which are let into the wood. These resist much better the wear of

the screws and prevent them from working loose. If, however, the strip is of very hard wood this is not always necessary.

A third method is that shown in Fig. 116. This is sometimes called the "button" method on account of the use of the small side pieces or buttons which fit over the center strip and hold the pieces of board together, at the same time allowing them to swell or shrink freely. Only the small pieces are screwed to the boards,

Fig. 114. Method of Binding Boards Together by Means of Dovetail Key

the center strip being fastened to one of the pieces only. This arrangement takes up a little more room than the others and looks somewhat more clumsy but is quite satisfactory otherwise. In all three of the methods described, the strip should be from 3 to 4 inches wide.

Dovetailing. There is another way of joining two pieces meeting at right angles, and it is better and stronger than any other but, on account of the work involved in the process of making the joint,

is seldom used except in the best work. This method is known as dovetailing and there are three different ways of arranging the dovetails as will be shown. The first is the simple dovetail which is illustrated in Fig. 117. As will be seen, it consists in cutting tenons in the end of one piece and mortises in the end of the other piece, which are of such a shape as to form a sort of locking device, so that the pieces

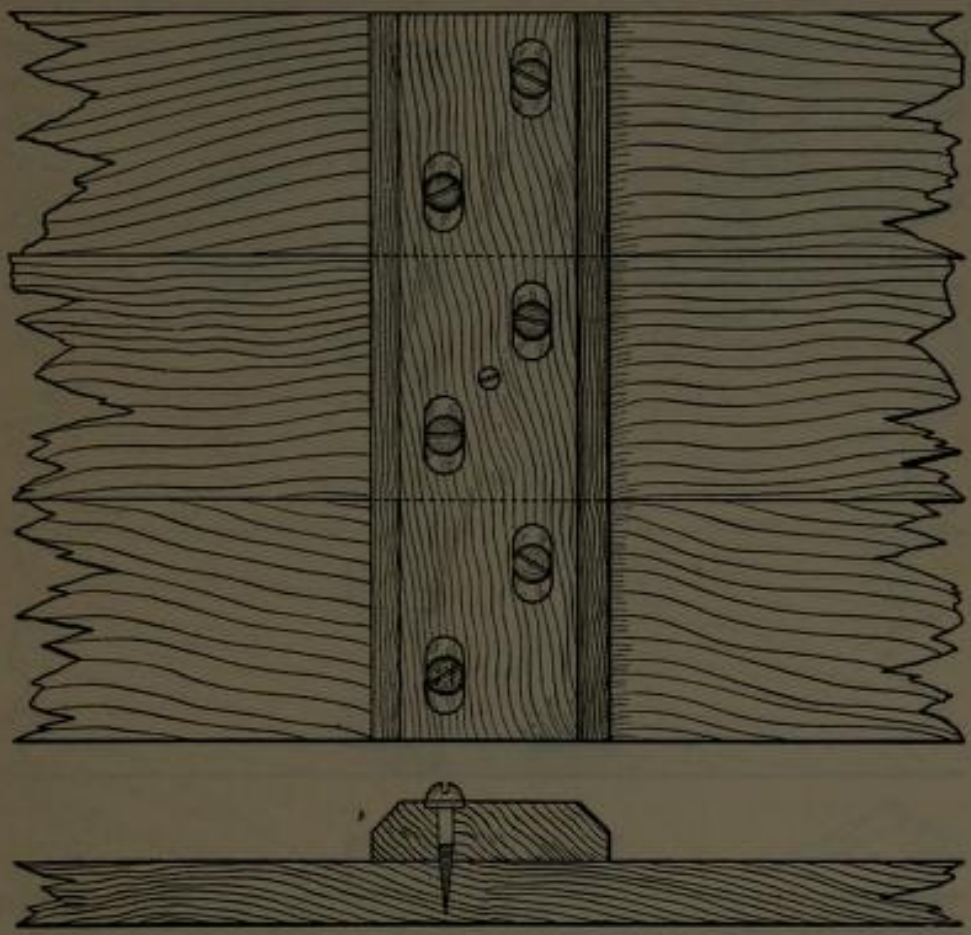


Fig. 115. Method of Binding Boards Together by Means of Strip with Slots and Screws

can be separated only by a pull in one particular direction. The use of glue makes the joint still stronger. Of course, the forming of a joint of this kind requires a large amount of time and considerable skill.

A variation of the simple dovetail joint which is much used in the manufacture of drawers and in any other position where it is desirable that the joint shall be concealed from one side only, is shown in Fig. 118. This is called a lap dovetail, its peculiarity

consisting in the fact that in one of the pieces the mortises are not cut the full thickness, but only partly through the wood, so as to leave a covering or lap, which prevents the joint from being seen.

A further development of the dovetail joint is shown in Fig. 119. In this case the work is so arranged that the joint cannot be seen

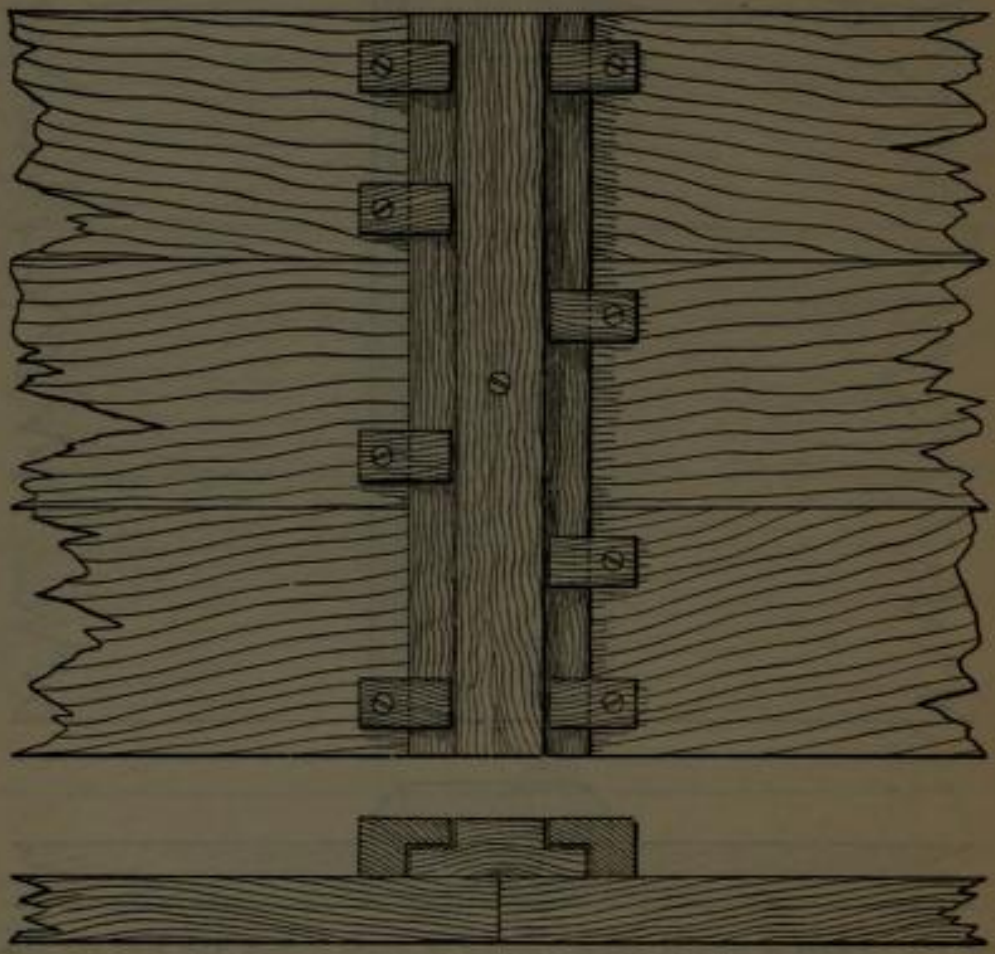


Fig. 116. Button Method of Binding Boards Together

from any side of the finished product. This is accomplished by cutting the same tenons and mortises as in the case of the simple dovetail joint, but not directly on the end of the pieces. They are so cut as to project at an angle of forty-five degrees, and thus to form a combination of the mitered joint and the dovetail joint with the tenons and mortises entirely out of sight when the pieces have been put together. This joint is obviously not so strong as

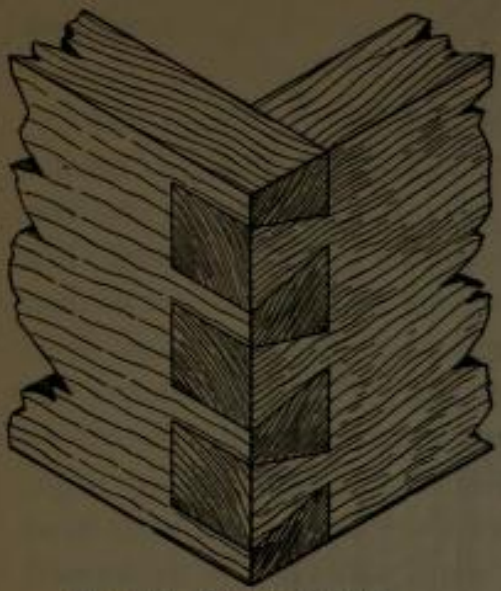


Fig. 117. Simple Dovetail

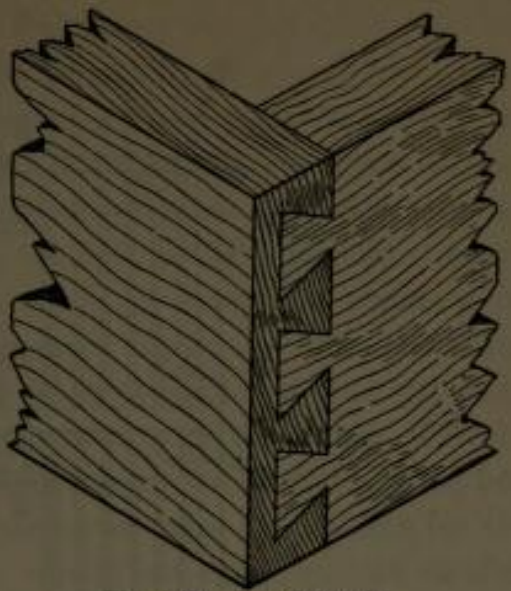


Fig. 118. Lap Dovetail

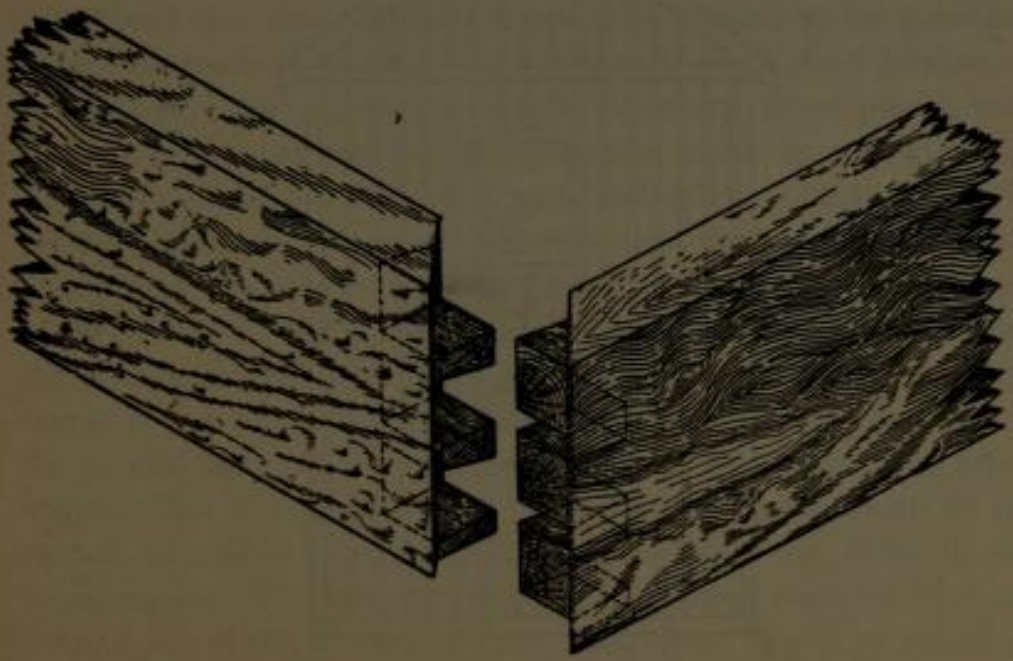


Fig. 119. Further Development of Dovetail Joint

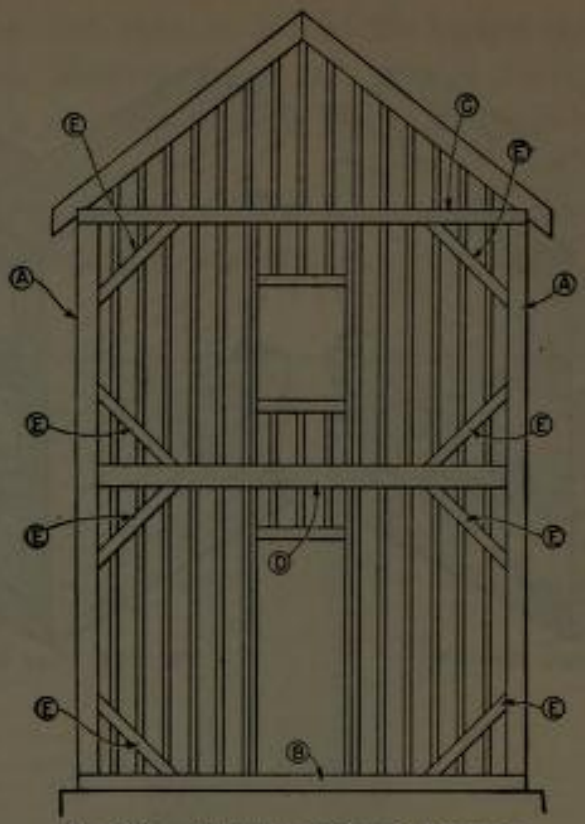


Fig. 120. Example of Braced Framing

Fig. 121. Example of Balloon Framing

are the other forms of dovetail joints because the tenons are not so large.

WALLS

Let us next consider the framing of the walls of a wood, or "frame" building. In carrying out this work there are two distinct methods of procedure known, respectively, as "braced framing" and "balloon framing," of which the first is the older and stronger method while the second is a modern development and claims to be more logical and at the same time more economical than the other. One hundred and fifty years ago when this country was still only partly settled, when timber was abundant but the means of working it up into lumber were primitive and much of the work had to be done by hand, it was cheaper to use large sized pieces for the framework of a building than it was to cut them up into smaller sizes, and since nails were at that time comparatively scarce and expensive and labor was cheap, it was the custom to frame the pieces together by mortise-and-tenon joints and fasten them in place with wooden pins. This custom persisted until about the middle of the nineteenth century, the sizes of the pieces used for the frame, however, becoming steadily smaller as the material became more expensive and the means for producing lumber in smaller sizes became more highly developed.

About this time buildings began to be framed up by a method known as "balloon framing" in which only small sized lumber, or "scantlings," were used, and where necessary these pieces were doubled or trebled and nailed together to make up a single piece of greater strength. Moreover, nails and spikes were beginning to get more plentiful and wages higher so that the joints were formed by spiking the pieces together instead of making mortise-and-tenon joints. As the framed joints used in the old method of framing could most easily be made on the ground it was customary to frame up the whole side of a building with the pieces lying flat on the ground and then to raise it into position as a single unit afterwards. This meant that there had to be strong braces at all the corners of such a frame to hold it square and true while it was being raised. The balloon frame, being nailed together in place instead of on the ground, did not need these braces so much, so they were often omitted. In the better class of work, however,

some form of bracing is employed at the corners, even in balloon framing, as it makes the frame more rigid and better able to withstand wind pressure, thus helping to avoid cracks in the plaster. Progress in this direction was slow, however, especially in the older and more thickly settled parts of the country, so that even now the braced frame method, or a modification of it, is still employed to some extent, particularly in the East. It has the advantage of being much stiffer than a balloon frame and more resistant to fire. Figs. 120 and 121 show the framing of one end of a small building by each of the two methods, the braced framing is shown in Fig. 120 and the balloon framing in Fig. 121. Another type of full-braced frame is shown in Fig. 161.

Braced Frame. For each of the walls of a braced framed building a framework was constructed consisting of two "corner posts" *AA*, Fig. 120, the "sill" *B*, and the "plate" *C*, together with a horizontal "girt" *D* at each story, to support the floors, and a diagonal "brace" *E* at each corner, which, by keeping the corner square, prevents the frame from being distorted.

Combination Frame. In a full-braced frame all the pieces should be fastened together with mortise-and-tenon joints, but this requirement is much modified in common practice, a so-called "combination" frame being used in which some pieces are mortised together and others are fastened by means of spikes only. Sometimes the sills, corner posts, and girts are of dimension timbers 4 x 8 inches or 6 x 8 inches in size, and are framed together, and 3 x 4-inch braces are set into the frame at each corner. The filling-in studs may be mortised into the sill but these studs are merely spiked to the girts and to the plate and the plate is ordinarily formed of two 2 x 4-inch scantlings set one on top of the other and spiked together. The joists forming the ceiling of the top story are commonly supported at the wall end by a "ledger board" about 1 x 7 inches set into the inside face of the studs and corner posts at the proper distance below the plate. Frequently the corner posts and the girts are built up out of 2 x 4-inch scantlings and 2 x 4-inch braces are cut in between the studs near the corners. The studs, moreover, are not mortised into the sill but are toenailed to the sill with four 8-penny nails, two on each side. If a joist comes next to a wall stud only one side is toenailed to the sill and the other side is

nailed to the joist with 16-penny nails. This is sometimes called the Modern Braced Frame and is illustrated in Fig. 122.

Balloon Frame. In a typical balloon frame the sill is composed of two pieces set one on top of the other, the same as shown for the modern braced frame in Fig. 122, or it may be a "box" sill, Fig.

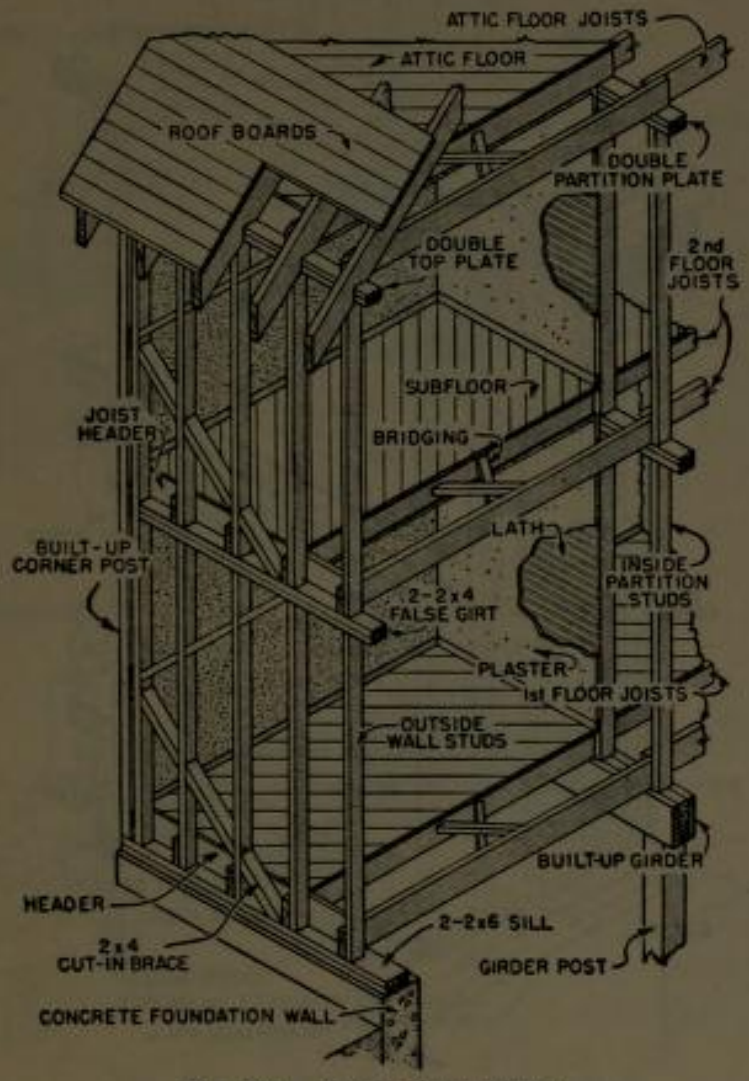


Fig. 122. Modern Braced Frame
Courtesy of Weyerhaeuser Forest Products

123. There are no braces or girts and the intermediate studs *FFF*, Fig. 121, are carried straight up from the sill *H* to the plate *K* with a light horizontal piece *J*, called a "ribband" or "ledger board" set into them at each floor level to support the floor joists. This piece is also sometimes called a "false girt." The balloon frame depends mainly upon the boarding for its stiffness, but sometimes light

diagonal braces are set into the studs at each corner to prevent distortion. The methods by which all these pieces are framed together will be explained in detail under the proper headings. Fig. 123 shows a typical Balloon frame with "box" sill.

Sill. The sill is the first part of the frame to be set in place.

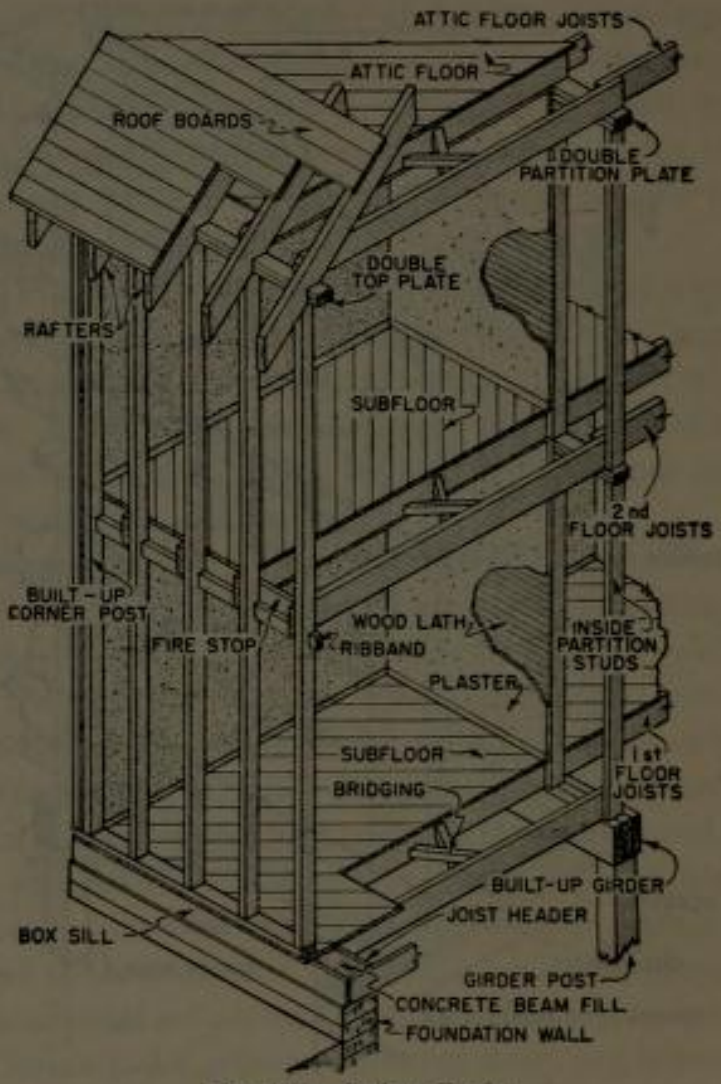


Fig. 123. Balloon Frame
Courtesy of Weyerhaeuser Forest Products

It rests directly on the foundation wall and extends all around the building being joined at the corners and spliced where necessary. In the old-fashioned full-braced frame 6 x 6-inch square timber or 6 x 8-inch stuff was used except for piazza sills which were made from 4 x 6-inch stuff. In modern work it is customary to make the sill of two pieces of 2 x 6-inch stuff placed one on top of the other

and nailed together with 16-penny nails staggered and placed 24 inches apart along both edges. This type of sill is shown in Fig. 124. The joints in such sills are made by lapping the top piece over the bottom piece so that the joints are broken. The corner joints are

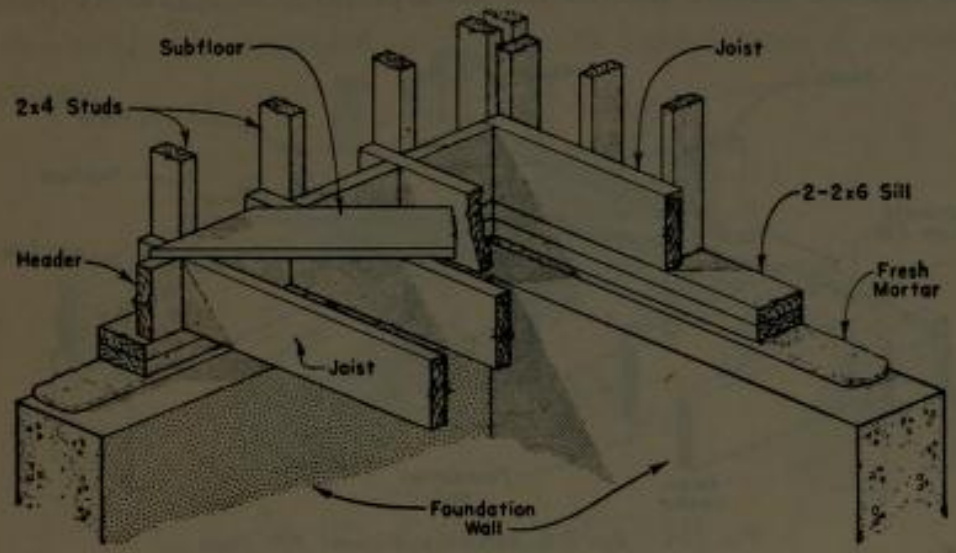


Fig. 124. Plain Sill Assembly
Courtesy of Weyerhaeuser Forest Products

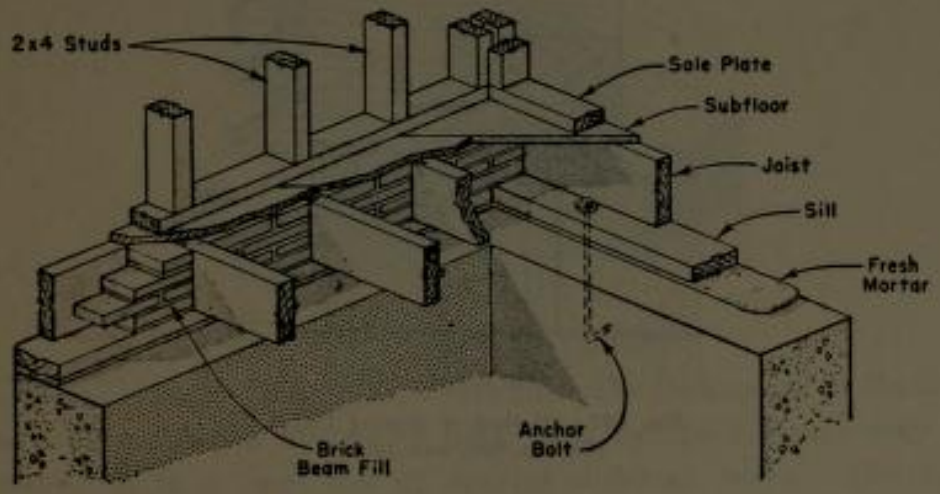


Fig. 125. Box Sill Assembly with Sill Plate
Courtesy of Weyerhaeuser Forest Products

made as shown in Fig. 141. Often the "box" sill, illustrated in Fig. 125, is used. The part of this sill which lies flat on the top of the wall is called the "sill-plate." Sometimes this sill-plate is omitted entirely and the sill is constructed without it as shown in Fig. 126. The material is generally spruce, although sometimes it is Norway pine or native pine (depending upon the locality).

The sill should be placed on the wall far enough back from the outside face to allow for the water table, which is a part of the outside finish, which will be described later; and 1 inch should be regarded as the minimum distance between the outside face of the sill and the outside face of the underpinning, Fig. 127. A bed of

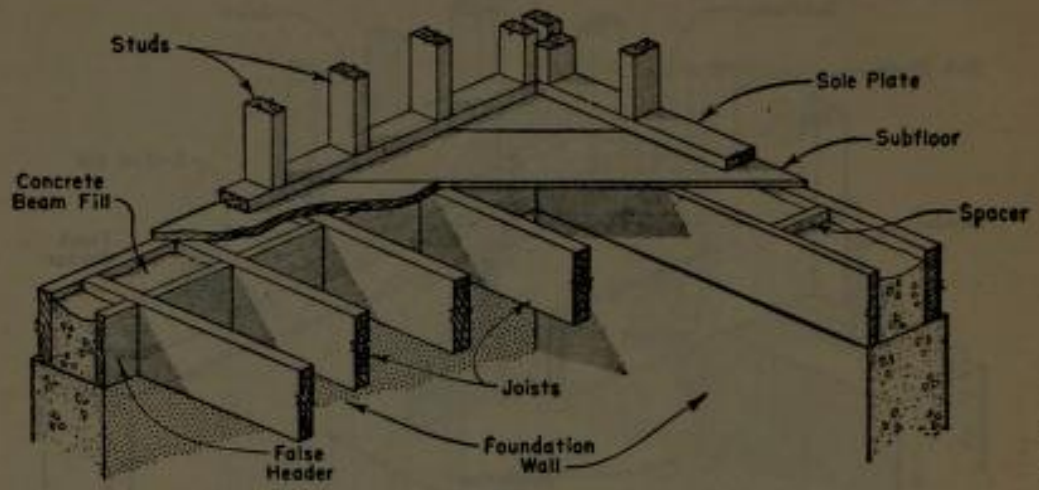


Fig. 126 Box Sill Assembly Without Sill Plate

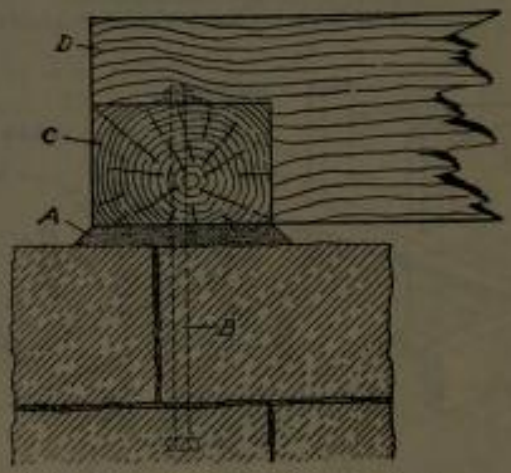


Fig. 127. Method of Setting Underpinning, Sill, and Joists

mortar *A*, preferably of cement mortar, should be prepared on the top of the underpinning, in which the sill *C* should rest; and the under side of the sill should be painted with one or two coats of linseed oil to prevent it from absorbing moisture from the masonry. Lumber containing sap wood should not be used for sills, as it will quickly decay when exposed to any dampness such as might be absorbed by the sill from the masonry of the foundation walls. Heart wood should be selected for this purpose.

In many cases, at intervals of from 8 to 10 feet, long bolts, *B*, are set into the masonry. These bolts extend up through holes bored in the sill to receive them and are fastened at the top of the sill by a washer and a nut screwed down tight. They fasten the sill, and consequently the whole frame securely to the underpinning, and should always be provided in the case of light frames in exposed positions.

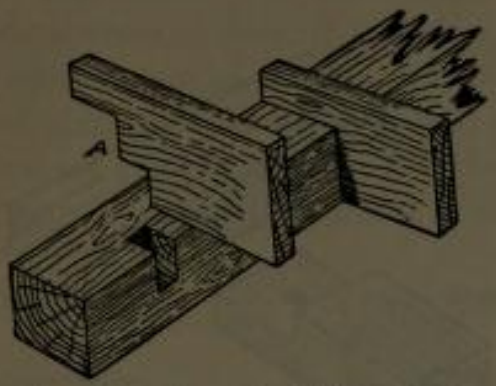


Fig. 128. Example of Sill Mortised to Receive Joist

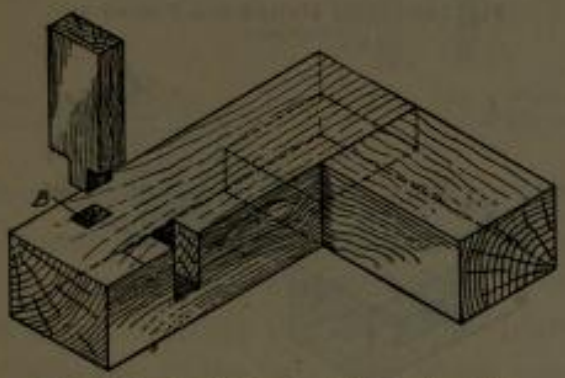


Fig. 129. Sills Mortised to Receive Studs

The beams or "joists" *D*, which form the framework of the first floor, are supported at one or both ends by the sill and may be fastened to it in any one of several different ways. The old-fashioned method is to cut a mortise in the sill to receive a tenon cut in the end of the joist, as shown at *A* in Fig. 128. The mortises are cut in the inside upper corner of the sill. They are about 4 inches deep and cut 2 inches into the width of the sill and are fixed in position by the spacing of the joists. This method of course can only be used when the sill is composed of one solid piece 6 x 6 inches or 6 x 8 inches.

In the full-braced frame as formerly used, mortises are also cut

in the sill to receive tenons cut in the lower ends of the studs, as shown at *B* in Fig. 129. They are cut the full thickness of the studding, about 1½ inches in the width of the sill and about 2 inches deep. The position of these mortises is fixed by the spacing of the studding, and by the condition that the outer face of the studding must be flush with the outer face of the sill in order to leave a plain surface for the boarding.

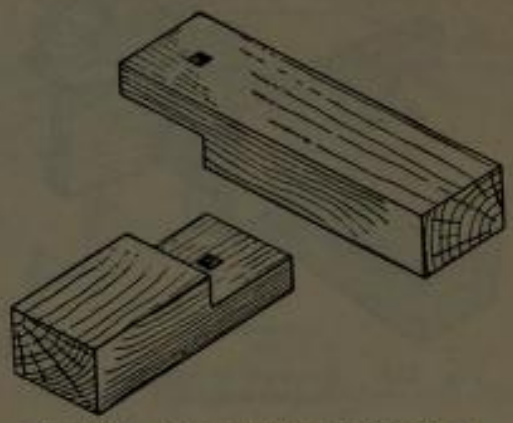


Fig. 130. Sills Halved and Pinned at Corners

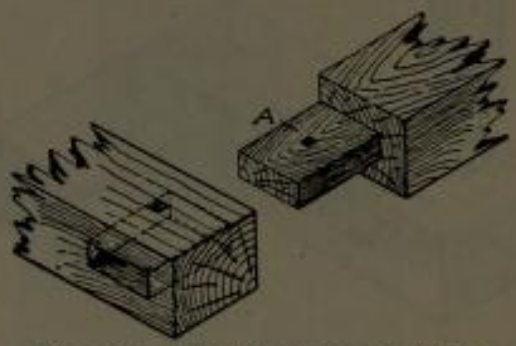


Fig. 131. Sills Sometimes Joined by Tenon Joint

Such sills were usually halved and pinned together at the corners, as shown in Fig. 130; but sometimes they were fastened together by means of a tenon *A* cut in one sill, which fits into a mortise cut in the other, as shown in Fig. 131. This method may be stronger than the other, but the advantage gained is not sufficient to compensate for the extra labor involved. Such methods of framing with solid sills in which mortises are cut for the joists and studs have long ago been discarded; the modern practice being to use built-up sills or "box" sills and to nail the joists and studs to the sills. The floor joists usually rest directly on top of the sill-plate

or on the wall. Fig. 126 shows joists resting directly on the wall without any sill-plate but with the vertical member of the "box" sill used and nailed to the ends of the joists. The regular "box" sill illustrated in Fig. 125 is better, because the floor joists do not come in contact with the top of the masonry wall from which they might absorb moisture.

Corner Posts. After the sill is in place, the first floor is usually framed and roughly covered at once, to furnish a surface on which to work, and a sheltered place in the cellar for the storage of tools and materials, after which the framing of the wall is continued. The corner posts are first set up, then the girts and the plate are framed in between them, with braces at the corners to keep everything in

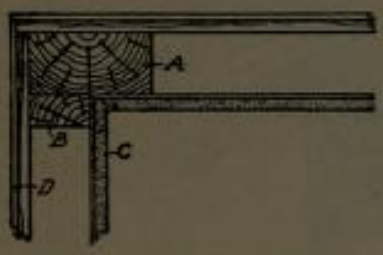


Fig. 132. Plan of Corner Post Details

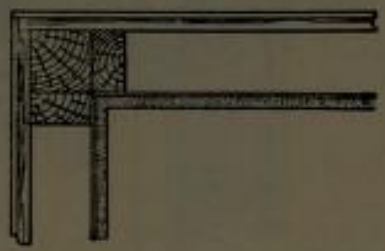


Fig. 133. Plan of Another Form of Corner Post

place; and lastly the frame is filled in with studding. The corner posts in a full-braced frame are pieces 4 x 8 inches, or sometimes two pieces 4 x 4 inches placed close together. Corner posts must be long enough to reach from the sill to the plate. The post is really a part of only one of the two walls which meet at the corner, and in the other wall a "furring stud" of 2 x 4-inch stuff is placed close up against the post so as to form a solid corner, and give a firm nailing for the lathing in both walls. This arrangement is shown in plan in Fig. 132, *A* is the corner post, *B* the furring stud, *C* the plastering, and *D* the boarding and shingling on the outside. Sometimes a 4 x 4-inch piece is used for the corner post and a 2 x 4-inch furring stud is set close against it in each wall to form a solid corner as shown in Fig. 133. Corner posts of this kind were used with the old-fashioned full-braced frame. The modern way is to build up the corner post out of three pieces of 2 x 4-inch stuff as shown in Fig. 124. In the braced frame the mortises *CC*, Fig. 134, were cut in the post at the proper level to receive the tenons cut on the ends

of the girts. Holes were bored to receive the pins, *DD*, which fasten these members to the post. Such work is no longer seen at the present time.

In the case of a balloon frame no mortises need be cut in the posts for the girts or braces, as they are omitted in this frame; but

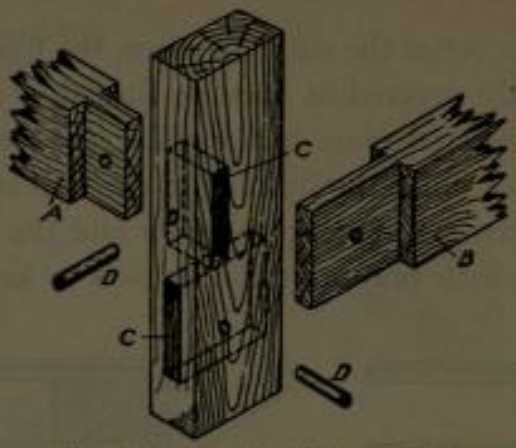


Fig. 134. Details of Tenon Joints for Corners

Fig. 135 Notched Post in Balloon Framing

the post must be notched instead, as shown in Fig. 135, to receive the ledger board or ribbon and the light braces which are sometimes used.

Girts. In a full-braced frame the girts were always made of the same width as the posts, being flush with the face of the post both outside and inside. A tenon at each end fit into the mortise cut in the post, and the whole was secured by means of a pin *DD*, as shown in Fig. 134. The pin was of hard wood and about ⅞ inch in

diameter. It is evident that if the girts in two adjoining walls were framed into the corner post at the same level, the tenons on the two girts would conflict with each other. For this reason the girts *A* which run parallel with the floor joists were raised above the girts *B* on which these joints rest, and were called "raised girts" to distinguish them from the others which were called "dropped girts."

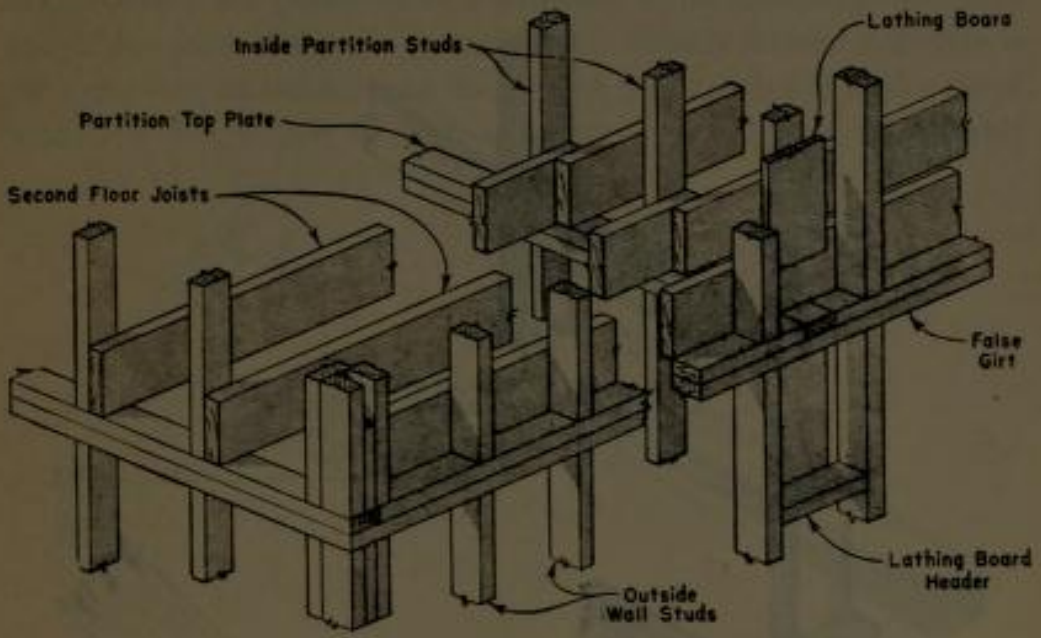


Fig. 136. Second Floor Joist Assembly in Braced Type of Frame

Courtesy of Weyerhaeuser Forest Products

The floor joists were carried by the dropped girts, and the raised girts so placed that they were just flush on top with the joists which were parallel to them.

In modern work mortises are not cut in the corner posts and there are no tenons cut on the ends of the girts so the necessity for raised girts and dropped girts no longer exists. The girts themselves are now usually made up out of two pieces of 2 x 4-inch stuff.

Fig. 136 shows how the so-called "false girts" in a modern braced frame are arranged and Fig. 156 shows the still later platform type.

Ledger Board. The girts are used only in the braced frame. In the balloon frame, light pieces called "ledger boards" or "ribbons" are substituted from them. These are usually made about $\frac{7}{8}$ inch

thick and 6 or 7 inches deep, and are notched into the posts and intermediate studs. This notching is shown in Fig. 137, in which *A* is the ledger board and *B* the stud. The ledger boards themselves are not cut at all, but the floor joists which they carry are notched over them, as shown in Fig. 138, and spiked to them and to the studding. In Fig. 138, *A* is the joist, *B* the ledger board, and *C* the

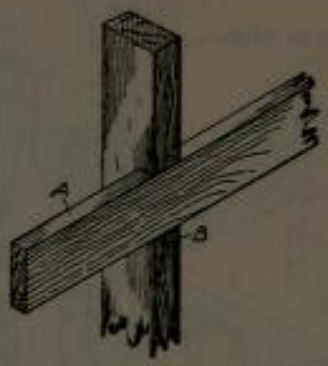


Fig. 137. Notched Stud with Ledger Board

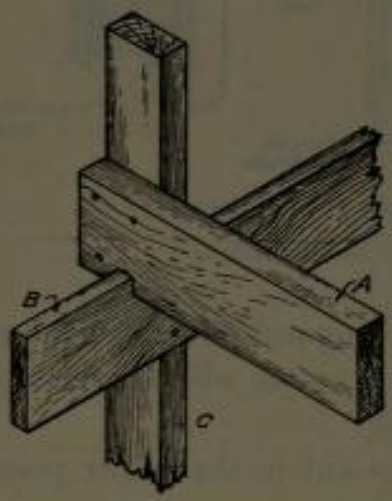


Fig. 138. Ledger Board with Notched Floor Joist in Place

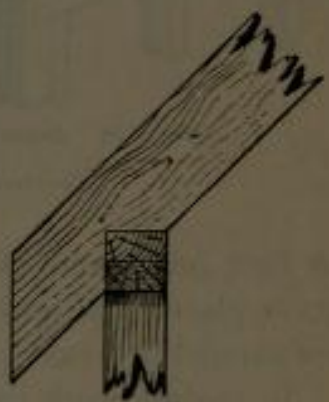


Fig. 139. Section of Plate between Studs and Rafters

stud. Even in the braced frame a ledger board is usually employed to support the joists of the attic floor, which carry little or no weight.

Plate. The plate serves two purposes: First, to tie the studding together at the top and form a finish for the wall; and second, to furnish a support for the lower ends of the rafters. See Fig. 139. It is thus a connecting link between the wall and the roof, just as the sill and the girts are connecting links between the floors and the wall. Sometimes the plate is also made to support the attic

floor joists, as shown in Fig. 140, in which *A* is a rafter, *B* the joist spiked to the rafter, *C* the plate built up from 2 x 4-inch pieces, and *D* the wall stud. It acts in this case like a girt, but this arrangement is not very common, the attic floor joists usually being supported on a ledger board, as shown in Fig. 138. The plate is merely spiked to the corner posts and to the top of the studding; but at the corner where the plates in two adjacent walls come together, they should be connected by a framed joint, usually halved together in the same way as the sill. In the braced frame, a fairly heavy piece, usually a 4 x 6-inch is used, although a 4 x 4-inch is probably

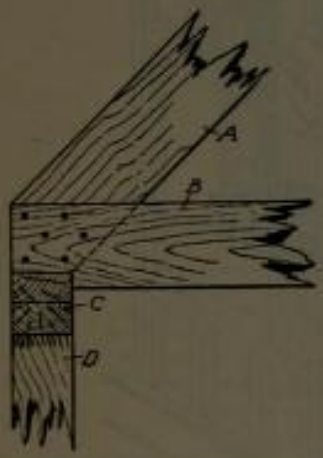


Fig. 140. Plate as Support for Attic Floor

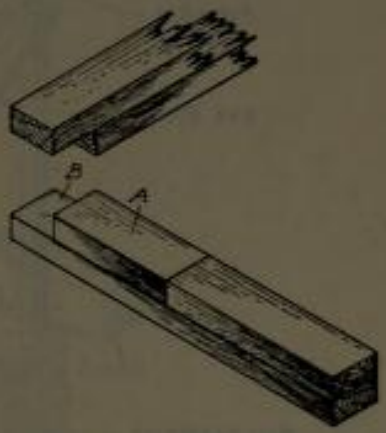


Fig. 141. Plates Used in Balloon Framing

sufficiently strong. In a balloon frame the usual practice is to use two 2 x 4-inch pieces placed one on top of the other and breaking joints, as shown at *A* in Fig. 141, in order to form a continuous piece. The corner joint is then formed, as shown at *B*. No cutting is done on the plate except at the corners, the rafters and the attic floor joists being cut over it, as shown in Figs. 140 and 122.

Braces. Braces are used as permanent parts of the structure only in braced frames, and serve to stiffen the wall, to keep the corners square and true, and to prevent the frame from being distorted by lateral forces, such as wind. In a full-braced frame, a brace is placed wherever a sill, girt, or plate makes an angle with a corner post, as shown at *E* in Fig. 120. Braces were placed so as to make an angle of forty-five degrees with the post, and were long enough to frame into the corner post at a height of from one-third to one-half the height of the story.

The braces were made the same width as the posts and girts, usually 4 inches, to be flush with these pieces both outside and inside, and were made of 3 x 4-inch or 4 x 4-inch stuff. They were framed into the posts and girders or sills, by means of a tenon cut in the end of the brace, and a mortise cut in the post or girt, and secured by a hardwood pin.

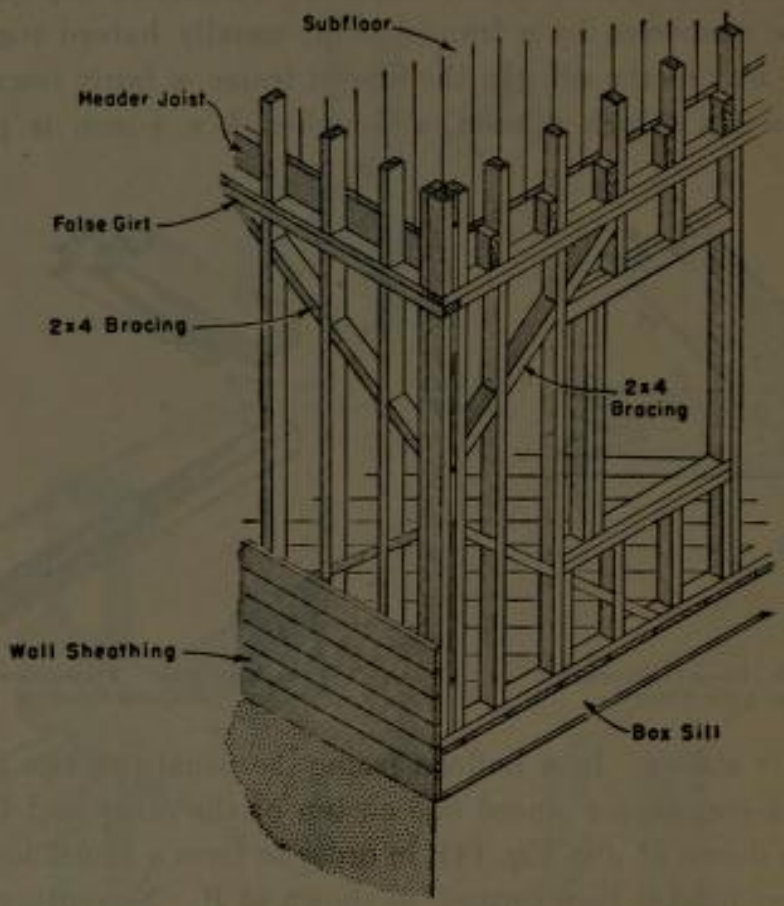


Fig. 142 Bracing 2"x4" Cut between Studs Sheathing Applied Horizontally
Courtesy of Weyerhaeuser Forest Products

Braces of this type are never used in modern frames. Even in modified braced frames none of the wall studding is cut in between braces which have been previously placed in the frame, but instead all of the wall studs are placed first so as to extend in one piece from the sill to the false girt and the braces in short sections are then cut-in and nailed in place diagonally between the wall studs nearest to the corners as shown in Fig. 122, two 10-penny nails being used at each stud for this purpose. Fig. 142 shows such "cut-

in" bracing in detail with wall sheathing or outside boarding placed horizontally.

In a balloon frame there are no permanent braces, but light strips are nailed across the corners while the framework is being erected, and before the boarding has been put on, to keep the frame in place. As soon as the outside boarding is in place these are removed. This practice is also modified, and sometimes light braces are used as permanent parts of even a balloon frame. They are not framed into the other members, however, but are merely notched

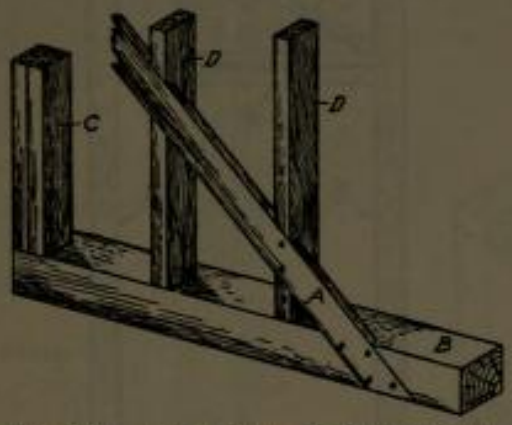


Fig. 143. Light Braces for Balloon Frame

into them and spiked, as shown in Fig. 143. *A* is the brace, *B* the sill, *C* the corner post, and *DD* are studs. In such a case every stud must be notched to receive the brace, which is really the same as the temporary brace mentioned above, except that it is notched into the studs instead of being merely nailed to them, and is not removed when the boarding is put on. These braces are usually made of 1 x 3-inch stuff or 1 x 4-inch stuff and are called "let-in" bracing.

Fig. 159 shows "let-in" bracing in place in the wall with wall sheathing applied horizontally while Fig. 159A shows a balloon frame with no bracing but with the wall sheathing applied diagonally so as to give to this frame something of the stiffness which the bracing imparts to a braced frame.

Studding. In a full-braced frame, when the sill, posts, girts, plates, and braces are in place, the only step that remains to complete the rough framing of the wall is the filling in of this framework with studding. The studding is of two kinds, viz., the heavy

pieces which form the frames for the door and window openings and the stops for the partitions; and the lighter pieces which are merely "filling-in" studs, and are known by that name, or as "intermediate" studding.

The frames for the door and window openings are usually made in a braced frame, from 4 x 4-inch pieces. A vertical stud *AA*, Fig. 144, is placed on each side of the opening, the proper distance

Fig. 144. Construction of Door and Window Openings

being left between them, and horizontal pieces *BB* are framed into them at a proper level to form the top and the bottom of the opening. For wide openings a small truss is formed above each opening by setting up two pieces of studding *CC* over the opening, in the form of a triangle. This is to receive any weight which comes from the studding directly above the opening, and to carry it to either side of the opening where it is received by the studding and in this way carried down to the sill. Such a truss is shown in Fig. 144. The pieces used are 2 x 4 inches, and may be either framed into the other members or merely spiked. There should be a space *D* of at least 1 inch between the piece *B* forming the top of the window frame and the piece *E* forming the bottom of the truss, so that if the truss sags at all it will not affect the window frame. This is

a point that is not generally recognized. The piece *B* is usually made to serve both as the top of the window opening and as the bottom member of the truss, and is often composed of two pieces of 2 x 4-inch stuff set on edge close together instead of on the flat, as shown in Fig. 145, which shows framing for a very wide opening

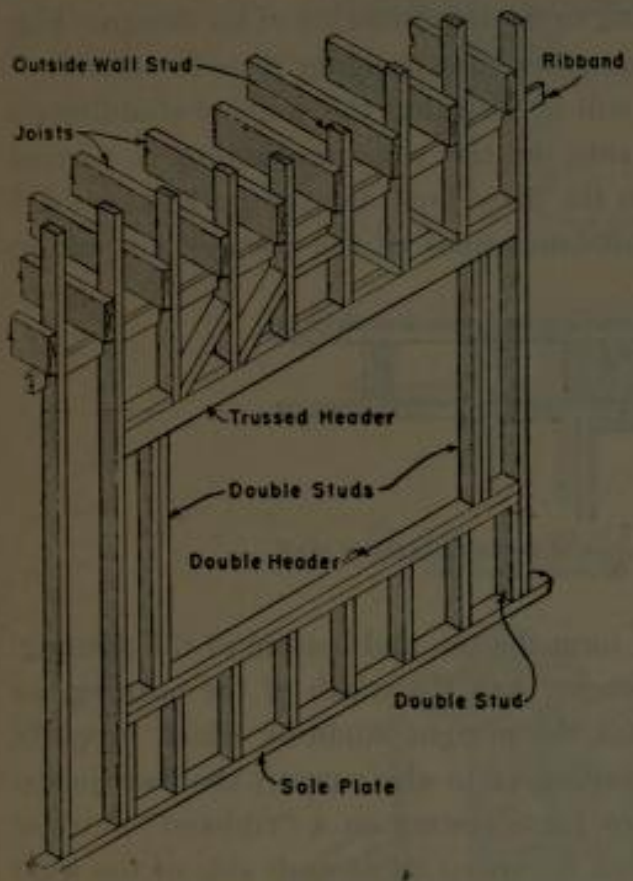


Fig. 145. Framing for Wide Window Openings

Fig. 146. Door and Window Studs in Balloon Frame

In a modern frame, the door and window studs are almost always made of two 2 x 4-inch pieces placed close together, and in this case the connection of the pieces forming the top and bottom of the window or door opening with those forming the sides is made as shown at *A* in Fig. 146. It should be noticed that in a balloon frame all studding is carried clear up from the sill to the plate, so that if there is an opening in the wall of the first story, and no corresponding openings in those of the second or third story, the door and window studding must still be carried double, clear up to the plate, and material is thus wasted. In designing for balloon frames, therefore, it is well to take care that the window openings

in the second story come directly above those in the first story wherever this is possible. The same difficulty does not occur in the case of a braced frame, because in such a frame the studding in each story is independent of that in the story above or below it; the window openings may, therefore, be arranged independently in the different stories according to the requirements of the design. Fig. 142 shows a method of framing for such openings so as to accommodate the joist spacing. It will be seen that the doubled studding on one side, the right-hand side, of the window opening is carried straight up from the sill to the plate but that the upright doubled studs at the other side (left-hand side) of the opening are cut in

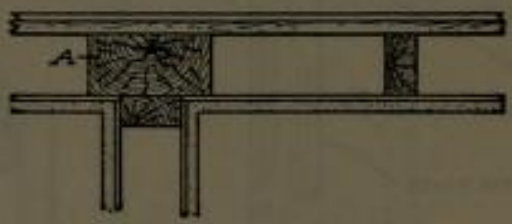


Fig. 147. Plan of Studding in Outer Wall Opposite Partition

between the headers which form the top and bottom of the opening. These headers are made longer than the width of the opening, as shown in the figure, so that the upright studding which supports them can come in such a position as to also support the floor joists. Fig. 145 shows the 2nd floor joists resting on a "ribband" notched into the wall studding, which is carried up at each side of the wide opening in such a position as to accommodate the joists.

Nailing Surfaces. Whenever a partition meets an outside wall, a stud wide enough to extend beyond the partition on both sides and to afford a solid nailing for the lathing must be inserted. A nailing surface must be provided for the lathing on both the outside wall and the partition, and the first stud in the partition wall is, therefore, set close up against the wall stud, forming a solid corner. This arrangement is shown in plan in Fig. 147. The large wall stud *A* is made of a 4 x 8-inch piece set flatwise in the wall, so that if the partition is, say 4 inches wide, there is a clear nailing surface of 2 inches on each side of the partition. A 4 x 6-inch piece could also be used here, leaving a clear nailing surface of 1 inch on each side of the partition.

Sometimes the same thing is accomplished by using two 4 x 4-inch pieces placed close together, as shown in plan in Fig. 148, instead of one 4 x 8-inch piece. Sometimes two pieces, 2 x 4 inches or 3 x 4 inches, are used, placed far enough apart so that they afford a

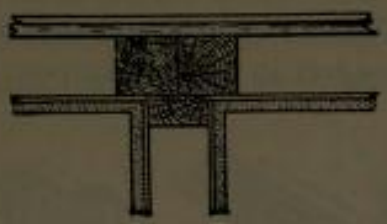


Fig. 148. Two-Piece Stud in Outer Wall Opposite Partition

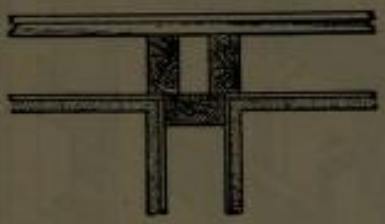


Fig. 149. Placing of 2 x 4 Studs to Give Nailing Surface

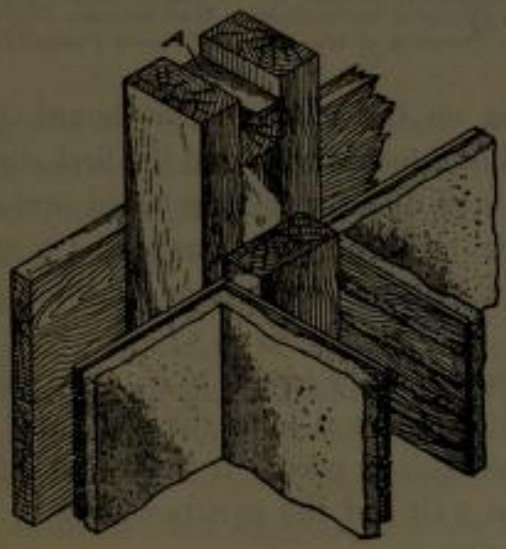


Fig. 150. Placing of Block Stiffeners in Construction Shown in Fig. 149

space for nailing on each side of the partition, as shown in plan in Fig. 149. Whenever this is done, small blocks *A*, Fig. 150, should be set in between the two studs at intervals of 2 to 3 feet throughout their entire height in order to give them added stiffness and make them act together. This is one of the methods usually employed in

modern work. A cheaper method and one which is especially applicable when the partition joins the outside wall at a point in between two wall studs is shown in Fig. 151 and consists in cutting 2 x 3-inch horizontal headers in between the two wall studs at intervals in the height of the wall so placed that they will be flush with the wall studs on the outside and so that a vertical 1-inch thick board nailed to the headers in an upright position will be flush with

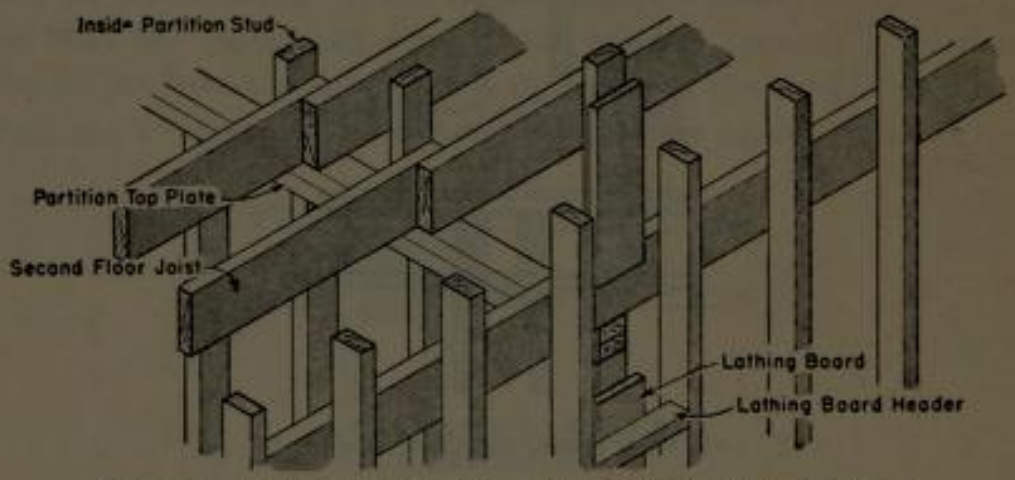


Fig. 151. Economical Method for Providing Ample Nailing Surfaces When Partition Meets Outside Wall between Two Studs
Courtesy of Weyerhaeuser Forest Products

the wall studding on the inside. This board, called a "lathing board", is made 6 or 8 inches wide and the first stud of the partition is nailed against it so that the lathing board projects an inch or so on each side of the partition stud thus giving a nailing surface for the laths. Such a "lathing board" and "lathing header" is shown in Fig. 151.

The end in view in every case is to obtain a solid corner on each side of the partition where it joins the wall, and any construction which accomplishes this is good. It makes no difference what the angle between the wall and the partition may be, but usually this angle is a right angle.

Intermediate Studding. The pieces which make up the largest part of the wall frame are the "filling-in" or "intermediate" studs. These, as the name implies, are used merely to fill up the frame made by the other heavier pieces, and afford a nailing surface for the boarding, which covers the frame on the outside, and the lathing, which covers it on the inside. The filling-in studs are

usually placed 16 inches apart, measured from the center of one stud to the center of the next. In especially good work they are sometimes placed only 12 inches apart on centers, but this is unusual. In no case should they be placed more than 16 inches apart, even in the lightest work. The studs are made the full width of the wall, usually 4 inches, but sometimes in large buildings (such as churches) 5 or even 6 inches and their thickness is almost always 2 inches,

Fig. 152. Intermediate Stud with Tenon

Fig. 153. Intermediate Stud with Tenon

2 x 4 inches being the more usual dimensions. The lengths of the intermediate studs are made to fit the rest of the frame.

In the old-fashioned full-braced frame, there must necessarily be a great deal of cutting of the intermediate studding, because all the large pieces are made the full width of the wall and the intermediate studding must be cut to fit between them. In the balloon frame, however, the intermediate studding in all cases extends clear up from the sill to the plate, and no cutting is necessary except the notching to receive the other parts of the frame. See Fig. 123.

In a balloon frame it often happens that the studs are not long enough to reach from the sill to the plate and they must be pieced out with short pieces which are spliced onto the long stud. This splicing is called "fishing," and it is accomplished by nailing a short thin strip of wood *AA* on each side of the stud, as shown in Fig. 84, in order to join the two pieces firmly together. The strips should be well nailed to each piece in order to give the required strength. In the old-fashioned braced frame all door and window studs have

a tenon cut at the foot of the piece to fit a mortise cut in the sill. Intermediate studs are merely spiked to the sill without being framed into it. The tenons are cut in two different ways, as shown in Figs. 152 and 153. They are always made the full thickness of the piece, and by the first method they are placed in the middle of the piece, as shown. The width of the tenon is about 1½ inches, leaving 1½ inches on the outside and 1 inch on the inside of the stud. Another way is to make the tenon on the inside of the stud, as shown in Fig. 153, the tenon being 1½ inches wide as before. There is no choice between these methods, both being good, but such framing is seldom, if ever, seen in these days.

Western Balloon Frame. The balloon frame was developed as a result of the necessity or desire for a cheaper method of construction than was afforded by the braced frame, and this was accomplished by eliminating the girts and braces and doing away with the expensive framing together of the heavy timbers.

In some of the Western States this tendency towards cheapening the work by the elimination of the heavier timbers has been carried even farther and instead of placing a heavy sill on top of the foundation walls around all sides of the building to receive and support the ends of the first floor joists, these joists rest directly on top of the foundation wall with the rough flooring laid diagonally on top of the joists and then on top of the rough flooring is placed a sort of modified sill or "sole plate" composed of 2 x 4-inch stuff laid flat. This sole-plate is carried right around all sides and ends of the building and to it the lower end of each of the exterior wall studs is spiked. See Fig. 126.

Of course the floor joists are at right angles to only one of the two walls which meet at any corner of the building and the ends of the joists rest on top of only one of these walls.

On top of the other wall, which runs parallel to the floor joists, are placed two floor joists set up on edge so that their top surface is level with the top of all the other floor joists, and on top of them is placed the sole piece or sill composed of 2 x 4-inch scantling to receive the wall studding for this wall. The joists are, of course, amply strong to carry the weight of the wall over any cellar-window openings which may occur in this wall. Should there be any cellar windows in the other wall which receives the ends of the floor joists

so that a joist might come over the opening, it is customary when this method of construction is employed to place a lintel over the opening composed of a piece of joist set on edge and long enough to span clear across the cellar-window opening. The ends of the first floor joists are framed into the inside face of this lintel, usually by means of a 2 x 4 or 3 x 4-inch "ledger strip" which is spiked to the side of the lintel in such a position that the ends of the joists can be notched over the ledger strip, and so be supported by it.

Another method of framing used in the West is illustrated in

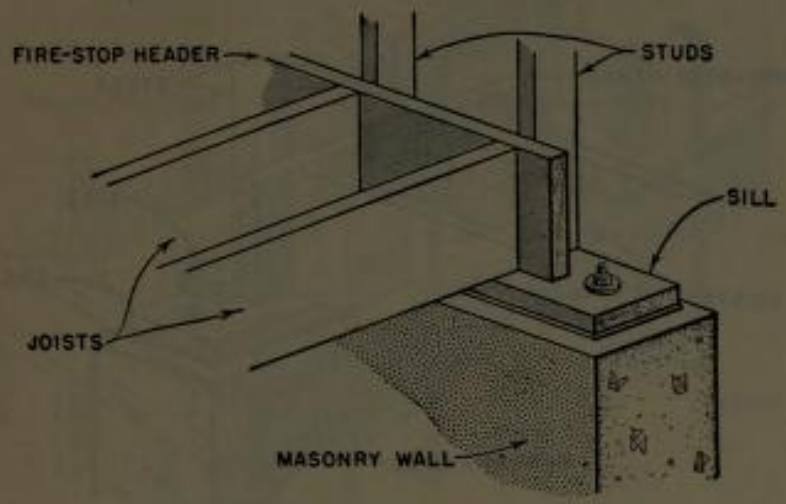


Fig. 154. Sill Construction Without Sole

Fig. 125. It is a modified sill consisting of a length of joist laid flat on its side on the top of the foundation wall with another length of joist set up on edge on top of it so as to form a sill of the L-shape, as illustrated in Fig. 125. Into this "box" sill the ends of the floor joists are set and then the rough flooring of the first floor is laid on the joists and brought out flush with the outside face of the sill. A piece of 2 x 4-inch scantling is laid flatwise on top of the rough flooring with one edge flush with the outside face of the sill all around so as to form a sole piece to receive the lower ends of the wall studding. The part of the "box" sill which is set up on edge gives the sill sufficient strength to carry the wall over any cellar-window openings. Sometimes this piece, which is called a "Header," instead of being set with its outside face flush with the outside edge of the sill is moved in, so that its outside face is flush with the inside face of the wall studding and the studs are carried down past it to rest on top of the flat portion of the sill, as in Fig. 154, or on a

2 x 4-inch sole piece which is placed on top of the flat portion of the sill all around the building to receive them. See Fig. 155. Such a sill is called a "T-sill" and is considered by some authorities to offer greater resistance to the spread of fire than does the "box" sill. The pieces of which these sills are composed are usually of the same breadth and thickness as the larger floor joists.

This same principle of using a member built up out of comparatively thin scantlings and joists in place of a large timber is sometimes applied, in the West, to the construction of girts in the

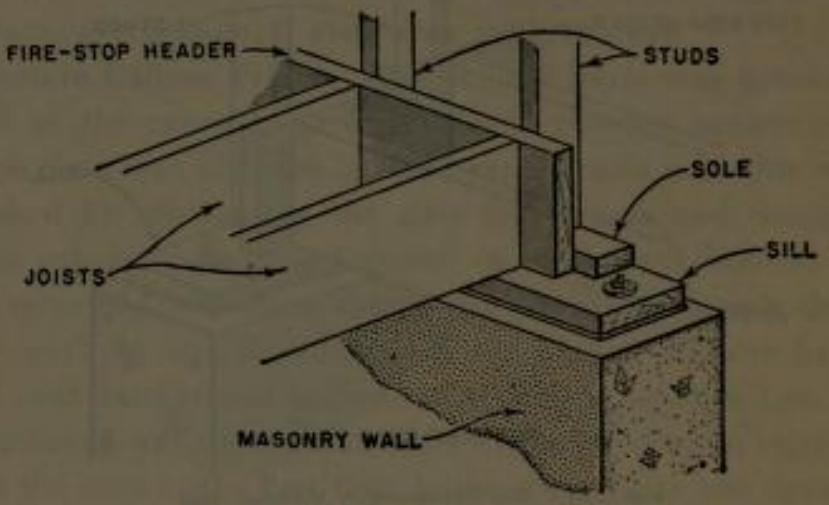


Fig. 155. Sill Construction with Sole

outside walls at the second floor level. Such girts may be composed of a couple of pieces of 2 x 4-inch scantling set flatwise, one on top of the other with a 2 x 8-inch or 2 x 10-inch joist set edgewise on top of them, the outside face being set flush with the outside edge of the scantlings, leaving a ledge about 2 inches wide for the second story floor joists to rest on. After these joists are set in place, the rough flooring of the second floor is laid and sawed off flush with the outside face of the girt and on top of this flooring a 2 x 4-inch sole piece is set flatwise to receive the lower ends of the second story wall studding. Girts of this kind are sometimes framed into the corner posts, or the corner posts themselves are built up out of three 2 x 4-inch scantlings and carried, in one length, only to the height of one story, the girt extending in each wall right out to the corner with the top of the first story corner post spiked to the under side of the girt and the second story corner post starting again on top of the

sole piece referred to above in the same way as the second story wall studding. Fig. 156 shows this type of construction.

Diagonal braces are often fitted in between the studs near the corners of the building as shown in Fig. 157. This form of construction might be called "Western Braced Frame Construction." It is also sometimes called a "platform frame."

The lumber used for framing varies in different parts of the country. In the North and East, Norway Pine, Spruce, and Hem-

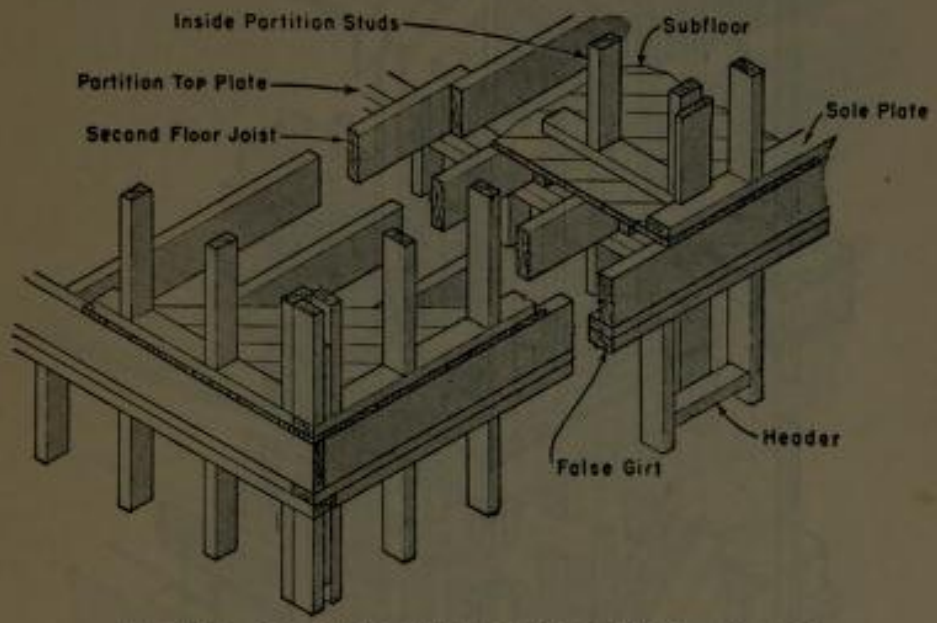


Fig. 156. Second Floor Joist Assembly in Platform Type of Frame
Courtesy of Weyerhaeuser Forest Products

lock are used. In the West, Douglas Fir, Western Hemlock, Red Fir, and Larch are common. In the South the Yellow Pine furnishes the framing lumber.

Brick Veneered Walls. It is quite a common practice in some parts of the country to construct the outside walls of a building in the manner described under the headings of "Braced Frame" and "Western Braced Frame," but to set the sills back about 5 inches from the outer edge of the foundation walls all around and then to build on the ledge thus formed a 4-inch thick facing of brickwork which will completely cover up the wooden framework from the outside and thus give the appearance of a brick building as well as providing a considerable protection against any fire which might originate in adjacent buildings.

When this method of construction is employed, the wood frame should be very well built and braced and absolutely plumb. As any shrinkage or movement in the wooden frame may be the cause

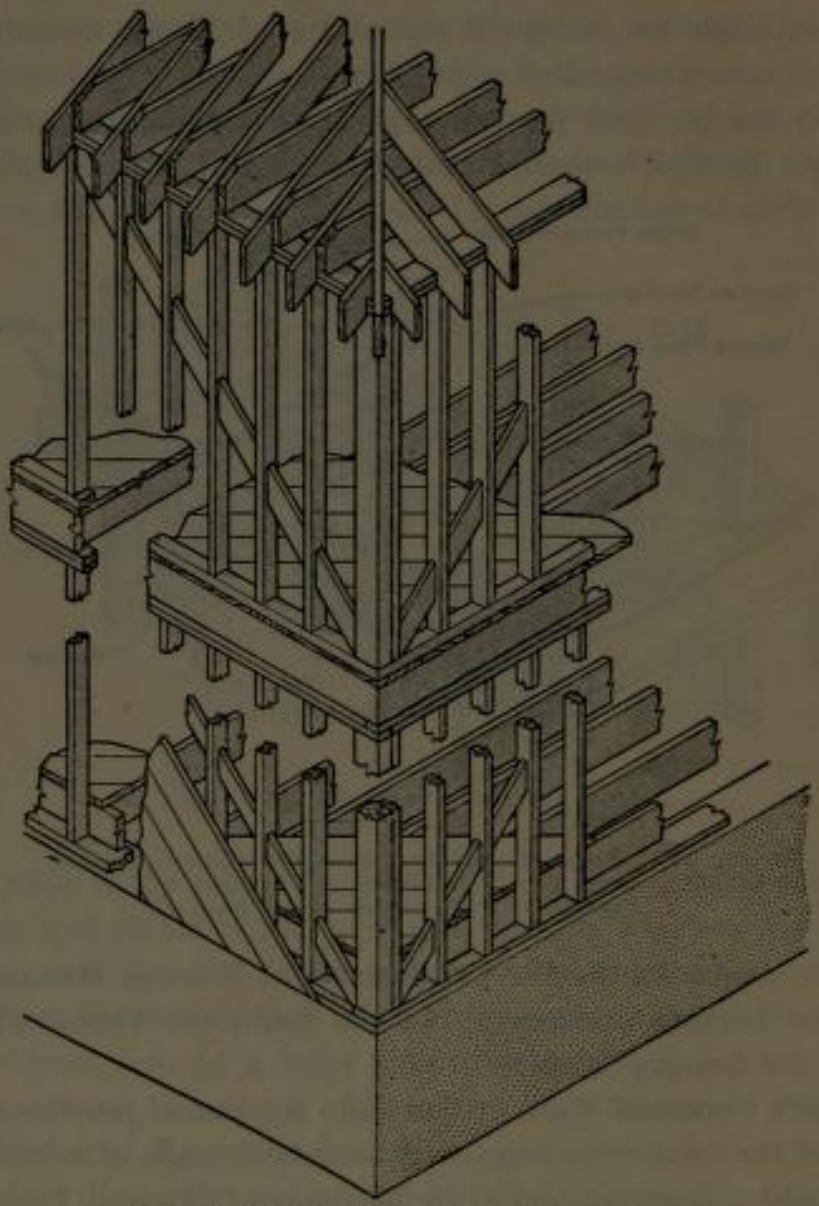


Fig. 157. Western Braced Frame Construction

of cracks or open joints in the brick facing, it is wise to be sure that the lumber used is well seasoned.

After the framework is constructed, it is covered on the outside with boarding which is usually set diagonally and the entire area of the outside wall surfaces is covered with building paper. Then the 4-inch thick brick wall is built leaving a space of about 1 inch

between the outside face of the wood frame and the inside face of the brickwork. As the brick wall goes up, metal ties made of wire or of narrow strips of 16 gauge galvanized sheet steel are nailed to the sheathing so that they will project out and be built into the joints of the brickwork, one tie for every second brick in every fifth course. These ties thus project across the 1-inch air space and hold the thin masonry wall and the wooden wall together. The window

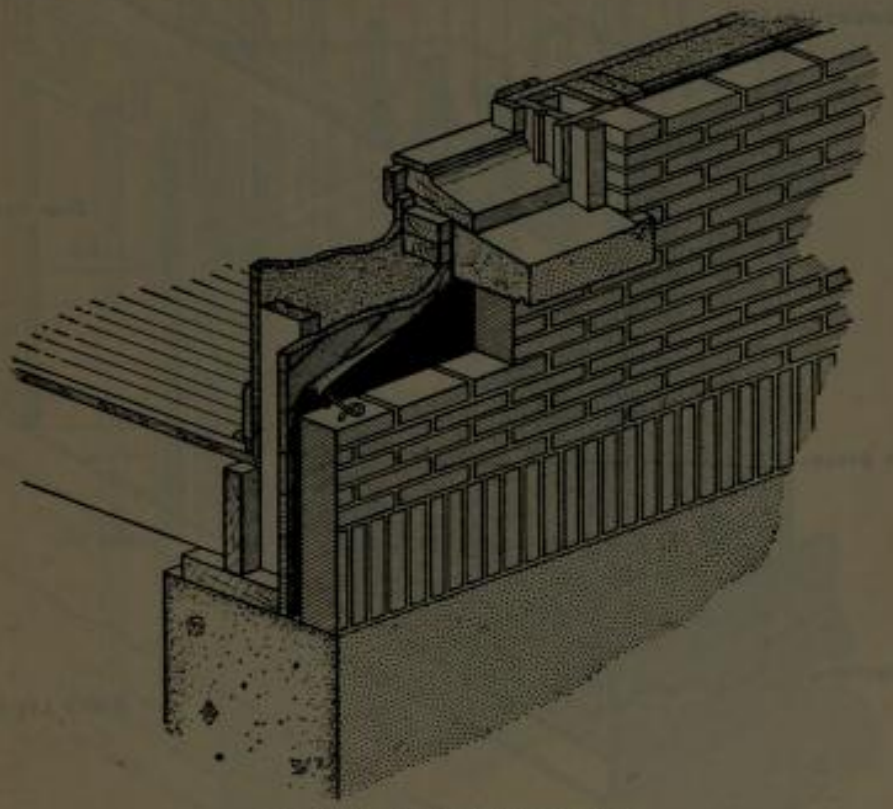


Fig. 158. Brick Veneered Wall

and door frames will have been previously set into the wood framed walls and the brickwork is built around them. Over the top of these openings, steel angles are placed with ends resting on the brickwork at each side of the opening to carry the masonry above. Often stone or brick sills are set into the brickwork but in many cases wooden sills are employed and there is no reason why they should not be satisfactory if the lumber used is well seasoned and the sills are kept well protected by paint.

The air space should be ventilated by leaving small openings in the brick wall up under the overhanging eaves or gables and by means of pipes extending through the foundation walls with one

end opening into the air space behind the brickwork and the other end opening into the cellar. These pipes are usually of tile about 2 inches in diameter. In addition to ventilating the space, they also

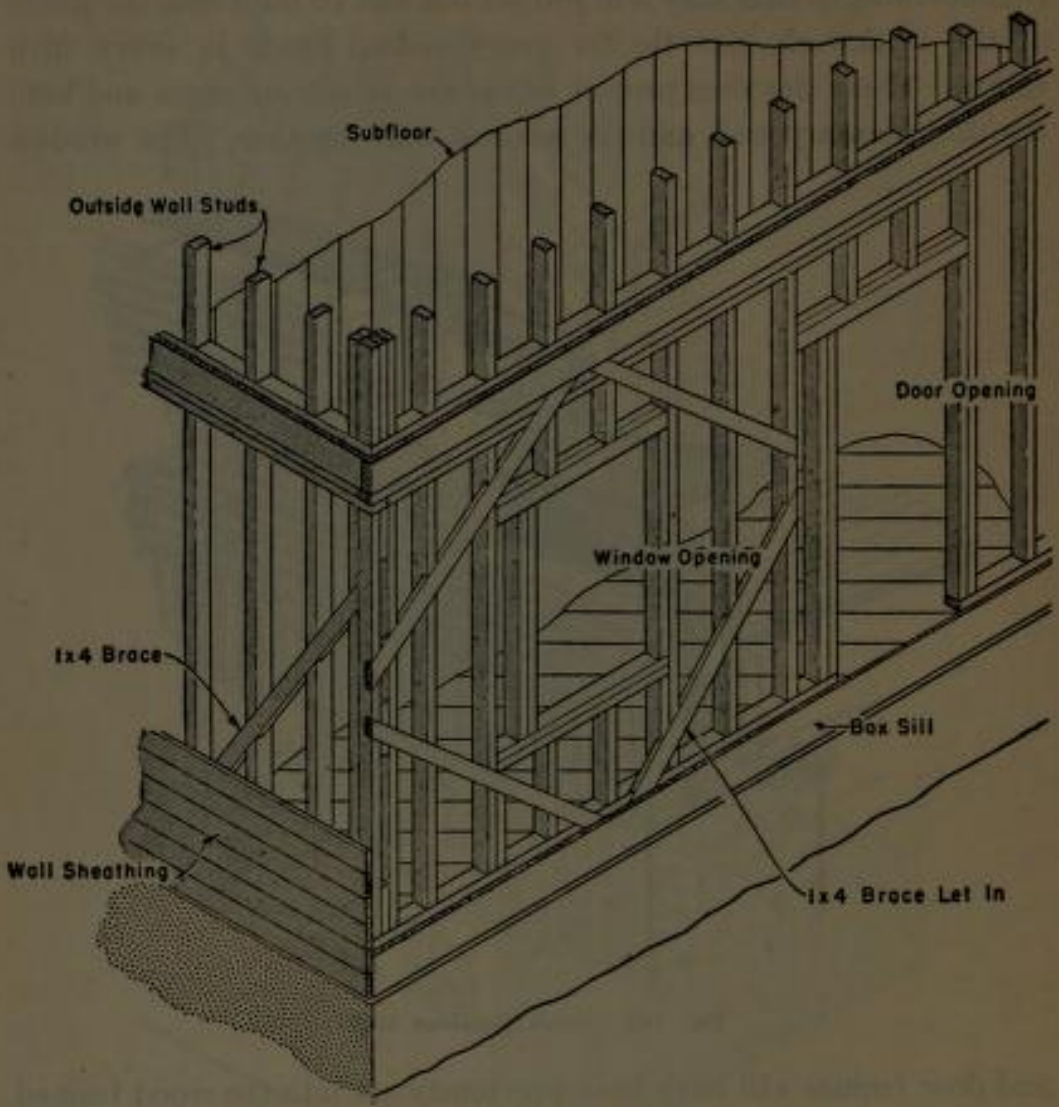


Fig. 159. Method of Door and Window Framing
Courtesy of Weyerhaeuser Forest Products

serve to drain off any small amount of water that might otherwise collect at the bottom of the air space due to condensation.

Sometimes these spaces are vented and drained to the outside through small openings in the wall and occasionally in the best work copper gutters are installed near the bottom of the space all around to catch any water that may get into the space and discharge it to the outside through the "weep-holes" mentioned above. Fig. 158 shows a section through a brick-veneered wall and also a

section taken vertically through the sill of a window frame and wood window sill in such a wall as well as a section taken horizontally through the jamb of the window frame showing the weight box.

Spacing of Wall Studding. The studs in exterior walls are almost always set at a distance of 16 inches apart center to center

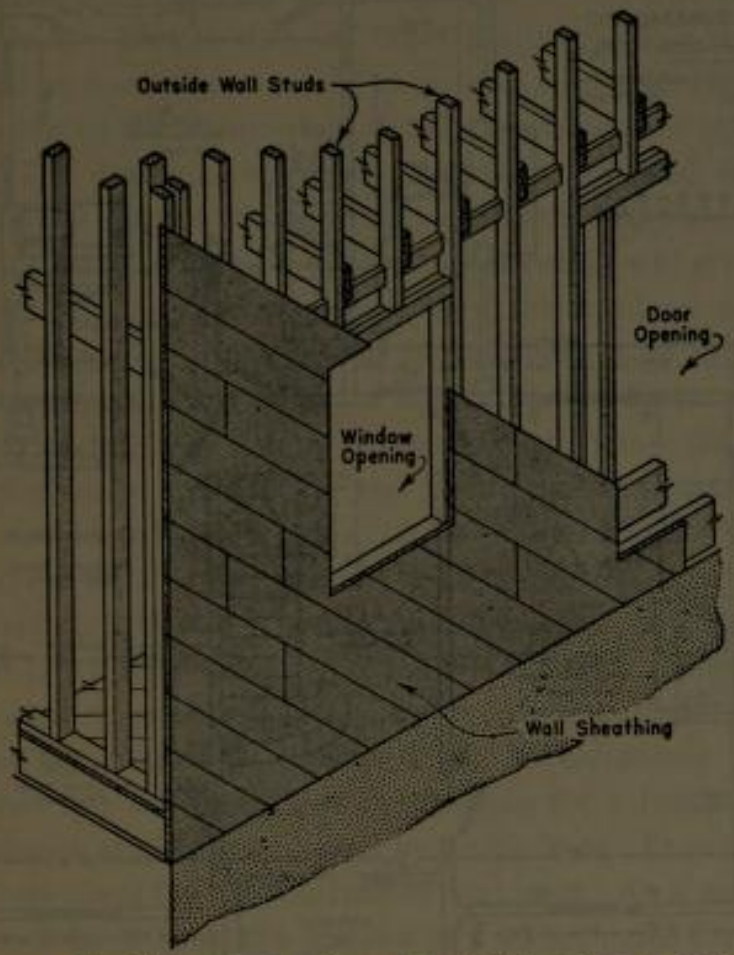
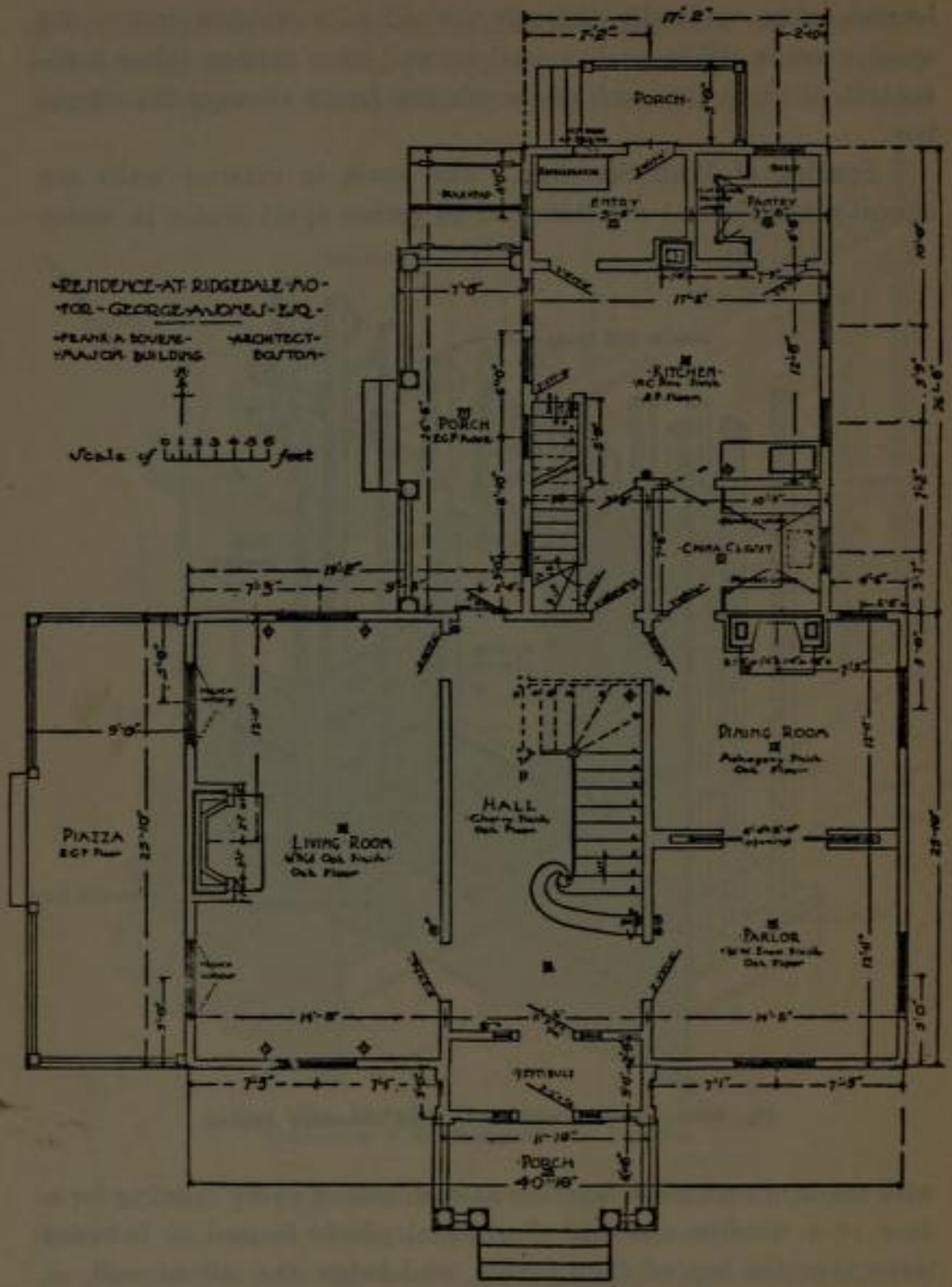


Fig. 159A. Bracing Secured by Wall Sheathing Applied Diagonally

with two studs set close together at each side of every opening for a door or a window and with horizontal pieces framed in between them over the top of the opening, and below the sill as well, in the case of window openings. For door openings the rough sill is formed by the first floor joists where they rest upon, or frame into, the main wall sill or by blocking set in between these joists. Fig. 159 shows the framing for a door opening and for a window opening. Fig. 159A shows how the sheathing is applied to secure bracing effect.



PLAN OF FIRST FLOOR

Fig. 160.

The question which arises when building the frame is how to determine the position of the pieces which will form the rough jambs and heads and sills of the openings and how far apart to space them so that the door and window frames can be fitted into place later.

From the plans and elevations of the building, it is almost always possible to determine the location of the center line of each door and window opening with respect to the outside corner of the nearest corner post so that the exact position of this center can in each case be marked out on the main wall sill. Fig. 160 shows how the spacing of the windows is usually indicated on the plan of a house. The drawings will also give the height and width of the doors and the kind of windows, that is, whether they are "casement" or "double hung" windows. The detail drawings will give the height and width of the window sashes, or if the windows are to be of stock sizes this information can be obtained from the catalogues of the manufacturers or from the mill or lumber dealer who is going to supply them. All that is necessary is to know the number of lights of glass in the window and the size of the glass as, for example, a window with "6 lights, 12 inches by 14 inches in the upper sash and one light 37 inches by 28½ inches in the lower sash." Then the outside height and width of the sashes can be obtained. Fig. 161, which is a front elevation of the house shown in plan in Fig. 160 and which is drawn up so as to show the framing, illustrates how the windows are frequently indicated on the elevations. It will be noted that this drawing shows the framing for a full-braced frame. The filling-in studs are indicated by single lines. Framing drawings are seldom made for balloon framed buildings. As a rule the width of the sash for a two light window is 4 inches more than the width of the glass and for a casement sash the total height is 5 inches more than the height of the glass. If there are horizontal muntins in the sash, add together the heights of all the lights of glass and then add ½ inch for each horizontal muntin and the total height will be 5 inches more than this sum. For a double-hung window, add together the heights of all the lights of glass, then add ½ inch for each horizontal muntin, if there are any, and 1 inch for the meeting rail and the total height will be 5 inches more than this sum.

At each side of a double-hung window frame there is a space for the weights as shown at the upper right-hand corner of Fig. 158,

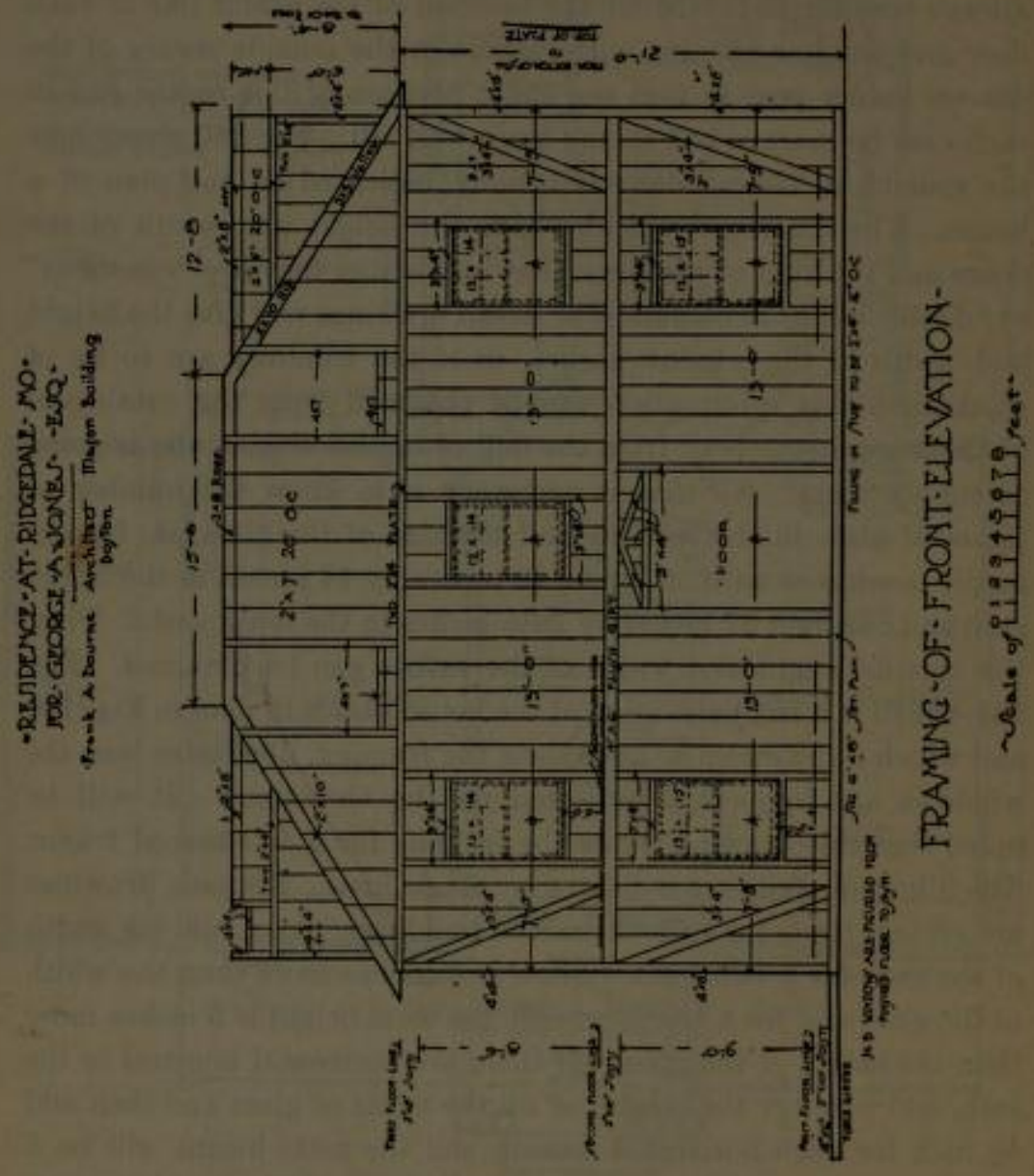

RESIDENCE AT RIDGEDALE, MO.
FOR GEORGE A. JONES, ESQ.
Frank A. Bourne Architect Majestic Building Dayton
FRAMING OF FRONT ELEVATION
Scale of 1/8 inch to the foot.

Fig. 161.

and in Fig. 163. To allow for this, it is the custom to set the studs which form the jambs of the rough window opening in such a posi-

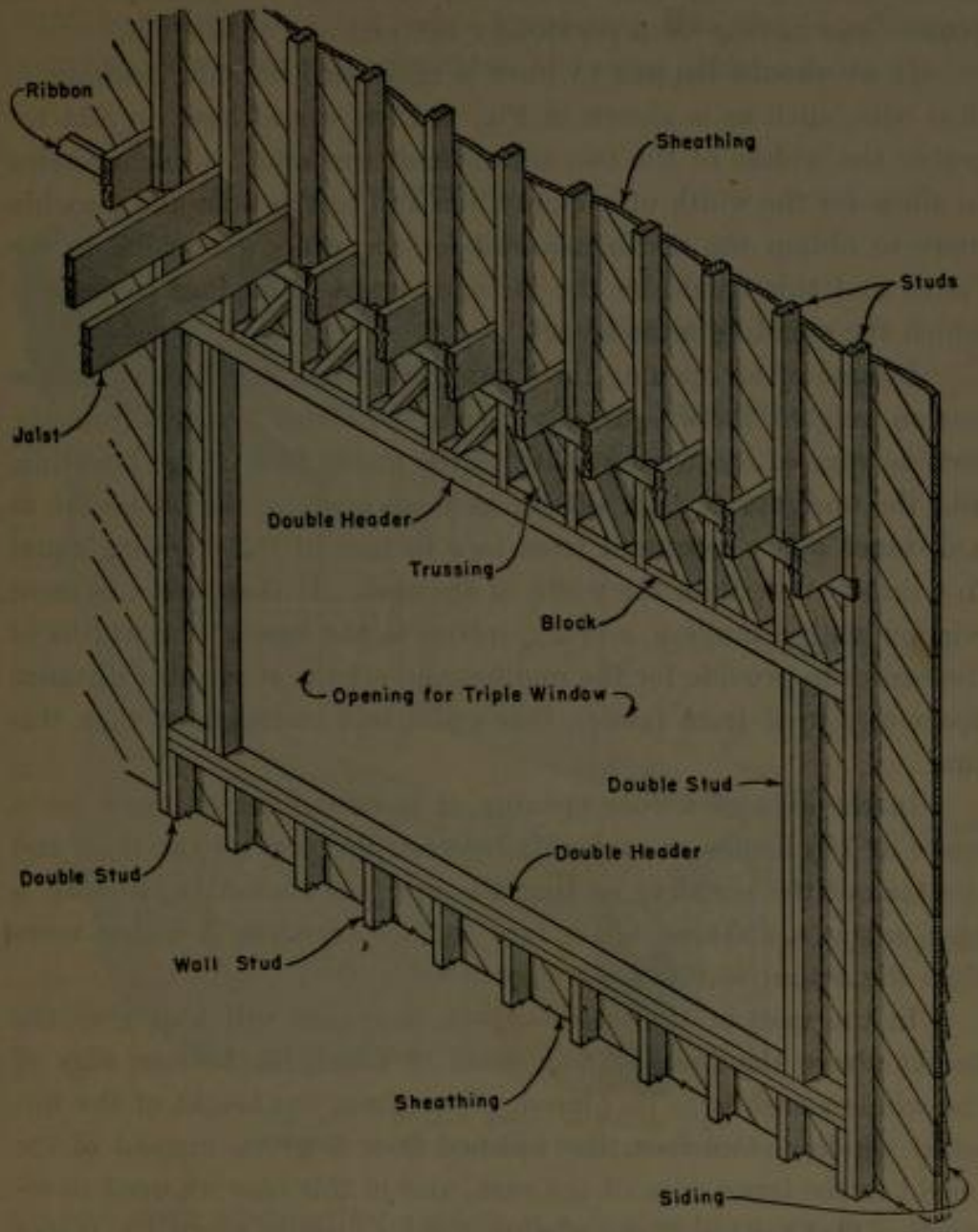


Fig. 162. Mullioned Triple Window Opening in Frame Wall
Courtesy of Weyerhaeuser Forest Products

tion that there will be a space of about 3 inches from the outside edge of the window sash to the inside face of the studding. This means that the width of the space provided in the framing for the window opening for double-hung windows, measured from face to

face of the studding, should be 6 inches more than the width of the window sash. Knowing this, we can set up these up-rights at each side of the center line of the window openings, the position of the center lines having been previously marked out on the sill.

If we should happen to have a mullioned window opening to deal with, such as is shown in Fig. 162, we would have to add together the widths of the two sashes and then add 5½ inches extra to allow for the width of each mullion and to this sum add 6 inches more to obtain the width required for the window opening in the frame and this would be the distance apart from face to face at which the studding must be set.

In case of an opening for a casement window, which of course has no weights, there is usually a space of about 2 inches from the outside edge of the window sash to the inside face of the studding, and the uprights at each side of such an opening should be set at a distance apart measured from face to face of the studding equal to 4 inches more than the width of the sash. If there is a casement window with a mullion, add 2½ inches to the sum of the widths of the sashes to provide for the mullion and set the studs at a distance apart measured from face to face equal to 4 inches more than this sum.

In the case of a door opening, it is customary to allow for a space of 1½ inches at each side between the edge of the door and the face of the studding so that the uprights should be, in such a case, set at a distance apart face to face equal to 3 inches more than the actual width of the door itself.

In the case of the windows, the drawings will also give the height above the finished floor level at which the bottom edge of the window sash is to be placed. Sometimes the height of the finished window stool from the finished floor is given instead of the height to the lower edge of the sash, and in this case we need to remember that the top of the window stool is usually about 1¼ inches higher from the floor than is the lower edge of the sash. This distance should be obtained from the detailed drawings if possible.

The only level which we have established is the top of the first floor joists, but we know that there will be a rough flooring and a finished flooring laid on top of them and if we allow ⅞ inches for the thickness of each of these and, therefore, add 1¾ inches onto the

figure given above as the height from the finished floor level up to the lower edge of the sash, we will have the height of this edge of the sash above the top of the joists. Of course, the top of the rough window sill will be set 2 inches lower than this, the exact amount varying, depending upon the detail and slope of the outside window

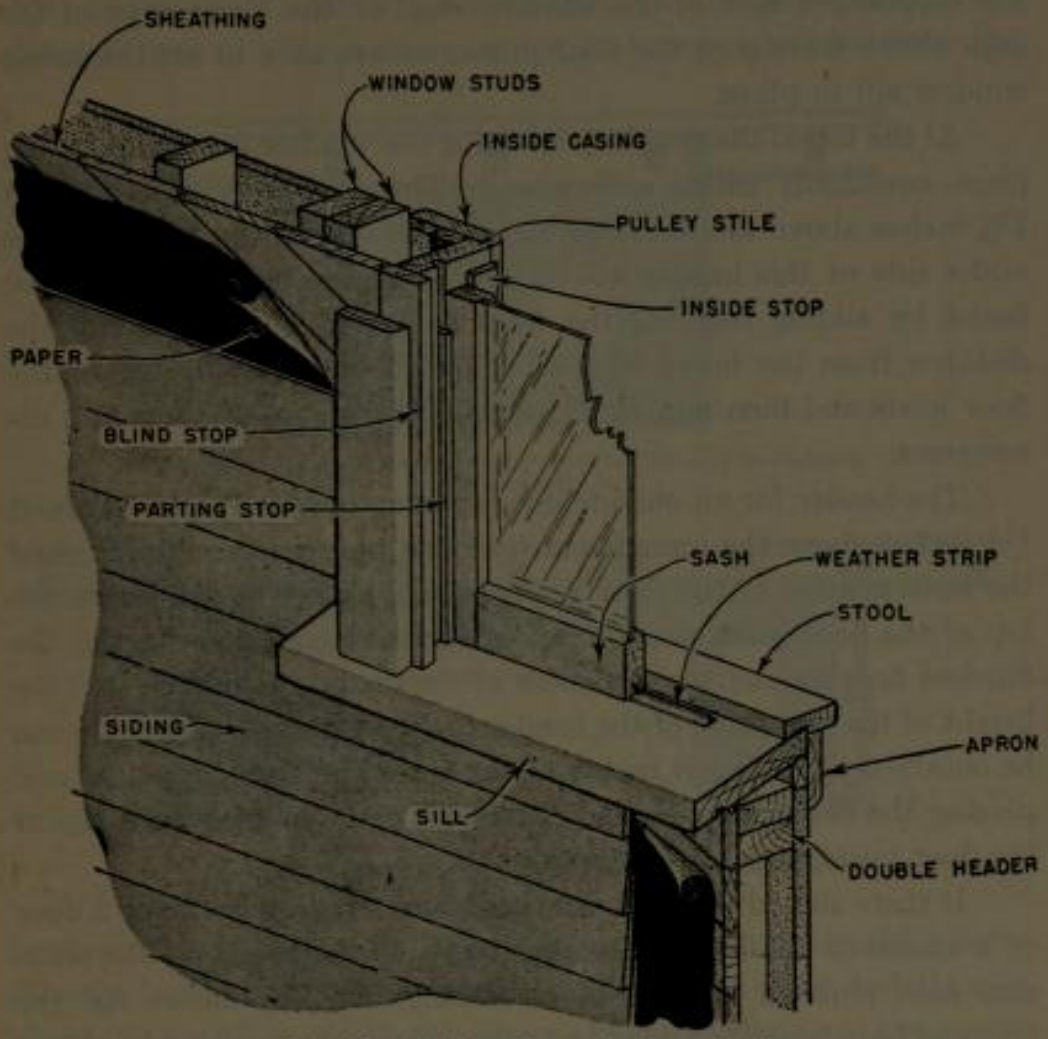


Fig. 163. Window Frame in Frame Wall
Courtesy of Weyerhaeuser Forest Products

sill and upon whether the window is a double-hung window or an out-swinging or an in-swinging casement window. For a double-hung window the top of the rough sill, called a "Double-Header," would ordinarily be set about 2¼ inches lower than the bottom edge of the sash, although with some types of rabbeted window sills this distance might have to be as much as 3 inches, while for brick-veneered buildings this distance might be as little as 1¾ inches. Fig.

163 shows a window frame in a frame wall and Fig. 158 shows brick veneer construction. For casement windows the distance from the top of the rough window sill to the lower edge of the sash might be 2½ inches for an in-swinging casement and 1½ inches for an out-swinging casement. With the above mentioned information about the proposed height of the window stool or the lower edge of the sash above the top of the floor joists, we are able to set the rough window sill in place.

At the top of the rough opening for the window is a similar cross piece, commonly called a "header." This is usually placed about 1¾ inches above the top edge of the sash and so the height of the under side of this header above the top of the floor joists may be found by adding together the total height of the sashes and the distance from the lower edge of the sash down to the top of the floor joists and then adding 1¾ inches to the sum of these two dimensions.

The header for an outside door opening is usually placed about 1½ inches above the top edge of the door (not the door frame) and the bottom edge of the door is placed about 2½ inches above the top of the floor joists so as to allow for the rough flooring and the finished flooring and the thickness of the door threshold so that the height of the underside of the header for the rough door opening can be obtained by adding 4 inches to the actual height of the door and placing the under side of the header at a distance above the top of the floor joists, equal to this sum.

If there should be a transom sash and transom bar over a door or a casement window, an amount equal to the height of the transom sash plus an amount of something like 2½ inches for the transom bar should be added on to the heights given above to obtain the proper position for the under side of the header.

The amount to be allowed for the height of the transom bar or for the width of mullions varies a great deal, depending upon the design of these members.

PARTITIONS

The studding used in partition walls is usually of 2 x 4-inch stuff, although 2 x 3-inch studding may sometimes be used to advantage if the partition does not support any floor joists.

Furring Walls. The partition walls are made 4 inches wide, the same as in the outer walls, except in the case of so-called "furring" partitions. These are built around chimney breasts and serve to conceal the brickwork and furnish a surface for plastering. They are formed by placing the studding flatwise, in order to make a thin wall; and as it is usually specified that no woodwork shall come within 1 inch of any chimney, a 1-inch space is left between the

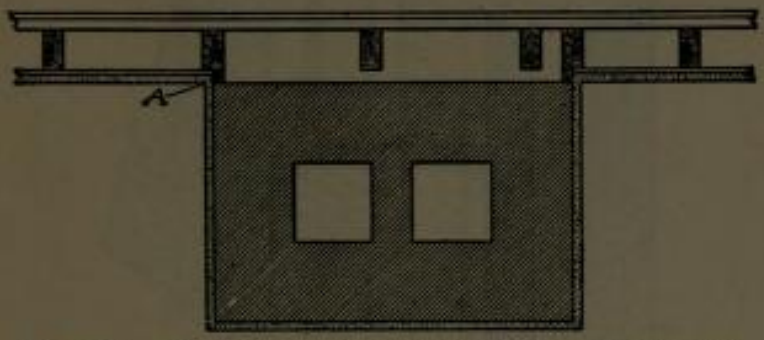


Fig. 164. Plan Showing Plaster Applied Directly to Chimney Brickwork

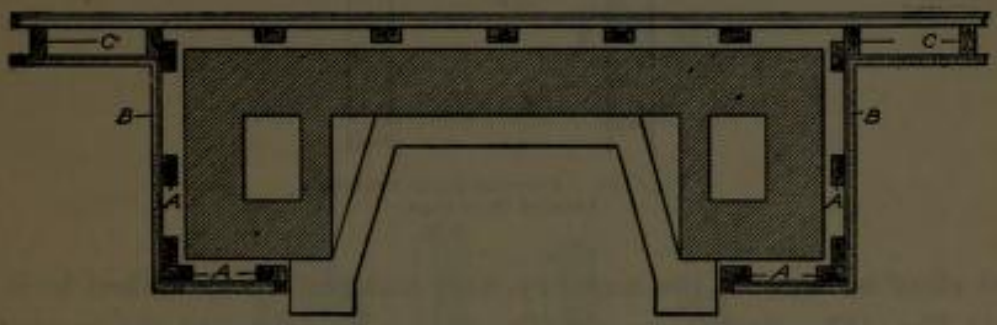


Fig. 165. Plan Showing Construction of Furring Wall

brickwork and the furring wall. It is possible to apply the plaster directly to the brickwork, and this is sometimes done, but there is always danger that cracks will appear in the plastering at the corner A, Fig. 164, between the chimney breasts and the outside wall. This cracking is due to the unequal settlement of the brickwork and the woodwork since the plastering goes with the wall to which it is applied. The method of constructing a furring wall is shown in plan in Fig. 165. *AA* are the furring studs, *B* is the plastering, and *CC* the studding in the outside wall. The arrangement without the furring wall is shown in plan in Fig. 164. If there are any openings in the furring wall, such as fireplaces, or "thimbles" for stove pipes, it is necessary to frame around them in the same way as

was explained for door and window openings in the outside walls. See Fig. 166. *AA* are furring studs, *BB* are pieces forming the top and bottom of the opening.

If the outside walls of the building are of brick or stone, a wood "furring" wall is usually built just inside of the outer wall; this furnishes a surface for plastering and for nailing the inside finish. The studding for these walls is 2 x 4 inches or 2 x 3 inches or 1 x 2 inches

Fig. 166. Furring Strip Frames Around Openings

set close up against the masonry wall and preferably spiked to it. See Fig. 167. Spikes are usually driven directly into the mortar between the bricks or stones of the wall, but sometimes wood blocks or wedges are inserted in the wall to afford a nailing surface.

Wherever a wood partition wall meets a masonry exterior wall at an angle, the last stud of the partition wall should be securely spiked in the masonry wall, to prevent cracks in the plastering.

Cap and Sole. All partition walls are finished at the top and bottom by horizontal pieces, called, respectively, the "cap" and the "sole." The sole rests directly on the rough flooring whenever there is no partition under the one which is being built; but if there is a partition in the story below, the cap of the lower partition is used as the sole for the one above. The sole is made wider than the studding forming the partition wall, so that it projects somewhat on each side and gives a nailing surface for the plasterer's grounds and for the

inside finish. It is usually made about 2 inches thick and 5½ inches wide, when the partition is composed of 4-inch studding, and this

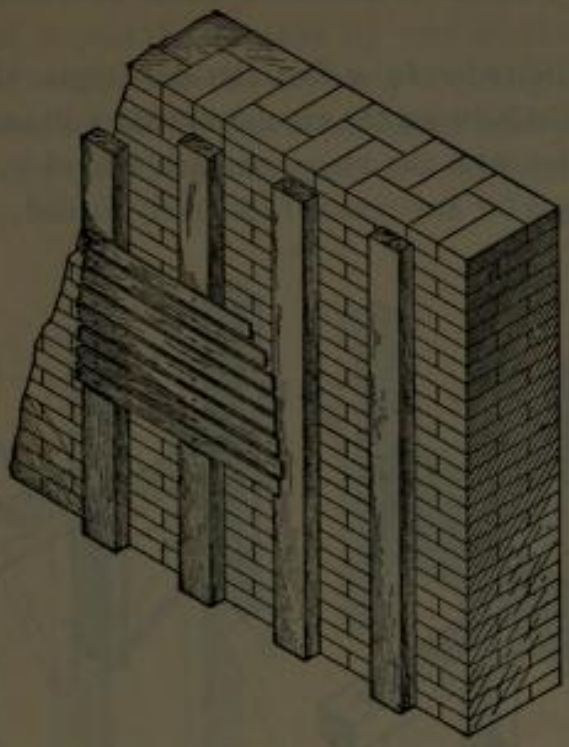


Fig. 167. Furring Strips on Outside Wall

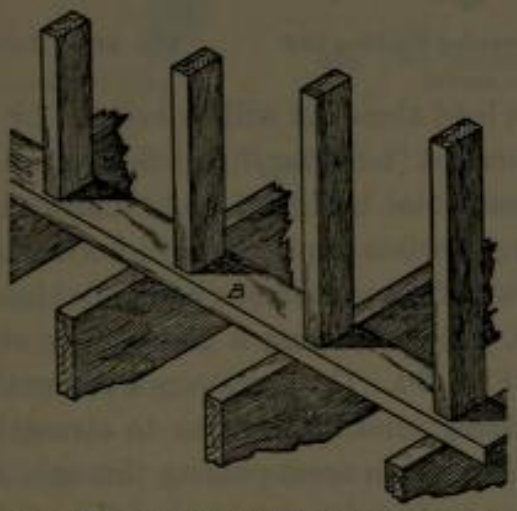


Fig. 168. Partition Framing Showing Sole

leaves a nailing surface of ¾ of an inch on each side. The sole is shown at *B* in Fig. 168. The cap is usually made the same width as the studding, and 2 inches thick, so that a 2 x 4-inch piece may be used in most cases; but if the partition is called upon to support the

floor beams of the floor above, the cap may have to be made 3 or even 4 inches thick, and some architects favor the use of hard wood such as Georgia pine for the partition caps. The cap is shown at *A*, Fig. 169.

Bridging. In order to stiffen the partitions, short pieces of studding are cut in between the regular studding in such a way as to connect each piece with the pieces on each side of it. Thus, if one piece of studding is for any reason excessively loaded, it will not have

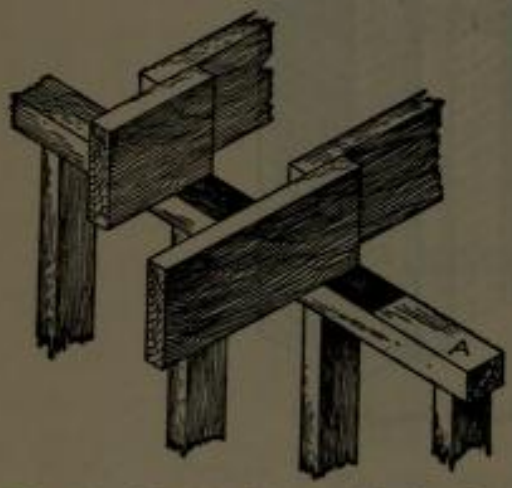


Fig. 169. Partition Framing Showing Cap

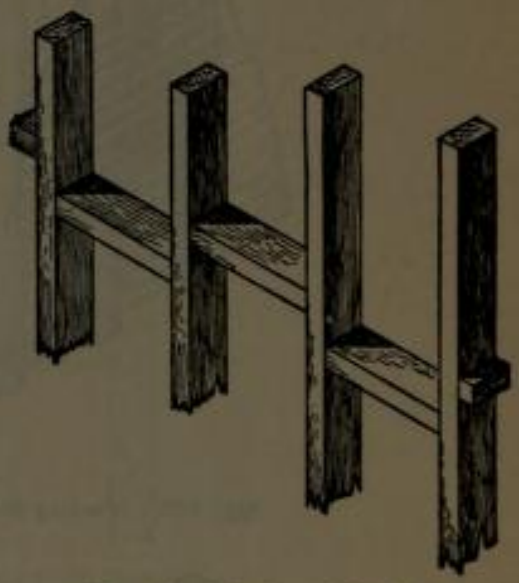


Fig. 170. Horizontal Bridging

to carry the whole load alone but will be assisted by the other pieces. This operation is called "bridging," and there are two kinds, which may be called "horizontal bridging" and "diagonal bridging." The horizontal bridging consists of pieces set in horizontally between the vertical studding to form a continuous horizontal line across the wall, every other piece, however, being a little above or below the next piece as shown in Fig. 170. The pieces are 2 inches thick and the full width of the studding; and in addition to strengthening the wall, they prevent fire or vermin from passing through, and also may be utilized as a nailing surface for any inside finish such as wainscoting or chair rails.

The second method, which we have called diagonal bridging, is more effective in preventing the partition from sagging than is the straight bridging, but both methods may be used with equal propriety. In the diagonal bridging the short pieces are set in diagonally,

as is shown in Fig. 171, instead of horizontally, between the vertical studding. This method is certainly more scientific than the other, since a continuous truss is formed across the wall.

All partitions should be bridged by one of these methods, at least once in the height of each story, and the bridging pieces should be securely nailed to the vertical studding at both ends. It is customary to specify two 10-penny nails in each end of each piece.

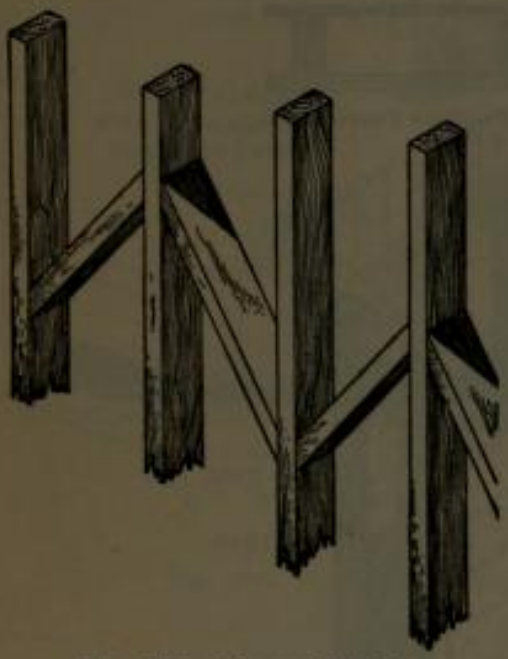


Fig. 171. Diagonal Bridging

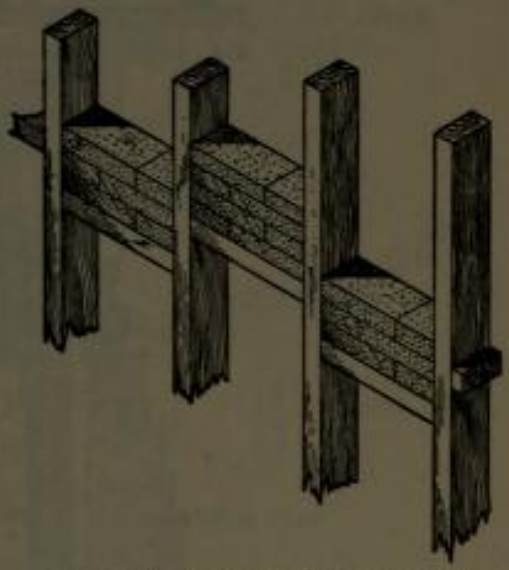


Fig. 172. Horizontal Bridging with Bricks laid on Top

Bridging should be placed in the exterior walls as well as in the partition walls; and as a further precaution against fire, it is good practice to lay three or four courses of brickwork, in mortar, on the top of the bridging in all walls, to prevent the fire from gaining headway in the wall before burning through and being discovered. This construction is shown in Fig. 172.

Special Partitions. A partition in which there is a sliding door must be made double to provide a space into which the door may slide when it is open. This is done by building two walls far enough apart to allow the door to slide in between them, the studding being of 2 x 4-inch or 2 x 3-inch stuff, and placed either flatwise or edgewise in the wall. If the studding is placed flatwise in the wall a thinner wall is possible, but the construction is not so good as in the case where the studs are placed edgewise. If the partition is to support

a floor, one wall must be made at least 4 inches thick to support it, and the studs in the other wall may then be placed flatwise if desired, and the floor supported entirely on the thick wall. The general arrangement is shown in plan in Fig. 173. It is better to use 2 x 4-inch studding set edgewise in each wall so as to make two 3-inch walls with

Fig. 173. Section of Partition Construction for Sliding Doors

Fig. 174. Details of Bracing in Double Partition

space enough between to allow the door to slide freely after the pocket has been lined with sheathing.

A piece of studding *A*, Fig. 174, should be cut in horizontally between each pair of studs *B*, 8 or 10 inches above the top of the door in order to keep the pocket true and square. The pocket should be lined on the inside with matched sheathing *C*.

An even better plan is to make use of asbestos board or gypsum board for lining these pockets. These boards come in large sheets so that they are easy to place and there are few joints. As they are

only ¼ or ⅜ inches thick they take up little room and, moreover, they have the great advantage of being fireproof. Fig. 175 shows a sliding door pocket lined with asbestos board. This figure also shows the framing for the support of the track for the sliding door.

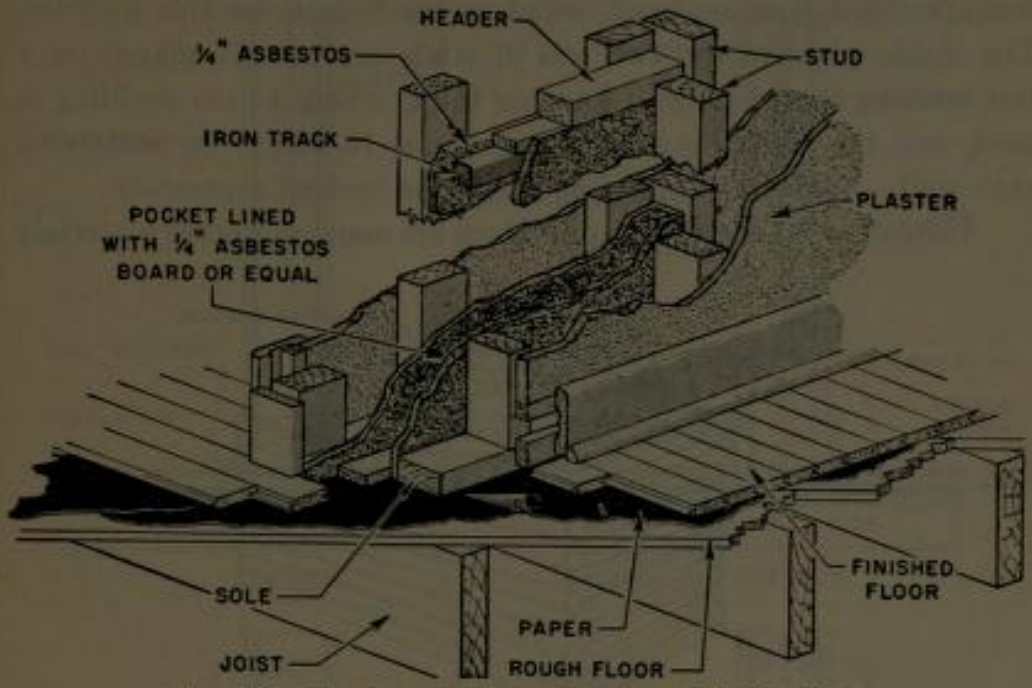


Fig. 175. Framing and Fireproofing Around Sliding Door

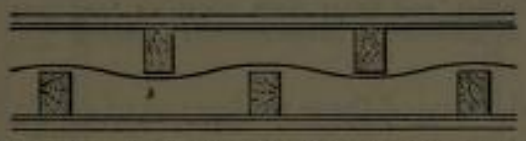


Fig. 176. Partition with Stagger Studding to Prevent Sound Transmission

It is well known that ordinary partitions are very good conductors of sound, and in certain cases, as in apartment houses, this is objectionable, so that special construction is required. If two walls are built entirely separate from each other and not touching at any place, the transmission of sound is much retarded; and if heavy felt paper or other material is put in between the walls, the partition is made still more nearly sound proof. In order to decrease the thickness of such a wall as much as possible, the "staggered" partition is used, in which there are two sets of studding, one for each side of the wall, but arranged alternately instead of in pairs as in the double

partition. The arrangement is shown in plan in Fig. 176. The two walls are entirely separate from each other and the felt paper may be worked in between the studs as shown, or the whole space may be packed full of some sound proof and fireproof material such as mineral wool. There is a so-called "quilting paper" or "sheathing-quilt" manufactured from seaweed, which is much used for this purpose. The inside edges of the two sets of studs are usually placed on a line, making the whole wall 8 inches thick, where 4-inch studding is used, and the studs may be placed about 16 inches on centers in each wall. Each set of studding should be bridged separately.

Instead of the sheathing-quilt there are numerous other materials

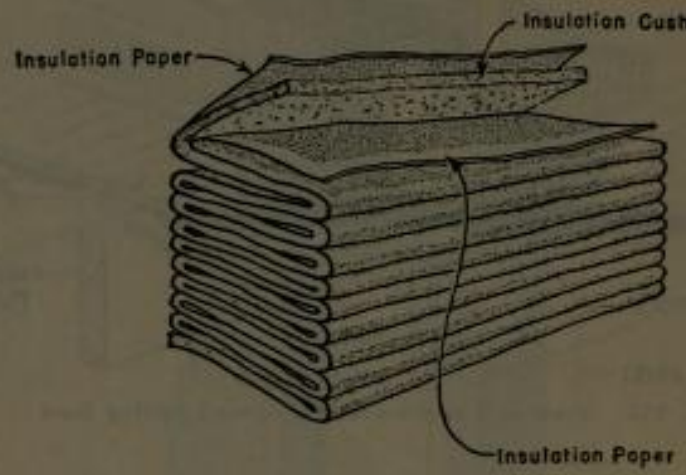


Fig. 177. This Illustration Shows How Hair-felt, Linofelt, and Other Such Materials Are Made
Courtesy of Johns-Manville Company

which may be used. One of these makes use of cattle hair compressed into a mat and held between two sheets of heavy paper while others use specially treated wood fibres or flax fibres in the same way so as to produce in each case a flexible sheet of quilt-like material which can be bent without breaking. These materials are called by a variety of names such as "Quilt," "Hair-felt," "Linofelt," "Flax-Li-Num," "Balsam Wool," and others. Fig. 177 shows how such material is made. In addition to these there are a number of sound-insulating materials which come in the form of large stiff sheets ½ inch or more in thickness which can be sawed and nailed but which cannot be bent without breaking them. Such insulating boards are placed in an upright position in the partition between two sets of studs similar to Fig. 176 except that the two sets of studs are set a little farther

apart. Sometimes 2 x 2-inch studs are used instead of 2 x 4-inch studs. Some of the various kinds of boards are "Celotex," "Insulite," "Upson Board," "Masonite," "Inso-board," "Maftex," and are manufactured from sugar cane fibre, wood fibre, straw fibre, flax fibre and licorice root. Cork board could also be used in the same way but is

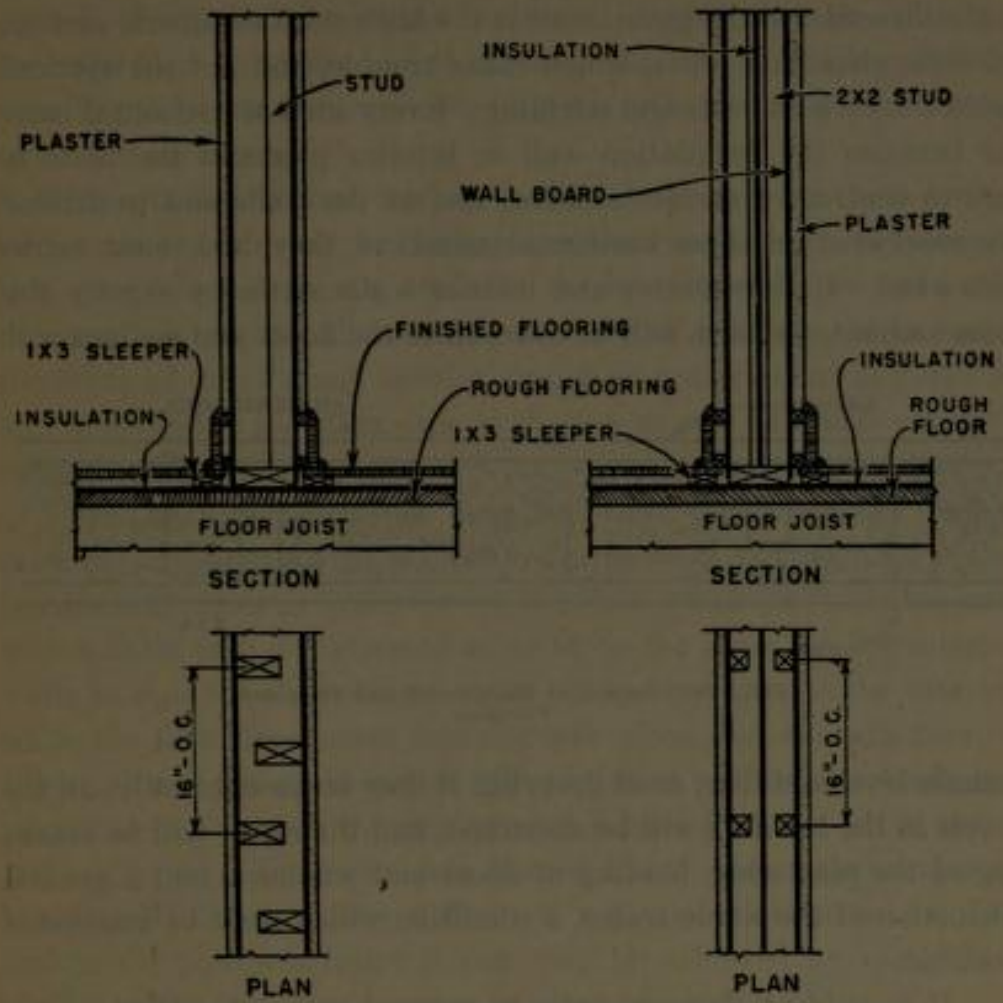


Fig. 178. Illustrating Use of Such Materials as Maftex in Partitions
Courtesy of National Gypsum Company

seldom obtainable except in greater thicknesses than are usually considered necessary and the cost is, as a rule, excessive. Fig. 178 shows in plan and section two ways in which the stiff board-like material is used in partitions and in floors.

Another method sometimes employed consists in staggering the studs, putting on the lathing and then filling the space between the studs solid full of a light porous fireproof material such as "Mineral Wool." Fig. 179 illustrates this method of sound proofing a partition.

SHRINKAGE AND SETTLEMENT

An important point which must be considered in connection with the framing of the walls and partitions, is the settlement due to the shrinkage of timber as it seasons after being put in place. Timber always shrinks considerably ACROSS the grain, but very little in the direction of the grain; so it is the horizontal members, such as the sills, girts, and joists, which cause trouble, and not the vertical members, such as posts and studding. Every inch of horizontal lumber between the foundation wall or interior pier and the plate is sure to contract a certain amount, and as the walls and partitions are supported on these horizontal members, they, too, must settle somewhat. If the exterior and interior walls settle by exactly the same amount, no harm will be done, since the floors and ceilings will

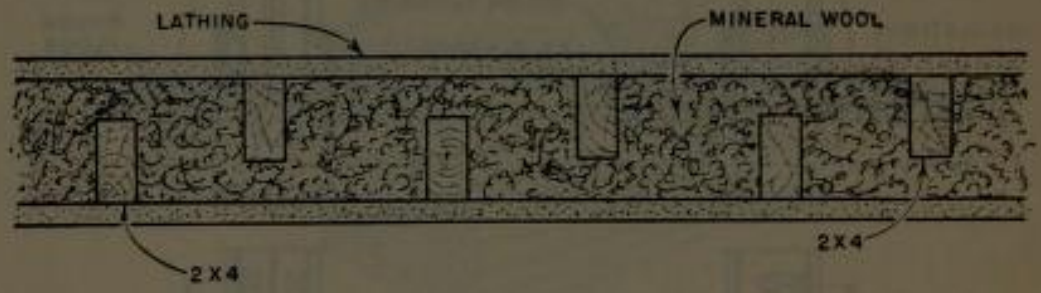


Fig. 179. Section of Soundproof and Fireproof Partition

remain level and true, as at first; but if they settle unequally, all the levels in the building will be disturbed, and the result will be cracking of the plastering, binding of doors and windows, and a general distortion of the whole frame, a condition which must be avoided if possible.

It is evident that one way to prevent unequal settlement, so far at least as it is due to the shrinkage of the timber, is to make the amount of horizontal lumber in the exterior and interior walls equal. Thus, in a full-braced frame, starting at the bottom, we have from the masonry of the foundation wall to the top of the first floor joists in the outside walls 10 inches, or the depth of the joists themselves, since these rest directly on the top of the wall. In the interior, we have, if the joints are framed flush into a girder of equal depth, the same amount, so that here the settlement will be equal. But the studding in the exterior wall rests, not on the top of the joists, but on the top of the 6-inch sill, while the interior studding rests on top of the 10-inch

girder. Here is an inequality of 4 inches which must be equalized before the second floor level is reached. If the outer ends of the second floor joists rest on the top of an 8-inch girt, and the inner ends on a 4-inch partition cap, this equalizes the horizontal lumber inside and outside, and the second floor is safe against settlement. The same process of equalization of the horizontal lumber may be continued for each floor up to the top of the building, and if this is carefully done it will go far toward preventing the evils resulting from settlement and shrinkage.

With a balloon frame this can not be done, because there are no girts in the outside wall, but only ledger boards which are so fastened that they can not shrink, while in the interior walls we have still the partition caps. All that can be done in this case, is to make the depth of the sills and interior girders as nearly equal as possible, and to make the partition caps as shallow as will be consistent with safety.

Fig. 180 shows how this equalization of the horizontal lumber may be accomplished in a balloon frame with a "box" sill. The horizontal lumber is indicated by the circles and its thickness can, with a little care, be adjusted so as to be the same for the interior walls as it is for the exterior walls. Thus we have for the exterior walls the first floor joists and the sole piece and the sub-floor, a thickness of perhaps 13 inches. The interior wall can be made approximately the same by employing a 4-inch partition plate and a 10-inch girder. In the modern braced frame, such equalization of horizontal lumber is very difficult if not impossible to accomplish and in the platform frame it can only be achieved by using steel girders in the first floor framing in place of wood.

FLOORS

After the wall, the next important part of the house frame to be considered is the floors, which are usually framed while the wall is being put up and before it is finished. They must be made not only strong enough to carry any load which may come upon them, but also stiff enough so that they will not vibrate when a person walks across the floor, as is the case in some cheaply-built houses. The floors are formed of girders and beams, or "joists," the girders being large, heavy timbers which support the lighter joists when it is impos-

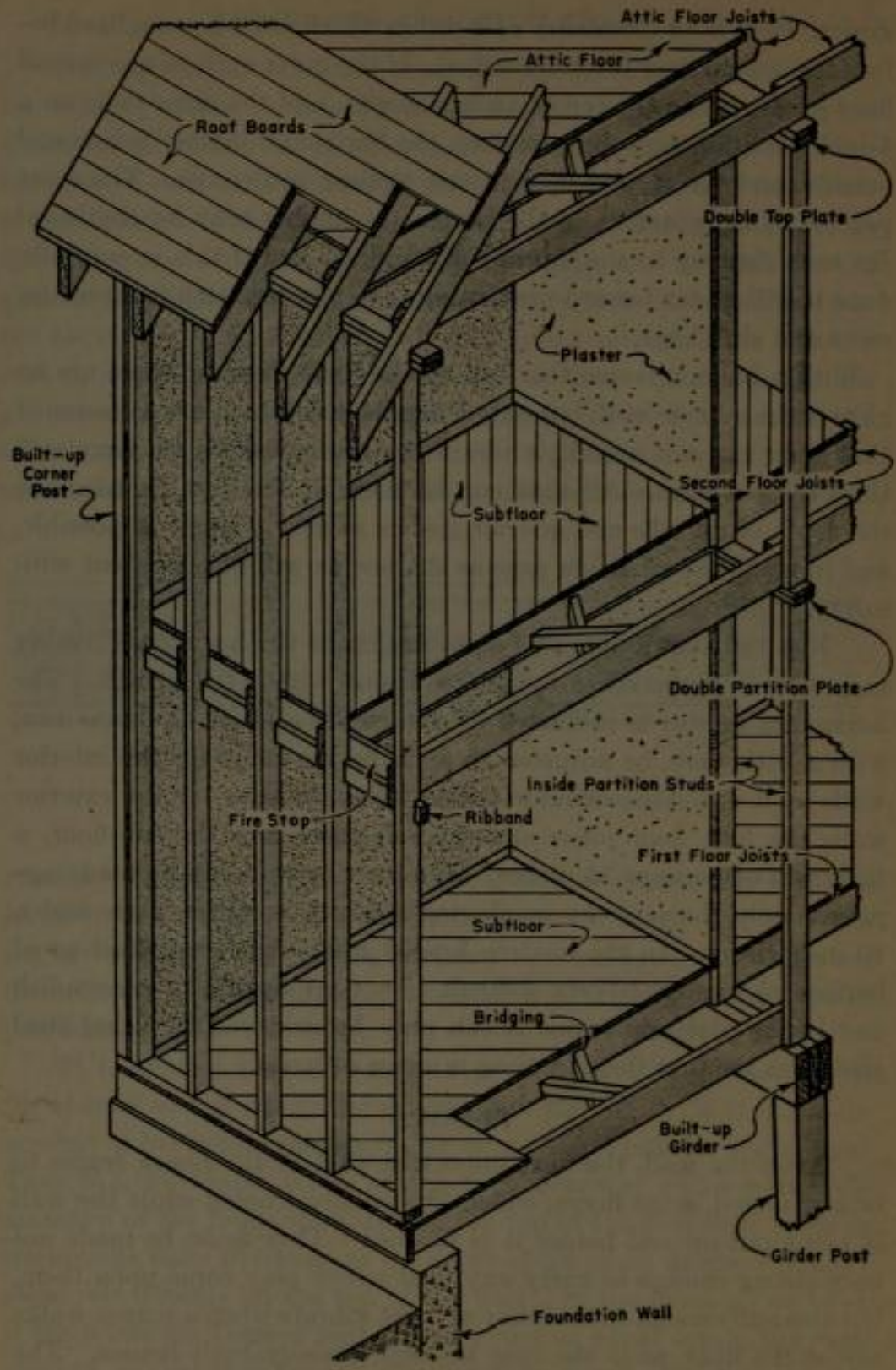


Fig. 180. Detail of Method for Securing Balanced Shrinkage

Courtesy of Weyerhaeuser Forest Products

sible to allow these to span the whole distance between the outside walls.

Girders. Girders are generally needed only in the first floor, since in all the other floors the inner ends of the joists may be supported by the partitions of the floor below. They are usually of wood, though it may sometimes be found economical to use steel beams in large buildings, and even in small buildings the use of steel for this purpose is increasing rapidly. However, when this is not found to be expedient, hard pine girders will answer very well. The girders may be of spruce or even of hemlock, but it is hard to

Fig. 181. Buckled Girder Showing Too Light Construction

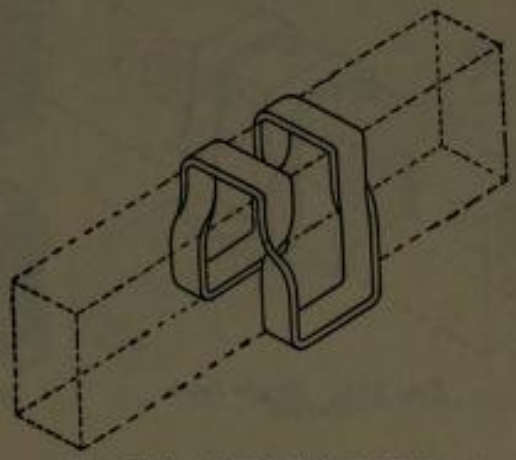


Fig. 182. Double Stirrup Joist Supporter

get the hemlock in such large sizes as would be required, and spruce, too, is hardly strong enough for the purpose. Southern pine, therefore, is usually employed for girders in the best work.

The size of the girder depends on the span, that is, the distance between the supporting walls, and upon the loads which the floor is expected to carry. In general, the size of a beam or girder varies directly as the square of the length of the span, so that if we have two spans, one of which is twice as great as the other, the girder for the longer span should be four times as strong as the girder for the smaller span. In ordinary houses, however, all the girders are made about 8 x 12 inches in section, although sometimes an 8 x 8-inch timber would suffice, and sometimes perhaps a 12-inch piece would be required.

It should be remembered in deciding upon the size of this piece, that any girder is increased in strength in direct proportion to the

width of the timber (that is, a girder 12 inches wide is twice as strong as one 6 inches wide), but in direct proportion also to the square of the depth (that is, a girder 12 inches deep is four times as strong as one 6 inches deep). Hence, the most economical girder is one which is deeper than it is wide, such as an 8 x 12-inch stick; and the width may be decreased by any amount so long as it is wide enough to provide sufficient stiffness, and the depth is sufficient to enable the piece to carry the load placed upon it. If

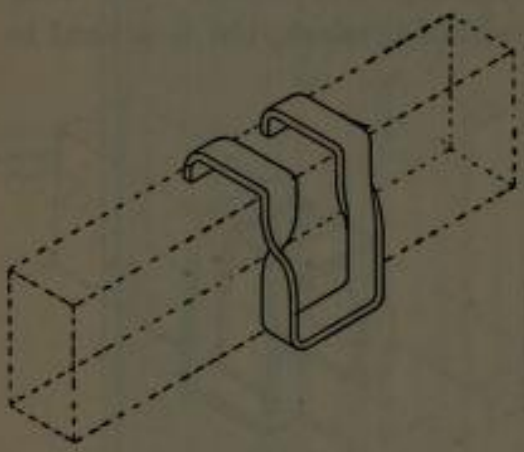


Fig. 183. Single Joist Hanger

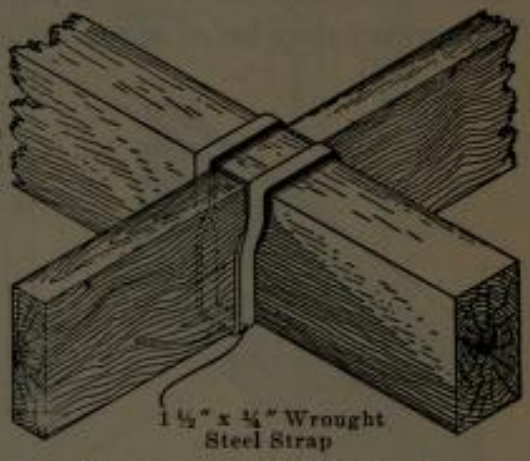


Fig. 184. Double Hanger with Joists in Place

the piece is made too narrow in proportion to its depth, however, it is likely to fail by "buckling," that is, it will bend as shown in Fig. 181. It has been found by experience that for safety the width should be at least equal to ⅙ of the depth.

Girders are often "built up" by placing two or more joists close together side by side and nailing them together as illustrated in Fig. 123, which shows a girder built up in a similar way. For girders composed of two joists, 10-penny nails should be used while those built up from three pieces will require 20-penny nails. The nails must be placed along the top and bottom edges spaced 24 inches apart and staggered and they should be driven alternately from both sides of the girder. About half way between the two ends of the girder, extra nails should be driven so as to make the nails in this portion of the stick come about 12 inches apart. When more than three joists are required for a built-up girder, the best way is to make a two-piece or three-piece girder as described above and then nail an extra joist on each side of it with 20-penny nails

spaced in the same way as for the thinner girders, but staggered with the other nails.

There are at least three ways in which the joists may be supported by a girder. The best, but most expensive method, is to support the ends of the joists in patent hangers or stirrup irons which connect with the girder. This method is the same as was described for the sill, except that with the girder a double stirrup iron, such as that shown in Fig. 182, may be used. These stirrup iron hangers

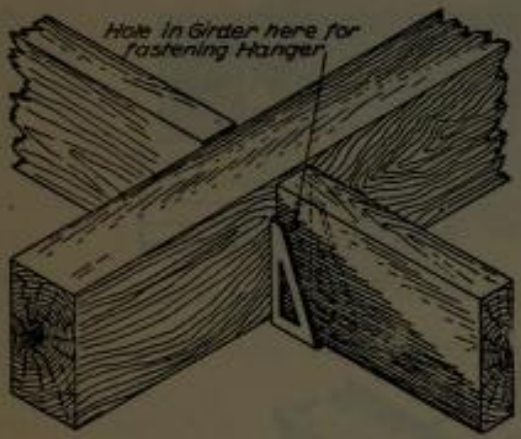


Fig. 185. Patent Hanger with Joists in Place

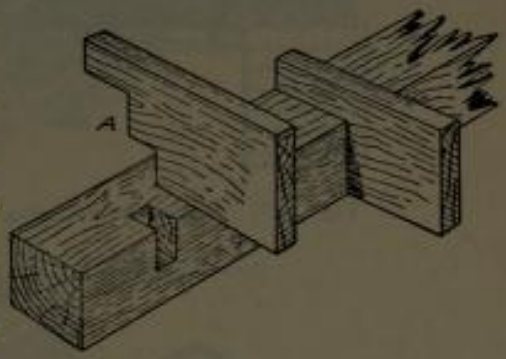


Fig. 186. Joists Framed into Sill

are made of steel, 1½ inches wide, and about ¼ inch thick, bent into the required shape. They usually fail by the crushing of the wood of the girders, especially when a single hanger, like that shown in Fig. 183, is used. Fig. 184 shows a double stirrup iron hanger in use. Patent hangers as shown in Fig. 185 are the most suitable.

If hangers of any kind are used, there will be no cutting of the girder except at the ends, where it frames into the sill, and even there a hanger may be used. The girder may be placed so that the joists will be flush with it on top, or so that it is flush with the sill on top. If the joists are flush with the girder on top, and are framed into the sill in the ordinary way, as shown in Fig. 186, the girder can not be flush on top with the sill; while, on the other hand, if the girder is flush with the sill on top, it can not at the same time be flush with the joists on top. If joist hangers are used on the girder to support the joists, they will probably be used on the sill as well, as explained in connection with the sill; and in this case the girder can be made

flush with the sill on top and the joists hung from both girder and sill with hangers, thus bringing both ends of a joist to the same level, as shown in Fig. 187. If the girder were framed into the sill at all, it would almost always be made flush with the sill on top, and by the proper adjustment of the hangers the joists would be arranged so as to be level.

For framing the girder into the sill, by the old-fashioned method, a tenon-and-tusk joint, as shown in Fig. 188, would be used if the

Fig. 187. Method of Bringing Joist Level When Resting on Sill

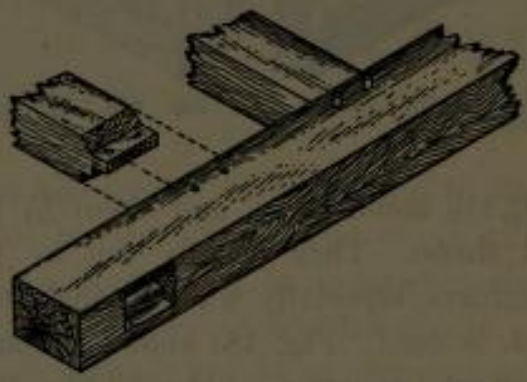


Fig. 188. Tenon-and-Tusk Joint between Sill and Girder

girder is to be flush with the sill on top. Since the girder would in most cases be deeper than the sill, the latter having a depth of only 6 inches, the wall would necessarily have to be cut away in order to make a place for the girder. This condition is clearly shown in Fig. 189. The girder itself should not be cut over the wall, as shown in Fig. 190, because this greatly weakens the girder.

The methods described above are not in common use today. For most ordinary buildings, the girders are built up out of two or more joists as described above and the sills are very often "box" sills. A more modern way of supporting floor joists on wooden girders

is illustrated in Fig. 191. Here, it will be seen, strips of 2 x 4-inch stuff called "ledger strips," as shown at *A A*, in the figure, are

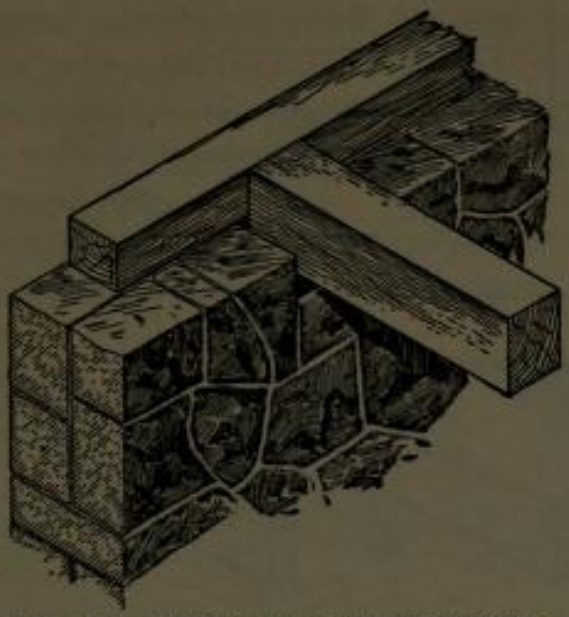


Fig. 189. Wall Cut Away to Allow Girder and Sill to Join at Same Level

Fig. 190. Cutting Girder Bad Practice on Account of Weakening Effect

secured to each side of the girder with 16-penny nails spaced 12 inches apart along both the top and the bottom edges of the strips and staggered. The joists are notched at the end to fit over and rest upon the ledger strip, and are toenailed to the girder and to the

ledger. For long joists carrying heavy loads, this method may not be sufficiently strong especially if the joists are flush on top with the girder. In this case the joists are liable to split at the point

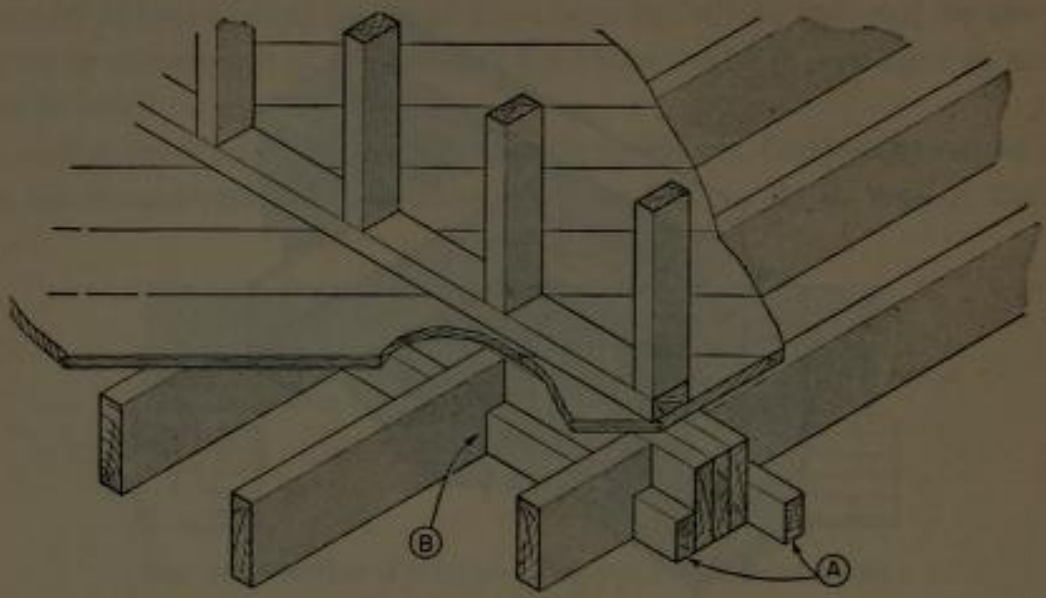


Fig. 191. Modern Manner of Supporting Floor Joists on Wood Girders

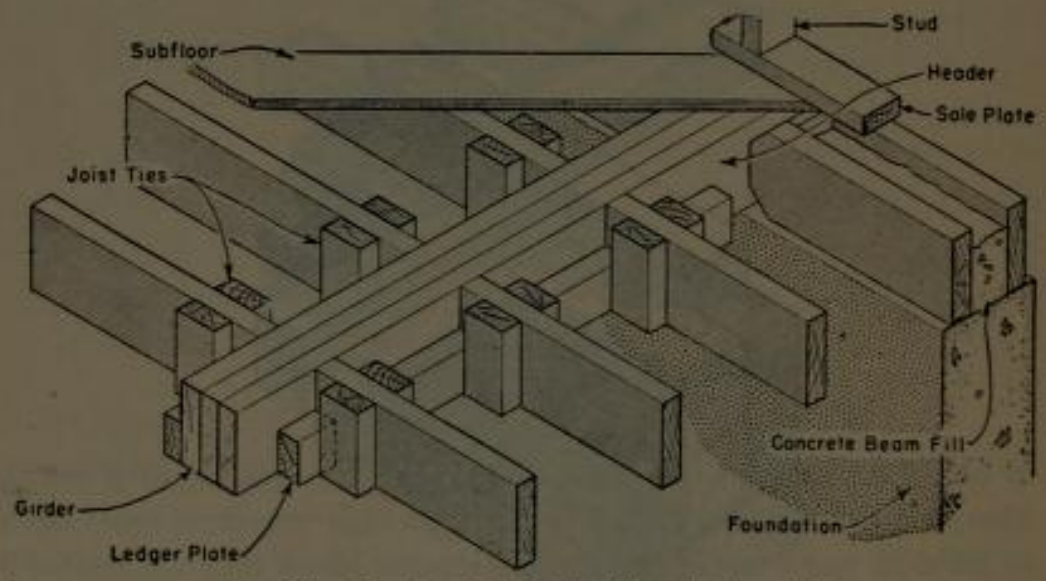


Fig. 192. Framing Joist Notched Over Ledger Strip
Courtesy of Weyerhaeuser Forest Products

marked *B* in Fig. 191, as shown in Fig. 195, and so they should be reinforced at these points by nailing a cleat of 1 by 4-inch stuff on each side of each joist. The cleats should reach from the top edge of the joist to the bottom edge and should be placed as close to the ledger as possible. Fig. 192 illustrates the use of such cleats.

Another method in common use is simply to "size down" the joists on the girder about 1 inch, as shown in Fig. 193. In this case, of course, the girder is much lower than the sill, usually so low that it cannot be framed into the sill at all, but must be supported by the walls independently. Holes are left in the wall where the girders come, the latter being run into the holes, and their ends resting directly on the wall, independent of the sill. This method is the one in most common use.

The girders serve to support the partitions as well as to support the floors, and should, therefore, be designed to come under

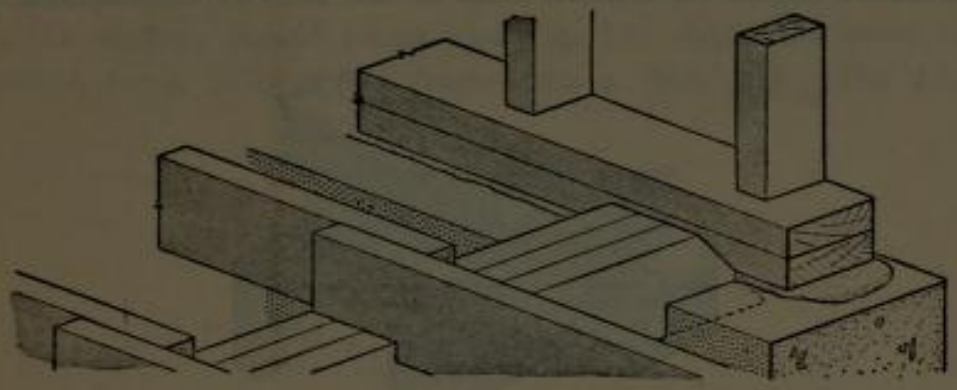


Fig. 193. Framing Joist on Top of Girder

the partitions whenever this is possible. When the distance between the outside walls is too great to be spanned by the girder, it is supported on brick piers or posts of hard wood or cast iron in the cellar. Such piers or posts should always be placed wherever girders running in different directions intersect. Girders are also often supported on brick cellar partitions.

Joists. Joists are the light pieces which make up the body of the floor frame and to which the flooring is nailed. They are almost always made of spruce, although other woods may be used, and may be found more economical in some localities. They are usually 2 or 3 inches thick, but the depth is varied to suit the conditions. Joists as small as 2 x 6 inches are sometimes used in very light buildings, but these are too small for any floor. They may sometimes be used for a ceiling where there are no rooms above, and, therefore, no weight on the floor. A very common size for joists is 2 x 8 inches, and these are probably large enough for any ordinary construction, but joists 2 x 10 inches make a stiffer floor. Occasionally joists as

large as 2 x 12 inches are used, especially in large city houses, and they make a very stiff floor, but tnis size is unusual. If a joist deeper than 12 inches is used, the thickness should be increased to 2½ or 3 inches, in order to prevent it from failing by buckling, as explained for girders. (See Fig. 181.) The size of the joists depends in general upon the span and the spacing.

The usual spacing is 16 or 20 inches between centers, and 16 inches makes a better spacing than 20 inches, because the joists can then be placed close against the studding in the outside walls and spiked to this studding. It is generally better to use light joists spaced 16 inches on centers than to use heavier ones spaced 20

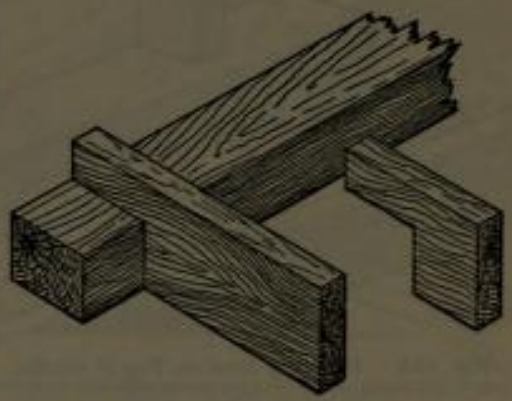


Fig. 194. Bad Method of Framing Joist to Sill

inches on centers. The spacing is seldom less than 16 inches and should never be more than 20 inches.

Joist Connection. *With Sill.* Joists were formerly "gained" into the sill, as shown in Fig. 128, in which case a mortise is cut in the sill and a corresponding tenon is cut in the end of the joist. The mortise was illustrated and described in connection with the sill, while the end of the joist is cut as shown in Fig. 128, the tenon being about 4 inches deep and gained into the sill about 2 inches. This brings the bottom of the joist flush with the bottom of the sill, and the top of the joist somewhat above the top of the sill, according to the depth of the joist. The top of a 10-inch joist would come 4 inches above the top of a 6-inch sill, and the joist would rest partly on the masonry wall, thus relieving the connection of a part of the stress due to the weight of the loaded joist. A common but very bad method of framing the joist to the sill is simply to "cut it over" the sill without mortising

the latter, as shown in Fig. 194. This does not make a strong connection even when the joist rests partly on the masonry wall; and if it is not so supported it is almost sure to fail by splitting, as shown in Fig. 195, under a very small loading. In fact, it would be much stronger if the joists were turned upside down.

In modern work, even with a braced frame, solid sills 6 x 6 inches or 6 x 8 inches are seldom used but instead a sill composed of two pieces of 2 x 6 inch stuff placed one on top of the other is employed or the sill is of the "box" type as shown in Fig. 123. With these sills the joists rest directly on top of the sill or on the sill-plate of the "box" sill. Fig. 124 shows how the joists connect to the sill in the modern braced frame and Fig. 125 shows the same connection for a balloon-type frame with a "box" sill. The 2-inch

Fig. 195. Crack in Joist Due to Bad Construction

header shown in Fig. 124 cut in between the joists at the inside edge of the sill is intended as a fire-stop to prevent the flames of a fire originating in the basement from spreading between the joists and up into the spaces between the wall studding. The bricks shown in Fig. 125 are for the same purpose.

With Girders. The framing of the joists into the girders may be accomplished in several ways, according to the position of the girder. The placing of the girder is quite an important point. The top of the floor, on which rest the sole-pieces of the cross-partitions, must remain always true and level, that is, the outside ends of the joists must be at the same level as the inside ends. Otherwise the doors in the cross-partitions will not fit their frames, and cannot be opened or shut and the plastering is almost sure to crack.

Both ends of the joists will sink somewhat, on account of the shrinkage of the lumber in seasoning, and the only way to make sure that the shrinkage at the two ends will be the same is to see that there is the same amount of horizontal lumber at each end between the top of the floor and the solid masonry. This is because timber

shrinks very much across the grain, but almost not at all along the grain. If the joists are framed properly into the sill, so that they are flush on the bottom with the sill, we have at the outer end of the joist a depth of horizontal lumber equal to the depth of the joist itself, as shown in Fig. 187; and in order to have the same depth of lumber at the inside, the bottom of the joist must be flush with the bottom of the girder, which usually rests on brick piers. Of course the top of the girder must not in any case come above the top of the floor joists; therefore, in general, the girder must be equal in depth to the floor joists and flush with these joists on top and

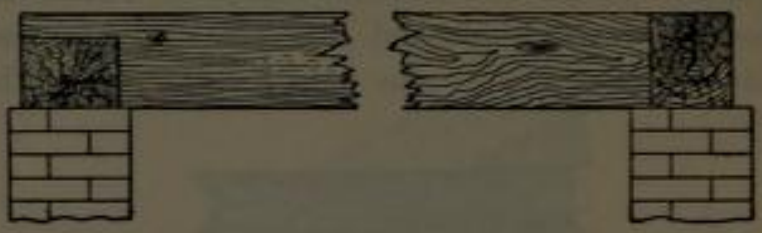


Fig. 196. Superior Floor Joist and Sill Construction

Fig. 197. Joist Sized Down on Girder

bottom, as shown in Fig. 196. This method is not always followed, however, in spite of its evident superiority; and the girder is often sunk below the tops of the floor joists, as shown in Fig. 197.

If the girder is sunk very much below the tops of the joists, as in Fig. 197, these will usually rest on the top of it and be fastened by spikes only, or will be "sized down" upon it about 1 inch, as shown. There is no mortising of the girder in either case. Joists are also thus sized down upon the girts and partition caps, and are notched over the ledger boards as shown in Fig. 138. In cutting the joists for sizing and notching, the measurements should be taken in every case from the top of the joists, since they may not be all of exactly the same depth, and the tops must be all on a level after they are in place. This is really the only reason why the joists should be

sized down at all, because otherwise they might simply rest upon the top of the girder, or girt, and be fastened by nailing.

All of these methods of framing are old-fashioned and are now seldom used as most girders are built up from several joists spiked together and connections are made to them with steel stirrups as shown in Fig. 198 or with ledger strips as shown in Fig. 192.

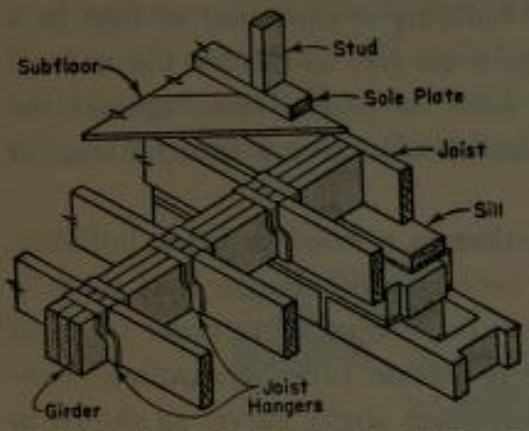


Fig. 198. Framing Joist Level with Top of Girder

Courtesy of Weyerhaeuser Forest Products

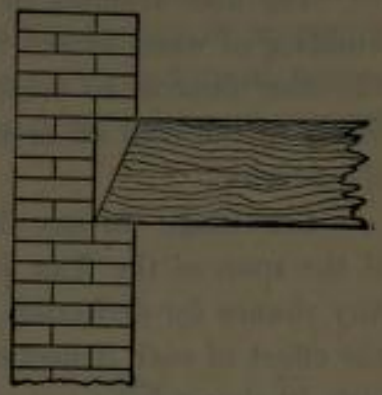


Fig. 199. Joist Supported by Brick Wall

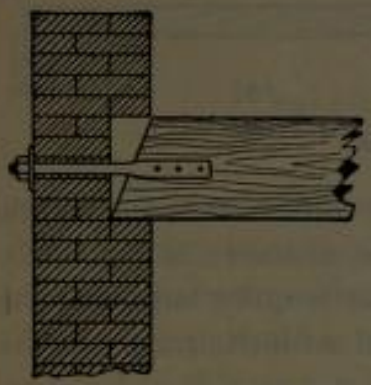


Fig. 200. Anchored Joist

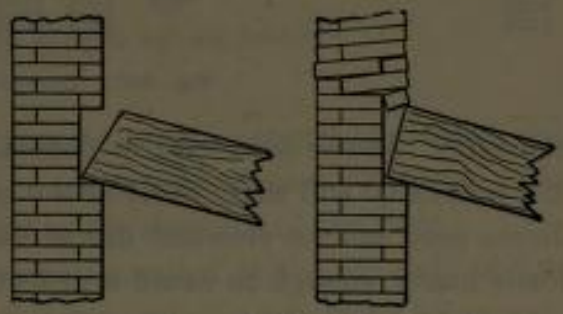


Fig. 201. Effect of Releasing Diagonal- and Square-Ended Joists

With Brick Wall. When a joist or girder is supported at either end on a brick wall, there will either be a hole left in the wall to receive it, or the wall will be corbeled out to form a seat for the beam. If the beam enters the wall the end should be cut as shown in Fig. 199, so that in case of the failure of the beam from overloading or from fire, it may fall out without injuring the wall. Every fifth or sixth joist is held in place by an anchor, as shown in Fig. 200, of which there are several kinds on the market. Fig. 201 shows the result when a beam which is cut off square on the end, falls out of the wall.

There must always be left around the end of a beam which is in the wall, a sufficient space to allow for proper ventilation to prevent dry rot, and the end should always be well painted to keep out the moisture. Patent wall-hangers and box anchors are often used to support the ends of joists in brick buildings, but only in case of heavy floors.

The floor framing in a brick building is the same as that in a building of wood except that there is no girt to receive the ends of the floor boards, so that a joist must be placed close against the inside of the wall all around the building to give a firm nailing for the flooring.

Crowning. In any floor, whether in a wood or brick building, if the span of the floor joists is very considerable so that there is any chance for deflection they must be "crowned" in order to offset the effect of such deflection. The operation called "crowning" consists in shaping the top of each joist to a slight curve, as shown in Fig. 202A, so that it is 1 inch or so higher in the middle than it is at

Fig. 202. Crowning Joist

the ends. As the joist sags or deflects, the top becomes level while the convexity will show itself in the bottom, as shown in Fig. 202B. Joists need not be crowned unless the span is quite large and the loads heavy enough to cause a deflection of an inch or more at the center of the joist.

Bridging. Floor frames are "bridged" in much the same way as was described for the walls, and for much the same purpose, namely, to stiffen the floor frame, to prevent unequal deflection of the joists and to enable an overloaded joist to get some assistance from the pieces on either side of it. Bridging is of two kinds, "plank bridging" and "cross bridging," of which the first has already been shown in connection with the partition supports. Plank bridging is not very effective for stiffening the floor, and cross bridging is always preferred. This bridging is somewhat like the diagonal bridging used in the walls, and consists of pieces of scantling, usually 1x3 inches or 2x3 inches in size, cut in diagonally between the

floor joists. Each piece is nailed to the top of one joist and to the bottom of the next; and two pieces which cross each other are set close together between the same two joists, forming a sort of St. Andrew's cross, whence we get the name "cross bridging" or "herring-bone bridging" as it is sometimes called. The arrangement is shown in Fig. 203, and the bridging should be placed in straight lines at intervals of 8 or 10 feet across the whole length of the floor. Each piece should be well nailed with two eightpenny or tenpenny nails in each end. If this is well done there will be formed a continuous truss across the whole length of the floor which will prevent

Fig. 203. Cross Bridging between Joists

any overloaded joist from sagging below the others, and which will greatly stiffen the whole floor so as to prevent any vibration. The bridging, however, adds nothing to the strength of the floor.

Bridging should in every case be nailed at the top only at first and left in this way with the lower end of each piece loose until after the under-flooring or rough flooring has been laid on top of the joists. Then, when the joists have adjusted themselves to their final position, the lower ends of the pieces of bridging should be nailed in place against the joists from underneath, thus completing this part of the job.

It takes considerable time to cut and fit the bridging and to nail each piece in place. With the object of reducing this labor, there has been placed on the market a type of bridging made out of steel in one piece which can be installed in a fraction of the time required for wood bridging. Fig. 204 illustrates this steel bridging. It is supplied in flat bundles of twenty-five pieces, in six sizes to suit

8-inch, 10-inch, and 12-inch joists and for 12-inch and 16-inch joist spacing.

Porch Floors. A word might be appropriately inserted at this point in regard to floors of piazzas and porches. These may be supported either on brick piers or on wood posts, but preferably on piers, as these are much more durable than posts. If piers are used, a sill, usually 4 x 6 inches in size, should be laid on the piers all around, and light girders should be inserted between the piers and the wall of the house, in order to divide the floor area into two or three panels. The joists may then be framed parallel to the

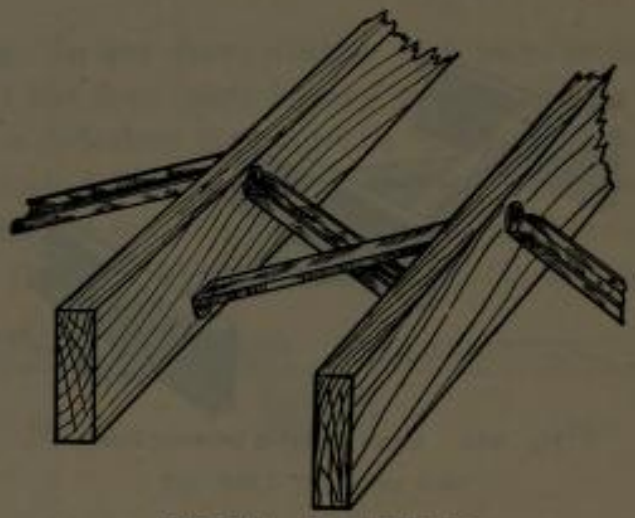


Fig. 204. Steel Bridging
Courtesy of The General Fireproofing Company

walls of the house, and the floor boards laid at right angles to these walls. The whole frame should be so constructed that it will pitch outward, away from the house at the rate of 1 inch in 5 or 6 feet, thus bringing the outside edge lower than the inside edge and giving an opportunity for the water to drain off.

Stairs. The stairs are built on frames called "stringers" or "carriages," which may be considered as a part of the floor framing. They consist of pieces of plank 2 to 3 inches thick and 12 or more inches wide, which are cut to form the steps of the stairs and which are then set up in place. There are usually three of these stringers under each flight of stairs, one at each side and a third in the center, and they are fastened at the bottom to the floor and at the top to the joists which form the stair well. Framing for open stairway is shown in Fig. 206.

Unsupported Corners. An interesting place in a floor framing plan is where we have a corner without any support beneath it, as at the corner *A* in Fig. 205. This corner must be supported from the three points *B*, *C*, and *D*, and the figure shows how this is accomplished. A piece of timber *E* is placed across from *B* to *C*, and another piece starts from *D* and rests on the piece *BC*, projecting beyond it to the corner *A*. This furnishes a sufficiently strong sup-

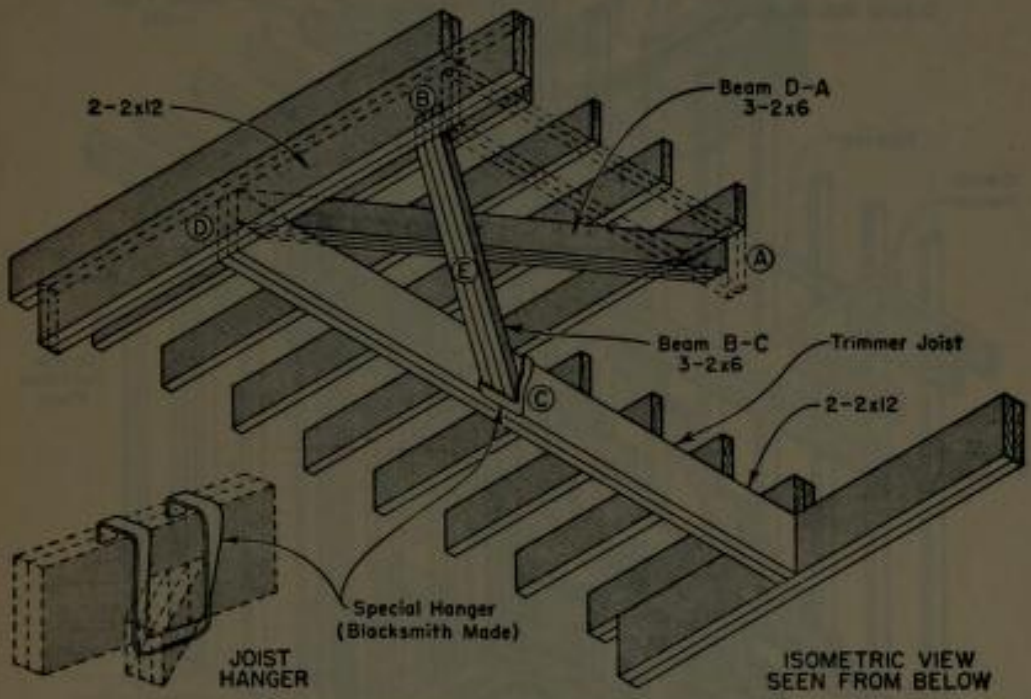


Fig. 205. Construction of Unsupported Corner

port for the corner. Fig. 206 shows a similar corner at an open stairway where the corner is supported by means of a post.

Supports and Partitions. In certain parts of the floor frame it may be necessary to double the joists or place two of them close together in order to support some very heavy concentrated load. This is the case whenever a partition runs parallel with the floor joists, unless there is another partition under it. Such partitions may be supported in several different ways. A very heavy joist, or two joists spiked together, may be placed under the partition, as shown at *A* in Fig. 207, *C* being the sole, *B* the under or rough flooring, and *DDD* the studding. This method is objectionable for two reasons: It is often found convenient to run pipes up in the partition, and if the single joist is placed directly under the partition,

this cannot be done except by cutting the joist and thus weakening it. Moreover, if the single joist is used, there is no solid nailing for the finished upper flooring, unless the joist is large enough to project beyond the partition studding on each side. The joist is seldom, if ever, large enough for this, and the finished flooring must, there-

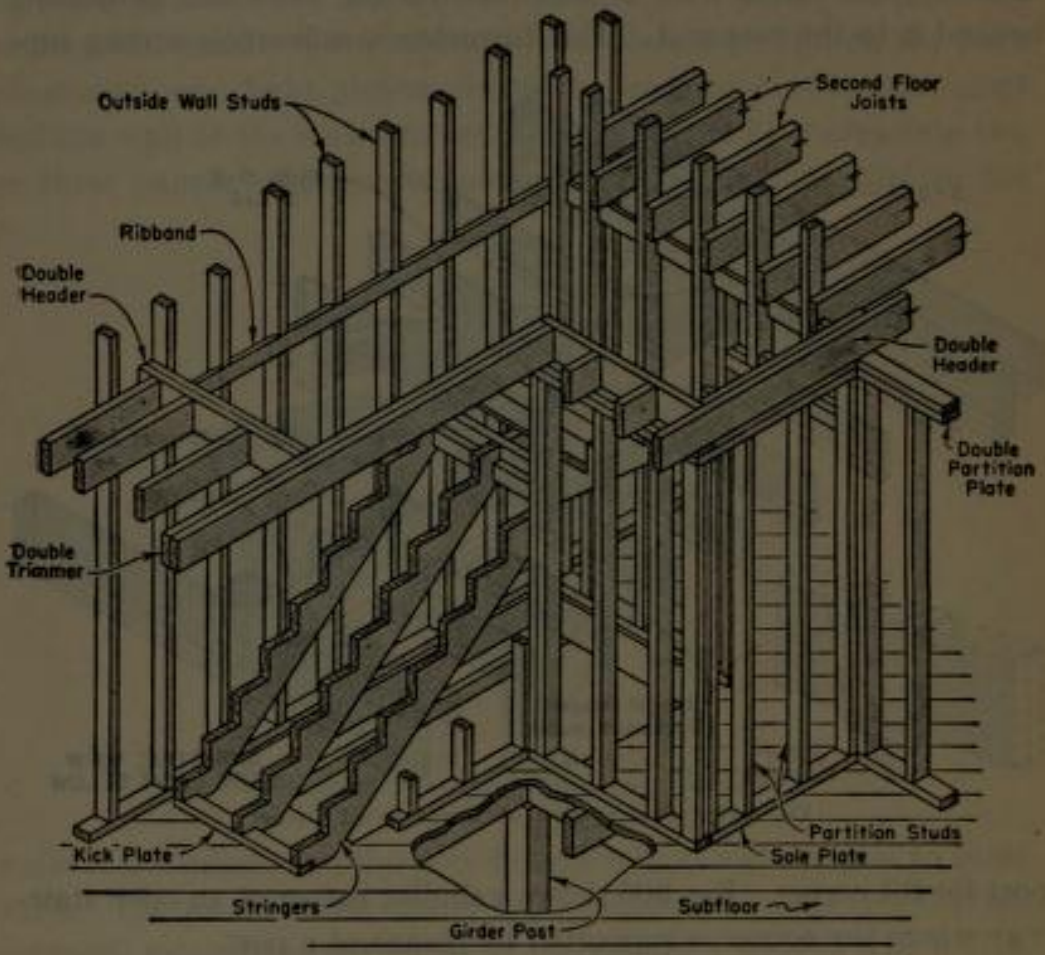


Fig. 206. Framing for Open Stairway
Courtesy of Weyerhaeuser Forest Products

fore, be nailed only to the under flooring at the end where it butts against the partition, so that a weak, insecure piece of work is the result. This may be seen by referring to the figure.

A much better way is to use two joists far enough apart to project a little on each side of the partition, as shown at *AA* in Fig. 208, and thus afford a nailing for the finished flooring. These joists must be large enough to support the weight of the partition without sagging any more than do the other joists of the floor, and, therefore, joists 3 or even 4 inches thick should be used. They should

be placed about 6 or 7 inches apart on centers, and plank bridging should be cut in between them at intervals of from 14 to 20 inches, as shown at *E* in Fig. 208, in order to stiffen them and make them act together. This plank bridging should be made of pieces of joist

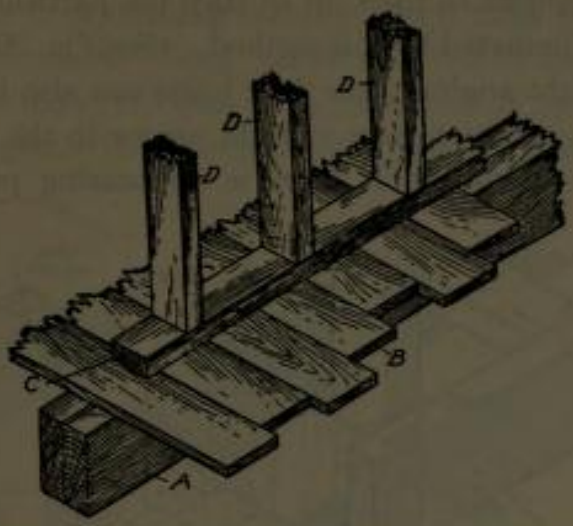


Fig. 207. Objectionable Construction for Partition Support

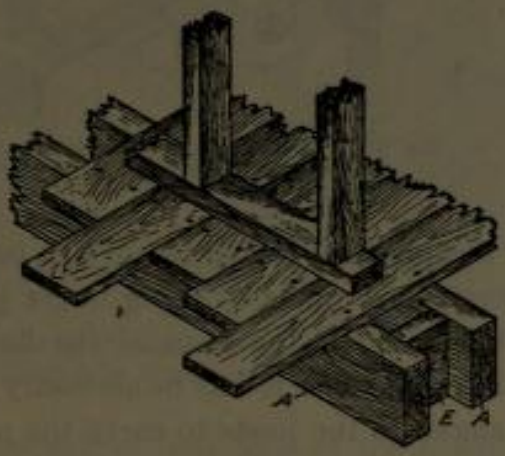


Fig. 208. Approved Construction for Partition Support

2 inches thick and of the same depth as the floor joists, and should be so placed that the grain will in every case be horizontal.

A partition, supported as just described, is bound to settle somewhat as the 10 or more inches of joist beneath it shrinks in seasoning, and the settlement may cause cracks in the plastering at the corner between the partition and an outside wall. In order to prevent this settlement, partitions running parallel with the floor joists are often supported on the Cap of a partition set directly

below. The first story partition is set up using a Cap (*C*) two inches wider than the studding, the bottom of the Cap being set flush with the bottom of the joists. This allows a nailing for the ceiling lath of the ceiling below on both sides. Blocks *BB* are cut between the joists and spiked to the Cap to stay the partitions. Shrinkage is practically eliminated by this method. (See Fig. 209.) Partitions which run at right angles to the floor joists can also be supported in this way. If a partition runs at right angles to the joists near the center of their span, and if there is no bearing partition below,

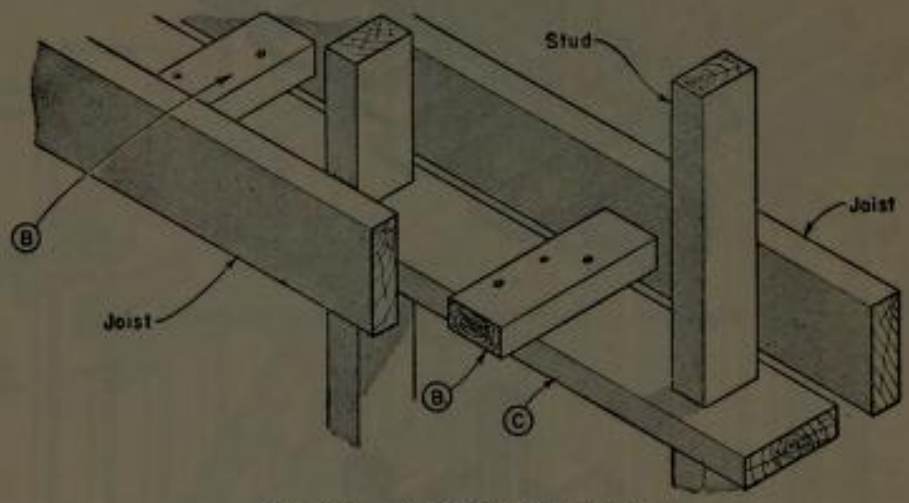


Fig. 209. Method of Framing to Eliminate Shrinkage

the tendency for the joists to sag under it will be very great, and they must be strengthened either by using larger joists, or by placing them closer together. If the span of the floor joists is large and the partition is a heavy one, it may be necessary to put in a girder running at right angles to the joists to carry the partition. In this case the partition stud will set directly on the girder, which may be a large timber, or in some cases, a steel I-beam.

Headers and Trimmers. Another case where a girder may be necessary in a floor above the first, is where an opening is to be left in the floor for a chimney or for a stair well. The timbers on each side of such an opening are called "trimmers," and must be made heavier than the ordinary joists; while a piece called a "header" must be framed in between them to receive the ends of the joists, as shown in Fig. 210. The trimmers may be made by simply doubling up the floor joists on each side of the opening, or, if necessary,

I-beams or heavy wood girders may be used. In most cases these trimmers may be built up by spiking together two or three joists, and the header may be made in the same way.

When the header has a greater length than 6 feet and where the width of the floor opening exceeds 3 feet, three joists should be used for the trimmers. Long headers, 3 feet 6 inches and over should be supported at the ends from the trimmers by means of steel stirrups or hangers. In all cases where headers and trimmers are

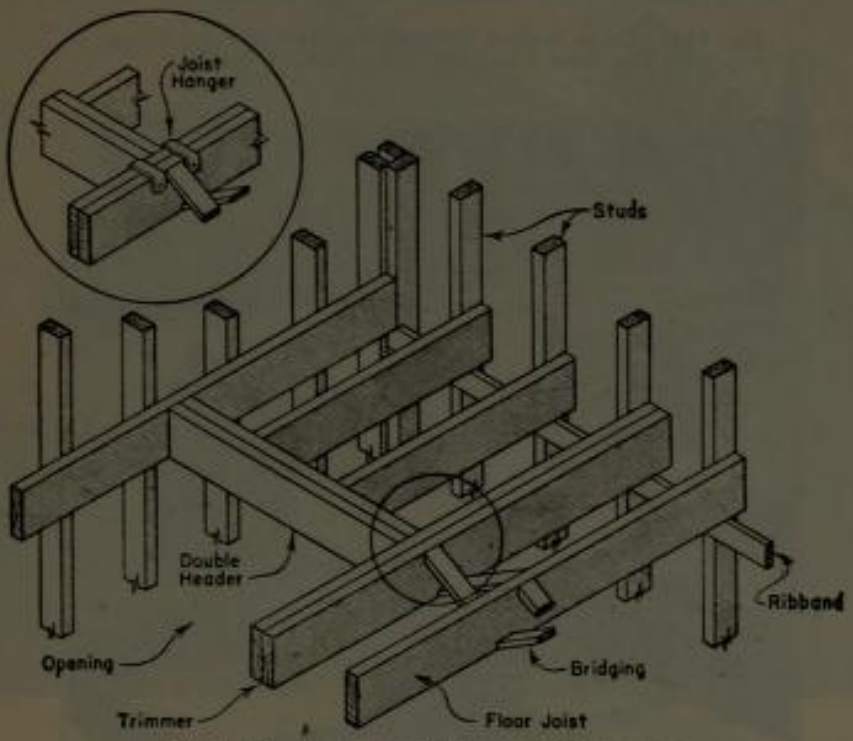


Fig. 210. Header and Trimmer Construction
Courtesy of Weyerhaeuser Forest Products

secured together by nailing, one joist of the header should first be nailed against the ends of all the floor joists supported by the header using 20-penny nails, three for small joists and four for large joists 10 inches or more deep. Then the second header joist should be nailed to the first one using 16-penny nails 16 inches apart along both edges. At each end of the header beam, one trimmer joist should first be nailed to the end of the header with six or eight 20-penny nails and then the other joists making up the trimmers should be nailed to the first trimmer joists using either 16-penny or 20-penny nails spaced 16 inches apart along both edges of the trimmers. Steel hangers may be used as shown in the circle in Fig. 210.

Wood Substitutes. Lately, a great deal of attention has been given to the manufacture and sale of substitutes for wood. These substitutes are generally known as wall boards and are produced not in the form of planks or boards of limited width but in sheets which may be as large as 8 feet wide by 12 feet long in a single piece

Fig. 211. Cross Section Through Gypsteel Gypsum Plank. In Partition Plank the Wire mesh Is Omitted

Fig. 212. Erection of Gypsteel Plant
Courtesy of Structural Gypsum Corporation

and may be of almost any thickness desired but usually are from ½ inch to 1 inch thick. The boards are, in many cases, manufactured from what were formerly considered to be waste products such as wood refuse from the saw-mills, sugar cane stalks, straw, and other vegetable matter from which has previously been extracted some other food or chemical product. The residue from the primary manufacturing process is treated chemically or crushed or ground into a sort of pulp and is then pressed into sheets with a suitable binder or glue to hold the material permanently together. Such wood substitutes can be sawed like wood, and nails can be driven

into them. Many of them will burn as lumber will, or even more readily, while others are chemically treated to render them fireproof and others again are made from fireproof materials such as asbestos or gypsum. Up to the present no successful attempts have been made to manufacture artificial lumber such as scantlings or planks or dimension timbers which could be used in the framework

Fig. 213. Use of Wallboard as Outside Sheathing
Courtesy of Gerber and Crossley, Inc.

of a building, although there is now available a product in the form of long planks of gypsum with metal flanges on the edges. See Figs. 211 and 212.

The so-called wall boards, however, have their own field of usefulness as a substitute for the usual outside boarding or sheathing on the walls and roofs of all types of frame buildings. The large size of the sheets and their comparatively light weight make the placing of this type of sheathing easy and cheap. Some doubt might be felt as to the strength of this form of construction but the various manufacturers have had tests made which seem to indicate that the boards tested have ample strength to prevent the frame from

being distorted by the winds. Figs. 213 and 214 illustrate the use of such wall board as outside sheathing.

In addition to their usefulness as outside sheathing, wall

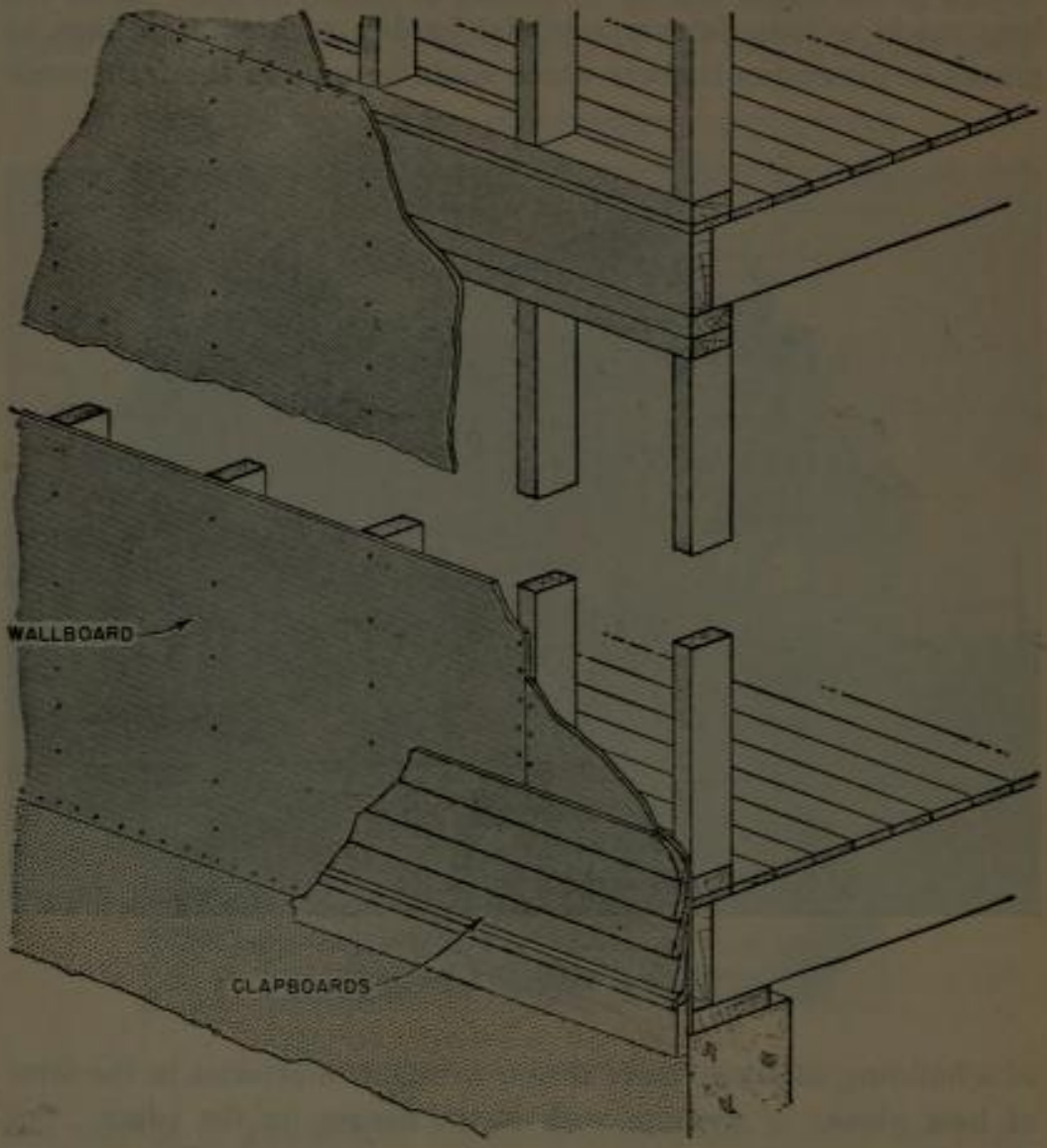


Fig. 214. Wallboard Used as Outside Sheathing
Courtesy of National Gypsum Company

boards are quite extensively utilized for covering the framing on the inside of the outside walls and both sides of interior partitions and for ceilings. In these locations the board takes the place of the more usual plaster finish. The joints between the large sheets of the material are covered by narrow strips of the same stuff or by strips of real wood which may be slightly beveled or moulded and

stained so as to produce a very pleasing appearance. A much better effect is obtained if the sheets are cut into such size that the joints will occur on the wall or ceiling with a certain amount of regularity so that the beveled-cover strips will form a sort of simple pattern on the wall or ceiling surface instead of coming at random in a haphazard manner. Some attention needs to be given to this when the framing for the walls and partitions is going up so as to provide nailing pieces cut in between the studding at the proper locations

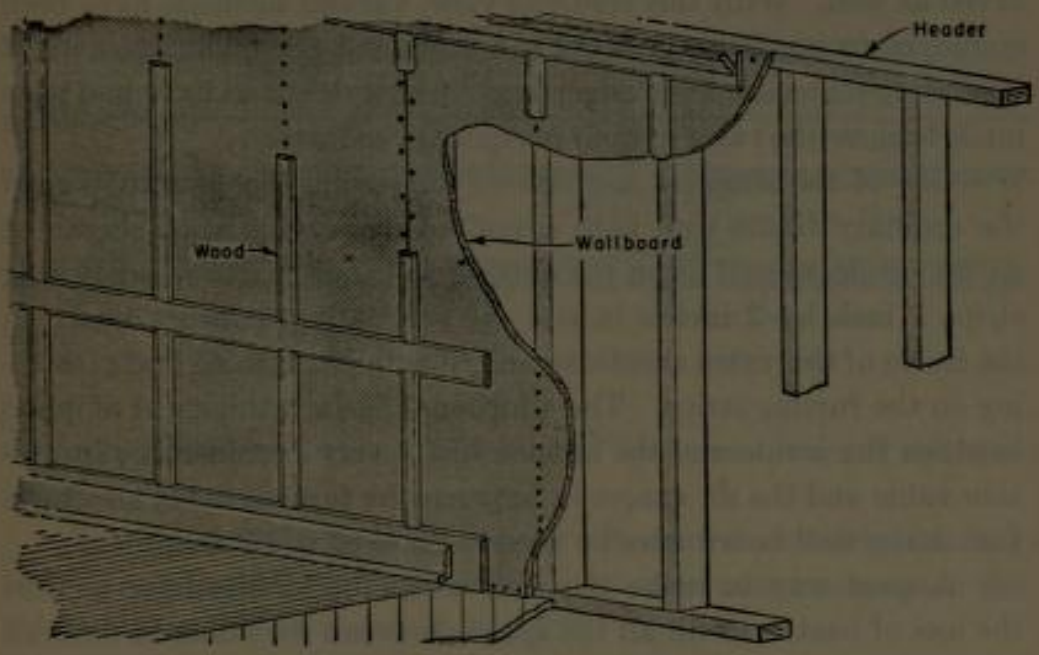


Fig. 215. Wallboard Applied to Interior Wall Studding with Wood Battens over the Joints

to receive the edges of the sheets of wall board and provide a firm nailing surface for them. Fig. 215 shows wall board applied to interior wall studding with wood battens over the joints in the board.

The substitutes for lumber above referred to find a further application in the case of a great variety of structures of a very temporary character such as stage scenery or triumphal arches for processions or buildings for fairs, band expositions, and for such purposes they can often be exposed to the weather for some time with satisfactory results. The more durable types, such as asbestos board, are frequently used on the outside of buildings as a permanent substitute for other forms of exterior finish, such as wood siding or stucco, and are quite satisfactory, being especially applicable where a half-timber effect is desired.

Insulation. In recent years much attention has been given by various authorities to the question of constructing buildings and particularly frame houses in such a way that they will be easier to heat in winter than they formerly were. The theory is that when a building is once heated this heat leaks out in all directions through the outside walls and roof and that if these walls and roofs can be constructed in such a way as to make the passage of heat through them relatively difficult then the heat will be saved and fuel will be saved as well. With this result in view, various methods have been employed to insulate the walls and roofs and the manufacturers of insulating materials have advertised them widely and have had tests made to show the value of their particular products.

One of the simplest methods of improving the construction of the ordinary frame wall is to cover the studs with wood sheathing on the inside as well as on the outside and then to put wood furring strips 1 inch by 2 inches in size set vertically 16 inches apart on the inside of this extra sheathing and then to put lathing and plastering on the furring strips. The additional ⅞-inch thickness of wood between the inside and the outside has a very considerable insulation value and the air spaces in between the furring strips also help. Insulating wall board may be used in place of wood sheathing.

A good way to make the wall a still better insulator against the loss of heat is to fill all the spaces between the studs in the wall and the rafters in the roof full of substance such as mineral wool. There are a number of other substances manufactured and sold which are suitable for this purpose. These materials depend for their insulating properties upon the immense number of very small air cells which they contain on account of their loose flaky or powder-like structure. One trouble with materials of this kind is that in pouring them into the hollow spaces in the walls they are apt to settle or shrink away from around the edges of openings for doors and windows leaving hollow spaces at the jambs and under the sills of such openings and these must be protected by the careful and liberal use of good building paper or some form of "quilt" such as was described in connection with "sound-proofing." There is a material of a flaky nature which is advertised and sold in conjunction with a method of application which consists in spraying or shooting the insulating substance against the studs and outside boarding from the inside, filling the

spaces between the studs to any degree desired and filling up all the little openings to the outside air before the inside lath and plaster are put on. Other manufacturers have assembled the rock wool into bundles called "bats" which are squeezed into the spaces between the outside wall studs.

The various quilt-like materials are also used for insulating the hollow spaces between the studs, being laid up against the inside surface of the outside boarding and folded around against the sides

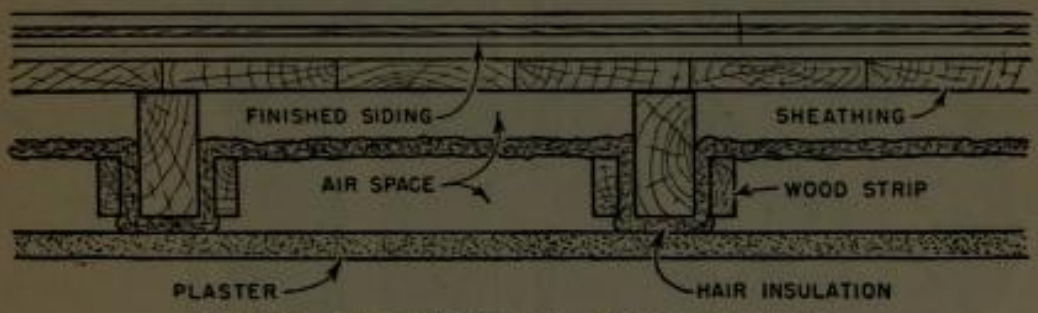


Fig. 216. Plan of Exterior Wall Frame Construction

of the studs to which the quilt is secured by means of wood cleats as shown in Fig. 216.

Sometimes it is placed against the outside of the outside boarding before the shingles or siding are put on so as to come underneath the shingles or siding as shown in Fig. 216.

Another method of insulating walls and roofs is to use an insulating board, similar to those described in connection with sound-proofing, on the inside of the wall studding, or on the under side of the rafters, in place of the usual lathing. These boards are made with a surface which will take and hold plaster just as lathing will and are known as "insulating lath" being furnished in sheets 18 inches wide and 4 feet long and about ½ inch thick. This method of insulation is somewhat like the one first described but has the advantage that no furring and lathing is required while the insulating value should be about the same. Fig. 217 shows an insulating board used in this way.

Forms for Foundation Walls. Before the advent of Portland cement concrete into the building field, the footings and foundation walls for buildings were always built by a mason using stone or brick and mortar so that the carpenter had nothing to do with

this part of the work. The enormous development in the manufacture and sale of cement which has taken place since the beginning

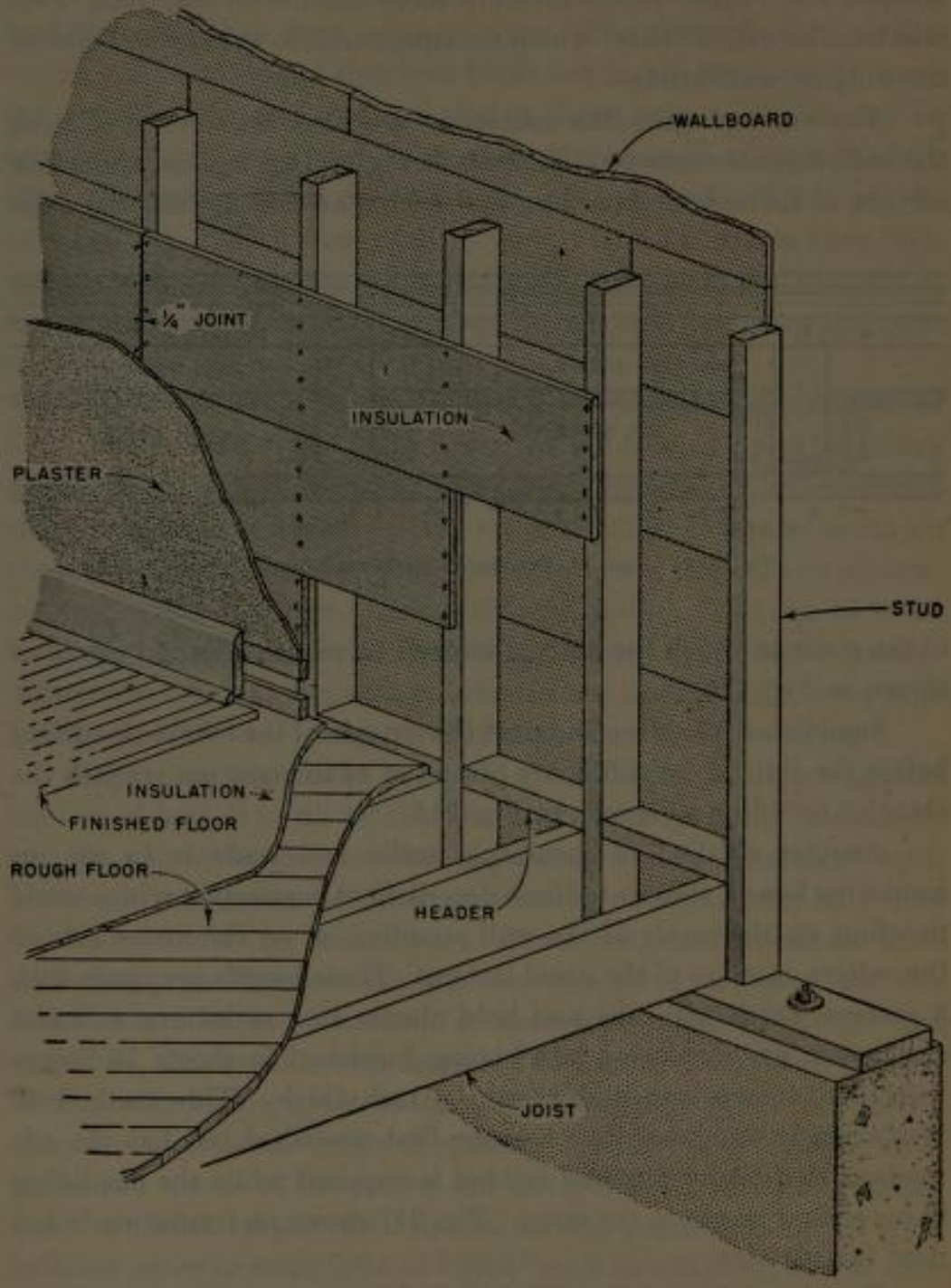


Fig. 217. Insulating Board Used as Plaster Base
Courtesy of National Gypsum Company

of the present century has, however, made the cost of cement so low that foundation walls and footings are now almost invariably con-

structed of concrete, which means that wooden forms must be built by the carpenters before the concrete for these walls can be poured.

If the soil is of such a kind that the sides of the excavation for the cellar will stand long enough for the concrete to be poured and to become set, then the earth bank itself can be utilized for the out-

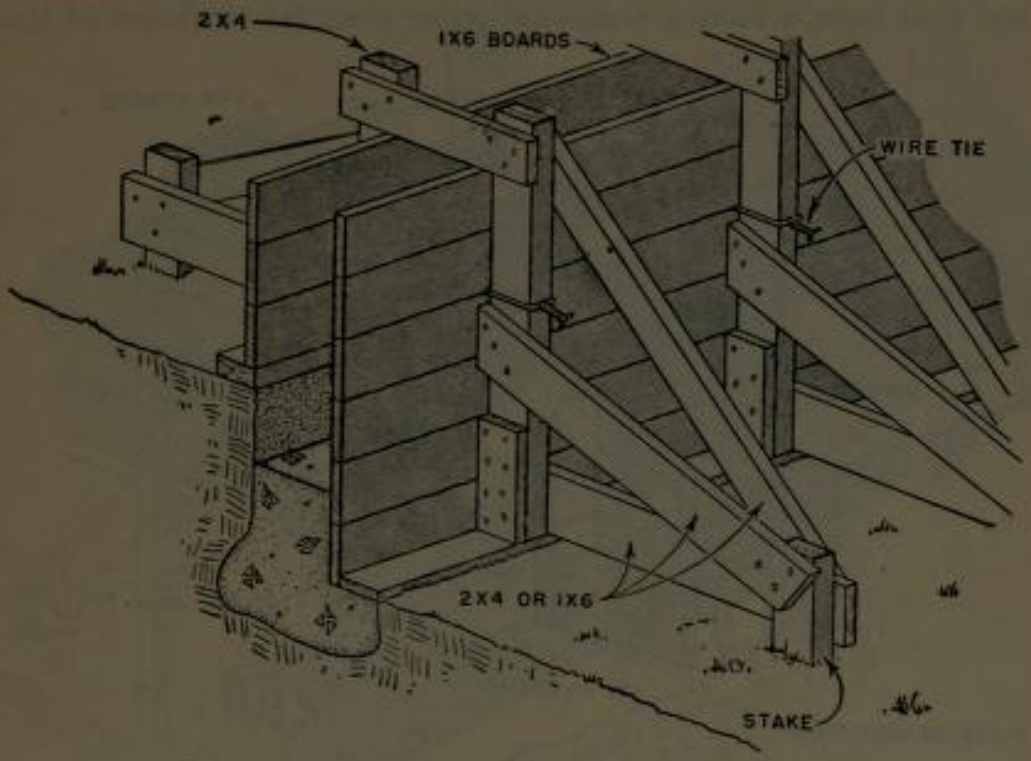


Fig. 218. A Wall Form for Foundation Walls and Cellar Walls Built in Firm Ground, in Which the Earth Side of the Excavation Will Stand Upright

Courtesy of Universal-Atlas Cement Company

side form and it will only be necessary to build the form for the inside of the basement wall as shown in Fig. 218.

If the earth is dry, however, it may take moisture from the wet concrete with the result that the concrete when it sets will be porous, while if the earth is wet and muddy the mud will sometimes mix with the concrete and weaken it, so that often specifications will not permit this method of forming basement walls but insist upon the construction of wood forms for the outside face of the wall as well. This method is illustrated in Fig. 219.

It is not customary to make wood forms for the footings unless they are in sand or gravel or unless the earth is very soft and wet. After the excavation for the cellar has been completed and the bottom

roughly leveled off, a shallow trench just the depth of the footing is dug all around against the bank, as shown in Fig. 219, and the wall forms are then constructed, set up on blocks above the level of the bottom of the trench so that the concrete when poured into the forms will be forced out under the forms at each side, as shown in Fig. 220, and thus form a footing somewhat wider than the thickness of the

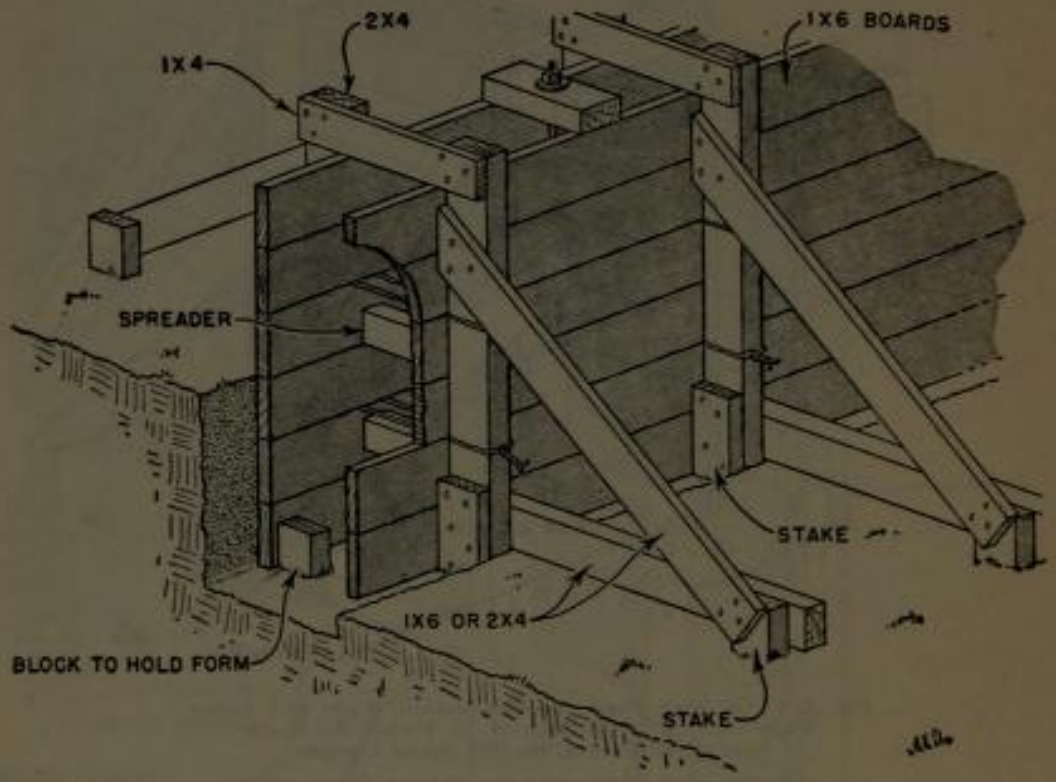


Fig. 219. Form for Foundation and Cellar Wall Located in Ground Which Is Not Firm—in Which Case Both Inside and Outside Forms Are Necessary

Courtesy of Universal-Atlas Cement Company

foundation wall above it, which is as it should be. Of course, if the earth bank is being used as the form for the outside of the wall, this extra width for the footing can be obtained on the inside only, the outside faces of the footing and wall being flush, unless it is possible to hollow out a place for the footing along the bottom of the earth bank as shown in Fig. 218.

Green lumber should not be used for forms because the exposure to the air and sun often causes the boards to shrink and the joints to open which allows part of the wet concrete to run out, leaving the larger stone or gravel in a porous state. One of the most important

requirements is that forms must be built so as to remain tight. If the lumber is too well-seasoned, it will swell when the wet concrete is placed against it and then the wall will not be straight. The lumber should not be too soft nor should it have many defects such as large loose knots or knot holes and shakes. Hemlock Spruce or Fir is often

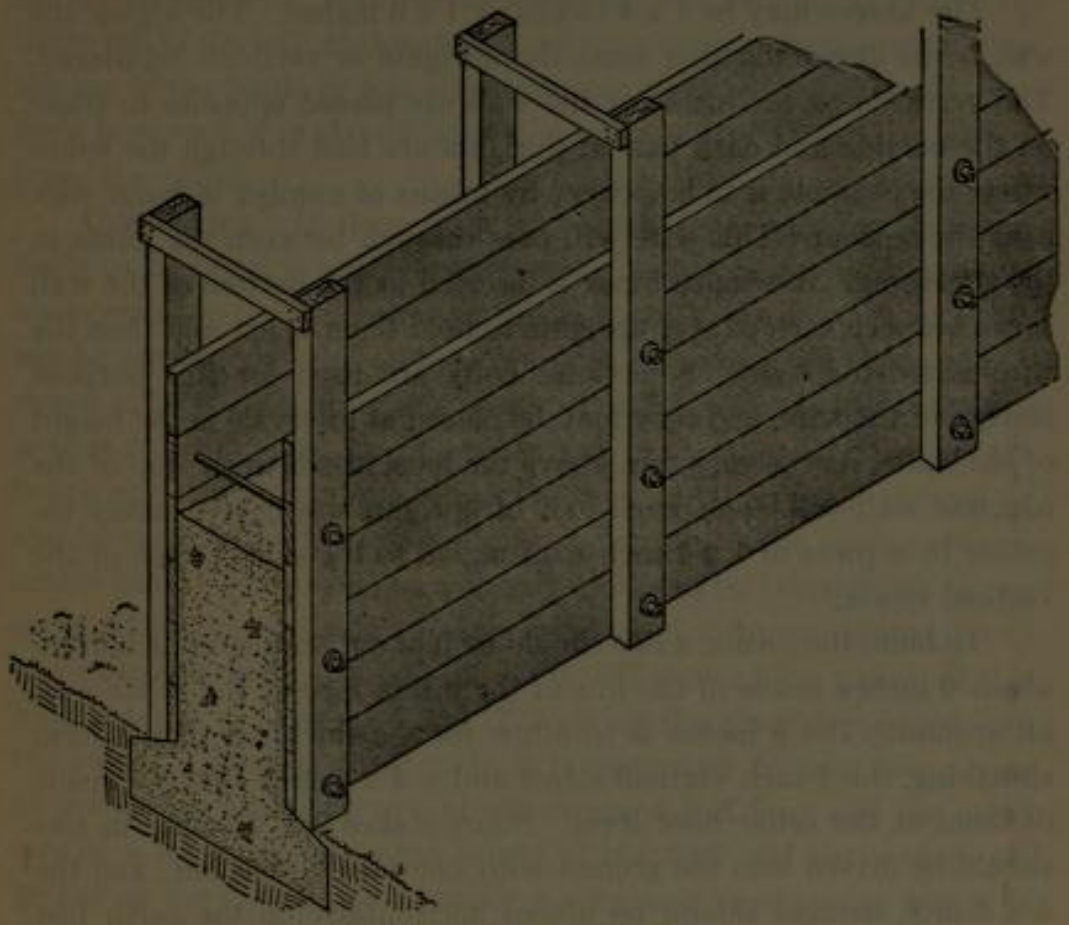


Fig. 220. Typical Forms for Wall

used as is also Yellow Pine but White Pine is generally considered to be too soft and to lack the necessary strength and is usually too expensive. Often the kind of material to be used and the sizes of the pieces are determined by the fact that much of this lumber can be carefully removed and cleaned after the concrete has set and then used again in the framework of the building, therefore, the sizes which will be most useful for this purpose are selected.

With this further use of the lumber in view, it is usual to employ $\frac{7}{8}$-inch thick boards from 8 to 10 inches wide dressed on one side and to place the boards so that the smooth face will come in contact

with the concrete when it is poured. It is best to use tongued and grooved boards as this makes the forms more liable to remain tight. The vertical cleats are commonly made of 2 x 4-inch scantlings and, as comparatively thin boards have been used for the sheathing, these verticals are spaced from 16 to 24 inches apart on centers.

The braces may be 1 x 4 inches or 1 x 6 inches. The higher the wall is the closer together must the uprights or verticals be placed. The verticals on the inside of the wall are placed opposite to those on the outside and each pair of uprights are tied through the space where the concrete is to be poured by means of number 9-gauge wire near the bottom. This wire will pass through between the joints in the sheathing. A wooden block is inserted at the bottom of the wall space between each pair of uprights to hold them apart and then the wire is twisted tight. Sometimes bolts are used for this purpose instead of the wire, and they may be placed at intervals in the height of the wall. At the very top, above the level at which the top of the concrete wall will come, each pair of uprights are held securely together by a piece of 1 x 4-inch stuff nailed to the side of each of the vertical cleats.

To build the forms, a line should be laid out on the cellar bottom about 9 inches inside of the line of the inside face of the cellar wall all around. The 9 inches is to allow for the thickness of the form sheathing, the 4-inch vertical cleats and a 4 x 4-inch stringer inside of them at the cellar floor level. Short stakes 2 x 4 inches in size should be driven into the ground with one face at the line, and the 4 x 4-inch stringer should be placed horizontally on the earth just between the stakes and the wall and nailed to the stakes. The inside face of this stringer will then be on a line with the outside edge of the vertical cleats. Two of the vertical cleats for the inside of the wall should now be set up, spaced about 14 feet apart and held together at the top by another horizontal stringer which may be of 2 x 4-inch scantling.

Stakes should be driven into the ground some 3 or 4 feet inside of each of the uprights and diagonal braces 1 x 6 inches nailed to the stakes and to the sides of the uprights near the top so as to hold them plumb. The other vertical cleats can now be put in place at the proper spacing and lined up with the two which were erected first, and the boarding nailed in place against the edge which will be next

to the wall, to the height of 1 foot or 2 feet at the bottom of the wall. We now have the line of the inside face of the wall definitely established. The vertical cleats for the form for the outside face of the wall can be set up and braced and tied to the uprights on the inside of the wall, and the outside sheathing completed right up to the top of the wall. The inside sheathing can also be completed up to the top of the wall at this time if the concrete is to be poured in from the top of the bank, or this sheathing can be put in place as the concrete is poured if it should be decided to mix and place the concrete from the cellar.

Unit Forms. If there is much of this formwork for basement walls to be done, it will sometimes pay better to prepare panels of a size equal to the full height of the wall and about 4 feet long which can be put together flat on the ground or on a bench and then can be raised into position all in one piece. The labor of making the forms is thus reduced since it is easier to put the lumber together on the bench and this work can be carried out under cover if desired or can be done while the excavation is being dug, thus saving considerable time. Moreover, these form panels can be taken down in one piece, after the concrete has set, and stored away in a yard ready to be used again on the next job. Fig. 221 shows form panels of this kind erected in place and Fig. 222 shows the concrete poured into the forms. To make these units, it is customary to take four pieces of 2 x 4-inch scantling two of which are 4 feet long and the other two of a length equal to the height of the wall and halve them together at the ends so as to make a square or rectangular frame as shown in Fig. 223. Another piece of 2 x 4-inch stuff is fitted into the middle of this frame, as shown, so as to stiffen it and then one side of the frame is covered with 1-inch thick boards about 6 inches wide well nailed to the framework. Sometimes these panels are made up in standard sizes exactly 4 feet wide by 4 feet high and others made exactly 4 feet wide by 2 feet high as shown in Fig. 224. These two panels are placed one on top of the other if required to make a form 6 feet high. The thickness of the panels is 5 inches, made up of 4 inches for the framework and 1 inch for the boarding. This boarding should be dressed on the side which is to be next to the concrete and should therefore be taken out of $1\frac{1}{8}$-inch stuff dressed down to 1 inch.

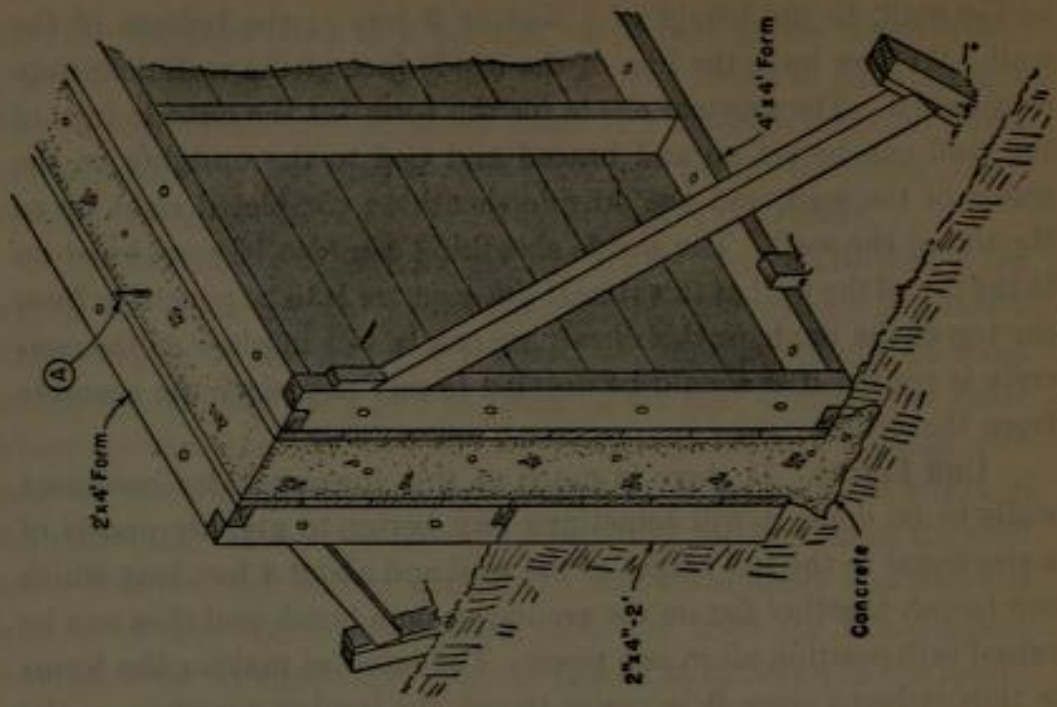


Fig. 232.

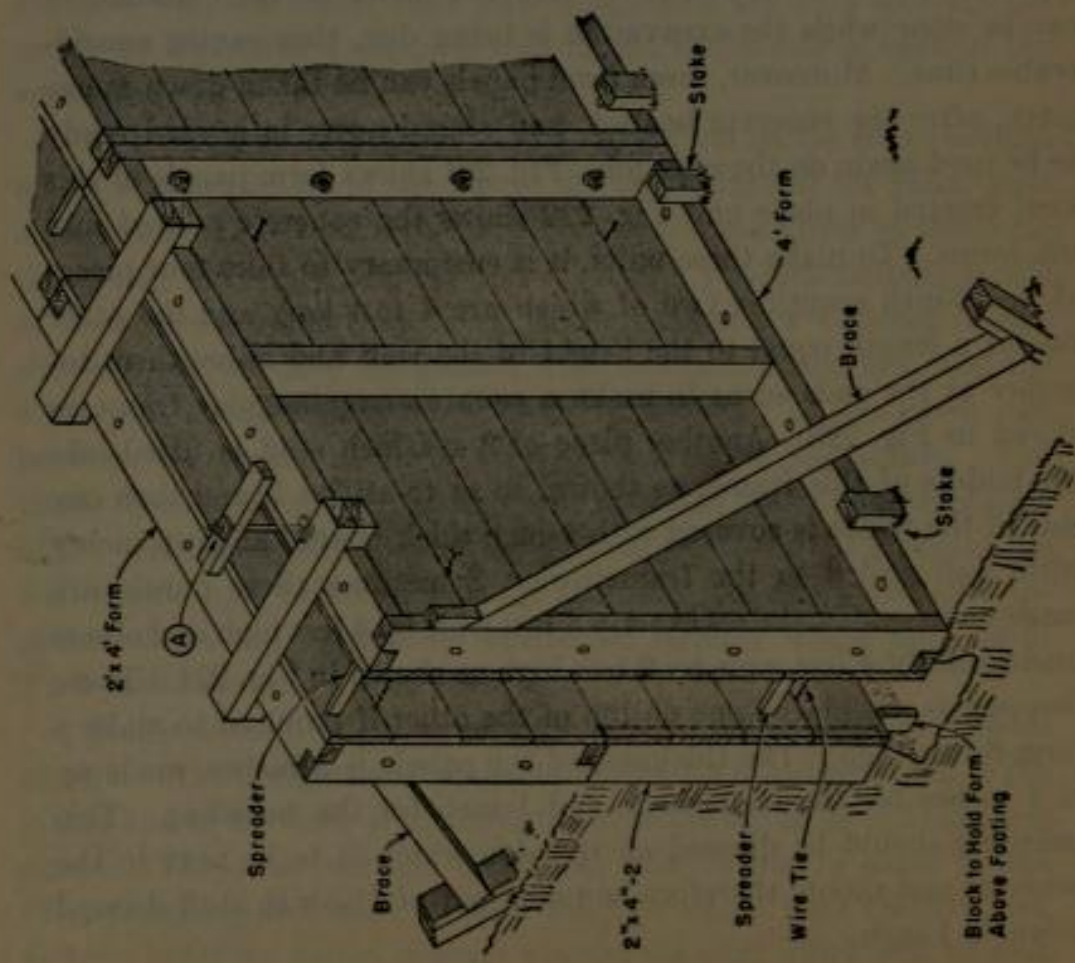


Fig. 231. Detail of Wall Forms

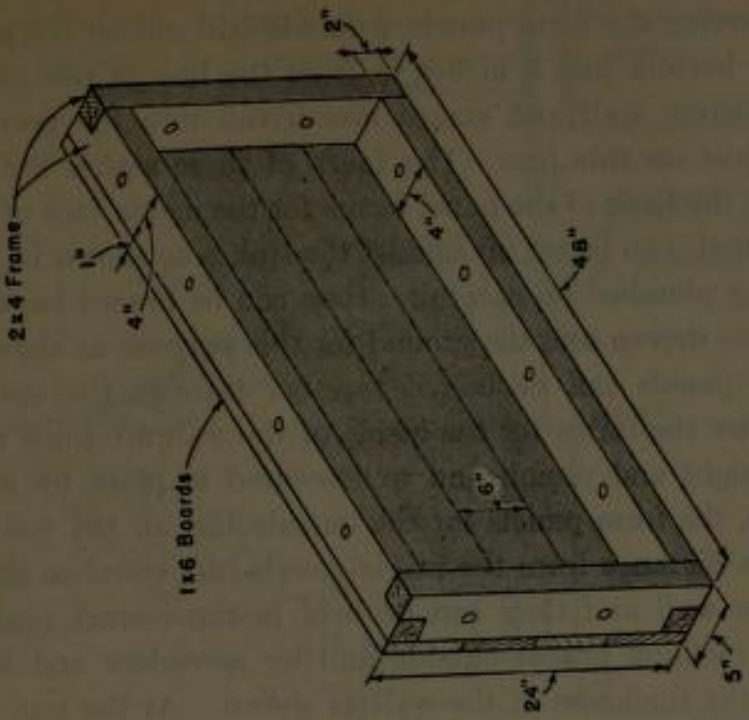


Fig. 224.

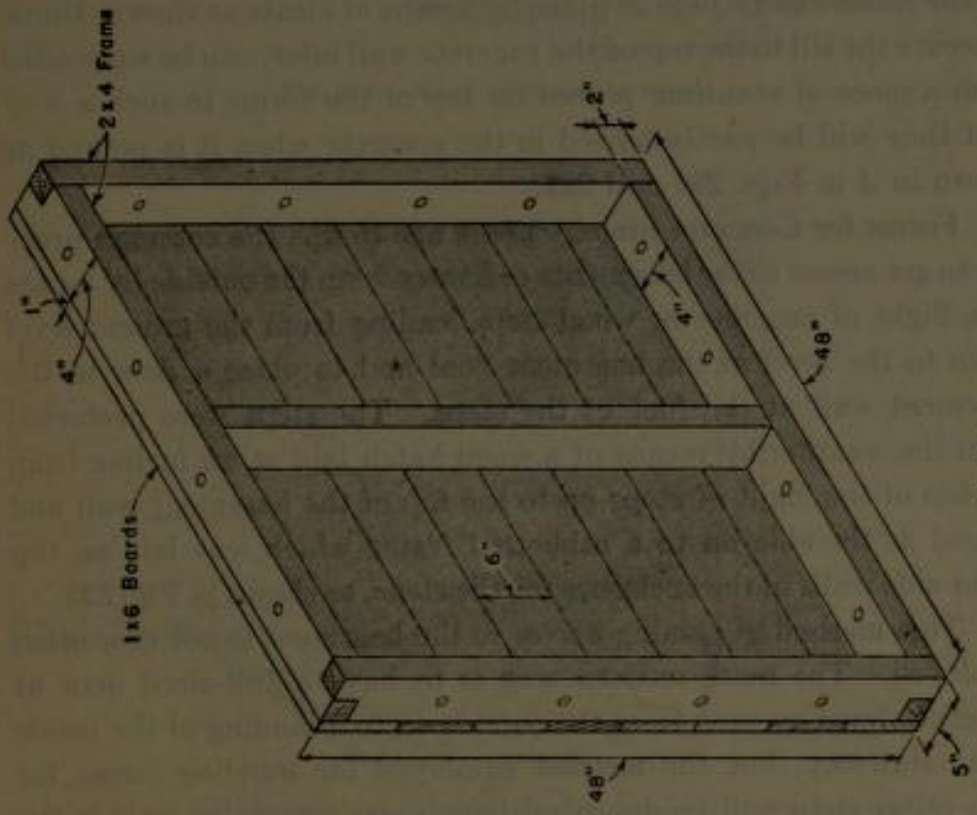


Fig. 223. Detail of Unit Forms

In erecting the form panels, a line is laid out on the ground of the cellar bottom just 5 inches in from the line of the inside face of the concrete wall and stakes are driven into the ground with one face just on this line. The faces of these stakes are then on the line of the back of the panel forms for the inside face of the wall and the panels can be set up against the stakes as shown in Fig. 221. After being plumbed up carefully, they can be braced back against other stakes driven into the ground for this purpose as shown. The successive panels can be bolted together through the uprights as shown. After the forms for the inside of the wall are lined up absolutely straight and plumb and well secured in place by means of the braces, the form panels for the outside face of the wall can be set up at a distance from the inside panels just equal to the thickness of the wall and they can be held in the correct position by means of inclined braces outside and by spreaders and wire ties placed in the thickness of the wall as shown. At the top, the two sets of forms can be held in place by means of cleats as shown. Bolts, to secure the sill to the top of the concrete wall later, can be suspended from a piece of scantling placed on top of the forms in such a way that they will be partly buried in the concrete when it is poured as shown in *A* in Figs. 221 and 222.

Forms for Concrete Steps. Years ago it was the common practice to get access to the basements of houses from the outside by means of a flight of concrete or wood steps leading from the ground level down to the level of the basement floor and to place a door in the basement wall at the foot of the steps. The steps were protected from the weather by means of a wood hatch laid at an incline from the top of the flight of steps up to the top of the basement wall and hinged at the side on to a rabbetted frame which was laid on top of the side walls of the enclosure for the steps, as shown in Fig. 225.

This method of gaining access to the basement is not now often employed. The more modern way is to have a full-sized door at the grade level opening from the outside on to a landing of the inside cellar stairway, but the method employed for building forms for such cellar steps will be described here, more especially as it is the same method which would be employed for any flight of concrete steps resting directly on the ground, such as might be encountered in connection with a concrete walk or terrace. As shown in Fig. 226,

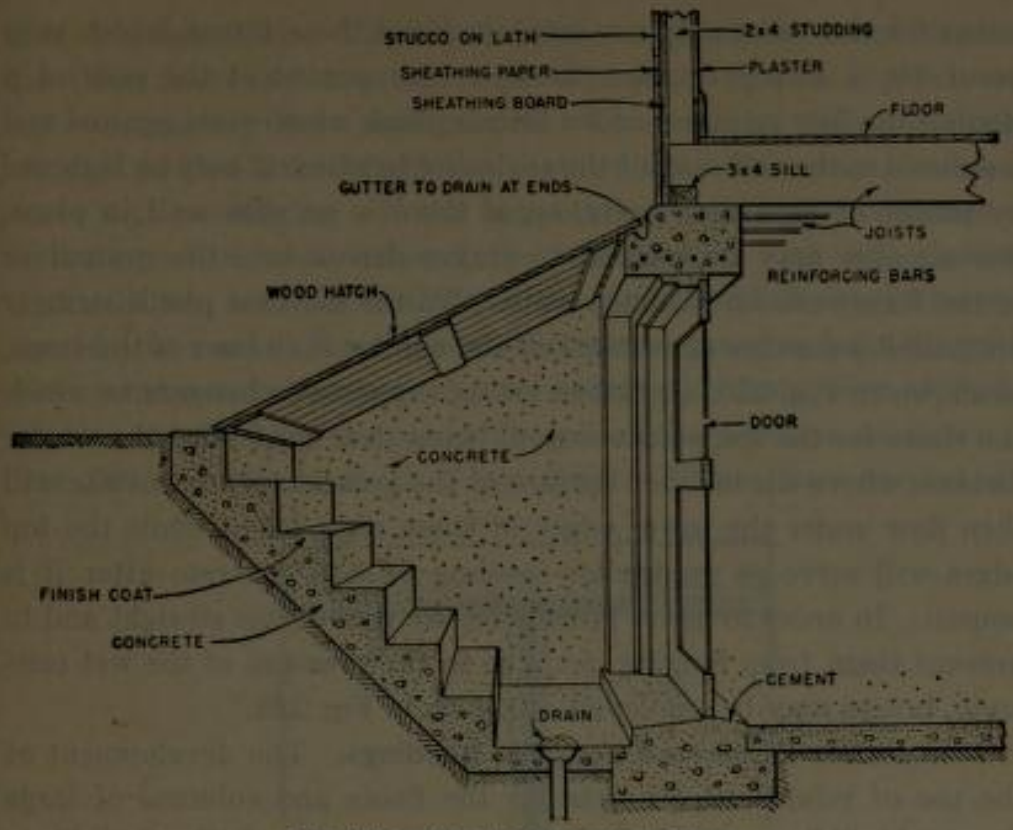


Fig. 225. Detail of Basement Stairs

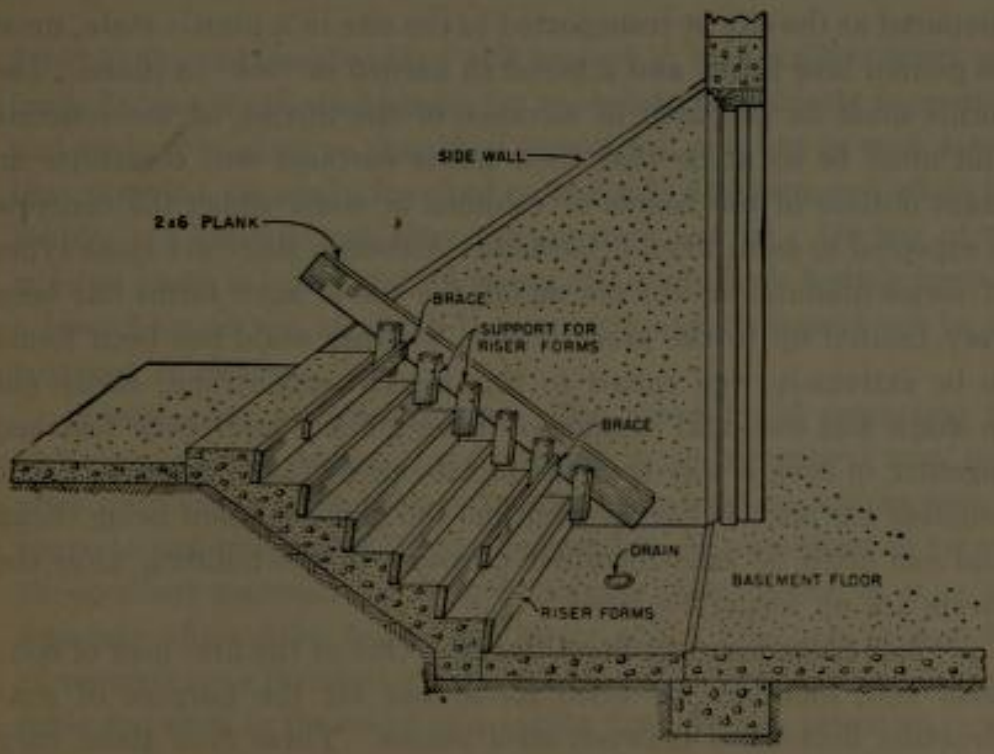


Fig. 226. Detail of Basement Stairs

forms for the risers only are employed and these forms, which may be of 1½ x 8-inch dressed plank, are supported at the ends of a sloping "hanger stringer" of 2 x 6-inch plank which rests against and is secured to the side wall of the enclosure to which it may be fastened by means of expansion bolts, or, if there is no side wall in place, this stringer may be secured to stakes driven into the ground or to the formwork for the side walls. To the inclined plank stringer are nailed a number of vertical cleats, one for each riser of the steps, as shown in Fig. 226, and these act as supports or hangers to which the risers for the steps are secured, being thus suspended the proper distance above the inclined surface of the ground. The concrete will then flow under the lower edges of these riser forms while the top edges will serve as guides for leveling off the concrete after it is poured. In order to assist in keeping the riser forms straight and to prevent them from bulging out, due to the pressure of the wet concrete, braces may be employed as shown in Fig. 226.

Forms for Reinforced Concrete Buildings. The development of the use of reinforced concrete for the floors and columns of large fireproof buildings, and even for the exterior walls of other buildings, opened up a new field for the carpenter because this material, being prepared at the site or transported to the site in a plastic state, must be poured into forms and allowed to harden or "set" in place. The forms must be prepared in advance of the mixing of the concrete and must be so made that their inside surfaces will constitute an exact outline of the beams or columns or walls which the concrete is expected to form when it hardens. Although there are some types of forms manufactured from metal, the use of such forms has been very limited up to the present time, whereas wood has been found to be extremely well suited to this work, being strong, easily cut to shape and size, and capable of being quickly and easily fastened together in such a way that the forms can be taken down after the concrete has set. It has, in addition, the advantages of being cheap and can often be used for other purposes in the building after the forms are no longer required.

Floor Slabs between Steel Beams. One of the first uses of concrete and, therefore, of wood forms was for the purpose of constructing floor slabs between steel beams. These floor slabs vary in thickness depending upon the spacing of the beams but are usually

3 or 4 inches thick. The plastic concrete which is poured in place for these floors is heavy and must be supported, until it sets hard, by a temporary floor construction which will be stiff and strong enough so that it will hold the heavy plastic floor slab absolutely level with no sagging. If the temporary floor construction sags or deflects even a small amount, the soft concrete slab will also sag and will then set hard in this position and the fault cannot be corrected afterwards. For this reason, it is customary to build a regular floor construction between the steel beams with floor joists of 2-inch plank supported on the lower flanges of the I-beams as shown in Fig. 227 and spaced about 2 feet apart. These joists are cut and

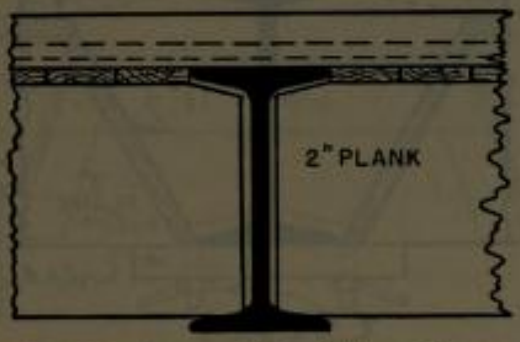


Fig. 227. Forms of Floor-Slab on I-Beams

fitted at the ends so that they will project in between the upper and lower flanges of the steel beams far enough to be properly supported, and wedged in place so that they cannot fall out, but in such a way that they can be easily knocked to one side and removed when the wedges are knocked out after the concrete has set. On top of the wooden joists is laid a tight flooring of 1-inch thick boards forming a level floor on top of which the concrete can be spread out to the required thickness.

Fireproofing of Steel Beams. The necessity of protecting the steel beams from damage by fire came to be recognized very soon after they began to be used in building construction and as soon as concrete was introduced for the floor slabs. It was found to be also an excellent material for fireproofing the steel beams as it is not seriously affected by flames and water and a thickness of 2 inches of concrete over the steel will prevent the steel from getting dangerously hot even in the midst of a raging fire. In this case also it was necessary to construct forms of wood around the steel floor beams

to hold the plastic concrete in place until it had time to set. The simplest and cheapest way to accomplish this was to devise some means by which the joists supporting the forms for the concrete floor slabs could be still supported from the flanges of the steel I-beams but have the ends cut back far enough to allow concrete to be poured so as to completely enclose all parts of the steel. One method of doing this is illustrated in Fig. 228. A piece of 2 x 4-inch scantling about 16 inches long is cut, and holes bored through it to take ⅝-inch diameter bolts spaced a distance apart equal to the width of the

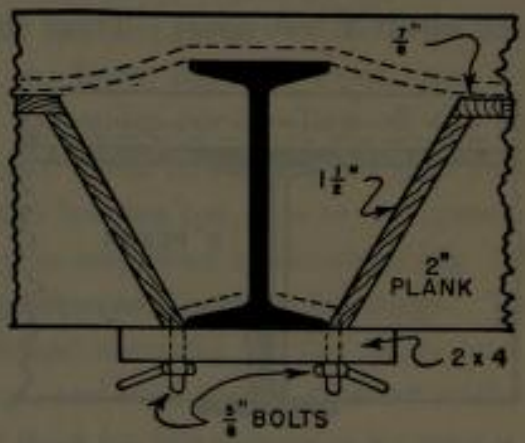


Fig. 228. Forms for Reinforced Concrete Slab between I-Beams

lower flange of the steel beam. Then two ⅝-inch diameter headless bolts threaded at one end are bent to fit over the flange of the beam and the threaded ends are passed through the holes in the 2 x 4-inch piece which is then hung from the lower flange of the beam by means of the bent bolts and secured tightly in place by means of nuts on the threaded ends. The pieces of 2 x 4-inch stuff are spaced along the lower flange at proper intervals to correspond to the proposed spacing of the wood joists and thus each one forms a projecting ledge 4 inches wide on each side of the beam flange on which the ends of the temporary wooden floor joists may be set. The ends of the wooden joists are cut back on a bevel and 1½-inch thick planks are laid against the beveled edges of the joists so as to form the sides of a beam form, of such a shape that, when it is filled with concrete, the steel beam will be almost entirely encased in this material. On top of the wooden joists are then laid ⅞-inch or 1-inch thick boards making the tight platform for the floor slab. After the concrete has

set, the loosening of the ⅝-inch bolts enables the 2 x 4-inch pieces to be taken down.

The wooden floor joists being then left without support are easily removed, together with the plank forms.

The construction just described has the great advantage in that the forms are entirely supported from the steel beams without the necessity for any vertical shoring, but it has the serious disadvantage that it leaves the under side of the lower flanges of the steel beams unprotected and exposed directly to the flames and heat of a fire. It is, therefore, only suitable in case there is to be a hung ceiling or some other means provided for protecting the lower flanges of the

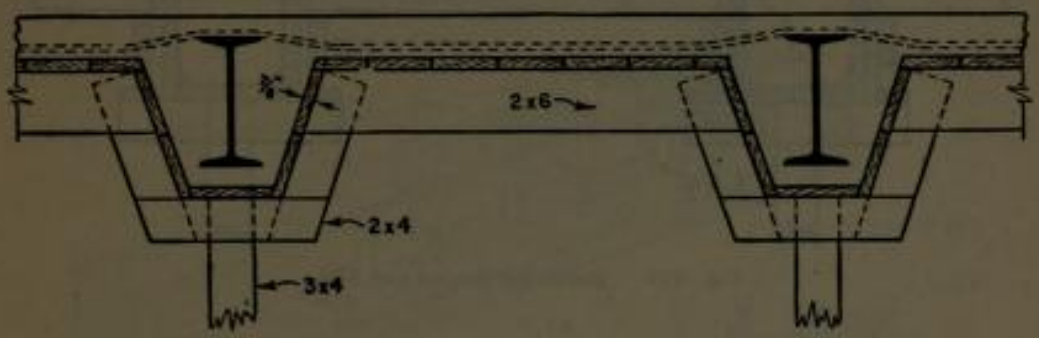


Fig. 229. Forms for Reinforced Concrete Slab Supported by I-Beams Fireproofed

beams. Where there is to be no hung ceiling it becomes necessary to build a form box completely around each steel beam in such a way that the concrete when poured into the forms will flow underneath the bottom flanges of the beams. The only way to accomplish this is to erect vertical shores resting on the floor construction of the floor beneath in such a position that they will come immediately under the steel beams and spaced about 2 feet apart, or at a distance apart equal to the spacing of the temporary wooden floor joists. These uprights may be 3 x 4 inches or 4 x 4 inches in size.

Across the top of each upright is nailed a piece of 2 x 4-inch stuff about 18 inches long, the top edge of which will be 3 inches below the under side of the lower flange of the steel beam as shown in Fig. 229. To the ends of the 2 x 4-inch cross piece are nailed inclined pieces extending up at each side of the steel beam and 3 inches clear of the edge of the lower flange. These pieces must be long enough so that at the top they will be 1 inch below the proposed level of the under side of the concrete floor slab. They will form

supports for the ends of the temporary wooden floor joists which will carry the platforms for the concrete floor slabs and will also serve as supports for the boards forming the sides of the boxes or troughs which enclose the steel beams. The boards forming the bottoms of these troughs will then rest on the 2 x 4-inch cross pieces at the top of the uprights; thus in each case completing the box around the steel beam as illustrated in Fig. 229.

In many buildings there are no steel beams and the entire floor construction, including the beams and girders, is of concrete

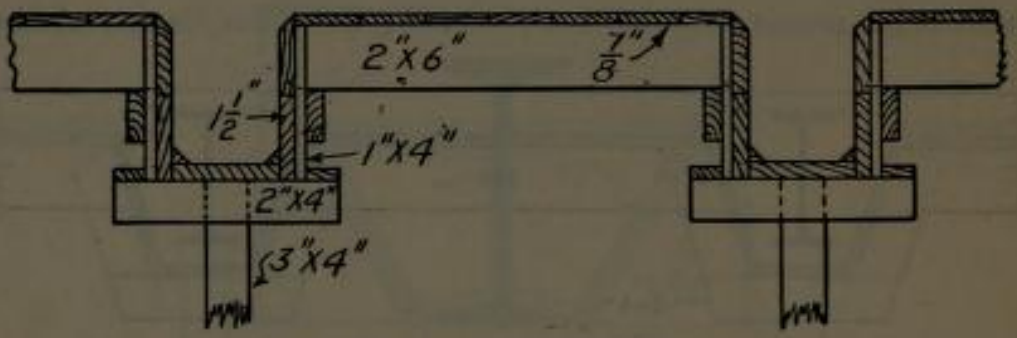


Fig. 230. Forms for Beams and Slabs

reinforced with steel rods. For this sort of building wooden formwork is of course necessary just as it is in the case of the steel beams, but in this case there is nothing to which the forms can be hung so that they must of necessity be supported on upright shores placed under the proposed location of the beams. These shores may be of the same size as the others previously described, 3 x 4 inches spaced about 4 feet apart, and may have similar 2 x 4-inch cross pieces at the upper end of each upright. The cross pieces should, however, have their top edges only about 1½ inches below the proposed level of the under side of the concrete beams and should be somewhat longer than those previously described for steel beams. They should be about 2 feet long so as to allow room for the width of the beam forms to rest on top of them and also to allow for horizontal cleats or "Stay Strips" 1 x 3 inches in size at each side of the beam forms to hold them in place. See Fig. 230. The boxes or troughs for the concrete beams are constructed with vertical sides called "Haunch Boards" built up of 1½-inch plank held together by means of cleats 1 x 6 inches or 2 x 4 inches in size placed vertically against the outside of the forms, and spaced about 3 feet apart. See

Fig. 231. Sometimes these cleats are spaced so as to come just to one side of the upright shores in each case.

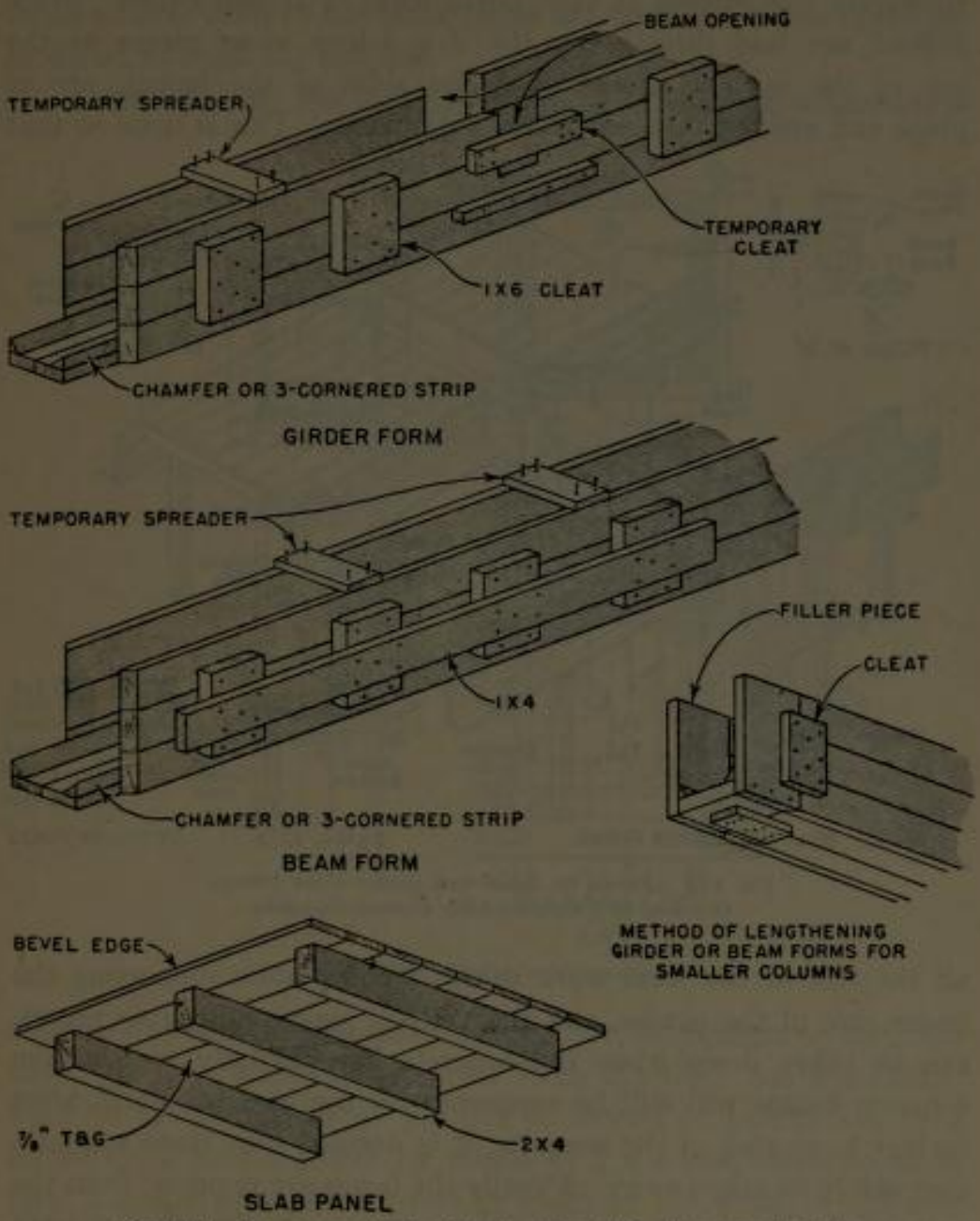


Fig. 231. Beam and Girder Construction. Slab, Beam and Girder Forms

Courtesy of Universal-Atlas Cement Company

To these vertical cleats are nailed horizontal runners or stringers sometimes called "ribbands" or "ledgers" which may be 1 x 4 inches in size and which support the ends of the temporary floor joists. In this way the floor joists may be spaced at any desired

distance apart and do not necessarily have to be spaced the same as the upright shores. The 1½-inch or 2-inch planks which constitute the bottom of each beam form or trough called "Beam Soffits" are laid directly on the 2 x 4-inch cross pieces at the top of the upright shores after the sides of the trough are in place and are not fastened to the side pieces. This is done so that

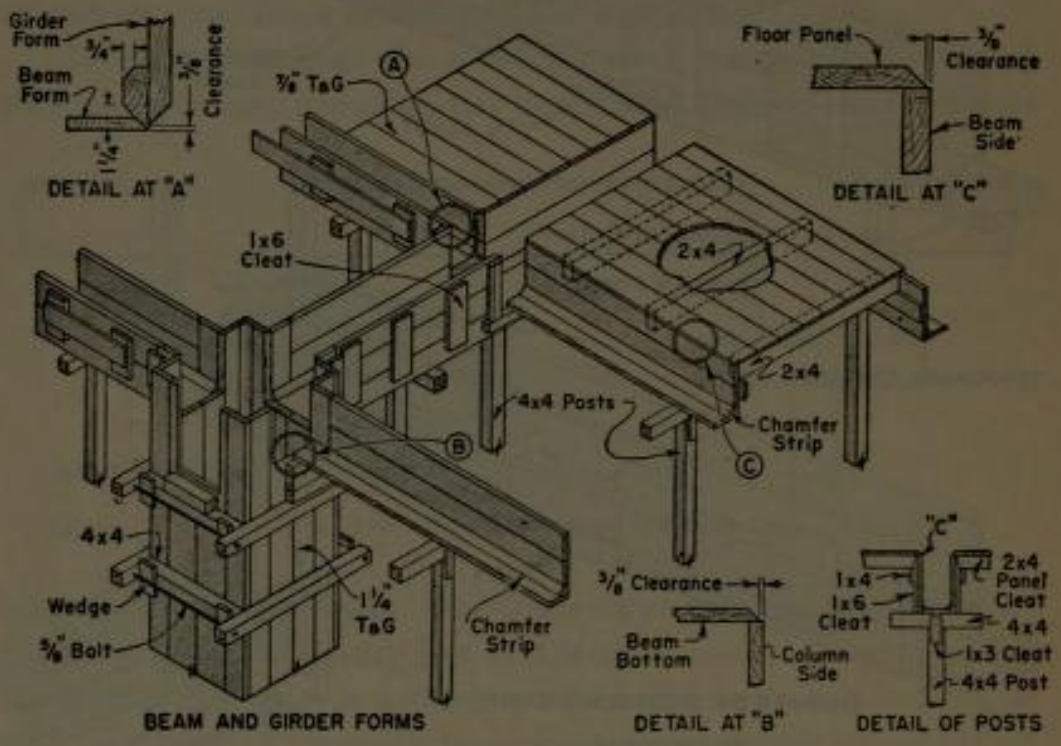


Fig. 232. Forms for Beam and Girder Floor System
Courtesy of Universal-Atlas Cement Company

all the rest of the form work except these planks supporting the under side of the beams, and the vertical shores and cross pieces, can be taken down when the concrete has partially set but the concrete beams will still be supported by the uprights until, after further hardening of the concrete, it is decided that these supports may safely be taken away. Usually the forms are removed from the sides of the beams three or four days or a week after the concrete has been poured, depending upon the weather conditions. The forms are removed sooner in bright summer weather than in cold, cloudy winter weather. The vertical shores are usually left in place for three or four weeks. Sometimes small three-cornered strips are inserted in the bottom of the beam forms along both sides at the bottom of the side pieces so as to form chamfers at the lower edges of the

concrete beams. Where beams are to frame into girders, rectangular openings just the size of the beams are cut in the sides of the girder forms and the ends of the beam forms are fitted into these openings, as shown in Figs. 231 and 232.

Column Forms. For each of the reinforced concrete columns it is

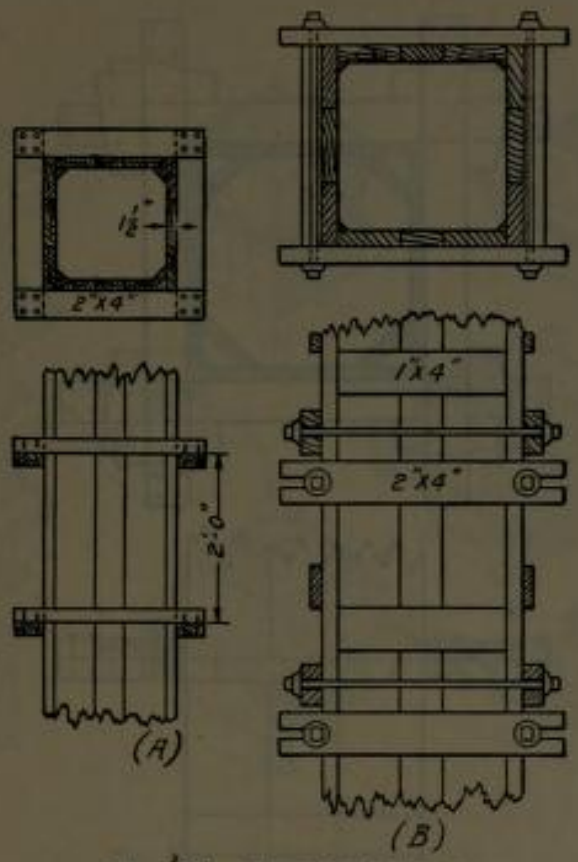


Fig. 233. Forms for Columns

necessary to build an elongated wooden box, set upright on end, into which the wet concrete is poured from the top. See Fig. 233A. Each of the four sides of the box is formed of planks 1½ or 2 inches thick held together by means of 1 x 4-inch cleats so as to form a single wide plank equal in width to the width of one side of the column, two of the sides being made wider so as to overlap the edges of the other two sides. The four sides are assembled in a vertical position and held together by means of horizontal cleats 2 x 4 inches or 4 x 4 inches in size, called "Yokes," which are placed outside of the planks forming the column form and held together in pairs by means of ⅝-inch diameter bolts passing through the ends of the horizontal "Yokes" which are cut long enough so as to

project beyond the corners of the column form and receive the ends of the bolts.

These yokes may be placed in pairs one above the other and slotted at the ends to receive the bolts as shown in Fig. 233B. The cleats and bolts are necessary because when the wet concrete is

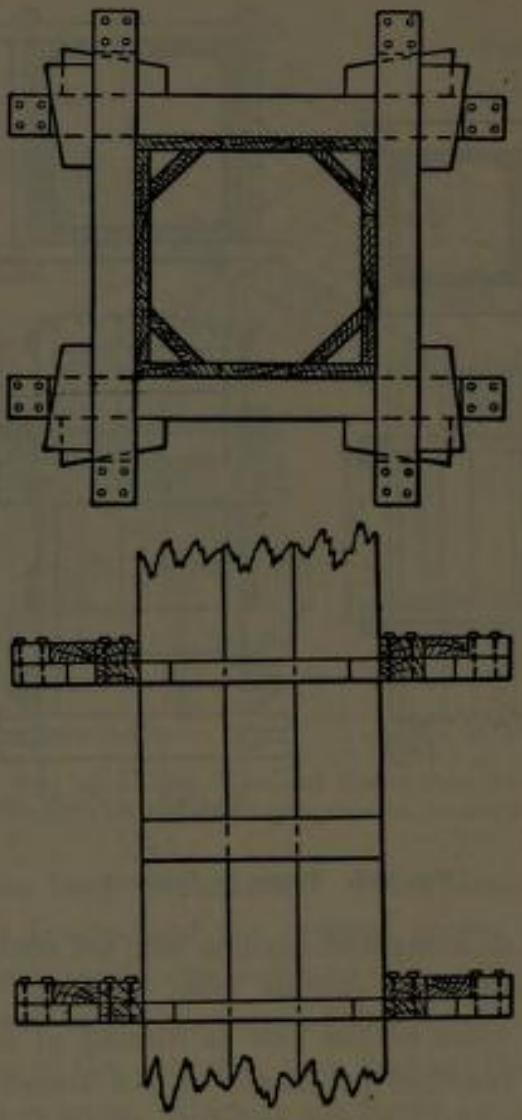


Fig. 234. Column Forms

poured into the form it exerts a very great pressure tending to burst the form apart, especially at the lower end of the column.

Small three-cornered strips may be placed inside the column form at each of the four corners as shown in the figure so as to form chamfered corners on the concrete column instead of sharp corners, or if an octagonal shaped column is required, it can be obtained by

building a square form and then inserting beveled edge planks inside of it at the four corners as shown in Fig. 234. This figure also shows how the four sides of the form can be held together without the use of steel rods, if this is necessary, by nailing small cleats on to the ends of the larger ones and then using wedges bearing against these small cleats to hold the whole form together against the pressure of the concrete.

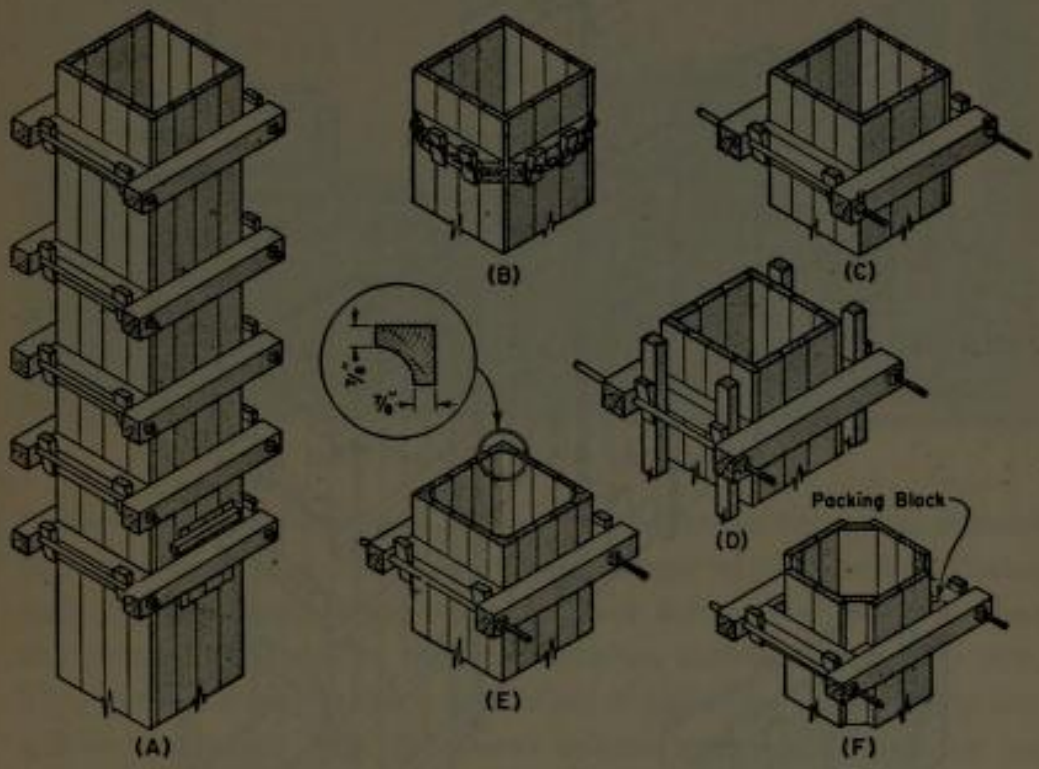


Fig. 235. Column Form Details
Courtesy of Universal-Atlas Cement Company

Where it is deemed desirable to use steel bolts to hold the ends of the yokes together but to employ as few of them as possible, the method illustrated at *A* in Fig. 235 is adopted. Here the yokes on two sides of the column form are cut only long enough so that their ends will come flush with the edges of the form sheathing. The yokes on the other two sides of the column form are cut longer so as to project several inches beyond the outside edges of the other yokes so that bolts can be passed through holes bored near the ends of these yokes to hold them together and so that wedges can be driven between the bolts and the other yokes to hold them in place. Fig. 235 shows several types of column forms in common use on

modern work. At *B* is illustrated the possible use of a chain to hold the sides of the column form together. The chain is hooked around the column fairly tight and then wedges are driven between the chain and the forms to make it still tighter.

At *C* is shown the use of a patented steel clamp which can be

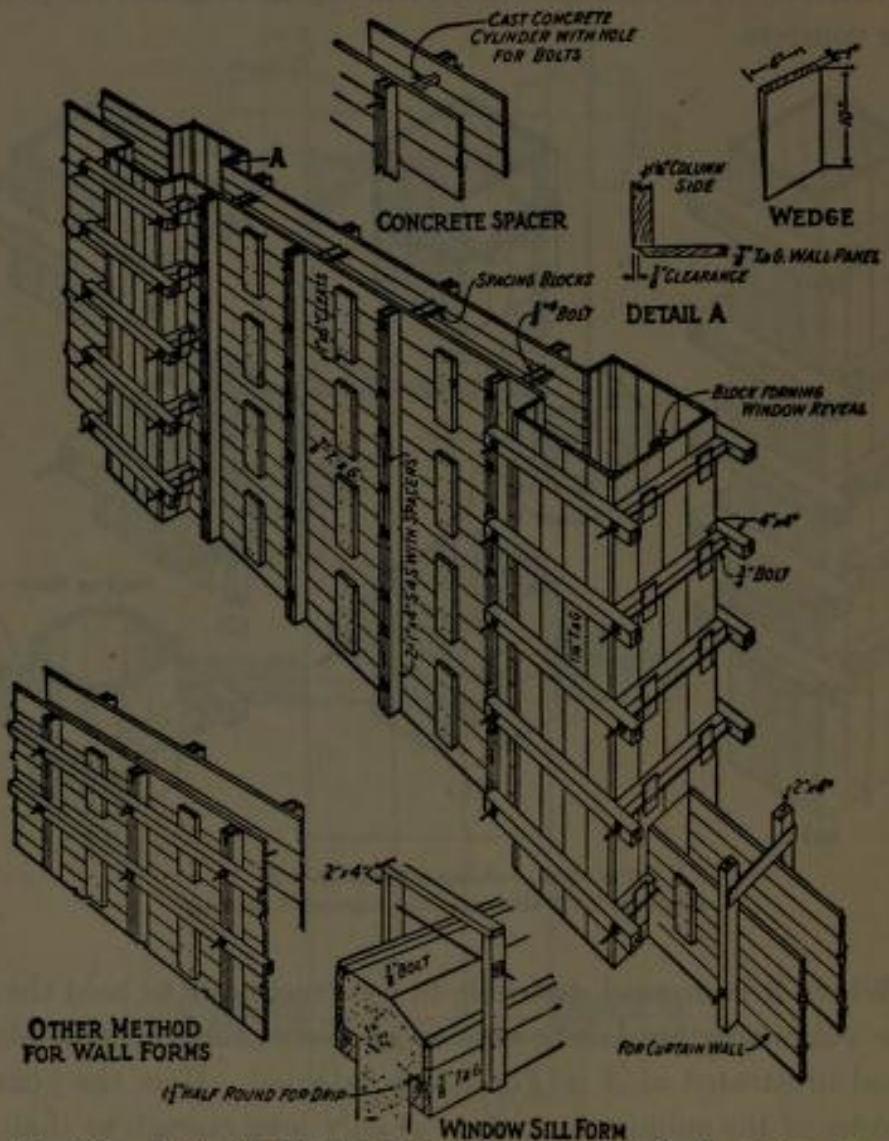


Fig. 236. Form for Curtain Walls, Showing Method of Joining into Column Forms

Courtesy of Universal-Atlas Cement Company

slipped over the ends of plain rods and held tightly in place by means of an adjustable set-screw. This makes possible the use of plain rods instead of the more expensive bolts.

At *D* is illustrated the use of wooden blocks or "packing strips" between the column forms and the wedges so that the same yokes can

be used for several columns of different sizes by varying the thickness of the packing strips.

At *E*, Fig. 235, is shown how a specially shaped strip can be used at each corner of a column form so as to give a rounded corner

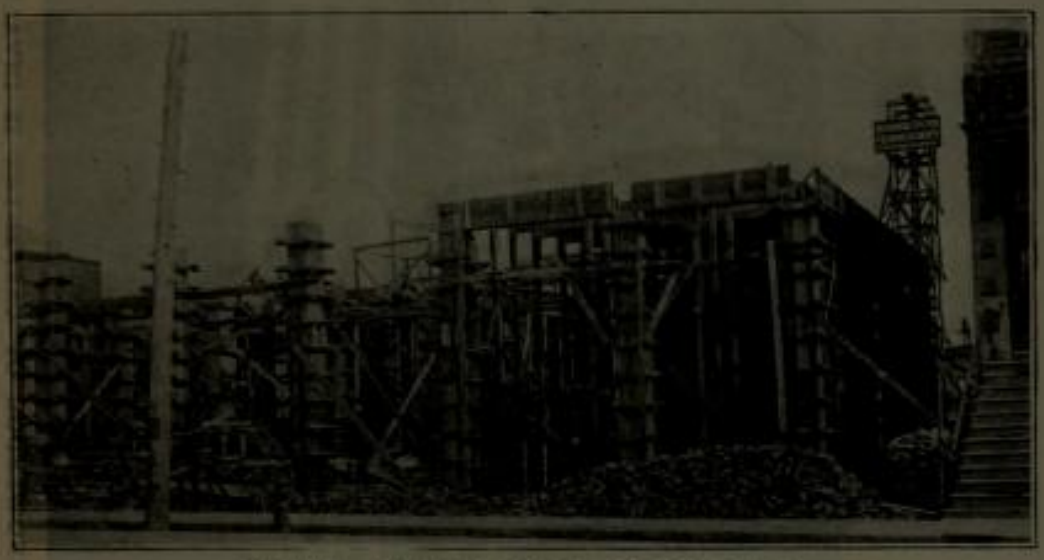


Fig. 237. Details of Column and Beam Forms

to the concrete column and at *F* is shown how an octagonal column can be formed. Fig. 236 shows column forms in place in an exterior wall and also shows wood forms in place for the wall itself so that the exterior wall can be made of concrete instead of brick or tile. This figure also shows the construction of forms for concrete window sills in the walls. Fig. 237 shows column and beam forms for an exterior wall in place.

IN THE UPKEEP AND MAINTENANCE OF FARM BUILDINGS A KNOWLEDGE OF CARPENTRY IS INVALUABLE TO THE FARMER

Courtesy of American Builder

CARPENTRY

PART III

THE ROOF

The framing of the roof is one of the most difficult problems wh which the carpenter has to deal, not because of the number of complicated details, for these are few, but because of the many dierent bevels which must be cut in order to allow the rafters to frme into one another properly.

There are many kinds of roofs, and before describing the differ- et varieties it will be well to consider briefly the purpose of the roof an its development from simple forms to those which are more elborate and perhaps more ornamental. The primary object of a rof in a temperate climate is, of course, to keep out the rain from th interior of the building and at the same time to keep out the cld. The roof must, therefore, be so constructed as to free itself frm the falling water as soon as possible, that is, it must be built toshed water and, consequently, it must be sloped or inclined to the hrizontal in some way. If it is necessary for the sake of economy o: for any other reason to construct the roof practically flat, it mst be made more secure against the passage of water than if it ismade sloping, and some provision must be made to carry off the wter, and to cause it to collect in one or two low places in the roof srface, from which pipes or *down spouts* may be provided to take itaway to a safe place outside the building. The roof covering mst be of some material through which water will not readily pnetrate, such as tin, galvanized iron, lead, or zinc or copper among th metals, or a composition of tar and gravel, if metal is not sutable to the purpose. This would be for a roof which is nearly flt; for a roof which slopes, and will shed the water, thus getting ri of it more quickly, a covering of slates, tile, or wood shingles my be employed as well as tin, copper or other metals.

There is also artificial slate made from asbestos and cement and shingles made from asphalt and felt. Sometimes these asphalt shingles are covered (on the portion of the surface which will be exposed when they are laid) with powdered slate and they can now be obtained with this portion of the surface coated all over with a film of copper. In addition to the shingles there is also what is called "ready roofing" which is made from felt and asphalt in strips about three feet wide and many feet long rolled up into rolls for shipment but which can be rolled out onto the roof surface. The slates or shingles would have to be laid in several thicknesses, the number depending upon the steepness of the slope of the roof, and in order to accomplish this they would have to be laid overlapping each other. In order that the water escaping from the roofs may not run down the sides of the building, making unsightly streaks and wetting the windows and doors, it is necessary that the roofs should project somewhat beyond the face of the walls all around. The projecting part of the roof is called the *eaves*.

See Fig. 237. In this figure the names usually applied to other parts of the roof are given and their meaning is illustrated. As such terms will be used many times in connection with roofs of different types it will be well to become familiar with their meaning.

ROOF CHARACTERISTICS

Styles of Roofs. The different varieties of roofs, from the simple pitch roof to the most complicated combination of hips and valleys, are developments of a few simple forms.

Lean-To Roof. The lean-to roof is the most simple of them all, and is usually employed for small sheds, piazzas, porches, ells, and in many other situations where appearance is not a matter of great moment, and where the essential thing is to obtain the shelter as cheaply and as easily as possible. The lean-to roof is shown in Fig. 238. It consists of a plain surface, one end or one side of which is raised to a higher level than the other side or end, and supported in this position by means of walls or by means of posts at the four corners. The position in which the surface is supported enables the rain water to drain freely from it, and thus it fulfills the requirements of a roof so long as it remains water-tight.

Pitch or Gable Roof. Next to the simple lean-to roof with a

single sloping surface comes the ordinary pitch or gable roof, which has two sloping surfaces one on each side of the center line of the building, coming together at the ridge in the middle. This form of roof, which is shown in Fig. 239, is very common and is also quite simple in design, and economical in construction, so that it has been

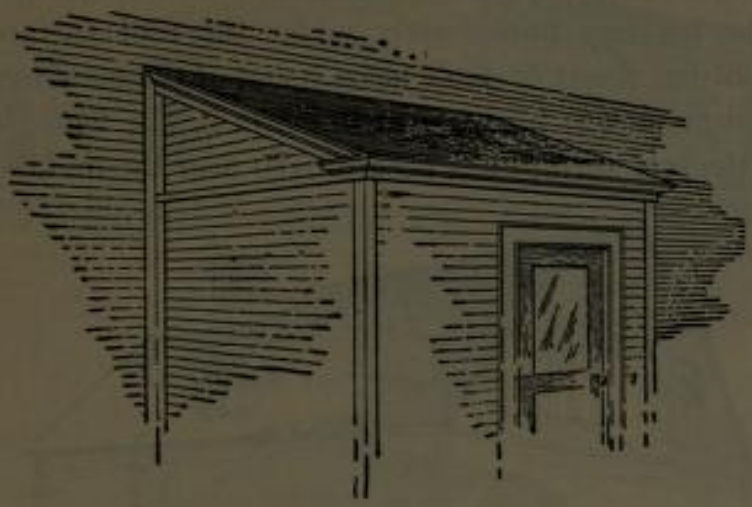


Fig. 238. Lean-To Roof

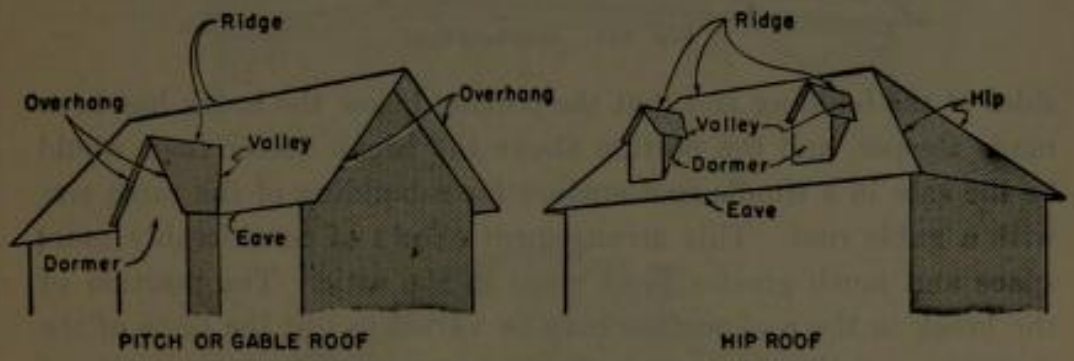


Fig. 239. Pitch or Gable and Hip Roofs

very popular indeed for all classes of buildings except very large structures and city buildings. The slope of the roof, that is, its "pitch" or its inclination to the horizontal, may be varied to an infinite extent, from a very flat slope to a very steep one, and these variations have been made in different countries and in different climates to suit either the taste of the designers or the practical requirements of the climate. The roof may be used in combination with roofs of other kinds and, indeed, it is usually used in this way, so much so that, although the simple gable roof is the base of almost

all the roofs of ordinary structures, it is sometimes hard to distinguish it from among the other roofs which have been added as additions to it.

Gambrel Roof. The gambrel roof is a variation of the simple pitch or gable roof and was probably developed from it to meet a new condition, namely, the necessity for more space in the portion of the building immediately under the roof surface. This form of roof has a sort of gable at each end of the building, but the gable is not triangular in shape, as is shown in Fig. 240. It will be seen that the roof surface has been broken near the middle on both

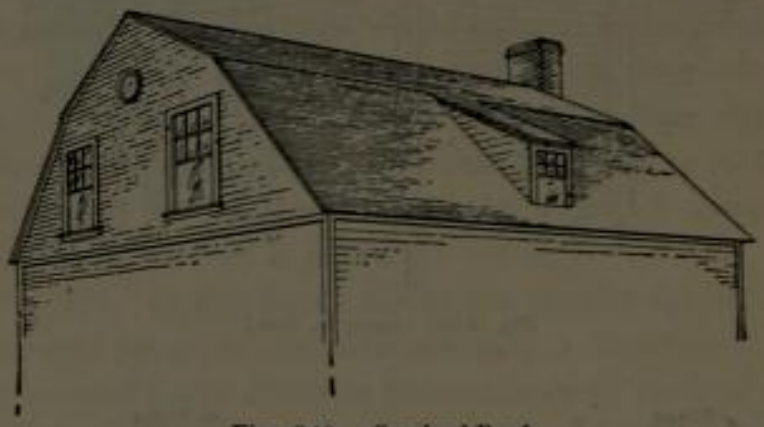


Fig. 240. Gambrel Roof

sides of the building and that the portion below the break has been made steeper, and the portion above the break flatter than would be the case in a simple roof surface for a building of the same size with a gable roof. This arrangement allows of considerably more space and much greater head room in the attic. The position of the break in the roof surface may be varied to suit the taste of the designer, and the slopes of both the upper and the lower parts of the roof may be arranged as desired. Gambrel roofs may be seen on many old houses built in the Colonial days, and they have lately come again into favor for the roofs of cottages and suburban or country houses.

Mansard Roof. The mansard roof, called by the name of the architect who introduced it, slopes very steeply from each wall toward the center, instead of from two opposite walls only, and it has a nearly flat *deck* on top. This form of roof gives better rooms in the attic space than does either of the two forms already described. It was at one time very popular for large suburban and

city houses, but it is now seldom employed. The mansard roof is shown in Fig. 241. It bears a close relation to the so-called *hip* roof.

Hip Roof. The hip roof also slopes from all four walls toward

Fig. 241. Mansard Roof

Fig. 242. Hip Roof with Ridge

Fig. 243. Hip Roof with Deck

the center, but not so steeply as does the mansard roof. It is usually brought to a point or a ridge at the top, as in Fig. 242, but sometimes it is finished with a small flat deck, as in Fig. 243. The hip roof as a rule allows of very little useful space in the attic, and

if this type of roof is employed it is usually done with the idea of sacrificing the attic space and doing without the rooms under the roof for the sake of the exterior appearance, or to save cost.

Valley Roof. In Fig. 244 is shown a very simple form of what is known as a valley roof. It is a combination of two simple pitch

Fig. 244. Valley Roof

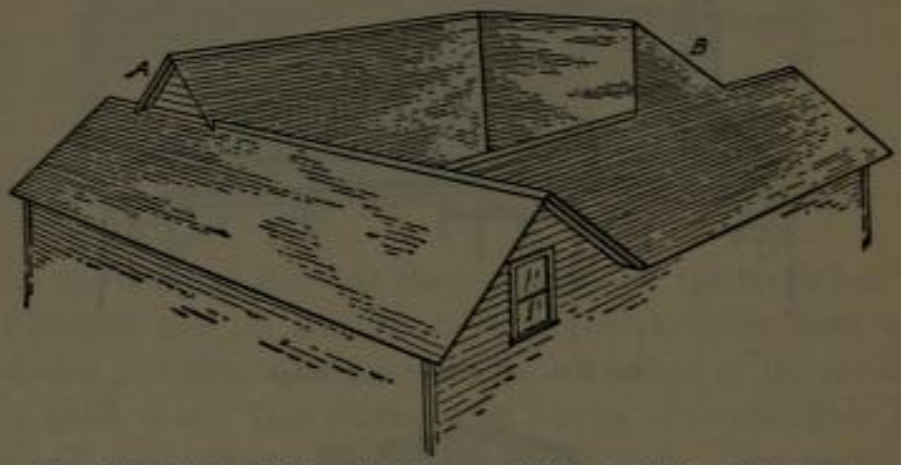


Fig. 245. Hip and Valley Roof Showing Different Roof Levels Around Inner Court

roofs which intersect each other at right angles. In the figure both ridges are shown at the same height, but they are not always built in this way. Either ridge may rise above the other, and the two roofs may have the same pitch or different pitches. If the ridge of the secondary roof rises above the ridge of the main roof, the end which projects above the main ridge is usually finished with a small gable *a*, or a small hip *b*, as shown in Fig. 245. This arrangement does not make a pleasing appearance, however, and should be avoided if possible. Almost all roofs are hip and valley roofs, as it is very seldom that a building of any considerable size can be cov-

ered with a simple roof of any of the forms described above. There are usually wings or projecting portions of some kind which must be covered with a separate roof which must be joined to the main body of the roof with valleys, and it is these valleys which are the cause of most of the leaky roofs, as a large quantity of water collects in them and it is no easy matter to make them water-tight.

The illustrations shown on the preceding pages are merely diagrams showing in their simplest form the five basic types of roofs. If we leave out the "lean-to" roof which can be used only for rough sheds or for porches and verandahs and the "mansard" roof, which

Fig. 246. Combination Hip Roof

is now seldom employed, there are left only the three types; namely, the "pitch or gable" roof, the "gambrel" roof and the "hip" roof from which we must choose if we have to design or build a sloping roof for any building. Of course, we do not have to restrict ourselves to such simple and crude forms as are shown by the diagrams nor are the buildings usually of the plain box-like shape illustrated by them. There has, however, during the last twenty-five years been a remarkable tendency towards simplifying both the plans and elevations of small buildings such as houses which are the sort of structures in which carpentry contractors are most likely to be interested. Previous to the year nineteen hundred most builders and architects seemed to try to make small buildings as complicated in plan and as confused in elevation and perspective as possible, usually working in a circular or octagonal tower somewhere and covering the exterior with elaborate ornament which has since come to be designated as "gingerbread" or "jigsaw" ornament. After the beginning

of the present century the taste of the building public underwent a complete change and the demand was for the more straightforward types which had been built during the earlier "Colonial" days.

Probably the cheapest way in which to roof over any space is by the use of some combination of hip roofs since this form reduces the cubic contents of the roof space down to the least possible amount for a sloping roof, reduces the length of many of the rafters, and

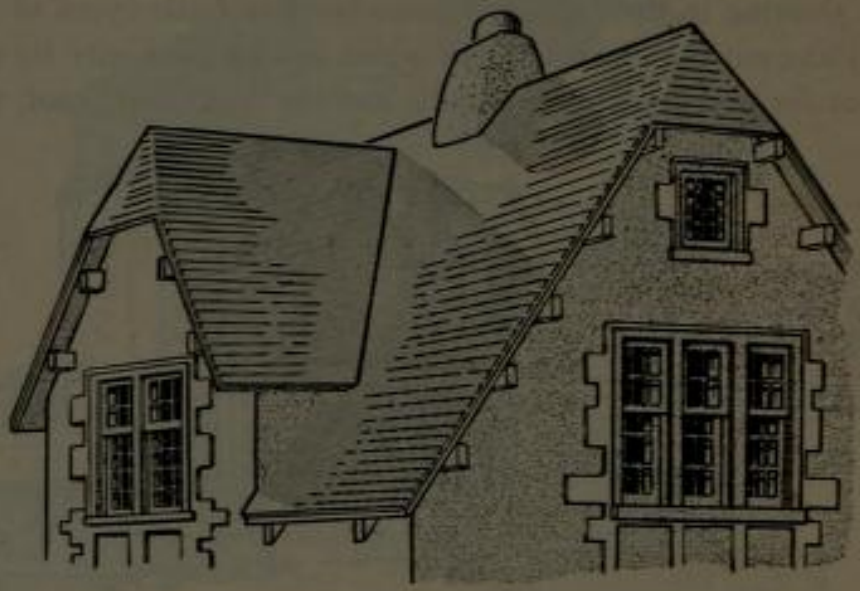


Fig. 247. Combination of Simple Pitched and Lean-to Roofs

eliminates the necessity for any exterior wall framing and finish above the level of the eaves. Fig. 246 shows a roof of this kind. Of course the flatter the slope is made the cheaper the roof will be to construct but there will be less usable attic space and besides the appearance has to be considered as well as the cost.

In addition to the main rectangle of the building the projecting ells and porches can also be covered with hipped roofs or they can have pitched roofs with gabled ends.

The simple pitched roof type is often combined with the "lean-to" roof so as to come down over a porch or some other part of the building which is intended to be only one story in height and above which no usable space is required on the second floor except possibly a closet which may be allowed to have a sloping ceiling and can therefore be worked in under the eaves of the sloping roof. This sort of roof is illustrated in Fig. 247 where the main roof continues in an unbroken line down to the level of the first floor ceiling on one

side. This illustration also shows another feature which is frequently incorporated in designs for pitched roofs and which consists in a small hip at the extreme top or peak of the gable so as to soften the outline of the roof at this point. In the design illustrated this has been done at both gable ends. Very often the secondary roof which intersects the main roof in a valley would be made as a hipped roof with the eaves carried straight across over the windows

Fig. 248. Pitched Roof Showing How Roof Slope Is Started at Gable Ends to Improve Appearance

in the side wall. As the attic space available at this point is of very little value anyway, there is not so much sacrificed by doing this and there might be a small saving. The appearance of the building, however, would certainly not be improved by a change of this kind.

Another thing which is sometimes done to make small buildings with pitched roofs more interesting in appearance is to start the roof slopes at the gable ends low down on the walls, perhaps at the level of the second floor, and to have them slope up rather steeply to the ridge as shown in Fig. 248. If the entire roof were to be constructed in this manner, there would be very little room in the second story, so, starting a very short distance back from the gable end, the side walls are carried up the full height to the second floor ceiling, and the main roof slope is started from this level and carried up to the same ridge level as the more steeply sloping roof

at the gable end, as shown in Fig. 248. This gives the impression of a building a story and a half high with a huge dormer window running nearly the full length of the structure, but in reality the main part of the house, in so far as the framing is concerned, is an ordinary two story building with a simple plain pitched roof of a rather flat slope, the only variation from this occurring at the two gable ends. Fig. 249 shows a gable end of a house where the same thing

Fig. 249. Roof Treatment Similar to Fig. 248 Except that Gable End in Effect Is Like a Gambrel Roof

has been done but the effect of the gable end is that of a building with a gambrel type of roof.

It can perhaps be said that the form of roof which has seen the greatest increase in popularity since the beginning of the twentieth century is the gambrel roof. This type is seldom used on buildings of more than two stories except for barns where it is quite generally employed, but thousands of dwellings have been built with gambrel roofs and the better ones have been much admired. The roof almost invariably starts low down on the side walls at about the level of the first floor ceiling. There are two generally accepted ways of dealing with the second story windows in the side walls. One way, but by no means the most common method, is that illustrated by Fig. 250 where the windows are cut into the nearly vertical roof surface. This gives the house a considerably wider appearance in the second story than does the other and more usual method of

treating the dormers illustrated in Fig. 251, but at the same time makes the bedroom floor a little more roomy. It provides an excellent place for flower boxes.

The design which is most common consists in treating each side

Fig. 250. Method of Cutting Second Story Windows in Nearly Vertical Roof Surface

Fig. 251. Dormer Method for Second Story Windows

of the building in the second story as one huge dormer continuing nearly, but not quite, the full length of the house. The roof over the long dormer is almost without exception a continuation of the upper part of the main gambrel roof. Fig. 252 shows this treatment of the problem. The eaves are sometimes straight as illustrated in Fig. 252, sometimes slightly curved, as in Fig. 250, and sometimes very

decidedly curved, but they nearly always are made to project well out over the side walls while at the gable ends the roof more usually finishes nearly flush with the wall as shown in Figs. 250 and 252.

Rafters. In all roofs the pieces which make up the main body of the frame work are called the rafters. They are for the roof what the joists are for the floor, and what the studs are for the wall. The rafters are inclined members, spaced from 16 to 24 inches apart on centers,

Fig. 252. Large and Single Dormer Method for Second Story Windows

which rest at the bottom on the plate, and are fastened at the top in various ways, according to the form of the roof. See Fig. 273. The plate, therefore, forms the connecting link between the wall and the roof and is really a part of both of them. The size of the rafters varies, depending upon their length and the distances at which they are spaced. It is sometimes allowable to use them as small as 2 x 4 inches, but this should be done only for the lightest work. The size of the rafters for an ordinary dwelling house is usually 2 x 8 inches. In larger buildings, such as school houses, it may be found necessary to use rafters as large as 2 x 10 inches, when they are of a considerable length.

The material usually employed for rafters is the same as that used for the joists and for the studding. This is generally spruce in the eastern states and yellow pine in the Mississippi Basin, but may be hemlock in very cheap work. The size and spacing of the rafters

vary to some extent with the location of the building, as in the northern part of the country the roof is called upon to carry a considerable weight of snow and ice, while in the south there is little or no snow and the roof is not called upon to carry so much weight. If snow freezes and packs on the roof it may weigh as much as twenty-five or thirty pounds per square foot of roof surface. The wind pressure must also be considered, as well as the weight of the material composing the roof itself.

Fig. 253. Rafter Extended to Form the Eaves

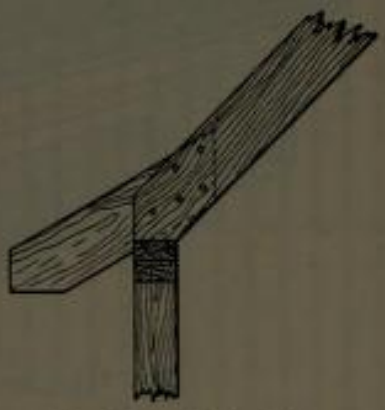


Fig. 254. False Rafter

The connection of the rafters to the wall is the same in all the types of roofs described above. They are not framed into the plate but are simply spiked to it, being cut at the bottom so as to rest on top of it. Usually they extend out for a considerable distance beyond the wall to form the eaves, as shown in Fig. 253, and they are then cut over the plate and allowed to continue beyond it. The usual length for the eaves is about 1 foot, but it may vary to suit the taste of the designer of the building. Sometimes the rafter itself is not extended beyond the plate, but is cut off, as shown in Fig. 254, just as though it was not intended that it should continue beyond the wall line, and a separate piece called a "false rafter" is nailed against it alongside to form the projection for the eaves, as shown in Fig. 254. This piece does not always continue in the same line with the real rafter, but may, and usually does, make an angle with it, as shown in the figure, so as to give a break in the roof line near the line of the eaves.

It is sometimes desired to form a concealed gutter around the eaves, and in order to do this the joists are allowed to extend 10 or

12 inches and on the ends of these a 2 x 4 is laid flat and nailed, and the rafters rest on this piece. The scantling is nailed directly above the plate and the gutter is run in notches cut in the over-

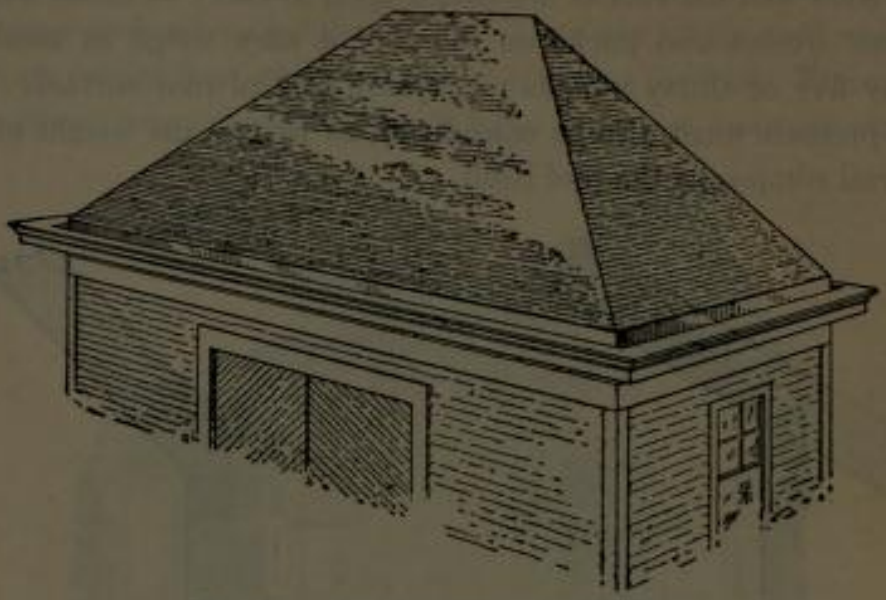


Fig. 255. Roof Showing Concealed Gutter

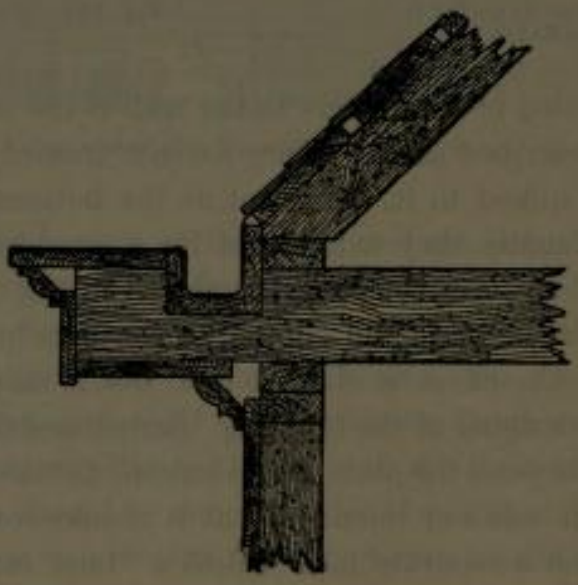


Fig. 256. Construction of Concealed Gutter of Fig. 255

hanging joists which also support the cornice. The general appearance is shown in Fig. 255 and the details of the construction in Fig. 256.

There are four different kinds of rafters used in framing roofs, all of which may sometimes be found in a single roof frame, if the

roof is of complicated design, while ordinary roofs may be framed with only the more simple forms of rafters. In Fig. 257 is shown in plan the framing for a roof in which all four kinds of rafters are to be found. *A A A* are the common rafters, which extend from the plate to the ridge and which are not connected with or crossed by any of the other rafters. *B B B* are *jack* rafters, which are shorter than the common rafters and which do not extend from the plate to

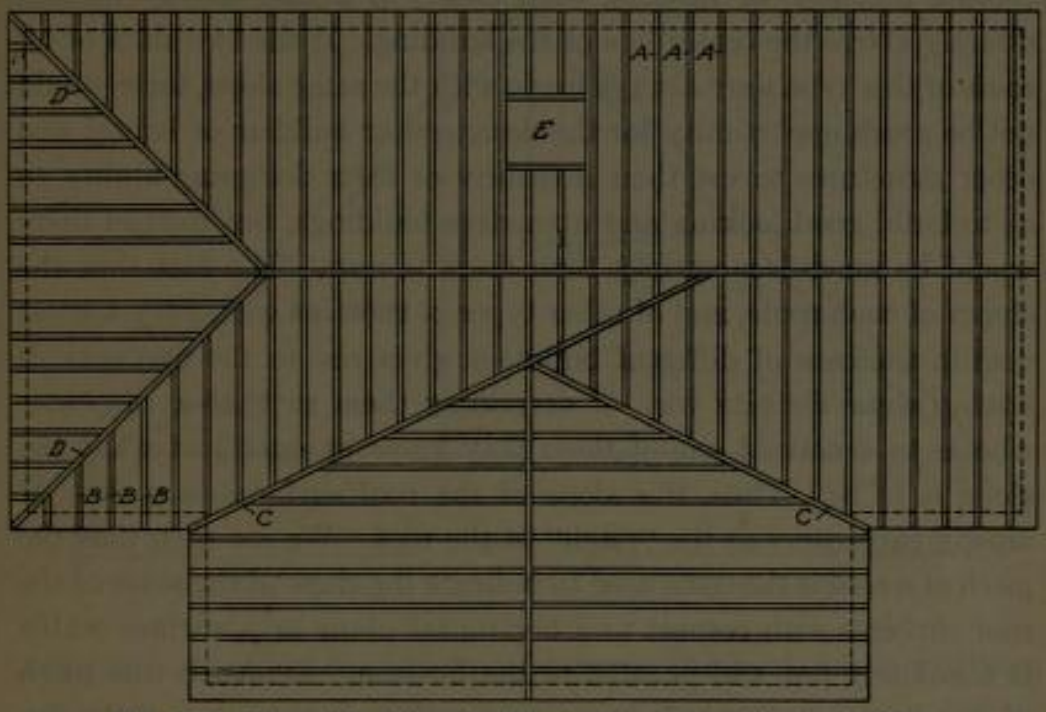


Fig. 257. Plan of Roof Framing Showing Use of Four Kinds of Rafters

the ridge, but are connected at one end to a *hip* rafter. *C C* are the valley rafters, which are needed at every corner between the main building and an ell or other projection, while the hip rafters *D D* are found at the outside corners. At the points where the valley rafters are situated there are troughs or valleys formed by the roof surfaces—as these pitch downward on both sides toward the valley rafter—while at the outside corners, where the hip rafters are found, the roof surfaces pitch upward on each side to the hip rafter. This may be seen and perhaps better understood by looking at any hip and valley roof as actually constructed, and as this type of roof is very common there will be no lack of examples.

The rafters which rest at the lower end against a valley rafter and at the upper end against a hip rafter or ridge are called "cripple

rafters" because they have no "foot," that is they have no bearing on the wall plate, just as a "jack" rafter has no "head," because it does not rest against the ridge.

Pitch of Roof. One of the types of roof described has been referred to as a "pitch roof" or a "pitched roof." Such a roof is called by this name because the two roof surfaces, one on each side of the building, slopes downward from the ridge or upward from the eaves, coming together, or meeting each other, in a line usually located directly above the center line of the building. If the two sides of all roofs of this type were always made with the same slope, there would not be much opportunity for the designers or builders of houses and other structures to use their ingenuity or their designing ability so as to build good looking and attractive buildings, but instead there would be much less variety than there is now. The fact that the slopes of such roofs, and of other types of roofs as well, vary a great deal in the case of different buildings gives rise to the necessity of having some definite way of describing them so that a carpenter who is to construct one of them may know at once just what the slope is to be. Thus, this slope of the roof surfaces is spoken of among carpenters as the "pitch" of the roof. We see then that the pitch of a roof is the term used to indicate the slope of the sides of the roof surfaces with respect to a horizontal plane or a surface which is absolutely flat and parallel to the horizon. Evidently the pitch of any roof may be made to vary according to the ideas of the designer or builder to an almost infinite extent. The roof surface may be made absolutely flat or it may be made practically vertical like the surfaces of the mansard roof shown in Fig. 241, or the roof may be inclined at any angle between these two limits. Thus the sides of a gambrel roof slope much less steeply than the sides of the mansard roof or, in other words, the sides of the mansard roof have a much steeper pitch than the sides of the gambrel roof, whereas the gambrel roof has a steeper pitch than the gable roof shown in Fig. 239.

Unfortunately, there are several systems in use for indicating the pitch, or the amount of the angle of the slope of a roof, so that there is likely to be some misunderstanding about it. Usually, however, some one system is in common use in any one section of the country and there is a general understanding that this is the system

intended in such a locality when speaking of the pitch of a roof. The most simple way of indicating the pitch and at the same time the most accurate way is to give the angle which the roof surface makes with a horizontal plane. If we were to take a very large book with stiff covers and lay it down flat on a table, the surface of the table would then represent a plane which is absolutely horizontal and parallel to the horizon. If we open the top cover of the book

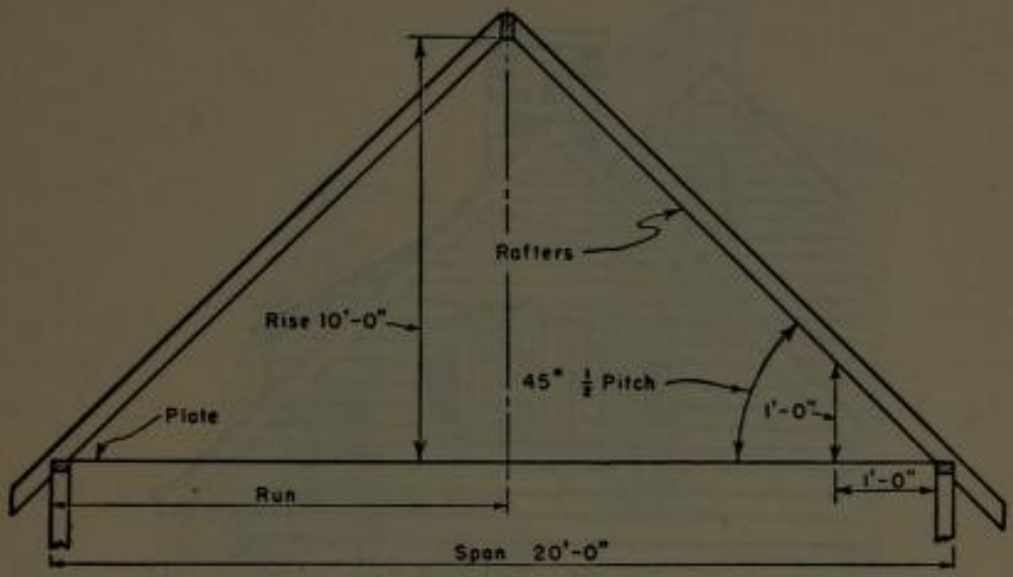


Fig. 258. Method of Indicating the Slope of the Roof Surfaces

until it is standing straight up and down, the book cover will then represent a plane or a surface which is at an angle of ninety degrees with the horizontal plane or surface. If the book cover is closed down flat, it will be at an angle of zero degrees with the horizontal and it can be opened part way so as to make an angle of thirty degrees, or forty-five degrees, or sixty degrees with the horizontal. In the same way the pitch of a roof may be thirty degrees, or forty-five degrees, or sixty degrees with respect to a horizontal plane assumed to pass through the lines of the eaves. This system is much in use among civil engineers by whom it is favored on account of its accuracy and the small probability of being misunderstood, but it is not much in use among carpenters and architects, as they generally prefer to use some other system.

Another method of indicating the slope of the roof surfaces is to take the rise of the roof at the center of the span, or the vertical distance from the top of the plate to the under side of the rafters

at the center of the span, and to divide this distance by the span itself or the distance between the inside edges of two rafters which come opposite to each other in the roof frame, at the point where they intersect the top surface of the plate, as illustrated in Fig. 258. The fraction thus obtained is used to express the degree of slope of the roof, or the angle that the roof surface makes with the horizontal plane, in the following way: If the span of the roof between the

Fig. 259. Half Pitch Roof

edges of the rafters at the level of the top of the plate is 20 feet and the rise of the roof at the center, measured vertically from the top of the plate to the under side of the rafters, is 10 feet, then the roof is of *half pitch*, since the fraction obtained by dividing the rise of the roof by the span of the roof is one over two or one half. The angle which this roof surface makes with the horizontal plane is forty-five degrees, since the rise at the center is equal to half the span, and the rise of the sloping rafter is equal to its *run* or its projection on the horizontal plane. This slope is also called a *square slope* or a *square pitch* for the reason that the rise of the rafter is equal to its run. In this roof also it will be seen that the rafter rises a distance of 12 inches for each foot of run, counting the rise always from the level of the top of the plate and the run from the point where the under side of the rafter intersects the top of the plate. Thus at the center of the roof the run is 10 feet and the rise is also 10 feet. Fig. 259 shows a roof of *half pitch*. If this same roof were one of

full pitch, as shown in Fig. 260, the rise at the center of the span would be 20 feet, equal to the span itself, and there would be 2 feet of rise for each foot of run. This would make a very steep roof, in fact it is very seldom so steep a roof is used in ordinary work. A two-thirds pitch would be a little less steep than the full pitch, between the full pitch and the half pitch, and this roof would have a rise of 16 inches for each foot of run, so that if the span were 20

Fig. 260. Full Pitch Roof

feet, as in the case of the other roofs just mentioned, the rise at the center of the span would be 160 inches or 13 feet and 4 inches. The reason why this pitch is called a *two-thirds pitch* is that in the case of a full pitch roof the rise for each foot of run is 24 inches, in this case the rise for each foot of run is 16 inches, and 16 inches is just two-thirds of 24 inches. Also the rise at the center of the span, 13 feet and 4 inches, is just two-thirds of the span, which is 20 feet. Whenever it is desired to give a roof a steeper pitch than the half pitch, the two-thirds pitch is generally employed.

If the roof is one of *one-third pitch*, the rise of the rafter for each foot of run will be one-third of the 24 inches which are required to make a full pitch, one-third of this being 8 inches. Thus a one-third pitch roof has a rise of 8 inches for each foot of run, and the rise at

the center of the span is one-third of the entire span. If the span of the roof is 20 feet, the rise at the center of the span will be 6 feet and 8 inches, or just one-half as much as in the case of the roof of the same span and with a two-third pitch. Fig. 261 shows a roof of one-third pitch.

If the roof has a "one-quarter pitch," this means that the rise of the rafter for each foot of run is one-quarter of 24 inches, which is 6 inches, and that the rise of the roof at the center of the span is one-quarter of the entire span. If the roof has a span of 20 feet,

Fig. 261. One-Third Pitch Roof

this will make the rise in the case of a one-quarter pitch equal to 5 feet.

The pitches mentioned above are the most common pitches and those most generally used, though, of course, any pitch may be used as desired. The two-thirds pitch corresponds to an angle with the horizontal of about fifty-three degrees, and the one-half pitch corresponds exactly with an angle of forty-five degrees. The one-third pitch corresponds to an angle of thirty-three and three-quarters degrees and the one-quarter pitch corresponds with an angle twenty-six and one-half degrees. From this it will be seen that the names of the pitches, *one-third*, *one-half*, and *one-quarter*, do not express the relation of the angles which the various slopes make with the horizontal to the angle made by the roof of *full* pitch.

There are several factors which enter into the problem of determining the most suitable pitch to give a roof, and they must be carefully considered before arriving at a decision. In the first place there is to be considered the appearance of the finished roof when the building is completed. In this connection it may be said that

personal preference and individual taste on the part of the designer are the determining factors, and that no hard and fast rules can be laid down. Another thing which must be thought of is the relative cost of the different slopes or pitches, as this is often of great impor-

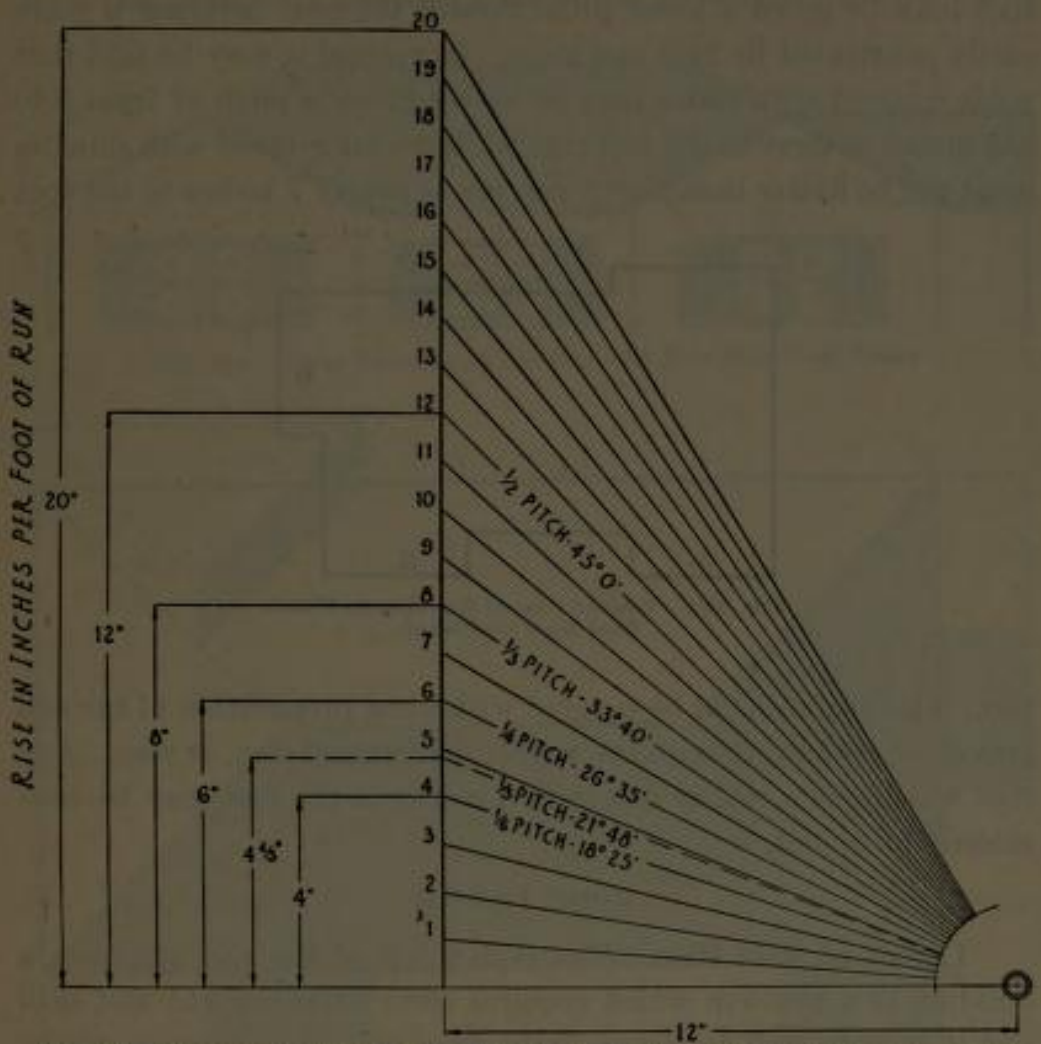


Fig. 262. Diagram Showing the Rise Per Foot of Run and the Angle for Horizontal Plane for Common Roof Pitches

Courtesy of Copper and Brass Research Association

tance and, in the case of a large number of buildings, would make considerable difference in cost. It may be said that in general a roof with a comparatively low pitch, say about thirty degrees, corresponding to a rise of approximately 6⅞ inches per foot of run, is the most economical so far as the roof framing alone is concerned. Of course such a roof gives no accommodation in the attic portion of the building.

Fig. 262 shows a convenient diagram which gives the rise per

foot of run and the angle with the horizontal plane for the five most common roof pitches. The character of the material to be used for covering the roof surfaces must also be remembered in determining the pitch, since if this roof covering is very impervious to water the roof may be given a lower pitch than if the roof covering is more easily penetrated by rain and snow. In general it may be said that roofs covered with slates may be safely given a pitch of from 5 to 5½ inches or more to the foot run, while a roof covered with shingles must not be flatter than thirty degrees or nearly 7 inches to the foot

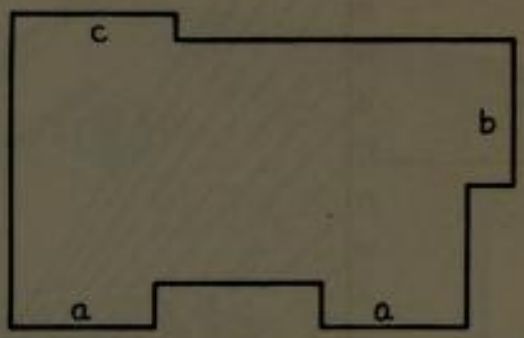


Fig. 263. Ground Plan of Building on Which Roof Must Be Placed

run. Flat roofs should be covered with some preparation of tar and gravel, or asphalt, or with tin, copper, galvanized iron, or zinc. Any roof which has a rise of less than 3 inches to the foot may be considered to be flat.

ROOF FRAME

Layout of Roof Plan. The laying out of the roof plan for a building is a problem which requires some little thought and skill and it may be well to give a little space to a consideration of the best way in which to approach this problem. Suppose that we have a frame building whose general outline in plan is as shown in Fig. 263, and on which we wish to plan a hip and valley roof. There are, we will say, two projections or wings on the front of the building, at *a a*, another wing on the right-hand side of the building at *b*, and another wing on the back of the building at *c*.

Fig. 264 shows diagramatically the front elevation of the building with the two projecting wings.

The first thing to do is to draw the rectangle *A B C D*, in Fig. 265, enclosing the main portion of the building, and leaving out the

wings or projections which are shown by dotted lines in this figure. From each corner of the rectangle *A B C D*, may be drawn a line at forty-five degrees, with the side of the rectangle, each pair of which will meet at the points *R R*, and these points *R R* may be connected by a line parallel to the long sides of the rectangle. This is a plan

Fig. 264. Front Elevation of Building with Two Projecting Wings

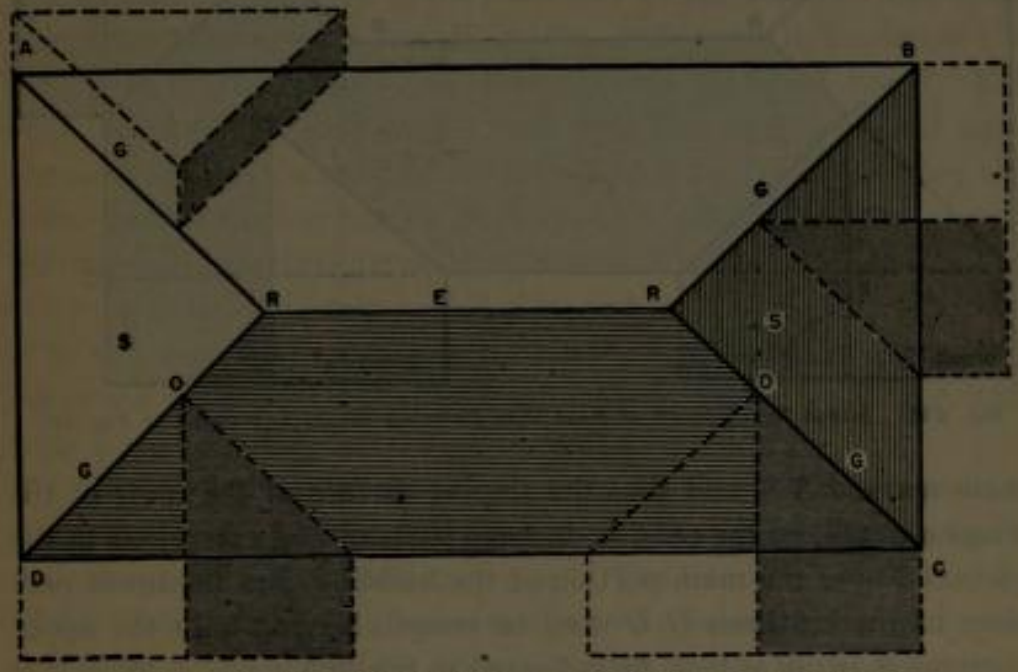


Fig. 265. Plan of Roof Covering Main Portions of the Building

of a simple hip roof covering the main portion of the building, *E* being the ridge and *G G G G* being the hip lines. The projecting portions or wings are, however, not yet covered and in order to take care of them some further planning is necessary. Let us consider the two wings on the front of the building, marked *a a*, in Fig. 263. We will decide to cover these with a simple gable roof and for this the first step is to draw in the ridges. These ridges will, of course, come exactly in the center of the wings and will be shown on the plan by a line in the

center of the plan of the wings, perpendicular to the line of the front. These lines should be drawn in as shown in Fig. 266, where they are marked *E E*. The lines *E E* intersect the hip lines marked *G G*, in Fig. 265, at a point about half way between the corners *D* and *C*, and the peaks *R R*. In order to look well, the slope or pitch of the sides of the pitch roof which covers the wings *a a*, must be the same as the slope or pitch of the end of the hip roof shown in Fig. 265 and

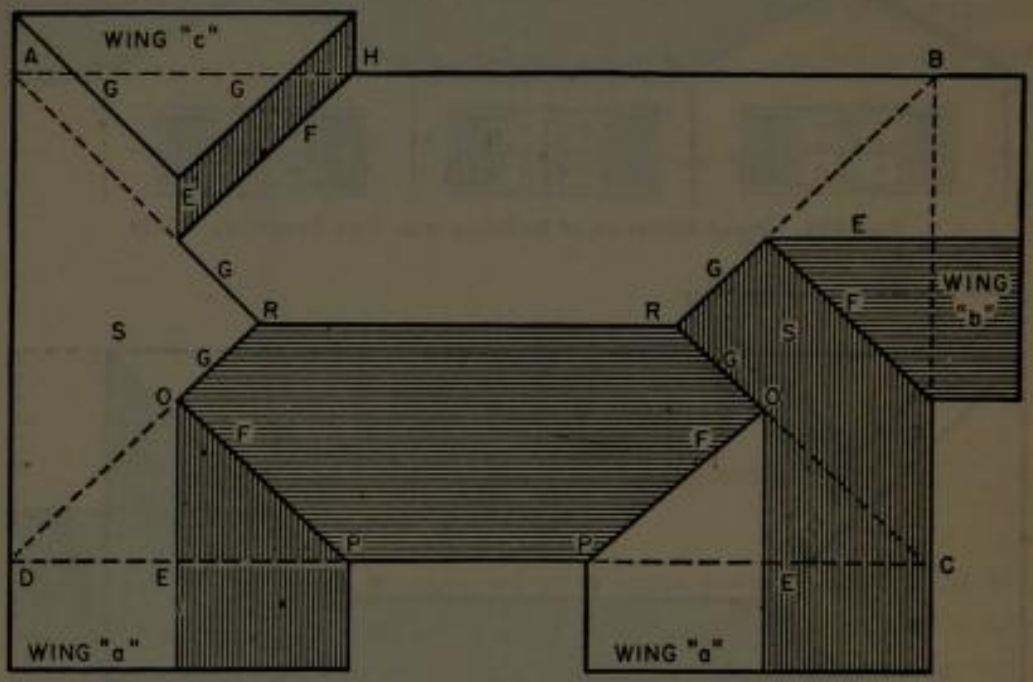


Fig. 266. Added Development of Roof Plan Covering Wings a, b and c of Fig. 263

there marked *S S*, and thus the sloping surface of the roofs of the wings *a a* will, on the outside, become parts of and extensions to the roofs *S S* over the main portion of the building, and the lower portions of the hip lines *G G* may be erased, leaving only the upper portions showing as hips, as indicated in Fig. 266.

The reason why these lines may be erased is that (because the outside sloping surfaces of the roofs of the wings, *a*, coincide with and become extensions to the sloping roof surfaces, *S S*, over the main portion of the building) the portions of the hips represented by these lines no longer exist as hips as there is no longer any break in the continuity of the roof surfaces at these lines. The other or inner slope of the pitch roof over the wing, *a*, will, however, not coincide with any slope in the roof over the main portion of the building and must be carried back until it intersects this roof in some line which

will be a valley. Since the ridge *E* of the wing roof is at the top of this sloping roof surface and the wall line of the wing, *a*, is at the bottom of this roof surface, that is, at the eaves, then a line drawn from the corner *P*, Fig. 266, in which the wall line of the wing intersects the wall line of the main portion of the building to the point *O*, Fig. 266, in which the ridge line of the wing roof intersects the hip line of the main roof, will be the line of intersection of the two roofs. This line is shown in Fig. 266, where it is marked *F*. The line *F* in the plan, Fig. 266, will represent a valley. Thus we have the two wings *a a*, Fig. 263, completely roofed over and the small wing roofs connected to the large main roof.

Suppose that we wish to cover the wing on the right-hand side of the building also with a simple gable roof. This wing is marked *b* in Fig. 263. We proceed in the same way as explained for the wings *a a*, drawing the ridge line *E*, in Fig. 266, until it intersects the hip line of the main roof *G* and then drawing the valley line *F*. The slope on the back side of the roof over the wing *b* should have the same slope as the back side of the main hip roof and, therefore, the lower part of the hip line *G*, starting at the point *B*, can be erased, leaving only the three lines, *E*, *F*, and *G*, shown in Fig. 266. Thus the wing *B* is completely roofed over and shown in plan. The line *F* in this case also represents a valley. Suppose that we wish to cover the wing on the back of the building, marked *c* in Fig. 263, with a hip roof instead of a gable roof.

We will start at the outside corners, and from these points draw lines *G G* in Fig. 266 at forty-five degrees with the front and side wall lines of the wing, until they meet. The lines must meet exactly in the center of the wing between the two side wall lines, and from this point a line should be drawn at right angles to the front wall line of the wing, but away from this wall line instead of towards it. This line is marked *E* in Fig. 266. It will intersect the hip line *G* of the main roof and from this point of intersection a line *F* should be drawn at forty-five degrees, which will meet the side wall line of the wing in the point in which this side wall line meets the main wall of the building. This point is marked *H*. One slope of the roof over the wing *c* will be the same as the slope *S* of the end of the main hip roof, and so the lower part of the line *G*, starting at the point *A*, may be erased and the upper part only left to show as a hip line. The

line *F* in this case also will be a valley line. Thus the wing *c*, Fig. 263, will be completely roofed over and properly shown on the plan. Our roof plan is now complete in outline, all the lines marked *E* being ridges, all the lines marked *G* being hip lines, and all the lines marked *F* being valley lines. The same method of procedure may be followed out in the case of any roof plan, and the final complete plan obtained by successive steps as explained above. The first step is always to lay out the roof over the main portion of the building and then to proceed with the roofing of the projecting portions or wings.

Ridge. In the lean-to roof the rafters rest at the top against

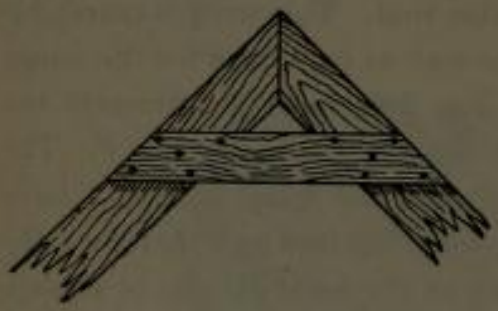


Fig. 267. Construction of Ridge

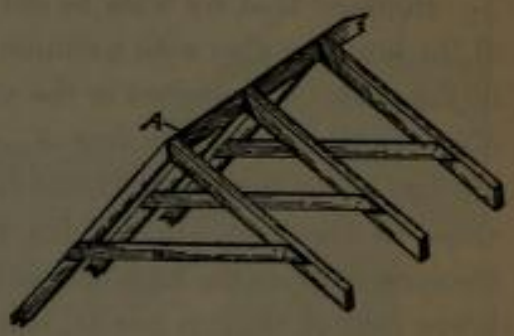


Fig. 268. Placing of Ridge Pole between Abutting Ends of Rafters

the wall of the building of which the ell, or porch, is a part; and the work of framing the roof consists simply in setting them up and securing them in place with spikes or nails. The pitch roof, however, is formed on the principle that two pieces which are inclined against each other will hold each other up, and so the rafters must rest against each other at the top in pairs, as shown in Fig. 267. It is customery to insert between the rafters, at the top, a piece of board about 1 inch in thickness and deep enough to receive the whole depth of the rafter, as shown at *A* in Fig. 268. This piece of board is called the *ridge* or the *ridge pole* and extends the whole length of the roof. It serves to keep the rafters from falling sideways, and keeps the roof frame in place until the roof boarding is on. It is sometimes extended above the rafters, and forms a center for some form of metal finish for the ridge, as shown in Fig. 269.

Interior Supports. In small roofs which have to cover only narrow buildings and in which the length of the rafters is short, there is no necessity for any interior support, and when the rafters

have been cut to the correct length, set up against the ridge, and secured in place, the roof framing is complete. In long spans, however, the roof would sag in the middle if it were not strengthened in some way, so it is customary to support long rafters as near the

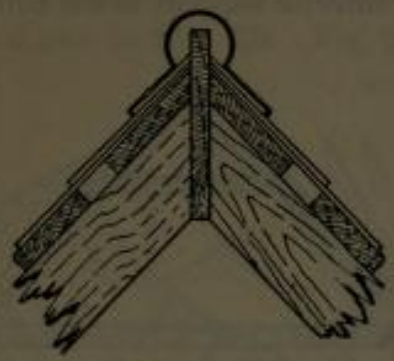


Fig. 269. Ridge Pole Extended above Roof

center as possible. This support may be formed by placing a piece of studding under each rafter, somewhere between the plate and the ridge, and if this is done very much lighter rafters can be used than would otherwise be considered safe. It is claimed by some that it is cheaper to do this than to use the heavy rafters. A more

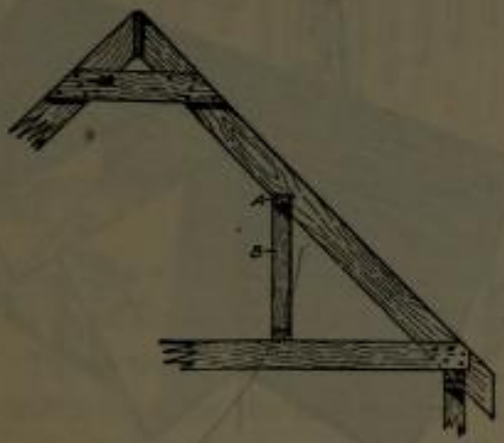


Fig. 270. System of Interior Supports for Rafters

common method is to use fewer upright pieces and to place a horizontal piece *A* on the top of them, running the whole length of the building and supporting each rafter. This is shown in Fig. 270. An upright piece *B* should be placed under every sixth or seventh rafter in order to give the necessary stiffness to the whole construction. For the uprights, pieces of ordinary studding 2 x 4 inches or 2 x 3

inches in size may be used. When there is to be a finished attic in the building, these upright studs may be made to form the side walls of the attic rooms, and are then spaced about 16 inches on centers to receive the laths. Such walls are called dwarf walls.

Another form of interior support is the collar beam or tie beam.

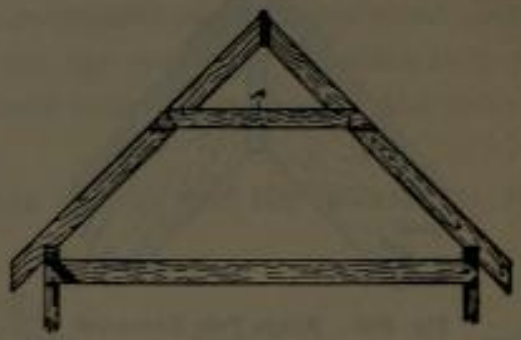


Fig. 271. Collar or Tie Beams as Interior Support for Rafters

This is a piece of timber which extends between the rafters on opposite sides of the roof and ties them together, as shown at *A* in Fig. 271. It may be a piece of board about 1 inch thick and 8 or 10

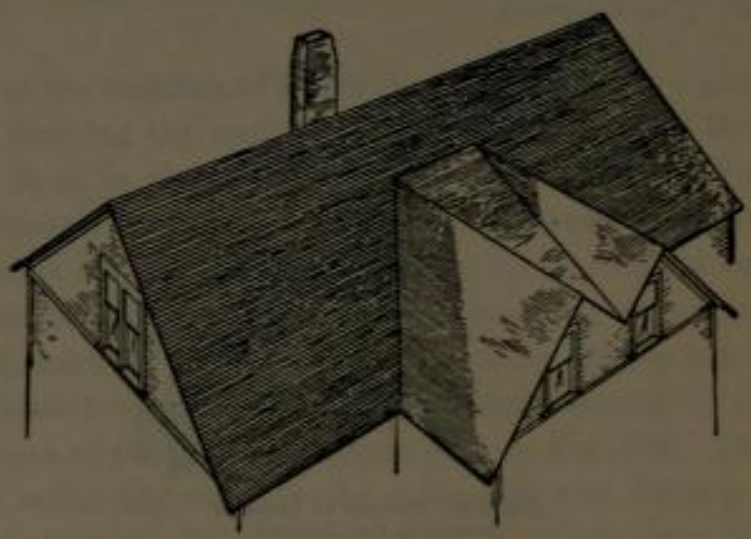


Fig. 272. Example of Double Gable Roof

inches wide, which is nailed onto the side of the rafter at each end. It is placed as near the center of the rafter as may be practicable, and in the case where a finished attic is required it forms the support for the ceiling. For this reason it must be at a considerable height from the attic floor, and can not always be placed very near

the center of the rafter. The important point is to see that it is well nailed at each end.

Double Gable Roof. A very interesting form of gable roof is that in which there is a double gable with a valley between, which forms the roof of an ell when the main roof is a simple pitch roof. This form of roof is shown in Fig. 272. Fig. 273 shows how such a

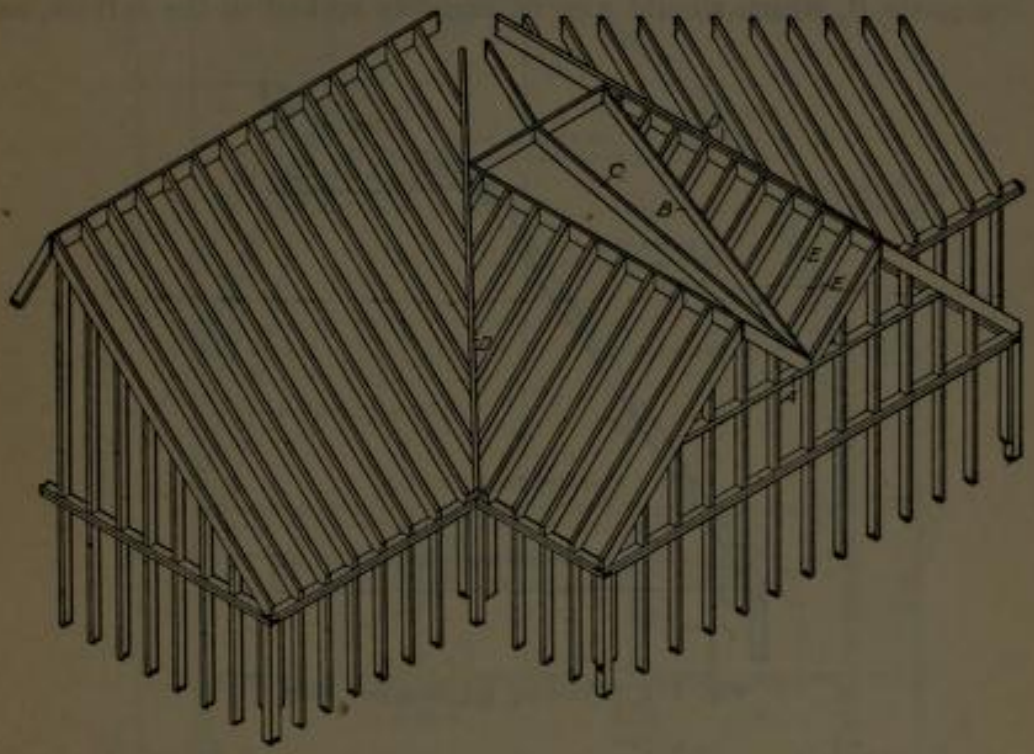


Fig. 273. Rafter and Wall Framing for Double Gable Roof

roof may be framed. The piece *A* is placed in the wall and supported by the studding so as to serve as a plate to receive the ends of the valley rafters *B*. These, together with the piece *C*, form the framing for the shallow valley between the two gables. The valley rafters on the outside, marked *D* in the figure, are similar to those used in the case of a single gable. The pieces *E E* are cripple rafters and are very short. This form of roof is not common, but in some places it gives a good effect.

Gambrel Roof. A gambrel roof is framed in very much the same way as is a pitch roof or a hip roof. The slope of the roof, however, is broken at a point between the plate and the ridge. The part of the roof above this break makes an angle with the hori-

zontal plane of less than forty-five degrees usually, while the portion below the break makes an angle with the horizontal plane greater than forty-five degrees. This is shown in Fig. 274.

The lower slope may almost be considered a part of the wall, and at the point where the slope changes there is a secondary plate from which the upper slope starts, as shown at *A* in Fig. 274. The secondary plate may be utilized as a support for the ends of the ceiling joists *B*, which should also be securely spiked to the rafters, as

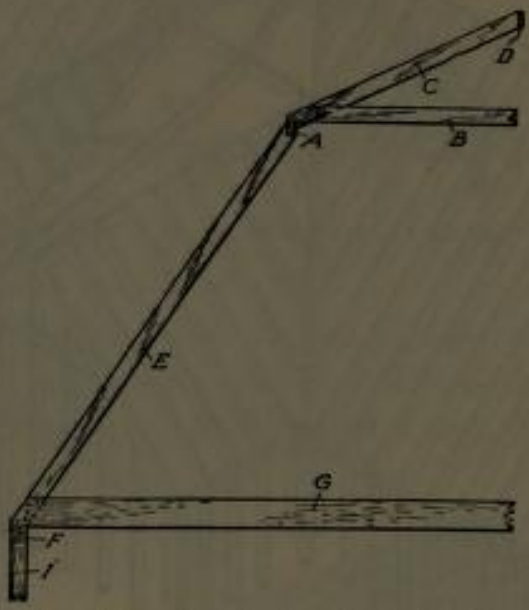


Fig. 274. Framing for Gambrel Roof

shown in the figure. The rafters *C* forming the upper slope, must be cut over the plate *A*, and firmly spiked to it, while at the top they rest against a ridge board *D*. The rafters *E*, forming the lower slope, are cut out at the top so as to form a seat for the plate *A*, and must be very securely fastened at the bottom to the main wall plate *F*. It is an excellent plan to have the floor joists *G* spiked to the lower rafters, so as to act like tie beams across the building and to counteract the outward thrust of the rafters. Sometimes these floor joists are dropped below the wall plate *F*, and are supported on a ledger board notched into the wall studding *I*. This construction is not so good as that shown in the figure, because the joist is not so effective as a tie across the building. If it is employed the floor joist must be securely nailed to the wall studding *I*, and they must not in any case be dropped more than 2 or 3 feet below the plate. The plate must

always be firmly nailed to each stud to prevent it from being forced outward as it receives the thrust from the rafters *E*.

Gambrel roofs of the type illustrated and described above are not very strong unless they are stiffened by cross partitions in the upper stories, and these should be provided wherever it is possible,

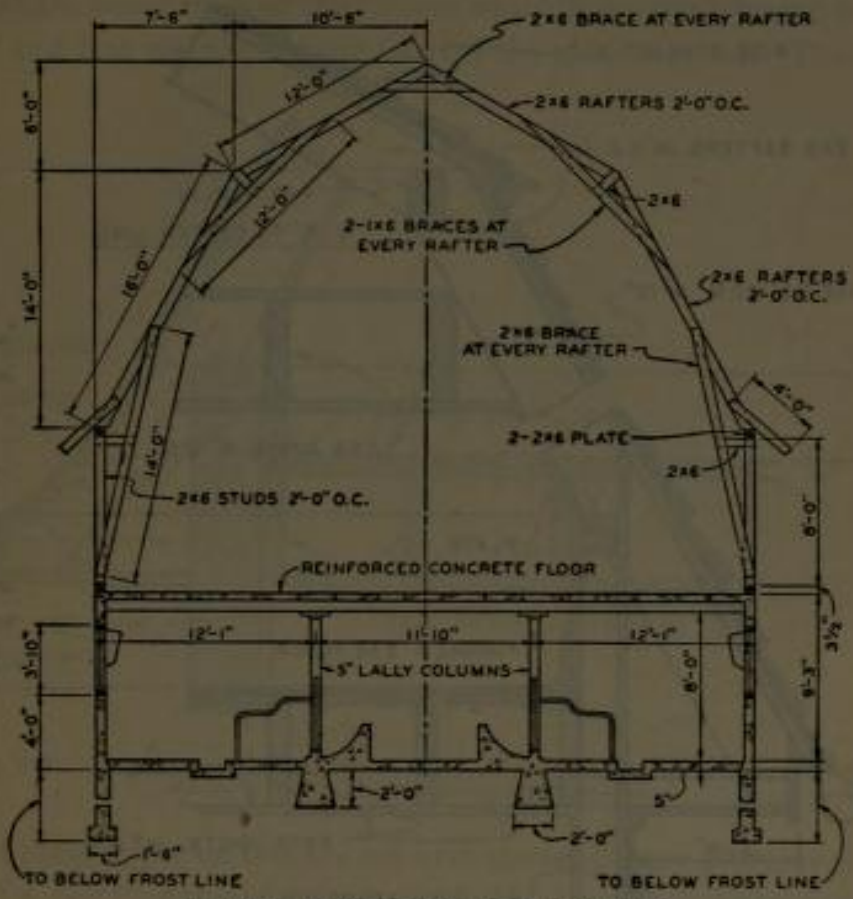


Fig. 275. A Rigid Type of Barn Framing

or such roofs should be stiffened by trussing the rafters as is done in the case of large barn roofs which are very often built in this style and for which it seems to be particularly well suited. For barn roofs long rafters are built up by combining into one long member a number of shorter ones in such a way that a long strong trussed rafter of the shape necessary to form a gambrel roof will be formed as shown in Fig. 275.

It is seldom that a gambrel type of roof is seen on a building which has two full stories, with the lower part of the gambrel roof starting at a plate located at the top of the wall framing at the level of the second floor ceiling. One reason for this is that such con-

struction would make the attic story too high and would necessitate the construction of cross partitions in the attic where they are not generally required except in this case for stiffening the roof structure. The more usual condition met with is where the gambrel roof framing starts at a plate located at the top of the first story wall a short

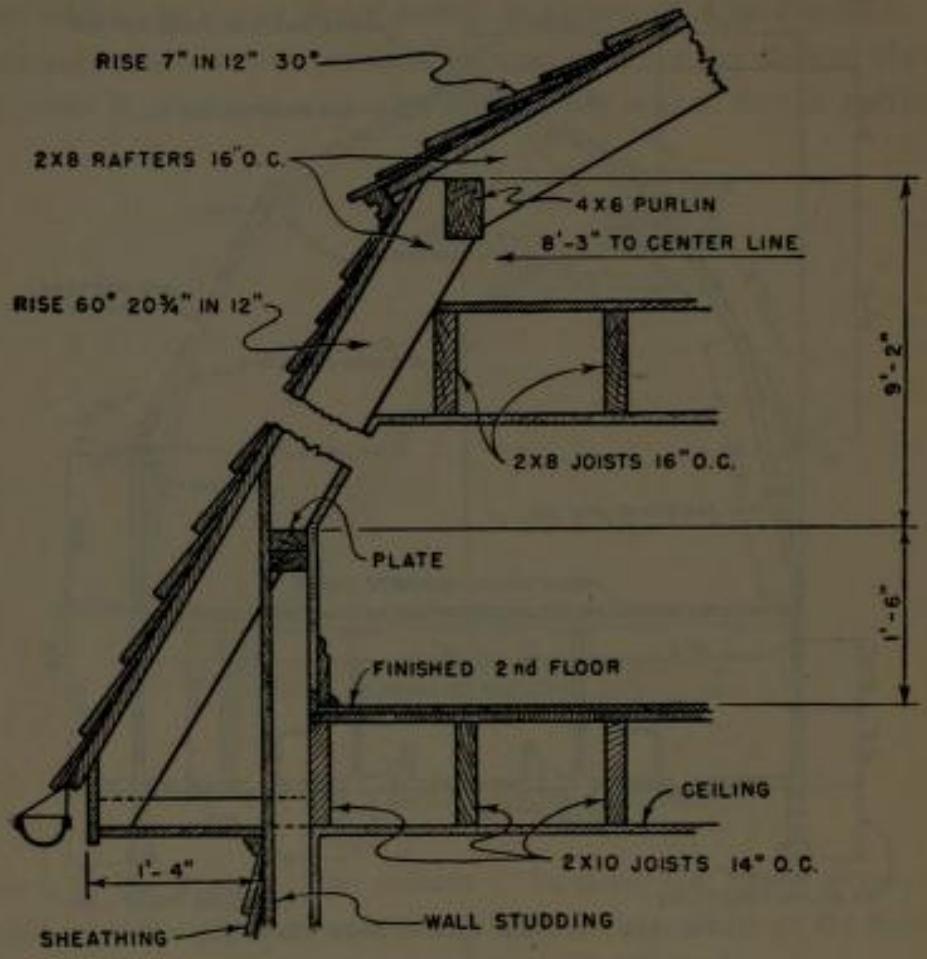


Fig. 276. Rafter Support Detail

distance only above the second floor level. There are almost always cross partitions required in the second story and these partitions will serve very effectively to give the required stiffness to the gambrel roof framing in this case.

For a roof frame of this kind the rafters would, as a rule, be made about 2 by 8 inches in size and would be spaced about 16 inches apart. They would rest upon, or be cut over, the main wall plate and would slope rather steeply up to a line somewhat above the level of the second floor ceiling where they would be cut in against the side and bottom of a secondary plate ("*A*," Fig. 274) which is

also sometimes called a "purlin." These rafters are actually supported against the joists forming the second story ceiling and they in turn are supported on the framing for the partitions in the second story so that the secondary plate is really carried and kept in place by the rafters, as shown in Fig. 276. This plate serves, however, to support the lower ends of the rafters which form the framing for the upper and less steeply sloping part of the gambrel roof. The lower

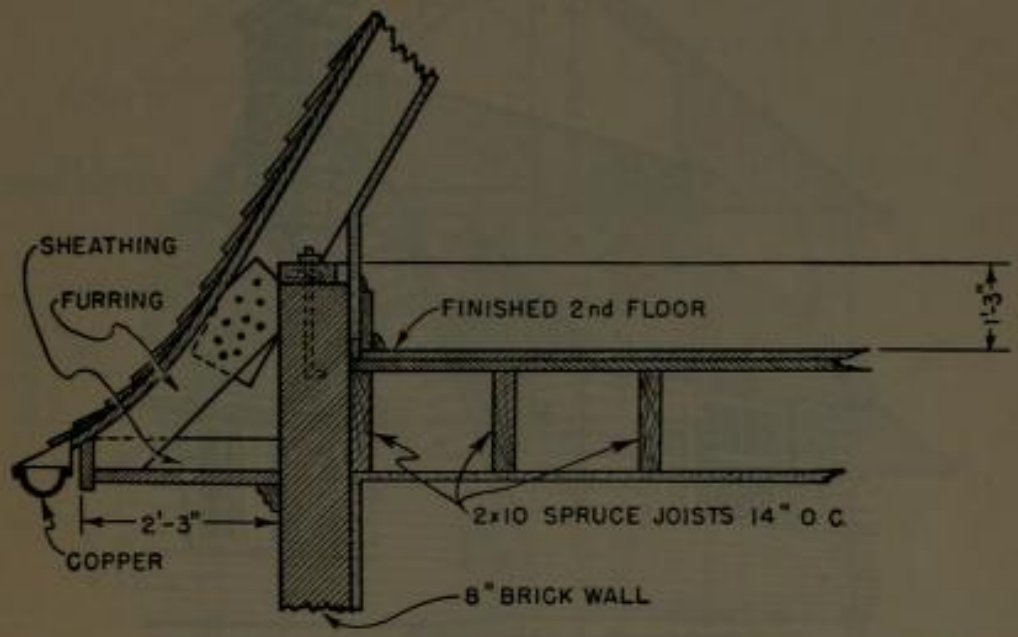


Fig. 277. Detail Showing How Rafters Are Constructed So As to Overhang the Eaves to Form Shelters Over Doorways, etc.

ends of these upper rafters are cut over the secondary plate, or purlin, in such a way that this plate not only holds them up, but also prevents them from sliding outwards.

At the other, or top end these upper rafters are supported by a ridge pole in the same way as is illustrated in Fig. 269, except that these rafters do not slope so steeply as those shown in the figure.

At the eaves, which in this case are at approximately the level of the first floor ceiling, the lower rafters, which slope steeply, may be carried straight down well below the level of the main wall plate after being cut over this plate, thus allowing the roof to overhang the walls to the extent of about 18 inches, as shown in Fig. 252. The heel of each rafter may be cut to receive the eave finish, as shown in Fig. 276.

Sometimes the designer or builder wishes to have the eaves over-

hang the wall by a greater amount than this so as to form a shelter over a doorway or to form the roof over a bay window and, in such a case, the lower rafters of the gambrel roof framing are continued only a short distance over or beyond the main wall plate as shown in Fig. 277, and false rafters are spiked onto the ends of them so as to change the slope of the roof at this point just as was illustrated

Fig. 278. Showing Finished Appearance of a Roof Where Rafters Overhang As in Fig. 277

in Fig. 254, but it is often considered more pleasing in the case of a gambrel roof to have a curved roof surface at this point so a wide rafter is used for the false rafter, maybe a 2 x 10 or a 2 x 12-inch piece, and then the upper surface or edge is cut out to form the curve desired as shown in Fig. 277. The finished appearance of a roof, the eaves of which are framed in this way, is shown in Fig. 278.

The principal characteristic of gambrel roofs of the type which is shown in Fig. 276 is the large dormer windows which usually occupy the greater part of each side of the lower and more steeply sloping portion of the roof. Where these dormer windows occur they are usually so placed that the framing for the main wall carries straight up to the level of the ceiling of the second floor where a wall plate is placed resting on the upper ends of the wall studding to

receive the lower ends of the rafters which form the roofs over the dormer windows. (See Fig. 278.) These are usually just a continuation of the rafters of the main roof which, at a section taken through the dormer windows, becomes the same in every respect as if it were

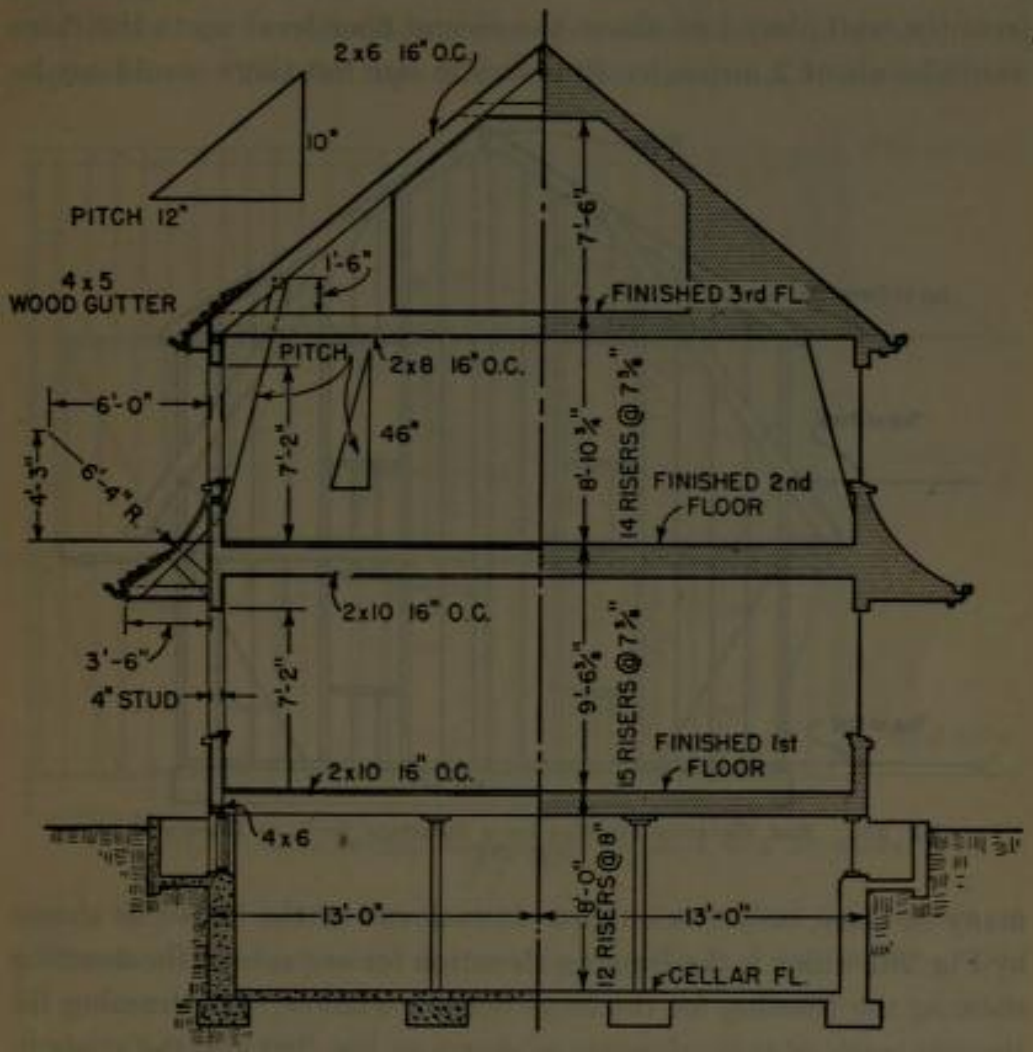


Fig. 279. Section through Wall and Roof Framing of a Gambrel Roof

an ordinary pitched roof. Fig. 279 shows a section through the wall and roof framing of a gambrel roof at the dormer window and Fig. 278 shows how the corner of a building with a roof of this kind actually appears. The curved eave finish at the first floor ceiling level is carried right across the wall in front of the dormer windows and the framing for this eave finish is formed of short pieces of scantling bracketed out from the wall studding as shown in Fig. 279.

Figure 280 shows a framing elevation of the end of a structure

of the type illustrated in Fig. 252. The ordinary filling-in studding is indicated by single lines while the larger timbers at each side of the windows and at the corners are indicated by double lines. A braced frame is indicated with heavy timbers for corner posts and girts. The main sloping rafters at the end of the building running from the wall plate just above the second floor level up to the ridge would be about 2 inches by 10 inches in size but there would not be

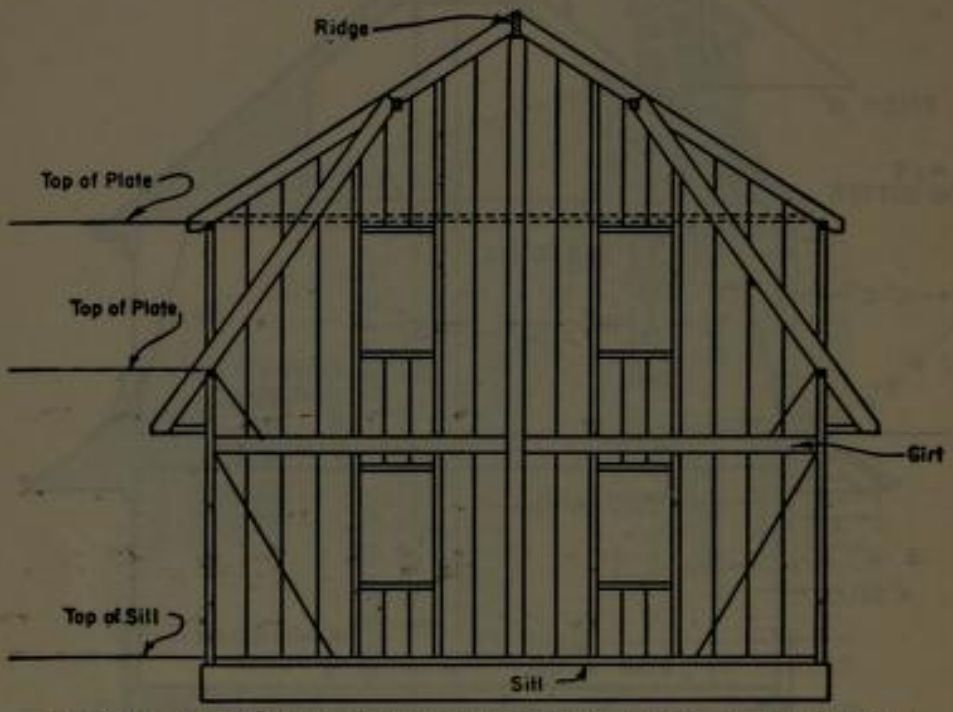


Fig. 280. End Elevation Framing for a Structure Such As Illustrated in Fig. 252

many of these, only two or three at each end of the house, as shown by Fig. 281 which is the framing elevation for one side of the dwelling showing the framing for the large dormer window. The framing for the side walls of these dormers is shown in Fig. 280 and the studs in these walls are carried on doubled 2 x 10-inch rafters similar to those shown in the end elevation, but these long rafters do not have to support any of the weight from the dormer roof which is carried on the 4 x 8 posts at the corners of the dormers. The rafters for the dormer window roofs may be 2 x 8 inches in size and rest at the wall end on a wall plate at the level of the ceiling of the second floor as shown. It will be seen from these framing elevations how little the framing for this type of roof differs from the framing for an ordinary pitch or gable roof. The only difference is at the two ends of

the building where a short piece of wall plate is inserted in the side wall framing at each of the four corners somewhat above the level of the second floor for the purpose of receiving the lower ends of the few longer and steeper rafters which occur only at the two ends of the building.

There are two distinct types of gambrel roofs in general use, one called the "Dutch" type and the other called the "New England"

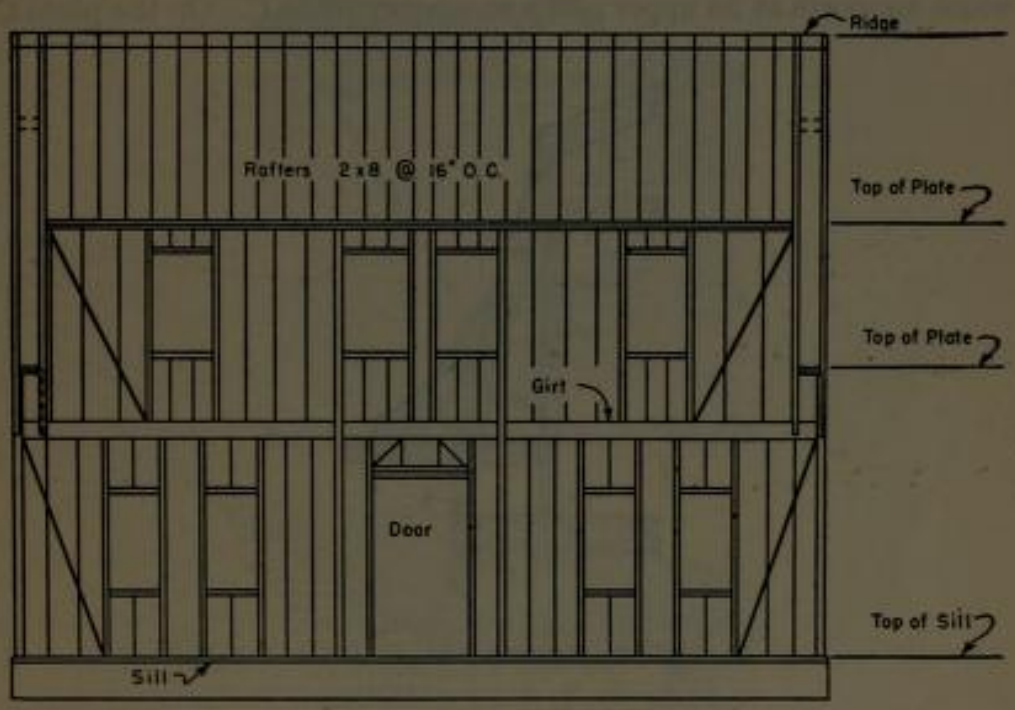


Fig. 281. Framing of Side Elevation for Structure Such As Shown in Fig. 252

type. The Dutch type has a curve at the eaves and then slopes up at an angle of forty-five degrees to the level of the purlin. The New England type has either straight or curved eaves and then slopes steeply up at an angle of about sixty degrees as shown in Fig. 276. In both types the upper and flatter part of the roof slopes upward at an angle of about thirty degrees. The New England type is used more often in modern houses as it gives much more room in the second story. In this type the most pleasing proportions are obtained when the height from eaves to ridge measured vertically is about equal to the width of the building and when the length of the flatter slope on the top of the roof between the ridge and the purlin is about two-thirds of the length of the steeper slope between the purlin and the eaves at the side walls.

Mansard Roof. Fig. 241 shows a mansard roof and Fig. 282 shows the framing for such a roof except that the slope of the roof in Fig. 241 is straight while Fig. 282 shows a roof that is curved just above the eaves.

A mansard roof is framed in very much the same way as is a gambrel roof, as may be seen in Fig. 282. Resting on the main wall plate *A*, we have a piece *B* which is inclined slightly inward, and which supports at its upper end a secondary plate *C*. On the plate *C*

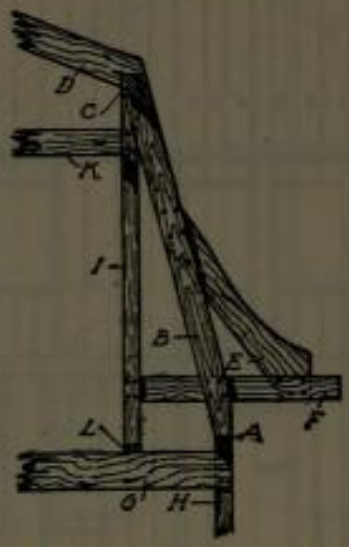


Fig. 282. Framing for Mansard Roof

rests the outer end of the deck rafter *D* which is nearly horizontal. The piece *B* is a piece of studding, 2 x 4 inches to 4 x 6 inches in size, depending upon the size of the roof. It supports the whole weight from the rafters, carrying this weight to the main wall plate and thence into the walls of the building. This member should always be straight, and the curved shape which is usual on mansard roofs is obtained by the use of the furring piece *E*. The piece *E* is nailed to the upright member *B* at the top, and at the bottom it is secured to the lookout *F*, which also forms a support for the projecting cornice. The floor joist *G* is supported on a ledger board *H*, or it may rest directly on the plate *A*. The piece of studding *I* is merely a furring stud to form the wall of the attic room. It may be omitted entirely if desired, or if the attics are to be unfinished. The ceiling joist *K* may be supported on a ledger board as shown, or may be simply spiked to the studding *I* or to the upright *B*. The

studding *I* may rest directly on the floor joist *G* with a sole piece *L* at the bottom as shown. The plate *C* should be of a good size, at least 4 x 6 inches, and should not be placed more than 2 or 3 feet above the ceiling joists *K*. The ceiling joists act as ties across the building and prevent the plates *C* from spreading apart, as they receive the thrust from the rafters *D*. For this reason it is better

Fig. 283. One Form of Dormer Window

Fig. 284. Another Form of Dormer Window

to have the ceiling joist *K* fastened to the upright *B* rather than to the furring stud *I*.

Dormer Windows. In Figs. 283 and 284 are shown what are known as dormer windows, this name being applied to all windows in the roofs of buildings, with the exception of skylights. The figures show two different kinds of dormer windows which are in general use, the one shown in Fig. 283 resting entirely on the roof, while the one shown in Fig. 284 is merely a continuation of the wall of the building above the line of the eaves.

Fig. 285 shows a dormer of this type in a masonry building.

In some cases where the eaves of the roof project far out beyond the walls for the purpose of covering a porch or a bay window, a dormer of a different type is employed which is recessed into the roof surface instead of resting on top of it. Fig. 286 shows such a dormer window and recess. As will be seen it is necessary in this case to have sheet metal (preferably copper) flashings very care-

Fig. 285. Dormer in Masonry Structure

fully and thoroughly applied as the recess in the slope of the roof forms a pocket which may hold rain and snow and create serious trouble if it is not made thoroughly water tight.

In order to construct a dormer window an opening must be made in the roof surface, and the window must be built up over the opening. Headers are framed in between two of the rafters as shown at *A* and *B* in Fig. 287, and thus a rectangular opening is formed in the roof frame. The rafters *C* and *D*, which form the sides of the opening, are called trimmers and should be much stronger than the common rafters. Usually the trimmers are made by doubling the ordinary rafters. The headers receive the ends of the rafters which are cut by the opening, and must be large enough to carry the weight which comes from them besides supporting the walls of the dormer. For light roofs these headers are usually built up of two pieces the

same size as the rafters but in wide openings or tile roofs heavier construction is necessary.

The headers are shown in section at *A* and *B* in Fig. 288, and

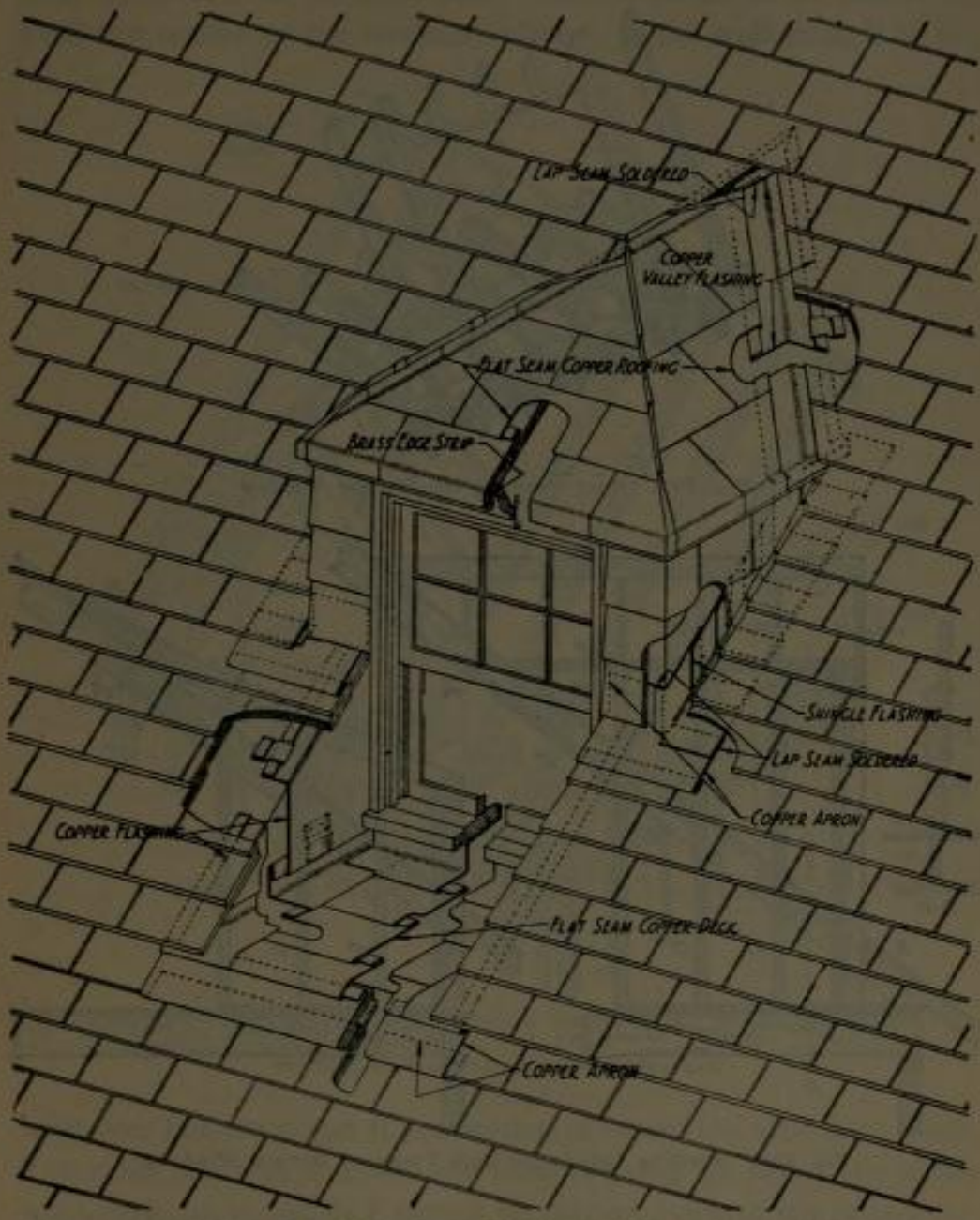


Fig. 286. Dormer Window and Recess
Courtesy of Copper and Brass Research Association

it will be noticed that they are not used in exactly the same way. The piece at the top *A* is so placed that its longer dimension is at right angles to the plane of the roof, while the piece at the bottom *B* has its longer dimension vertical. In the case shown in Fig. 284,

where the front wall of the dormer is merely an extension of the main wall of the building, there is no need of the lower header *B*, the main wall plate taking its place and supporting the studding

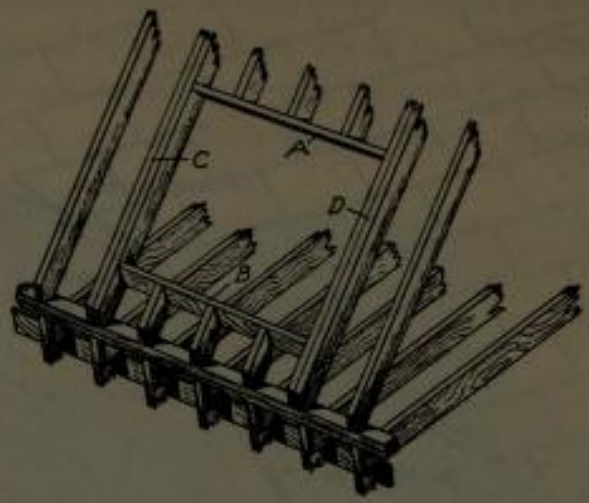


Fig. 287. Roof Framing for Dormer Window

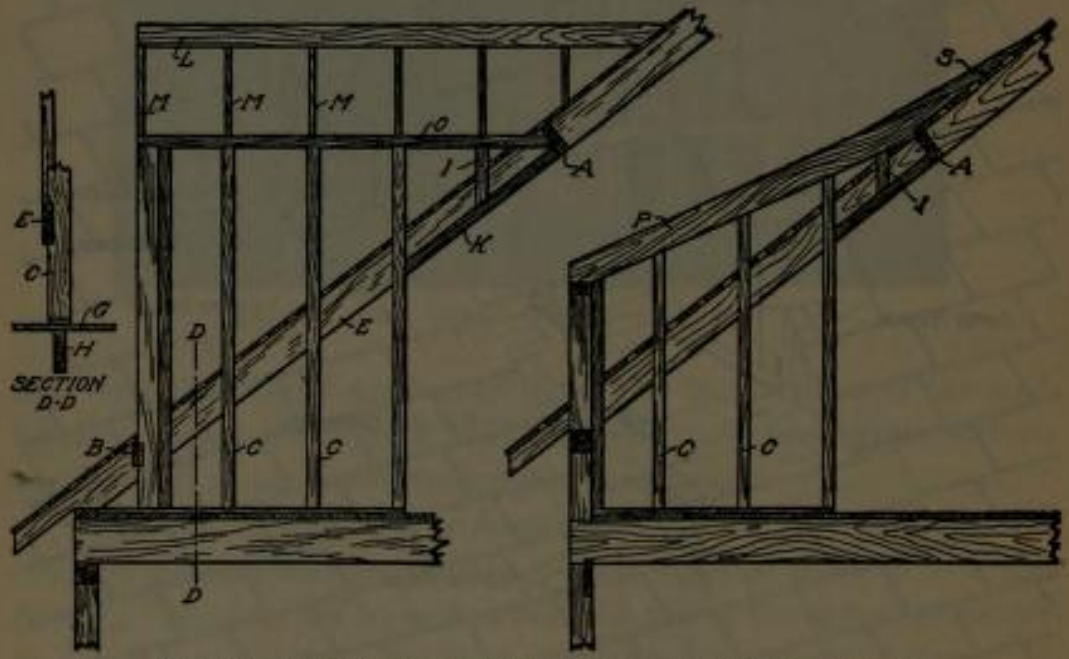


Fig. 288. Framing Details for Both Types of Dormer Windows

for the front wall of the dormer, as shown at the right-hand side of Fig. 288.

Fig. 288 shows sections taken through two dormers of the types mentioned above, parallel to the direction of the main rafters and at right angles to the main wall plate of the building. At the left is a section taken through the type of dormer shown in Fig. 283,

while at the right a section of the other type is shown. The studs *C C* which form the side walls of the dormer, are notched over the trimmer rafters and roof boarding about 1 inch, and allowed to continue downward to the attic floor. This is shown at section *D D*. At *E* is a section of the trimmer rafter, *C* is the wall stud, *G* is the

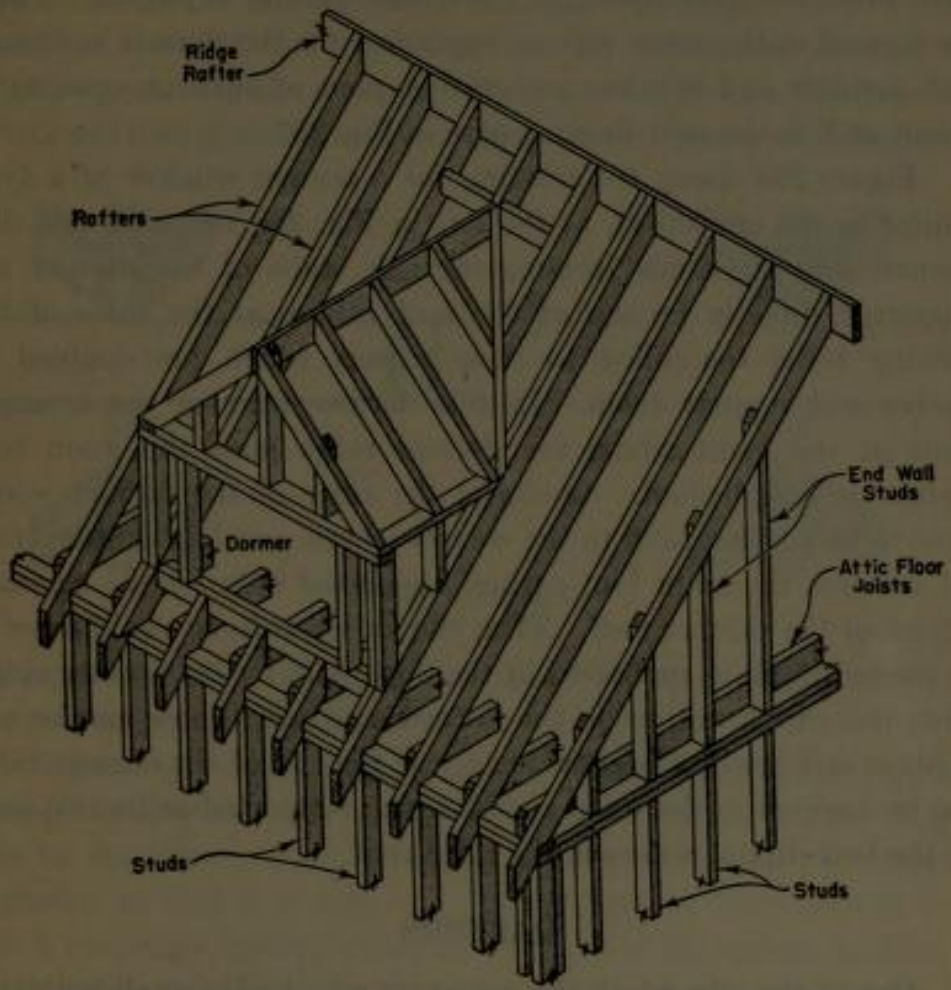


Fig. 289. Framing for Dormer Window Similar to the Dormer Shown at Left in Fig. 288
Courtesy of Weyerhaeuser Forest Products

attic floor boarding, and *H* is a section of one of the attic floor joists. The studs *N* are in line with the studs forming the side walls of the attic room, so the studs *I* cannot be carried down to the attic floor. They are stopped, at the bottom, against a 2 x 3 inch strip *K* which is nailed to the side of the trimmer rafter. At *L* is the ridge board, and *M M M* are the short rafters which form the pitch roof of the dormer. They may be very light, as they are short and carry little weight. They rest, at the foot, on a plate *O*, and at the top bear

against the ridge board *L*. In the dormer shown on the right of the figure the rafters *P* are in planes parallel to the main rafters, and a furring piece *S* may be nailed to each of them so as to give the dormer roof any desired curve.

Besides the openings in the roof frame for dormer windows there must be other openings for chimneys and skylights. These are formed in the same way as explained for the dormer openings, with headers and trimmer rafters. A plan of such an opening is shown at *E* in the roof framing plan in Fig. 257.

Figure 289 shows the framing for a dormer window of a type similar to the one shown at the left in Fig. 288 but with this difference, that the studs forming the side walls of the dormer are supported directly on top of the roof rafters at the sides of the opening being toe-nailed to these rafters which are doubled to receive and support them. In this dormer framing the arrangement at the point where the dormer ridge joins the main roof surface is complicated. As shown the ridge of the dormer would have to be cut carefully to the correct length and left cantilevering out towards the main roof surface supported only by the common rafters of the dormer roof. Then the valley rafters would have to be erected in place supported at the upper end by the dormer ridge. Then the cripple rafters in the dormer and main roofs can be put in place and finally the short header at the end of the dormer ridge can be inserted in the main roof framing supported at its two ends by the two cripple rafters in the main roof.

RAFTERS

One of the jobs which the carpenter who builds small buildings and dwellings is very often called upon to perform is the cutting of the rafters for the sloping roofs so that they will be of the correct length and will fit together properly when they are placed in the positions which they are to occupy in the finished roof. To a carpenter of long years of experience, the work of cutting the rafters for the ordinary types of roofs presents no difficulties but to the younger man even the simpler roofs give problems which at first require a lot of explanation or study and there are roofs so complicated that the cutting of the rafters for some parts of them will cause even the most experienced workman a lot of puzzling before

he can get them out with the assurance that they are going to go together without a hitch. When the carpenter first starts to work all that he has to work with are some planks and timbers somewhat longer than required; a steel square, a pencil, and the necessary tools for cutting the timbers up into rafters. Add to these a knowledge of the kind of roof which is to be constructed, that is, the "pitch" of the roof, the "rise" and "run" of the rafters, the amount of the projection at the eaves and the power to imagine just how the rafters will look in their final position in the roof structure. Probably

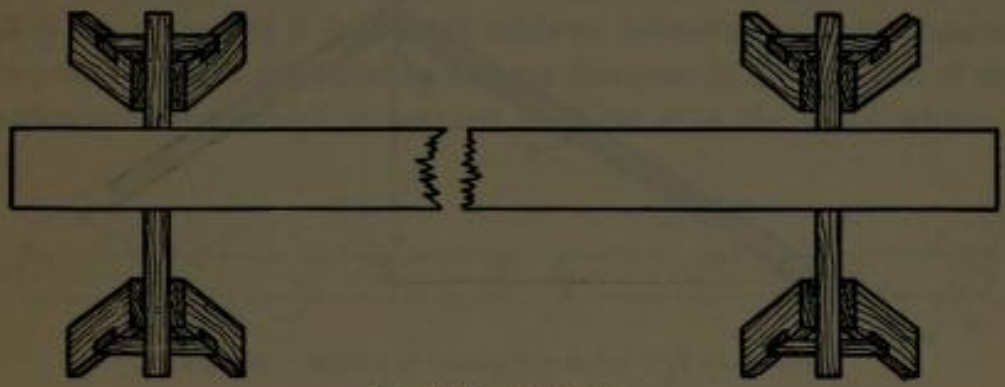


Fig. 290. Sawhorses

the most helpful of all these things are the steel square and the power of the imagination.

Rafters are usually laid out for cutting by setting up two "horses" as shown in Fig. 290 and laying the piece of lumber which is to be cut into a rafter flat on its side on top of the two horses, as shown, so that it is at a convenient height to work over and so that a carpenter looking down at the tops of the horses, as shown in the figure, when bending over his work can imagine himself to be looking at the side of the rafter. He can imagine that the left-hand end of the stick is the lower end of the rafter which will rest on the wall plate or against a valley rafter and that the right-hand end of the stick is the upper end which will rest against the ridge or against a hip rafter.

Common Rafters. Suppose we are to lay out and cut a common rafter. The first thing we need to know is how long the rough stick must be in order that the finished rafter can be cut from it. If we are working from a set of plans and there is a roof plan, the rafters may be located to scale on this plan and the distance across

the building from one wall to the other may be measured to scale so that the distance from the outside edge of the wall plate on one wall to the outside edge of the wall plate on the opposite wall may be determined. If there is not a roof plan, the carpenter may know what this distance is to be. Finding one-half of this distance would be the first step towards finding the length of the rafter, but this would not be the actual length of the rafter because this distance

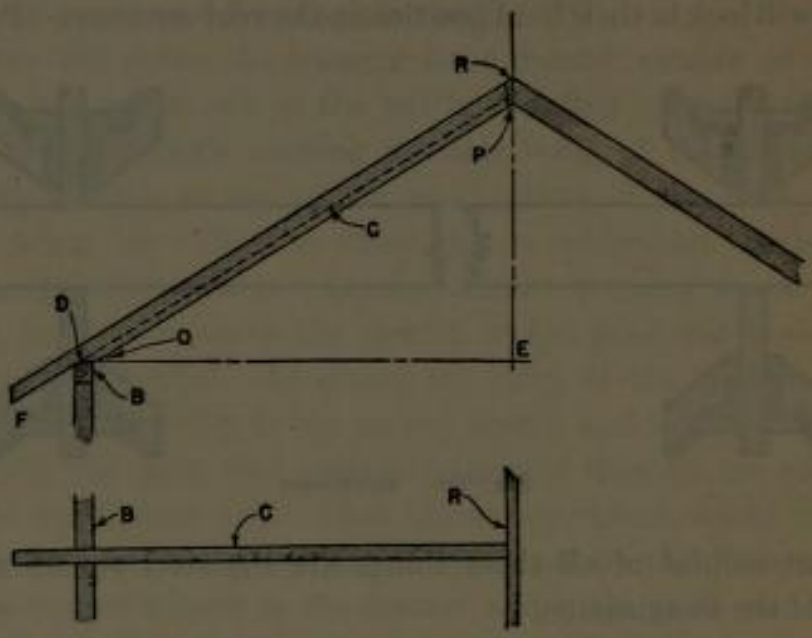


Fig. 291. Diagram Showing Bevel Used on Common Rafters

measured on the plan, or on the flat, would be what is usually called the "run" of the rafter. We still have to consider the effect of the "rise" of the rafter on its length. The words "run" and "rise" commonly used when speaking of rafters refer to the length of the base (run) and the height (rise) of a right-angle triangle the sloping side of which would be the actual rafter when in place while the length of base would be one-half the distance between the two wall plates on opposite sides of the building. The height or "rise" would be the vertical distance from the level of the top of the wall plates up to the ridge. This is illustrated in Fig. 291 which shows a rafter in place, and where the distance *D E* (one-half the span) is the "run" and the distance *E P* is the "rise," the length would be the distance *D P*, measured along the sloping rafter, but our stick of lumber must be enough longer than this to allow for the

overhang at the eaves, which is represented in Fig. 291 by the distance *D F*. The end elevation of the building will show the length of the rafters if the roof is a simple pitch or gable roof, or if we know the run and the rise of the rafters the length *D P* can be found with the aid of the steel square as explained further along. Having determined the approximate length required we can select a suitable stick of lumber and lay it on the horses. The next thing is to lay out and cut the bevels for the rafter.

Figure 291 shows the bevels that are used on the common rafters in a simple gable roof such as is illustrated in Fig. 239. In Fig. 291, *B* is the plate and *E* is a point midway between the two plates on opposite sides of the building and the distance *D E* is the run of the common rafter which is marked *C*. Now *P* is the point where a

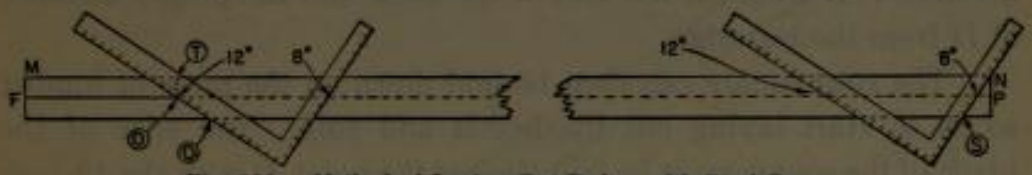


Fig. 292. Method of Laying Out Rafter with Steel Square

line drawn through the outside upper corner of the wall plate, marked D, and parallel to the edges of the rafter intersects the center of the ridge and this point is directly above the point *E* in the actual roof frame. The distance *D P* is usually taken as the length of the rafter. The dotted line, *D P*, is called the "Work Line." The length is taken as the distance between these points because the distance *D E* represents the run and *E P* represents the rise for this run. The exact run of the rafter, however, is the distance *D E* less one-half of the thickness of the ridge piece which is marked *R* in Fig. 291 and which is shown more clearly in Fig. 294.

As our stick of lumber lies before us on the horses we have to decide which edge shall be the "back" or upper edge of the rafter and which edge shall be the underneath edge. Many carpenters, in laying out rafters work with the "back" of the rafter towards them but it will be easier to understand the explanations if we work with the "back" away from us as the stick lies on the horses. We can imagine the stick shown in Fig. 292 to be placed before us on the horses in this way.

The first step to take in laying out the rafter is to locate the

point *D* on the uncut piece as shown in Fig. 292. This point is placed so that it will be far enough from the left end or heel of the rafter to form the eaves, *F D*, Fig. 291. The distance from the work line *D P* to the back of the rafter (represented by the line *M N* in Fig. 292, must be decided upon. It is usually 2 inches less than the depth of the rafter so that the distance, *D O*, Fig. 291, will be at least 4 inches. This will make the distance *T D* in Fig. 292 2 inches on a 2 x 4-inch stick and 3 inches or more on larger sized rafters. It is well to remember that the measurement is to be taken from the top of the rafter, and the same in each case, in order that the roof surface as fixed by the top edges of all the rafters may be even and smooth throughout. Knowing now the distances *F D* and *T D*, the point *D* can be marked on the stick of lumber at the proper distance *F D* from the left end of the stick and the proper distance *T D* from the top edge.

The steel square can then be laid down on the piece of lumber so as to start laying out the bevels and cuts. The edge of the blade of the square must be laid against the point *D* with the 12-inch mark on the blade at *D*, but the position which the square will take depends entirely on the pitch of the roof of which this rafter will be a part. The distance from the point *D* (at which the 12-inch mark on the blade of the square is placed) to the heel of the square now represents 1 foot of the "run" of the rafter measured from the outside upper corner of the wall plate which is represented by the point *D*. As the square is moved about keeping the 12-inch mark on the blade always at the point *D*, some mark on the tongue of the square will always fall on the work line *D P*. What point this should be when the square is in the correct position depends upon the "rise" of the roof per foot of run. If the rise of the rafter is 12 inches to the foot, then 12 inches should be used on the tongue also. If the rise is 10 inches, use 10 inches on the tongue. In Fig. 293 the rise is 8 inches to the foot. This would be correct in a case where the total run was 12 feet and the total rise was 8 feet. The run is 12 feet, the rise is 8 feet and 12 and 8 are the figures used on the blade and tongue of the square in Fig. 292.

The second method is as follows: For example, the rise is 8 inches and the square of the rise is 64. The run is 12 inches and the

square of the run is 144. The sum of the square of the rise and the square of the run is 64 plus 144 which is 208, thus: —64+144=208. Then the square root of 208 is 14.42 which is nearly $14\frac{5}{12}$ and that is the same as 14 feet and 5 inches.

The third method is to measure the distance in inches and twelfths from the 12 on the blade of the square to the 8 on the tongue. Each inch represents one foot of length and each twelfth represents 1 inch. The distance is 14 feet 5 inches. The fourth method is

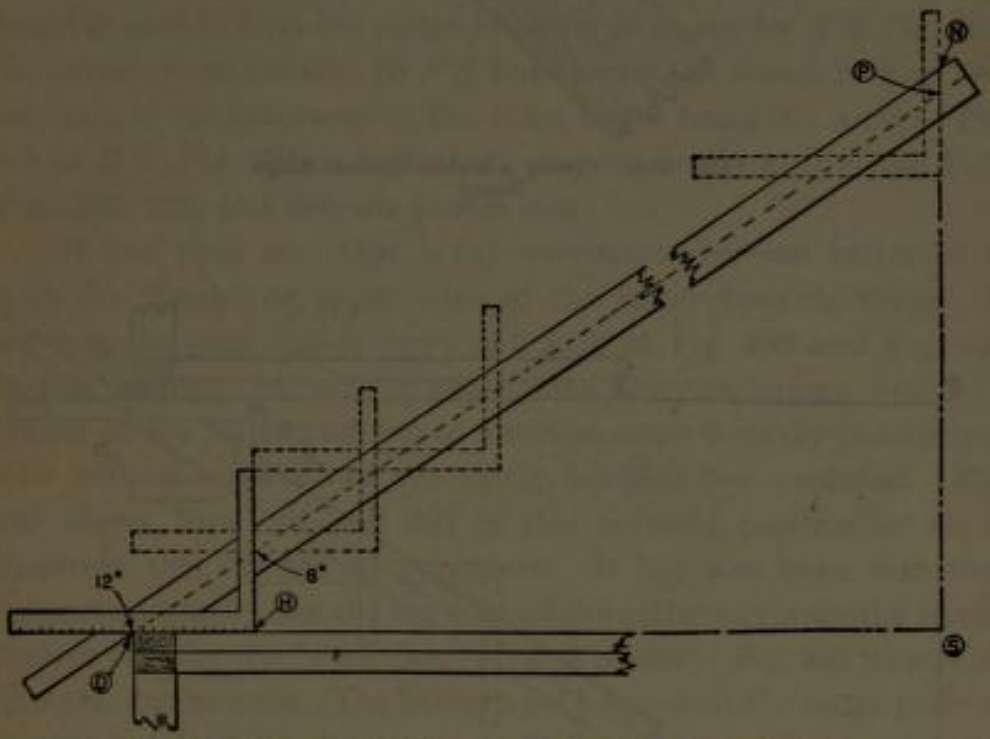


Fig. 293. Method of Cutting the Bevel at the Top of the Rafter

to use the one illustrated in Fig. 293. First locate the line *D P* and then beginning at *D* move the square along the edge of the rafter as many times as there are feet and fractions of feet in the run; thus the point *P* is determined.

A little study of the figures will suffice to reveal to anyone the reason for this method of procedure. Every time the square is moved into a new position it has advanced 12 inches or 1 foot along the run of the rafter, since the distance *D H* is 12 inches and is measured horizontally. After the square has been moved twelve times it has advanced 12 feet along the run of the rafter or the distance required. This gives the position of the top bevel. It should be

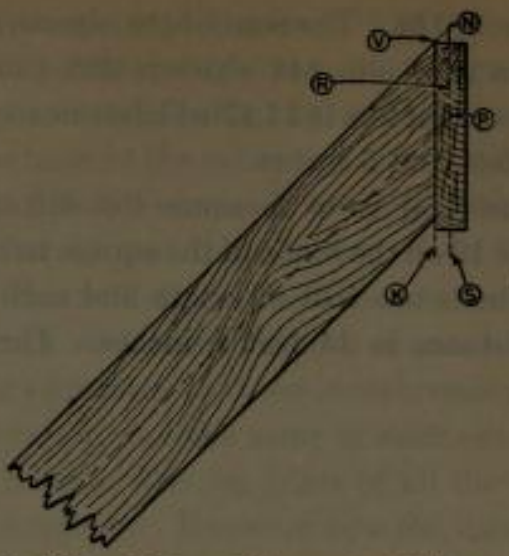


Fig. 294. Fitting a Rafter against Ridge Board

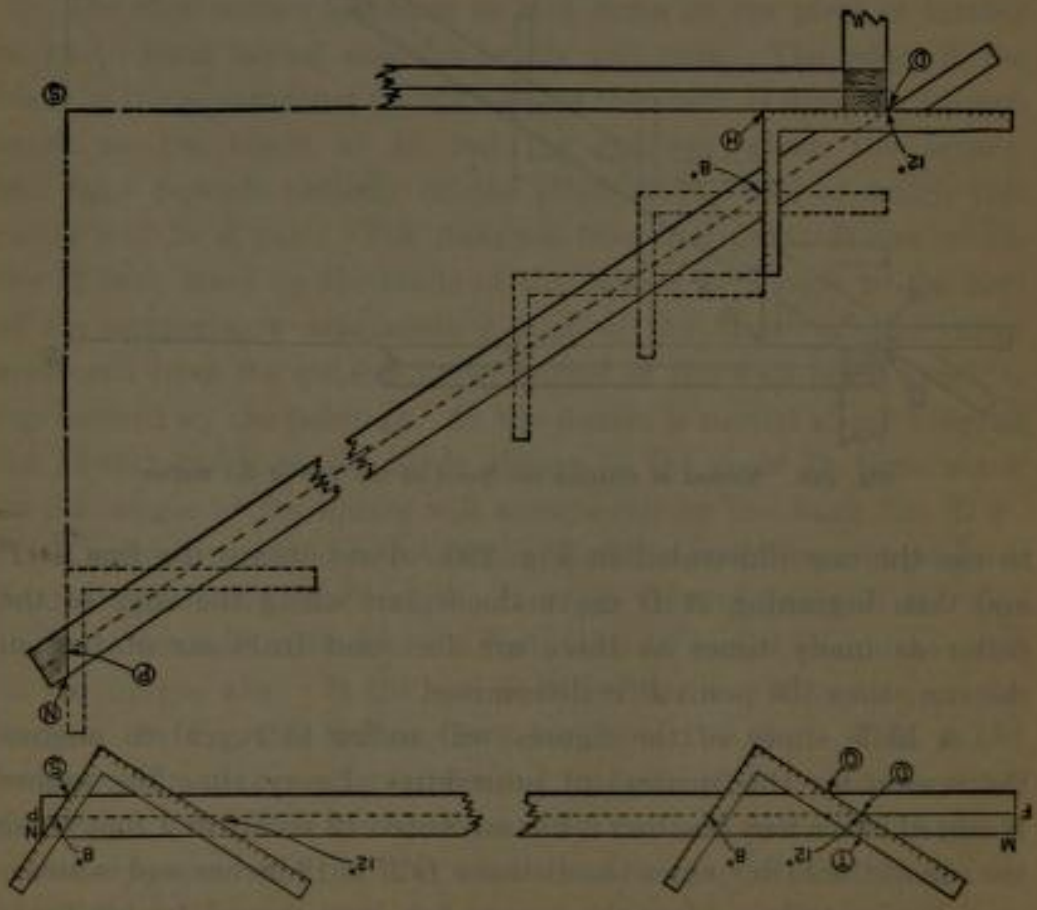


Fig. 295. Shows Figs. 292 and 293 in Reversed Position

noticed that for a run of 12 feet the square must be moved along twelve times; for a run of 8 feet, eight times; and so on. The run of the rafter may be easily obtained by subtracting one-half the thickness of the ridge board from one-half of the total span of the roof from outside to outside of wall plates.

Fig. 293 shows the rafter in the position which it would occupy in a building, the plate and a part of the wall studding being indicated. When the rafter is cut along the line *N S*, Fig. 292, it is ready to be put on the building. In case, however, that a ridge board is used to hold the rafter in place, as shown by *R* in Fig. 291, the rafter is cut parallel to *N S* but shorter, as shown in Fig. 294, one-half of the thickness of the ridge board being cut away. The cut at *D O*, Fig. 291, is horizontal, and the bevels at *N S* and *V K*, Figs. 292, 293, and 294, are plumb cuts.

It has been said that many carpenters lay out rafter work with the "back" or upper edge of the rafter towards them. If we turn the page upside down and look at Fig. 292 and Fig. 293 in this position, we will be able to see how the square would be placed on the rafter and moved about in order to make the various cuts with the "back" of the rafter towards the workman. Fig. 295 shows Figs. 292 and 293 in this reversed position so as to illustrate this method of procedure. It has also been said that carpenters usually use the top edge of the rafter to obtain the bevels instead of using the "work-line" (*D P*, Fig. 292). Fig. 296 illustrates how this can be done. The letters *a b c g* represent the rough piece of lumber before it has been cut at all, laid out on its side with the top edge away from the workman. Let us choose some point as the point *d* on the edge of the piece near one end, which we will take as the point in which the upper edge of the rafter is to intersect the line of the outside face of the wall plate. Let us suppose that the pitch of the roof surface is to be 8 inches to the foot. Then we will apply the square to the piece of lumber, as shown in the figure by the full lines, with the 8-inch mark on the tongue at the point *d*, and with the 12-inch mark on the blade also on this same edge of the rafter at the point *f*.

In this figure the square has been shown with the heel of the square held away from the workman instead of towards him as was the case in the method illustrated by Fig. 293. If there are no

overhanging eaves, the rafter will be cut at the wall plate as illustrated in Fig. 297 or as in Fig. 298.

Valley Rafters. We will now consider the valley rafters and the bevels which must be cut for them. We have seen that, in the case of the common rafters, the bevels were determined by the pitch

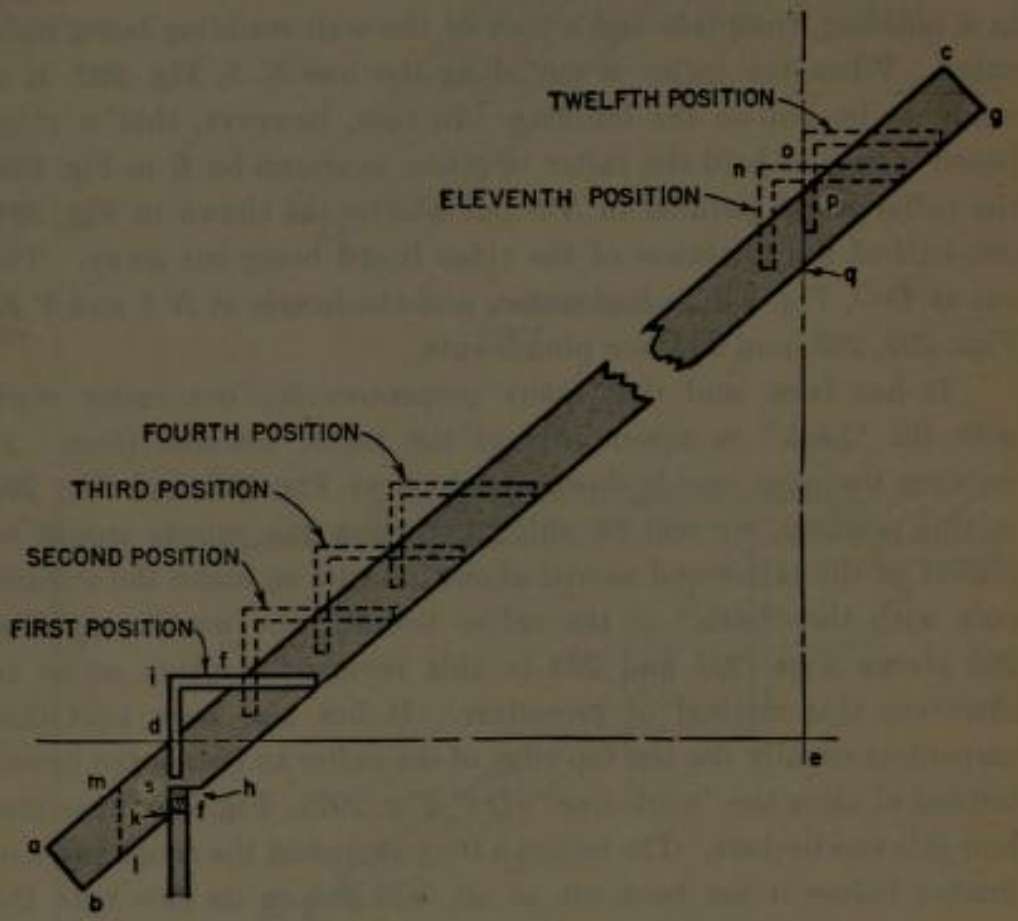


Fig. 296. Cutting Bevel at Top of Rafter

of the rafter. The same thing holds true for the valley rafters. In Fig. 299 it will be seen that the rafter which occurs in the roof framing under the valley *fy* is a part of two different roof surfaces *A* and *B* and that it forms a connecting link between them.

Figure 300 shows the framing plan for this valley, *C F* being the valley rafter shown in plan, that is, as if we were looking straight down at it from above. The distance *C F* then is not the true length of the valley rafter, but is what is known as the "run" of the rafter. This particular figure as well as Fig. 299 illustrates the intersection of two roofs of unequal width but of the same

pitch, namely, 10 inches in 12 inches. Since the two roofs have the same pitch the valley rafter *C F* intersects the ridge of the wider main roof in the point *F*, which, in plan, is just as far from the point *A* as is the point *C*. In other words, distance *A F*, measured in a horizontal direction along the ridge of the main roof is equal to

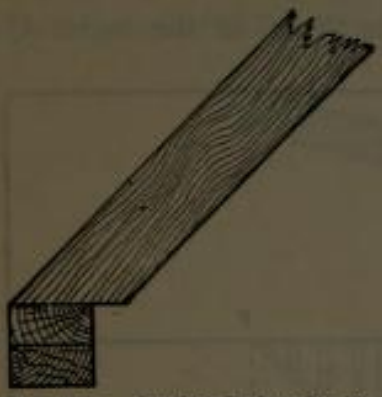


Fig. 297. Cutting Rafter for No Overhang

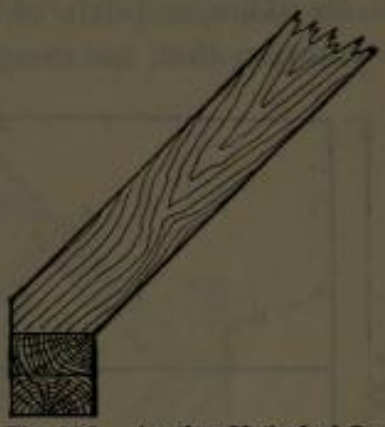


Fig. 298. Another Method of Cutting Rafters for No Overhang

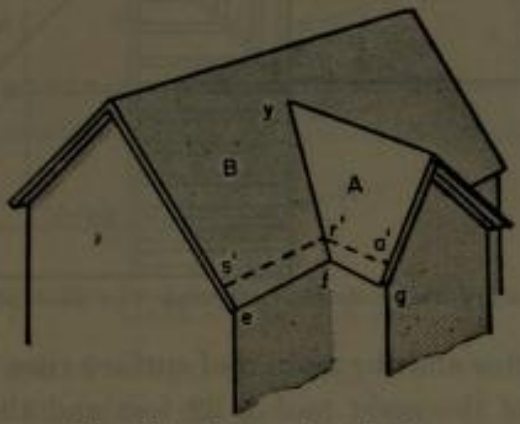


Fig. 299. Intersecting Roofs

the distance *A C*, measured in plan, that is, on a flat horizontal plane. The distance *A C*, however, represents in the plan the "run" or horizontal projection of the common rafter in the main roof. Since the main roof is 32 feet wide, the distance *A C* is 16 feet and the distance *A F* is also 16 feet. If the two roofs had been of the same width, the dotted line *F M* would have been the ridge of the smaller roof, but as this roof is actually only 20 feet wide, instead of 32 feet, the line *B D* is the ridge of the narrower roof and it intersects the valley rafter at *B*. The valley rafter is carried on

up to the main ridge at *F*, so as to be supported at its upper end by the main ridge and so as to be able to support the inner end, *B*, of the secondary ridge.

The point *F* is at the same distance measured vertically above the level of the top of the wall plate as is the point *A*, and this distance is the "rise" of the common rafter *A C*. Now let us suppose that the slope, or pitch, of the main roof is 10 inches to the foot which means that, for every foot in the "run" of the rafter *C A*,

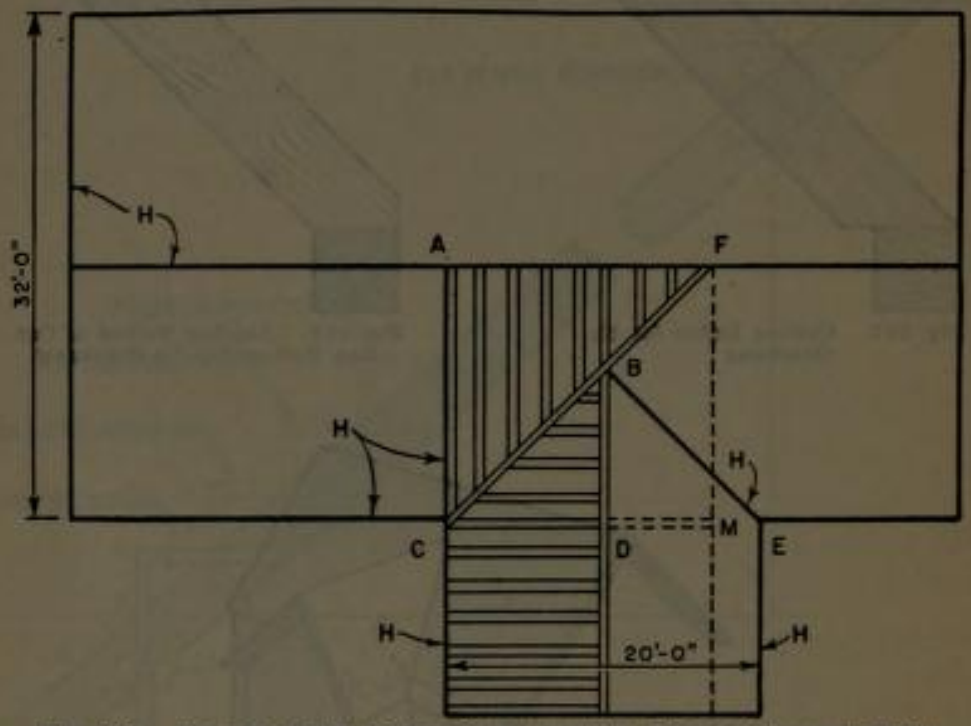


Fig. 300. Plan for Valley Rafter Connecting Two Roofs of Unequal Width

Fig. 300, this rafter and the main roof surface rises 10 inches. Then, since the span of the main roof is 32 feet and the half-span is 16 feet, it is seen that the total rise is 16 x 10 inches or 160 inches. This is also the rise of the valley rafter *C F* but since the two roofs are of the same pitch a run of 16 x 12 inches along *C A* from *C* towards *A* corresponds to a run of 16 x 12 inches along *A F* from *A* to *F* and corresponds also to a run of 16 x ? inches along the valley rafter from *C to F*. We do not know at first how many inches should be placed in the space occupied by the question mark in the last sentence but since the two distances *C A* and *A F* are equal to each other it would appear that this would be equal to the length of the long side or "hypotenuse" of a right triangle, the other two

sides of which are each 12 inches. We can take a steel square, find the 12-inch mark on the tongue and the 12-inch mark on the blade and with a rule or another square measure the distance between these marks as shown in Fig. 301 and we will find it to be almost exactly 17 inches. Then the run of the valley rafter is 16 x 17 inches. At a point 17 inches from the point *C*, measured along the run of the valley rafter *C F*, the rise of this rafter is 10 inches and thus the slope or pitch of the valley rafter is 10 inches in 17 inches. Fig. 301

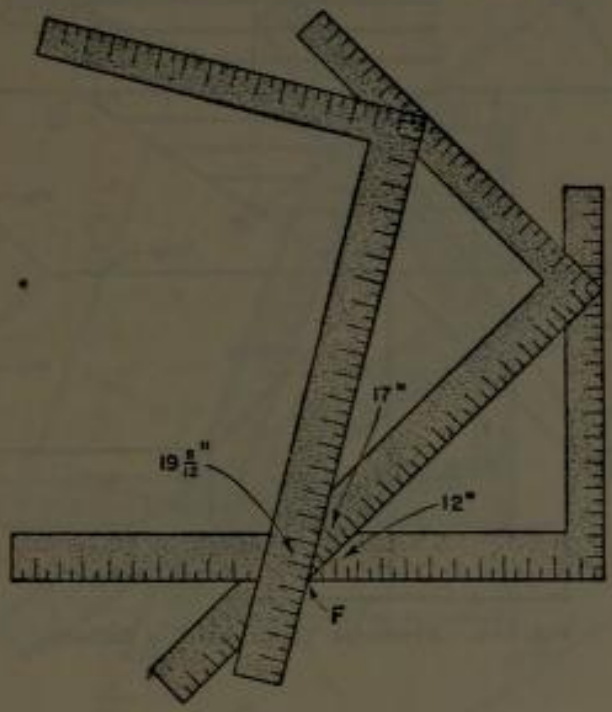


Fig. 301. How Steel Square Is Used to Calculate Actual Length of Valley Rafters

shows that the length of this portion ($\frac{1}{16}$) of the valley rafter will be $19\frac{5}{12}$ inches and therefore the actual length of the valley rafter will be 16 x $19\frac{5}{12}$ inches.

In Fig. 302 is shown the framing plan of an intersection of two roofs of equal width but of unequal pitch. The main roof will have a steep pitch of 15 inches to the foot and the secondary roof will have a pitch of 10 inches to the foot. Then, since the half-span in each case is 12 feet, the height of the main ridge above the level of the wall plate is 15 feet and the height of the secondary ridge, *R M*, is 10 feet. Then, since 10 feet is $\frac{2}{3}$ or $\frac{8}{12}$ of 15 feet, the distance *R M* should be $\frac{8}{12}$ of 12 feet, or 8 feet, measured horizontally along the secondary ridge from *R* to *M*.

In Fig. 302 the run of the shorter valley rafter is the distance $C\ M$ measured on the plan or on a flat level surface at the level of the top of the wall plate. It is equal to the longest side or "hypotenuse" of a triangle with the distance $C\ R$ for one side and the distance $R\ M$ for the other side. $C\ R$ is 12 feet and $R\ M$ is 8 feet so the run

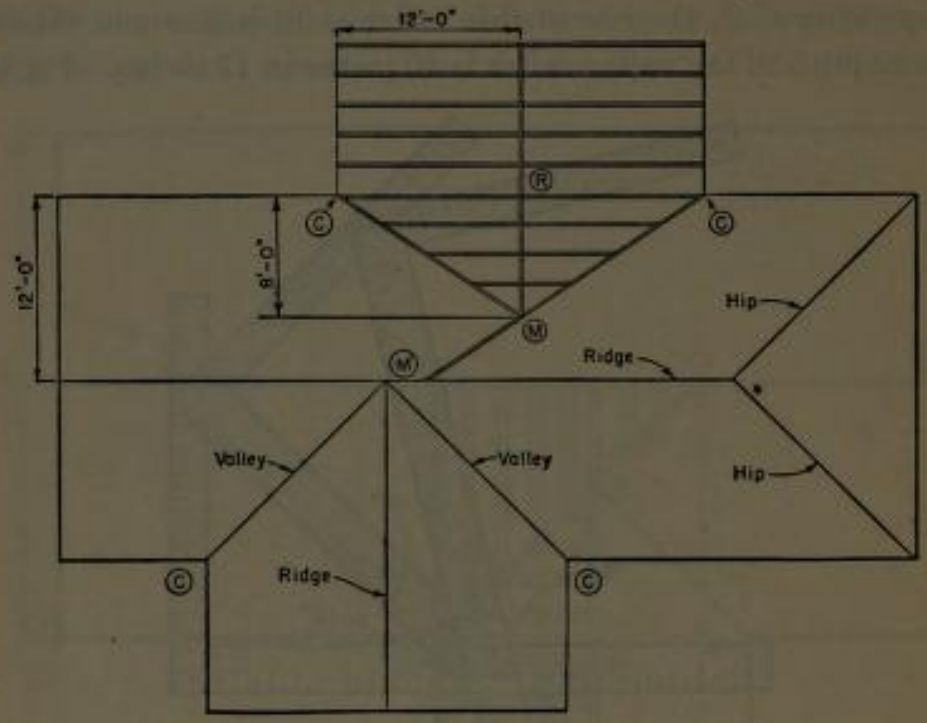


Fig. 302. Bevels for Valley and Hip Rafters

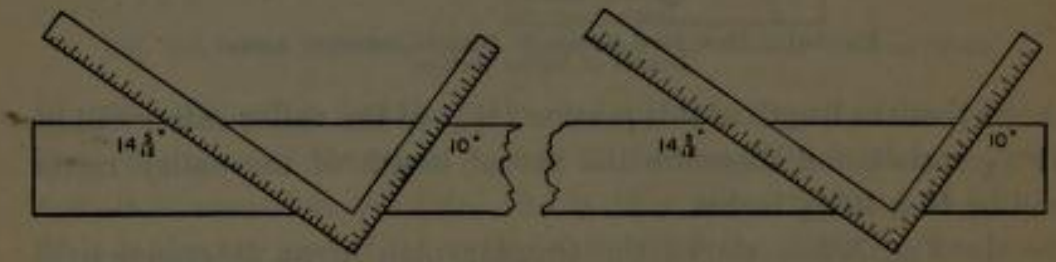


Fig. 303. Cutting Bevels on Valley Rafter

of the valley $C\ M$ is found by measuring off the distance diagonally between the 12-inch mark on the blade of the square and the 8-inch mark on the tongue of the square. It is $14\frac{5}{12}$ inches showing that the run of the valley taken in feet is $14\frac{5}{12}$ feet, that is, it is 14 feet and 5 inches. If either of the distances $C\ R$ or $R\ M$ had happened to be in feet and inches, the corresponding points on the blade and tongue of the square could have been taken as so many inches and

twelfths of an inch from the heel of the square since, on the standard steel square, the graduations or divisions of the outside edge of the back of the blade, and of the tongue also, are in twelfths. Now the rise of the valley rafter is the same as the rise of the common rafter *C R*, that is, it is 10 feet. Knowing, then, the run of the valley rafter $14\frac{5}{12}$ feet and its rise 10 feet, we can proceed to lay out the rafter and to make the cuts in the same way as was explained for

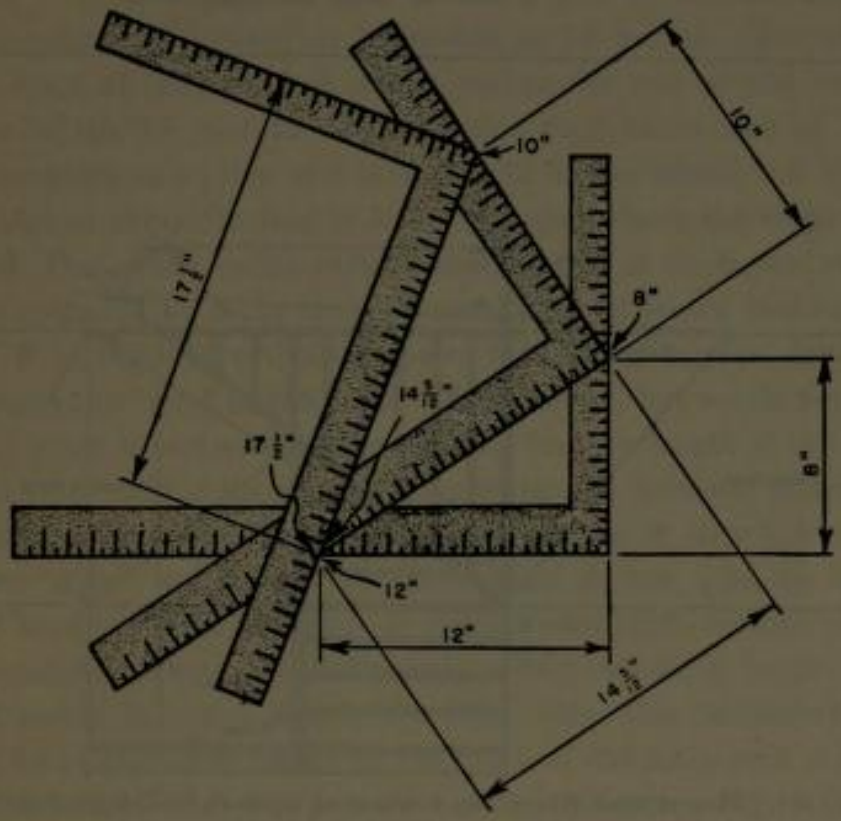


Fig. 304. Method of Finding Bevels for Various Runs of Rafters

the common rafter. The square is laid on the stick of lumber as shown in Fig. 303 and the bevel at the foot of the rafter is cut along the blade of the square when the figures reading $14\frac{5}{12}$ inches on the blade and 10 inches on the tongue are placed so as to coincide with the edge of the stick which will be the top edge or "back" of the rafter, or with the "work-line," if a work-line is used.

The plumb cut at the top of the rafter is made by holding the square in the same position and cutting along the tongue. In making these cuts it must be remembered that the valley rafters do not fit square against the ridge as does the common rafter but come against

it at an angle which depends upon the pitches of the two roof surfaces coming together in the valley.

The length of the valley rafter may be determined from tables given on the standard steel squares. It may also be found by measuring the distance diagonally across from the $14\frac{5}{12}$-inch point on the blade of the square to the 10-inch point on the tongue of the square, as shown in Fig. 304, and reading feet and inches instead of inches and twelfths of an inch.

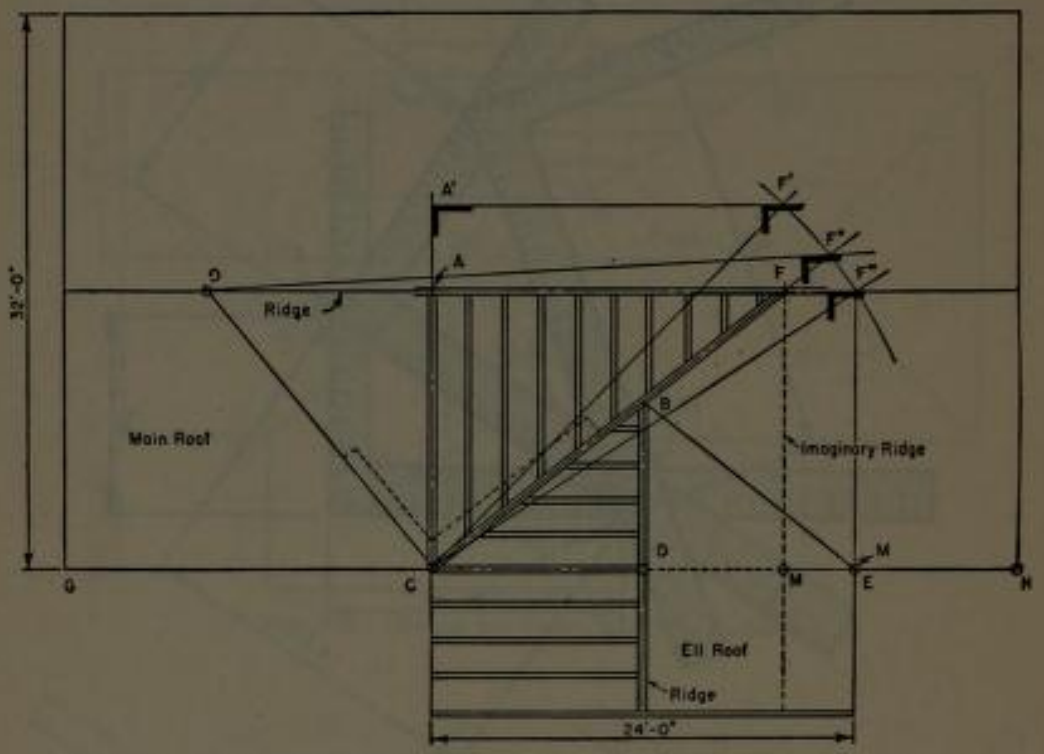


Fig. 305. Plan of Roof Where Two Surfaces of Unequal Pitch Come Together

The length of the valley rafter may be figured out by mathematics if we take the three dimensions referred to as the run and rise of the common rafter in one roof and the run of the common rafter in the other roof, as shown in Fig. 304, namely, 12 feet, 10 feet and 8 feet, and square each one so as to make 144 and 100 and 64. We should then add these three figures together making 308 and extract the square root of this figure which will give us $17\frac{1}{2}$ or 17 feet and 6 inches. This method is too tedious and difficult to use when dealing with feet and inches and is only mentioned in order to illustrate the mathematical principle involved.

When a valley rafter serves to connect two roofs of unequal

pitch, that is, two roof surfaces which slope upward from the eaves at different angles, the problem of laying out and cutting the rafter is more difficult than when the two roof surfaces have the same pitch. Fig. 305 shows the plan of a roof where two surfaces of unequal pitch come together in a valley. (Bear in mind that in this view we are looking straight down on the roof.) The main roof has a span of 32 feet which makes the run of the common rafters 16 feet. We will suppose that it has a rise of 13 feet 4 inches, corresponding to a pitch of 10 inches in 12 inches. The ell roof has a span of only 24 feet which makes the run of the common rafters in the ell roof 12 feet and this roof has a rise of 8 feet corresponding to a pitch of 8 inches in 12 inches which is a ⅓ pitch. The ridge of the main roof is 5 feet 4 inches above the ridge of the ell roof. One of the valley rafters, marked *C F* in the figure, runs up to the ridge of the main roof, its rise being 13 feet 4 inches. The line *C F* in Fig. 305 of course shows this rafter in plan, that is, it represents the "run" or the "seat" of the rafter, but we do not know what this run is and without it we cannot find the length of the rafter We do know that if the ell roof were wider the common rafter *C D*, as it slopes upward, would rise higher before it struck the ridge and its "rise" would then be more than 8 feet, just as its run would be more than 12 feet. If the ell were wide enough so that the common rafter *C D* (extended) would rise to a height of 13 feet 4 inches before it struck the ridge, then this imaginary ridge would be at the same height as the ridge of the main roof *A F*, and would intersect it at the point *F* on the roof plan, Fig. 305. Let the dotted line *F M* represent this imaginary or false ridge on the roof plan. Note that it is at the same height as the ridge of the main roof *A F* and that therefore the point *M* on this ridge would be at an elevation 13 feet 4 inches above the point *C* whereas, the point *D* on the real ridge of the ell roof is only 8 feet above the point *C*. The distance *C M* on the plan would be the run of the common rafter *C D* if it were extended to the point *M* just as the distance *C D* on the plan (12′-0″) is the run of the actual common rafter *C D*. Moreover, if we can find out what the distance *C M* is on the plan we can find the distance *A F* on the ridge of the main roof since these two distances are the same as each other. The rise of the imaginary extended common rafter *C M* at the point *M*

is 13 feet 4 inches or 160 inches and the rise of this same rafter at the point D is 8 feet or 96 inches so we may say that the rise of the imaginary extended rafter $C\,M$ is $^{160}/_{96}$ of the rise of the real rafter $C\,D$. In the same way, then, we may say that the run, $C\,M$, of the imaginary extended rafter is $^{160}/_{96}$ or $^{5}/_{3}$ of the run of the real common rafter $C\,D$. But we know that the run of the common rafter $C\,D$ is 12 feet, therefore, we can say that the run of the imaginary extended rafter $C\,M$ is $^{5}/_{3}$ of 12 feet or 20 feet. This is also the amount of the distance $A\,F$. The run of the valley rafter $C\,F$ is, therefore, equal to the diagonal of a rectangle one side of which, $A\,C$, is 16 feet (the run of the common rafter in the main roof) while the other side $C\,M$ or $A\,F$ is 20 feet. The run of the valley rafter $C\,F$ is the hypotenuse or longest side of a right-angled triangle whose other two sides are respectively 16 feet and 20 feet. To find the run of the valley rafter $C\,F$ take the steel square and measure off the diagonal distance between the 16-inch mark on the tongue and the mark on the blade corresponding to 20 inches. This distance will be found to be 25 and 7⅓ twelfths inches, showing that the run of the valley rafter $C\,F$ is 25 feet and 7⅓ inches. It would be difficult to figure this out by mathematics although it could be done with the help of certain books.

We now have the run of the valley rafter, $C\,F$ (25′ 7⅓″) and we know that its rise is 13 feet 4 inches so we can find its length with the help of the square again by measuring the diagonal distance between the mark for 25 and 7⅓ twelfths inches on the blade and 13⅓ inches on the tongue. We will find this distance to be 28 inches and 10½ twelfths of an inch, showing that the length of the valley is 28 feet 10½ inches.

At this point we run into difficulty since the blade of the standard steel square is only 24 inches long. The way out of our trouble is to divide each of the figures by 2 so as to use 12 and 9⅔ twelfths inches on the blade and 6 and $^{5}/_{12}$ inches on the tongue. The diagonal distance between these two marks will be 14 and 5¼ twelfths inches which we must multiply by 2, giving the result of 28 and 10½ twelfths inches. To get the horizontal plate cut and the plumb cut, the distances corresponding to the run and the rise of the valley rafter will be used on the blade and tongue of the steel square just as was done in the case of the common rafter.

The side bevel or "cheek cut" at the top of the valley rafter $C\,F$ (Fig. 305) would be cut by imagining that the sloping surface of the main roof outlined by the triangle $C\,A\,F$ is swung down or pivoted about the line $G\,C\,D\,M\,E\,H$ (which is the line of the eaves of the main roof) until the true length of the rafter $A\,C$ and of the valley rafter $C\,F$ can be seen on the plan, as shown in Fig. 305 as $C\,A^1\,F^1$. The true length of the valley rafter is the distance $C\,F^1$ and the true length of the common rafter $C\,A$ is the distance $C\,A^1$. To get the correct bevel when the rafter is not backed, it is necessary that the true length of the valley rafter ($C\,F^1$), should be laid off as a continuation or extension of the line $C\,F$ which represents the run or "seat" of the valley rafter. This is shown as the distance $C\,F^{11}$ in Fig. 305. To get this we have to draw a line, $C\,O$, from the point, C, at right angles to the valley rafter, $C\,F$, until it intersects the ridge line, $A\,F$, at the point O. Then lay off the distance, $C\,F^{11}$, equal to $C\,F^1$ (the true length of the valley rafter). To make the cheek cut on the actual rafter, the numbers corresponding to the distances $C\,O$ and $C\,F^{11}$ are used on the blade and tongue of the steel square but we do not yet know the amount in feet and inches of the distance $C\,O$, although we know from our previous figuring that $C\,F^{11}$ (the actual length of the valley rafter) is 28 feet 10½ inches. We might draw a diagram to scale and measure off the distance $C\,O$, or we can get it by proportion. Since the triangles $C\,A\,F$ (Fig. 305) and $O\,C\,F$ are both right-angled triangles, we know from Geometry that the angle $A\,C\,O$ is the same as angle $A\,F\,C$, and that the distance $C\,O$ bears the same relation to the distance $C\,F$ (which we know to be 25 feet and 7⅓ inches) as the distance $A\,C$ (16 feet) bears to the distance $A\,F$. The distance $A\,F$ we found to be the same as the distance $C\,M$ (20 feet). As $A\,C$ is less than $A\,F$, so will $C\,O$ be less than $C\,F$ and in exactly the same proportion, that is $C\,O = {}^{16}\!/_{20}$ of ($C\,F$) which is the same as saying that $C\,O = {}^{16}\!/_{20}$ x (25′ 7⅓″). Since it is difficult to multiply these figures out when given in feet and inches it is usually easier to again make use of the steel square as shown in Fig. 306. On the blade find the point F distant 20 inches from the heel of the square (corresponding to distance $A\,F$ in Fig. 305). Then on the tongue of the square find the point C distant 16 inches from the heel of the square, corresponding to distance $A\,C$. The distance measured off diagonally between these

two points will be 25 and 7⅓ twelfths inches, corresponding to the distance *C F*. Now lay a straight edge across the blade and tongue of the steel square along this line. Now mark the point, *C*, on the blade of the square distant just 16 inches from the heel of the square corresponding to the distance *A C* (Fig. 305). Then pass another line through the point *C* on the blade of the square exactly parallel to the straight edge. Where this second line passes across the tongue

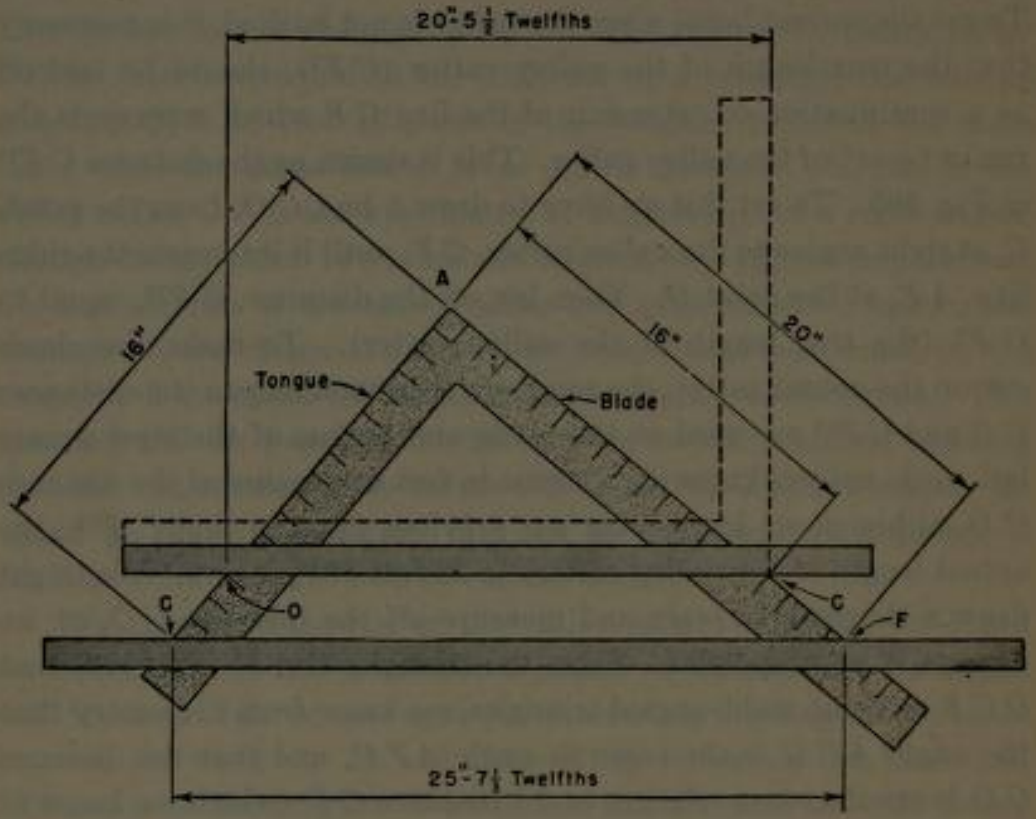


Fig. 306. How Steel Square Is Used to Calculate Distance CO in Fig. 305

of the square will be found the point *O*, and the distance *C O* may be measured off in inches and twelfths of an inch. It will be found to be 20 inches and 5½ twelfths of an inch, showing that the distance *C O* is 20 feet and 5½ inches.

Having found the distance *C O*, Fig. 305, we can now use it (with the distance *C F*[11] which we already know) on the steel square to make the cheek cut on the end of the valley rafter so that it can fit against the ridge. In Fig. 305 the line *O F*[11] represents the ridge and the line *C F*[11] represents the valley rafter and these lines represent these two members (which must be fitted together) when they

are swung down into a flat or horizontal position such as they would occupy if the valley rafter were lying on its edge on the ground or on a couple of horses. We must, then, cut the end of the valley rafter just as the line $C\,F^{11}$ is cut by the line $O\,F^{11}$. If we lay a square down on the drawing, Fig. 305, so that the heel comes at the point C, then one arm of the square will be along the line $C\,O$ while the other arm will be along the line $C\,F^{11}$. Suppose we place it so that the tongue coincides with the line $C\ O$ while the blade lies along the line $C\,F^{11}$ which represents the valley. Then the blade of the square represents the actual length of the valley and we should lay off a distance on the blade in inches and twelfths (28 and 10½ twelfths inches) corresponding to the length of the valley rafter in feet and inches (28′ 10½″) while the tongue of the square represents the distance $C\,O$ and we should lay off a distance on it in inches and twelfths (20 and 5½ twelfths inches) corresponding to the distance $C\,O$ in feet and inches (20′ 5½″). Right here we strike a snag because the blade is only 24 inches long and the tongue only 16 inches. To overcome this difficulty, we can take one half of each of these dimensions which will not alter the relation between them and lay off 14 inches and 5¼ twelfths on the blade and 10 inches and 2¾ twelfths on the tongue. Bearing these reduced figures in mind or marking them in some way so as not to forget them, we note that in order to fit against the ridge line $O\,F^{11}$ at the point F^{11} the square would have to be turned completely over and that the cut on the edge of the rafter would be made along the blade of the square.

As our stick of lumber now lies before us on edge on the horses, we can imagine it to represent the line $C\,F^{11}$ in Fig. 305, if this figure were twisted around so that we could see the view or plan of the valley rafter directly in front of us. See Fig. 307. Taking the square, we lay it across the edge of the stick of lumber at the right-hand or top, end (with the blade at our right hand and the tongue at our left hand and the heel away from us) in such a position that the figures 14 and 5¼ twelfths on the blade (corresponding to the true length of the valley) and the figures 10 and 2¾ twelfths on the tongue (corresponding to the distance $C\ O$, Fig. 305) are both at the edge of the stick. Then we can mark and cut along the blade.

It must be understood that these directions for making the cut to fit the valley rafter against the ridge apply only in case the valley rafter is not "backed," that is, in case the top edge of the rafter is left square with the sides of the rafter and is not cut to make it lie in either one of the sloping roof surfaces. Carpenters seldom back valley rafters but instead they set them so that the edges of the top surface will come a little below the roof surfaces at either side of the rafter.

If the valley rafter were backed so that the top edge would

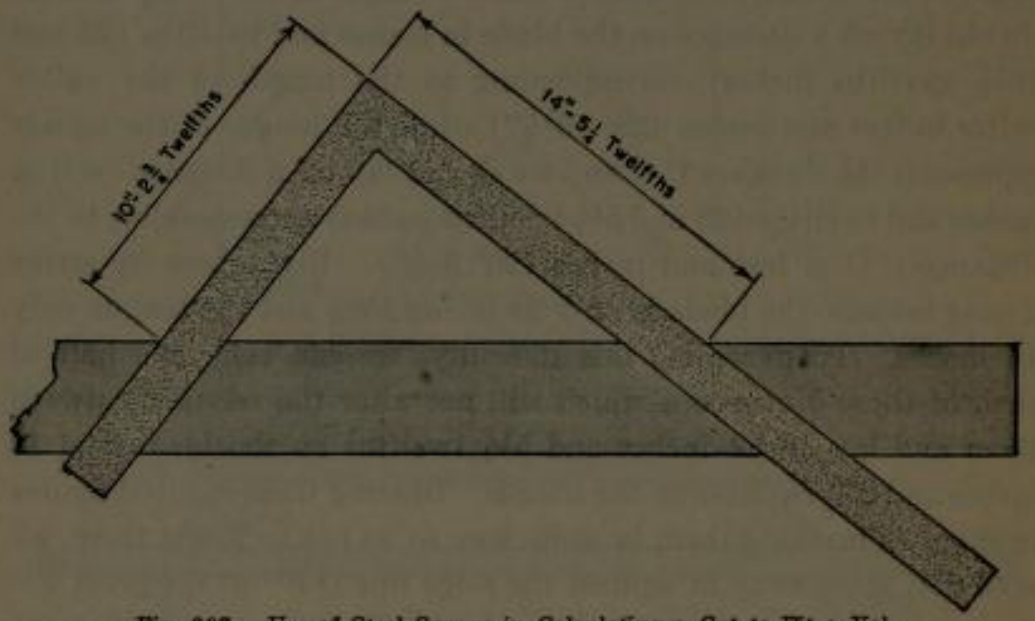


Fig. 307. Use of Steel Square in Calculating a Cut to Fit a Valley Rafter

be entirely in the surface of the main roof, and if the square were laid against this "backed" surface or edge of the rafter to mark off the cheek cut at the ridge, then this cut would have to be made as shown at F^1 in Fig. 305, using distances A^1 F^1 on the blade and A^1 C on the tongue of the square, and cutting along the blade. If the valley rafter were backed so that the top edge would lie entirely in the surface of the ell roof and if the square were laid against this backed surface or edge of the rafter to mark off the cheek cut at the ridge, then this cut would have to be made as shown at F^{111} in Fig. 305, using distances C M^1 on the blade and C A on the tongue and cutting along the blade. (Distance C A is equal to distance M^1 F^{111}.)

For the rafter B E, Fig. 305, the horizontal cut at E is obtained

by using 25 feet and 7⅓ inches (the run or seat of the long valley *C F*) and 13 feet 4 inches (the rise of the long valley) and is the same as the cut at *C*. Mark off 25 and 7⅓ twelfths inches on the blade of the square and 13⅓ inches on the tongue and mark the cut just as was explained for the heel cut of the common rafter except that the distance *T D*, Fig. 290, should be made enough greater than it was in the case of the common rafter to bring the upper edge of the valley rafter into the proper relation to the two sloping roof surfaces. The distance *D F* (Fig. 291) must also be made greater for the valley rafter. The method for doing this is explained in the Instruction Paper "The Steel Square."

The length of the rafter can be found by using proportion or by finding the distance *B D* and using this distance in combination with the length of the common rafter *C D* to get the length of the valley. In using proportion it can be seen from Fig. 305 that *B E* (the run of the short valley) is to *C F* (the run of the long valley) as the rise of the short valley *B E* (8′ 0″) is to the rise of the long valley *C F* (13′ 4″). Eight feet equals 96 inches and 13 feet 4 inches equals 160 inches so we can say that the run of *B E* is $^{96}/_{160}$ of the run of *C F*. The run of *C F* was found to be 25′ 7⅓″ so we can say that the run of *B E* is $^{96}/_{160}$ of 25′ 7⅓″, which is 15 feet 4½ inches. Combining this run with the known rise of 8 feet at the point *B* and using the steel square, the same as was explained in connection with the common rafter, will give us the length of the valley *B E* which is 17 feet 4 inches. Take 15 and 4½ twelfths inches on the blade of the steel square and 8 inches on the tongue of the square. Then the diagonal distance between these points will be found to measure 17½ inches.

Another way in which the length of the valley *B E* can be found is to get the distance *B D*, Fig. 305, where the ridge of the ell roof intersects the main roof surface. The intersection point *B* is at an elevation of 8′ 0″ (96 inches) above the point *C* while the point *A*, 16 feet distant from *C* (measured on the flat) is 13′ 4″ (160 inches) above point *C*. The distance *B D* then, is $^{96}/_{160}$ of the run of the common rafter *C A* (which is 16′ 0″), so *B D* is $^{96}/_{160}$ of 16 feet, which is 9⅗ feet. Hence the run of the rafter *B E* can be found with the steel square. Take 12″ (corresponding to distance *D E*), on the blade and 9⅗ inches on the tongue. The diagonal dis-

tance is 15′ 4½″ and then the length of the rafter can be found the same as before from the run and the rise, knowing the rise to be eight feet. The end cut on *B E* at *B*, that is, the bevel that fits against the long valley *C F* will be practically a square cut.

Hip Rafters. Fig. 308 shows the plan of a roof in which there are some hip rafters. At one end we have a square hip *A*, and at the opposite end we have a skew hip *B*. The hip rafters are shown at *a b*, *a c*, *d e*, and *d f*. They rest on the plate at the foot, and bear against the ridge board *a d* at the top. At *g h* is shown also a

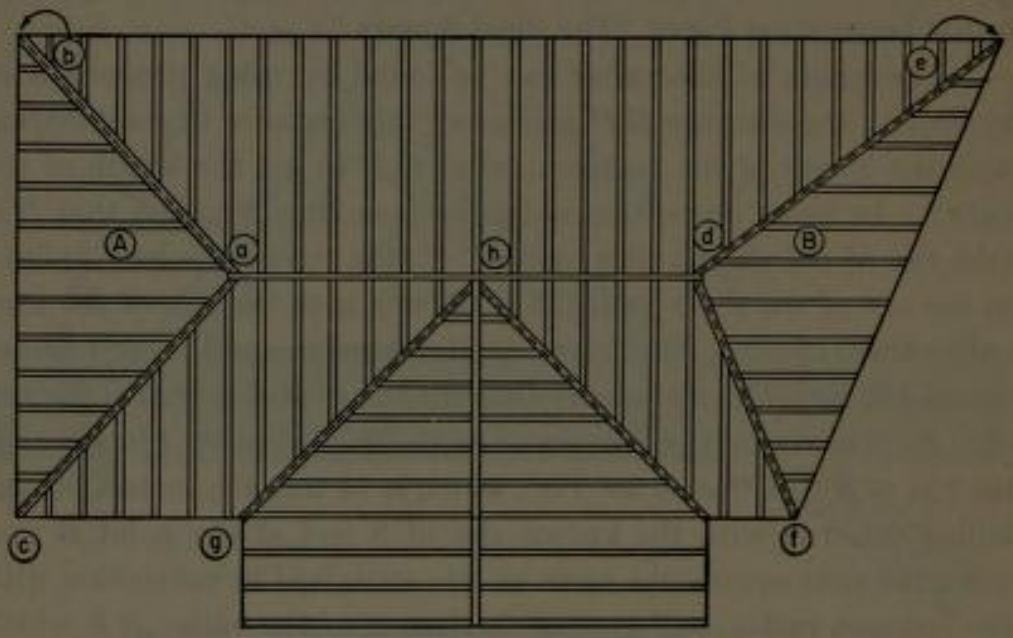


Fig. 308. Plan View of Roof Where There Are Hip Rafters

valley rafter. It will be seen that the hip rafter is exactly the same as the valley rafter. It has the same pitch, or inclination, toward the ridge *a d*. Its pitch must be the same since it lies in the same roof surface, and is parallel to the valley. This similarity between hip and valley rafters is characteristic, and the same methods of cutting bevels which were explained in connection with valley rafters are equally applicable in the case of hip rafters. The pitch of the hip roofs *A* and *B* may be varied to suit the design, but usually the hip roofs have the same pitch as the main roof. The position of the hip rafter on the plan is determined from the pitch of the two roof surfaces of which it is a part in the same way as was explained for valley rafters. All lines in the roof surfaces *A* and *B* which are

parallel to the plates *b c* and *e f* are horizontal, and have the same elevation throughout their length. There is but one bevel at the top of the hip rafter where it bears against the ridge and this is similar to that at the top of the valley. It is cut in the same way as the valley rafter. The layout of a hip rafter is the same in principle as the layout of a valley rafter. Whenever we have two roof surfaces which start to slope upward from the top of two walls and these two walls come together at an outside corner of the building, these two sloping roof surfaces will also have to come together in a sloping line which is called a hip. If both of the roof surfaces slope upward at the same angle, then the two roofs are said to be of equal pitch, but if they slope upward at different angles the two roofs are said to be of unequal pitch. The line of the hip, as it slopes upward from the corner of the building will, at the top, meet the ridge as shown in plan in Fig. 308. Usually there will be another hip rafter meeting the ridge at this same point. There will be common rafters sloping down from this meeting point to the wall in each of the roof surfaces and if the two roofs are of equal pitch the "run" of each of these two common rafters will be the same. Also the "rise" of each of the two common rafters must be the same since they meet together at one point and the rise of the "hip" rafter at the hip line must also be equal to the rise of the two common rafters. Let us say this rise is 10 feet. We now have to find the run of the hip rafter. If the two roofs coming together in the hip line are of equal pitch, then the run of the hip rafter will be the diagonal of the square, the two sides of which are equal to the runs of the two common rafters. If the run of each of the two common rafters is 10 feet, then the run of the hip rafter is the longest side or the "hypotenuse" of a right triangle whose other two sides are each 10 feet. This distance can be found with the aid of the steel square by measuring the diagonal distance between the 10 mark on the blade and the 10 mark on the tongue, which will be found to be 14⅛ inches and ⅔ of another twelfth, therefore, the distance in feet and inches will be 14 feet 1⅔ inches. This is the run of the hip rafter. It is also equal to the square root of the sum of 10 squared plus 10 squared by mathematics. We now have the rise of the hip rafter (ten feet) and the run of this rafter (14 feet 1⅔ inches) and we can find its length by measuring

on the steel square the distance diagonally between the mark on the blade for 14 feet and 1⅔ inches and the mark on the tongue for 10 inches. This distance will be found to be 17$\frac{3}{12}$ inches so the length of the hip rafter is 17¼ feet or 17 feet 3 inches. The length of the hip rafter can be read off directly from the "Hip Rafter Table" which is found on the blade of the standard steel square. To compute this length by mathematics, we would have to extract the square root of the sum of the squares of the two runs of the

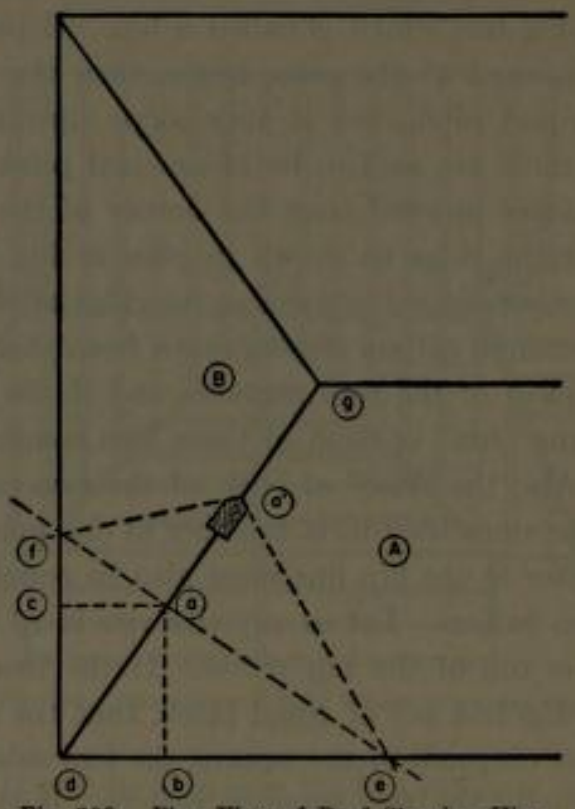


Fig. 309. Plan View of Roof Showing Hips

common rafters (10 feet each) and the rise of the hip rafter (10 feet) which would be the square root of three hundred, which is 17¼.

BACKING OF RAFTERS

Hip Rafters. In Fig. 309 we have a plan, in outline, of a part of a roof with a hip *g d* in which the two surfaces *A* and *B* come together. Let us suppose that the pitch of the roof surface *A* is 8 inches to the foot, and that of the surface *B* is 12 inches to the foot. Let the lines *f c d* and *d b e* represent the outside faces of the two wall plates, which come together at the corner, and let the

dotted lines just inside of these represent the inside faces of the plates. Suppose that the distance $a\ b$ is just 12 inches, and we have the point a just 8 inches above the points b, d and c, since the pitch of the surface A is 8 inches to the foot. As the pitch of the surface B is 12 inches to the foot, the distance $c\ a$ must be 8 inches, in order to give a rise of 8 inches at the point a, and the distance $d\ b$ must also be 8 inches, and $c\ d$ must be the same as $a\ b$, which is 12 inches.

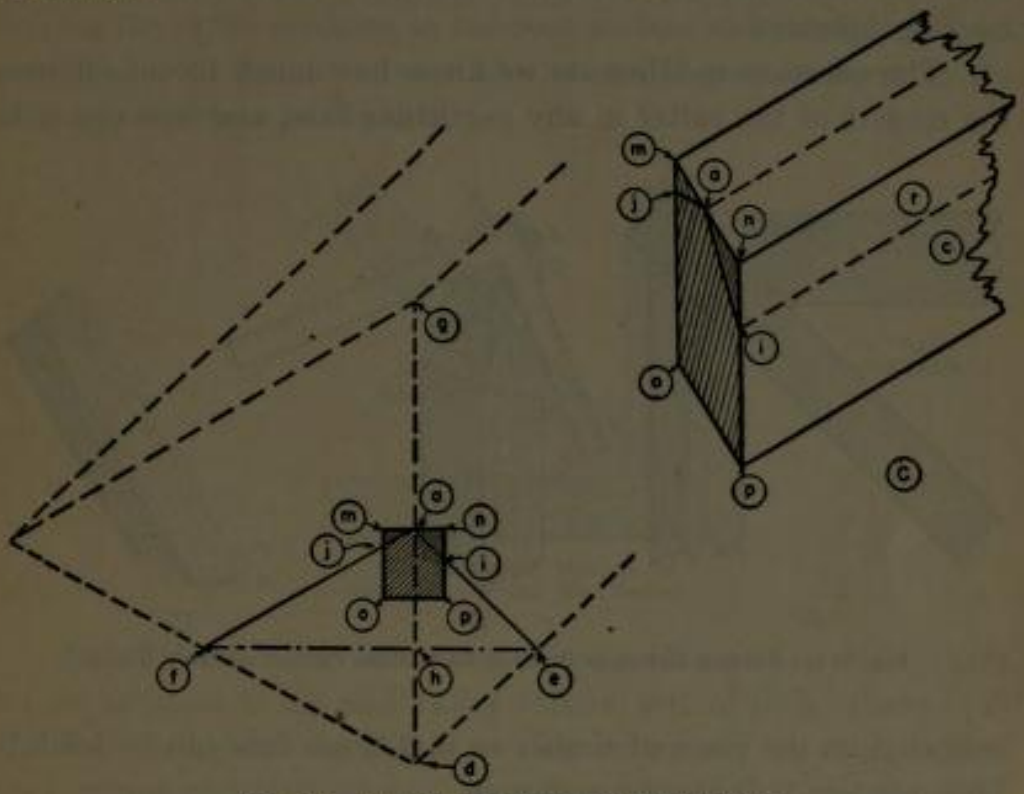


Fig. 310. Section of Roof Cut by Vertical Plane

Now suppose that the line $f\ a\ e$ be drawn through the point a perpendicular to the hip line $d\ g$, and let it represent *a vertical* plane which is passed down through the roof surfaces, perpendicular to the plan of the hip line, cutting the hip rafter and plates.

If this vertical plane is revolved about the base line $f\ a\ e$, until it lies flat on the plan of Fig. 309, then the point a, on the hip line will move to the point a^1, the distance $a\ a^1$ being 8 inches.

Fig. 310 shows the section of the roof surfaces cut out by this plane. We have the point a, 8 inches above the points f and e, making the distance $a\ h$ 8 inches. The dotted lines show the roof surfaces, and $a\ e$ and $a\ f$ are the lines which are cut out out of these

surfaces by the vertical plane. The section *m n o p* shows, much exaggerated in size, the section of the hip rafter cut out by the vertical plane, and it will be noticed that the upper corners of this rafter *a m j* and *a n i* project out into the roof surfaces on each side. These projecting corners must be cut off, so that the section of the rafter will be *a i p o j* and this is called *backing* the rafter. At *C* is shown an isometric drawing of the rafter, lettered the same as in the section, so that it may be more easily understood just what the *backing* involves.

The question is "How do we know how much to cut off from the corners of the rafter in any particular case, and how can it be

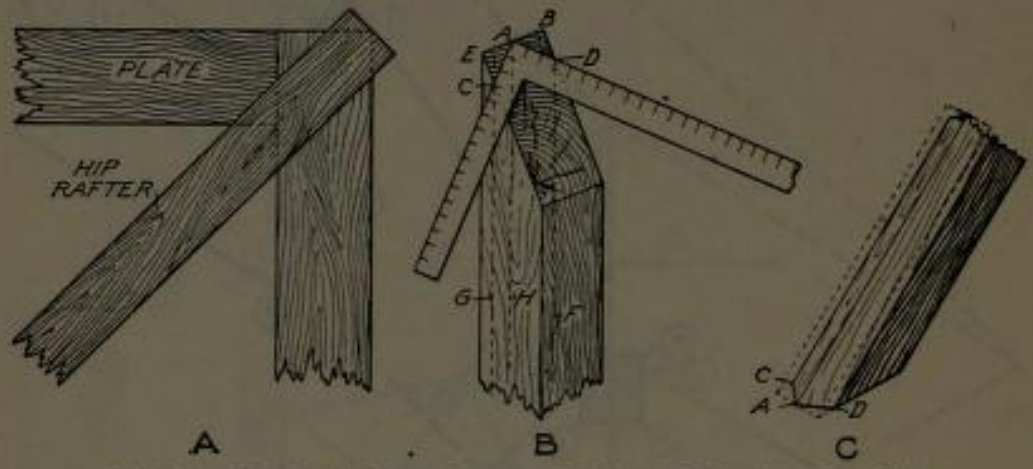


Fig. 311. Cutting Rafter to Prevent Ends from Projecting Over Plate

indicated on the piece of timber so that these cuts can be made?" This question will now be answered.

In making the foot cut on the rafter, we have to cut out just such a vertical section as is indicated in Fig. 310. We can find the point *a* on this section in the center of the top edge of the rafter and draw lines *a j* and *a i* directly on the section of the piece and from the points *i* and *j* lines like *i r*, in the isometric view at *C*, can be drawn on the sides of the rafter which will show the amount to be cut off from the corners. In order to do this, however, we must know the bevel of the lines *a e* and *a f*, that is, we must know the angles *n a i* and *m a j* for any particular case. There are ways of finding these angles by mathematics but they are complicated and there is at least one simpler method which can be used whenever the lower end of the hip rafter is cut off in a horizontal plane to

rest on the plate at the top of the wall. Fig. 311 shows how the edges of a hip rafter extend over the plate at the bottom. To overcome this the rafter can be backed or cut shorter as shown in Figs. 311B and 311C. To back the rafter, lay the square on the bevel at the bottom end in the position the plate will occupy. Now mark the points *C D* and draw the lines *D F* and *C G* from these points parallel to the edge of the rafter and cut away the triangular part *A B D F H* and *A E C G H*. This is an expensive means of making the rafter conform to the roof surface and most carpenters merely shorten the rafter until the outside corners conform to the surfaces, as shown in Fig. 312.

Fig. 312. Simpler Method of Avoiding Projecting Hip Rafter

Jack Rafters. Fig. 313 shows the plan of a roof in which there are, in addition to hip and valley rafters, sets of jack rafters. *A B* and *B D* are hip rafters, *C E* is a valley rafter and the other rafters are common and jack rafters. At *B E* and *E H* are shown the ridge boards. Of the jack rafters there are three different kinds: those like *I J* which run from the valley rafter to the ridge board which are sometimes called "cripple" rafters because they have no foot resting on the plate, such as those like *K L* which run from hip rafter to plate; and those like *N T*, which run between the hip and valley rafters. These jack rafters differ only in respect to the bevels which have to be cut on them. The rafter *I J* is a simple plumb cut at the top, similar to the cuts at the top of the common rafters, and at the bottom where the rafter meets the valley there are two cuts—a plumb cut and the side cheek cut—which are similar to the cuts in a valley rafter where it comes against a ridge board. This cut has been previously explained.

The rafter $K\ L$ has a simple horizontal cut at the bottom like that used on the common rafter, but at the top there are two cuts similar to those at the foot of rafter $I\ J$. The rafter $N\ T$ has two cuts at both top and bottom. All these bevels are obtained just as the bevels for the hip and valley rafters.

The length of a jack rafter is proportional to its distance from the ridge or plate to which it is parallel. The longest jack rafter is

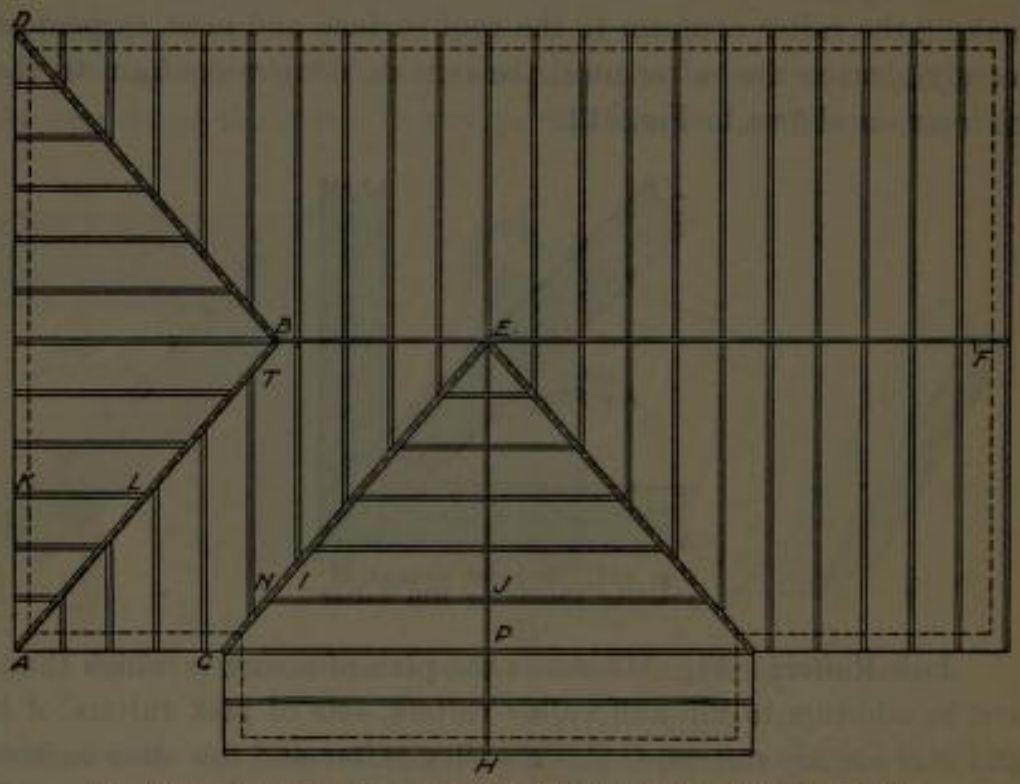


Fig. 318. Roof Plan Showing Hip and Valley Rafters and Jack Rafters

equal in length to a common rafter, and the length steadily decreases as the distance of the rafter from its first full length rafter decreases. The exact difference in length between the first jack rafter and the next, is determined by finding how far apart the jack rafters are to be placed, and comparing this distance with the distance from the top of the first full length jack rafter to the point where the hip or valley rafter rests on the ridge board or plate. Suppose, for instance, that the rafters are to be spaced 2 feet apart, and the length $(C\ P)$, of the common rafter, is 12 feet. If the distance $(P\ E)$, from the top of this rafter to the point where the valley rafter is fitted against the ridge is 12 feet, it is evident that each

rafter will be 2 feet shorter. That is, the second rafter will be 10 feet and the next 8 feet and so on. We use five spaces, although there are only five rafters, there being no rafter used where the valley and the ridge join as at *E*.

Curved Hip Rafters. A form of hip rafter which is sometimes a source of considerable trouble is one which occurs in a curved roof, such as an ogee roof over a bay window, or a curved tower roof. The slope of the curve to which the top edges of the common rafters must be cut, is determined from the shape of the section of the curved roof surface, but the curve at the top of the hip rafter

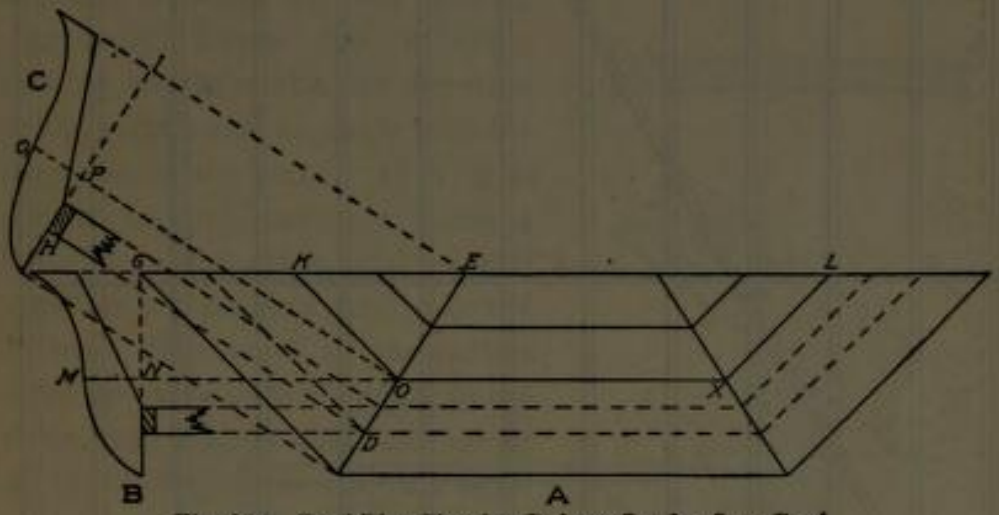


Fig. 314. Roof Plan Showing Rafters Cut for Ogee Roof

is entirely different and must be determined in another way. The principle used in finding this curve is the same as was employed in the case of the valley rafter, namely, that any line drawn in the roof surface parallel to the wall plate must be horizontal, or that it must be at exactly the same elevation throughout its entire length.

Fig. 314 shows how this principle may be applied. At *A* is shown a plan of an ogee roof over a bay window with a hip rafter *D E* and common rafters. At *B* is shown an elevation of one of the common rafters cut to coincide with the curve of the roof surface. The shape of the curve may be varied to suit the fancy of the designer. At *C* is shown an elevation of the hip rafter *D E*, showing the curve to which it must be cut in order to fit into the roof.

To determine this curve we draw on the roof plan at *A* any number of lines, parallel to the wall plate. These must be horizontal, so that any point in either of the lines is at the same height above the top of the plate as is every other point in the same line. The lines *F G* and *H I* in the elevation, shown at *B* and *C*, represent the level of the top of the plate. By projection we find that the line *K O X L*, for example, is at a distance *M N* above the top of the plate at the point where it crosses the common rafter shown at *B*. Every other

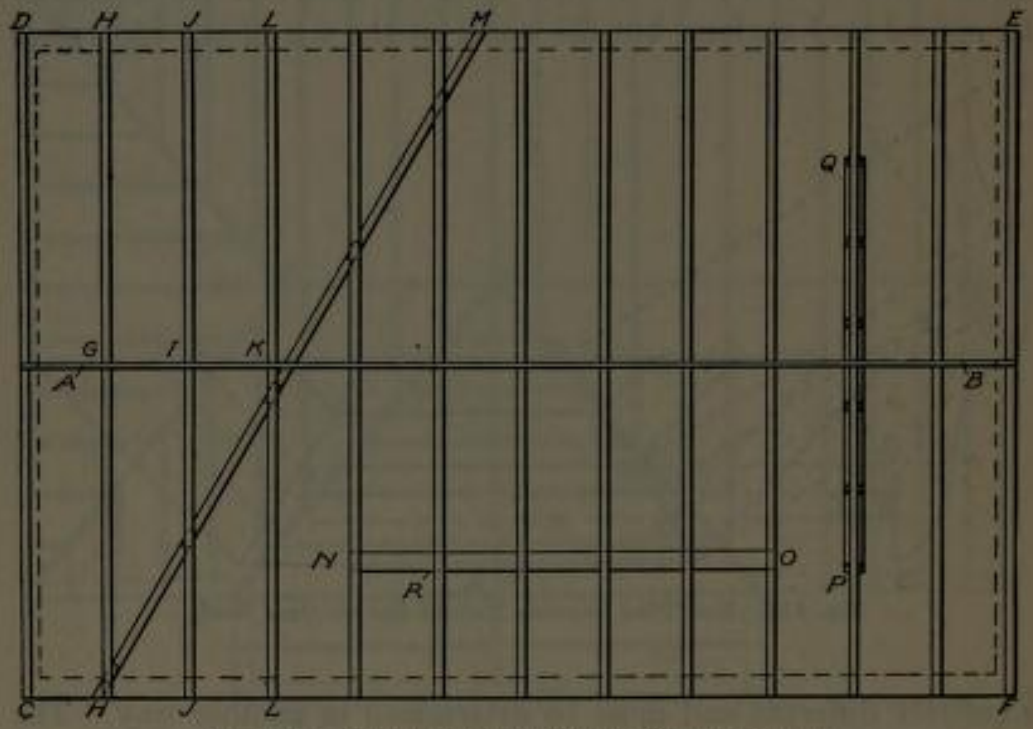


Fig. 315. Framing Plan of Roof of Simple Building

point in this line is at the same elevation, including the point *O*, in which it intersects the center line of the hip rafter *D E*. By projection we can locate the point *O* in the elevation shown at *C*, making the distance *O P* equal to the distance *M N*.

In the same way we can obtain as many points in the curve of the hip rafter as we have lines drawn on the roof plan. The lines may be drawn as close together as we wish, and the number of points obtained may thus be increased indefinitely. When a sufficient number of points have been located, the curve can be drawn through them, and a pattern for the hip rafter is thus obtained. The shape of the curve for a valley rafter is found in the same way as explained for a hip rafter.

ATTIC PARTITIONS

It is often necessary to build partitions in the story directly beneath the roof, and such partitions must extend clear up to the under side of the rafters and be connected with them in some way. This makes it necessary to cut the tops of the studs on a bevel to correspond with the pitch of the rafters, and the cutting of this bevel is not always an easy task. Fig. 315 shows the framing plan of the roof of a small simple building. In this figure *A B* is the ridge. The plate extends around the outside from *C* to *D* to *E* to *F*, and back again to *C;* and *G H I J K L* are the rafters. A partition *H M* is shown beneath the roof running diagonally across the building, making an angle with the direction of the rafters and an angle with the direction of the ridge. At *N O* is shown another partition running parallel to the ridge, and at *P Q* still another, running parallel to the rafters. Now since all the rafters slope upwards from the plate to the ridge, it is evident that the tops of all the studs must be cut on a bevel if they are to fit closely against the under sides of the rafters. This is illustrated in Fig. 316, where the stud *A* must fit against the rafter *B*.

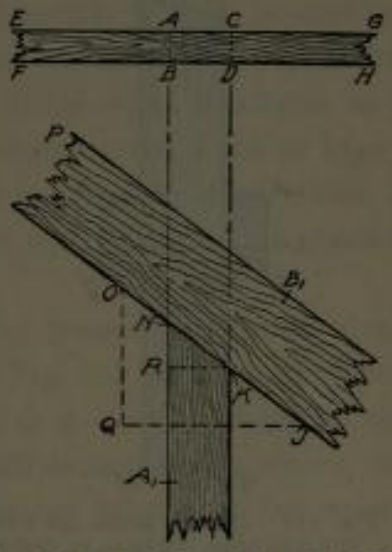


Fig. 316. Studs Beveled to Fit Under Side of Rafter

To take the simplest case first, let us consider the stud marked *R*, Fig. 315. Since all the rafters have the same pitch or slope, all the studs in the partition *N O* will have the same bevel at the top, and if we find the bevel for one we can cut the bevel for all. Fig. 316 shows this stud drawn to a larger scale and separated from the rest; *A B D C* is a plan of the stud, and the rafter is shown at *E F H G*. We will take the distance *F H*, or the run of the part of the rafter shown, as one foot exactly. Now if A_1 and B_1 represent a side elevation of the rafter and stud, the run of the part of the rafter shown is the distance *J Q*, and the distance *Q O* should be equal to the rise of the rafter in one foot. Let the rise in this case be 9 inches. Then *K N* shows the bevel of the top of the stud. If

the stud is a 2 x 4 stick, the distance $K\,R$ is just 4 inches or one-third of the run of the rafter, and consequently the distance $R\,N$ is just 3 inches, or one third of the rise of the rafter. It should be remembered that lumber sizes are actually 2 x 4, 2 x 6, etc., but are as shown in Fig. 18.

In the case of the studs forming the partition $P\,Q$ in Fig. 315, the bevel is found in the same way, the only difference being that the rafter now crosses the stud, as shown in Fig. 317, where $A\,B\,C\,D$ is the stud and $E\,F\,G\,H$ the rafter, both shown in plan. Drawing

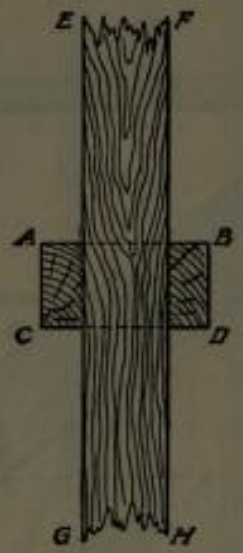


Fig. 317. Cutting Studs for Partition Running Parallel to Rafter

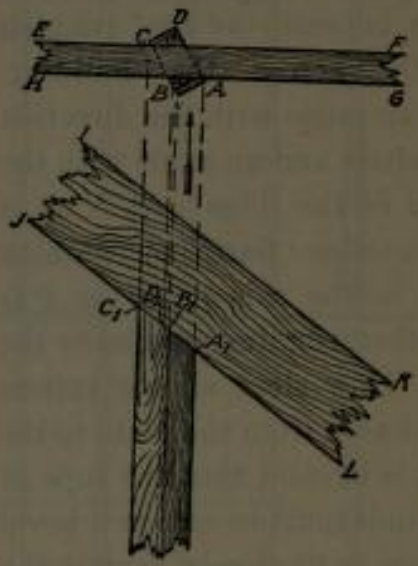


Fig. 318. Cutting Studs for Partition Running Diagonally

rough sketches of such details help to visualize them more readily.

In the case of the partition $H\,M$, Fig. 315, we have to deal with a somewhat more difficult problem because the rafter crosses the stud diagonally and the studs must be beveled diagonally on top so that the bevel will run from corner to corner instead of straight across the stud from side to side. An enlarged plan of one stud with the rafter running across it is shown in Fig. 318. Let $A\,B\,C\,D$ be the stud and $E\,F\,G\,H$ the rafter; $I\,J\,L\,K$ shows the rafter in elevation looking in the direction shown by the arrow, and $A_1\,B_1\,C_1\,D_1$ shows the stud as seen from this same direction. The edge D_1 of the stud can not be seen from this side and is shown as a dotted line in the figure. The rafter runs across the stud, thus giving the bevel $A_1\,B_1\,C_1\,D_1$ as shown in the figure.

SPECIAL FRAMING

We have, in the preceding pages, considered the framing which enters into a building of light construction, such as an ordinary dwelling house, but there are certain classes of structures which call for heavier framing, or framing of special character. Among these may be mentioned trussed partitions; inclined and bowled floors; special forms of reinforced beams and girders; the framing for balconies and galleries; timber trusses, towers and spires.

Trussed Partitions. It is very often necessary to construct a partition in some story of a building above the first and in such a position that there can be no support beneath it such as another partition. In this case the partition must be made self-supporting in some way. The usual method is to build what is known as a "trussed partition." This consists of a timber truss, light or heavy according as the distance to be spanned is small or large, which is built into the partition and covered over with lathing and plastering or with sheathing.

Figs. 319 and 320 show two forms of trussed partitions which are in common use. The one shown in Fig. 319 may be employed for a solid partition, or a partition with a door opening in the middle, while the one shown in Fig. 320 is applicable where the wall must be pierced by door openings set relatively far apart. The truss must be so designed that it will occupy as little space as possible in a lateral direction, so that the partition need not be abnormally thick. If possible, it is best to make the truss so that it will go into a 4-inch partition, but if necessary 5- or 6-inch studding may be used and the truss members may be increased in size accordingly. The faces of the truss members should be flush with the faces of the partition studding.

The size of the truss members depends entirely upon the weight which the partition is called upon to carry. Besides its own weight, a partition is often called upon to carry one end of a set of floor joists and sometimes it supports columns which receive the whole weight of a story above. In any case, the pieces must be very strongly framed or spiked together, and sound material free from shakes and knot holes must be used.

In Fig. 321 is shown another form of trussed partition spanning

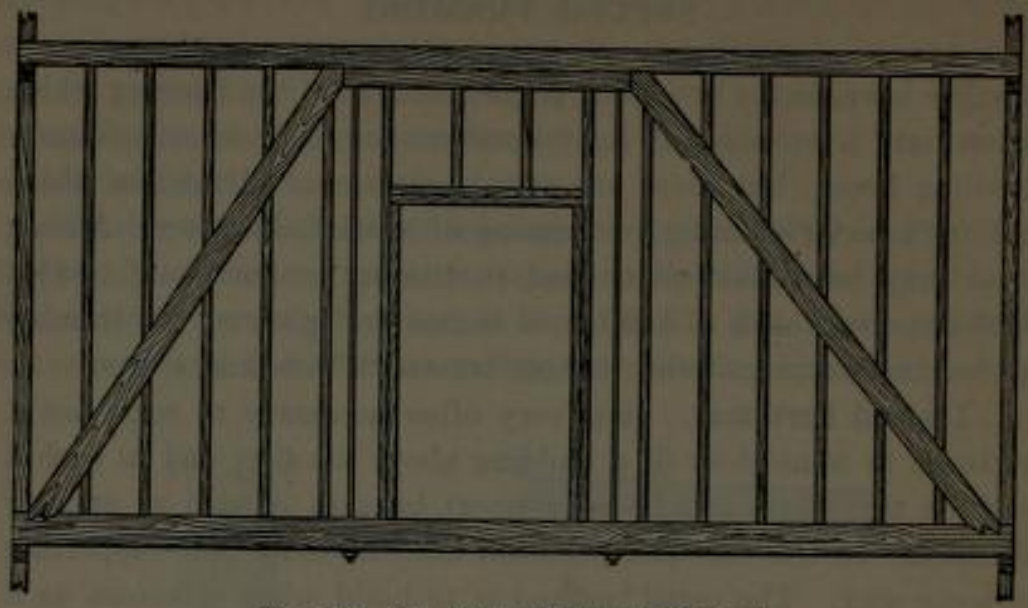


Fig. 319. One Form of Trussed Partition

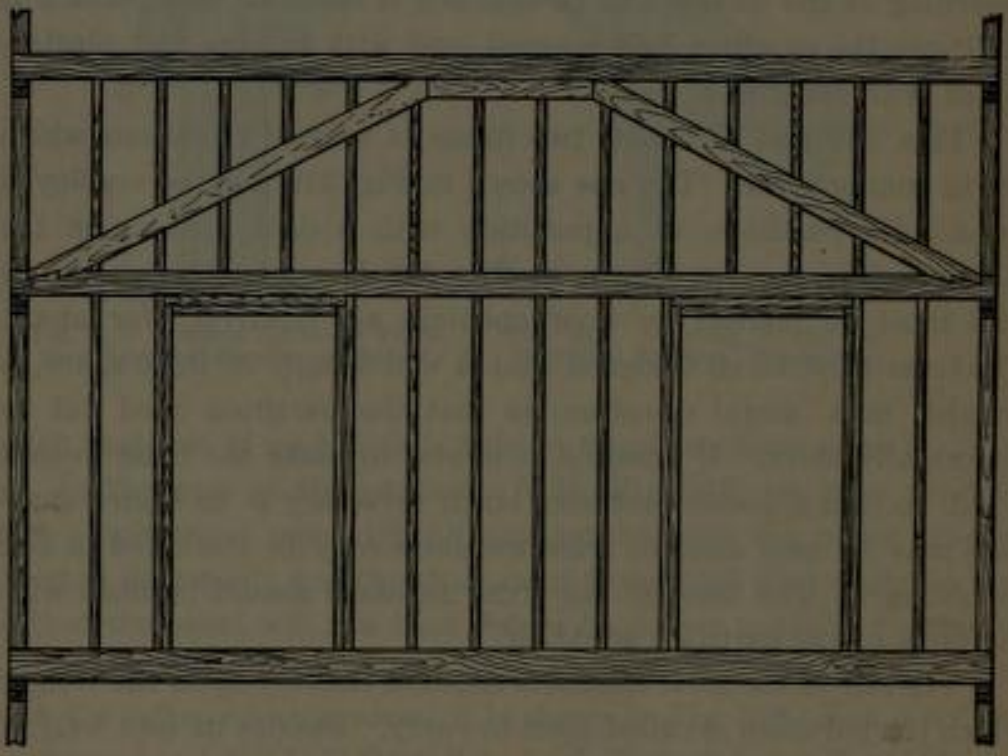


Fig. 320. Another Form of Trussed Partition

the space between two masonry walls. As will be seen this partition is constructed in a slightly different way from the others illustrated and described above. At the two sides of the opening, which is in this case in the center of the partition, are two uprights which are

made considerably heavier and stronger than the ordinary studding of which the frame of the partition is composed. In the figure, the opening is marked *A*, and the uprights at the sides of the opening are marked *B B*. In the upright pieces shoulders are formed, as shown at *C* in the figure, and into the shoulders are fitted braces which go diagonally across the partition to the lower corners near the wall where they are notched into the lowest member of the trussed frame. These diagonal pieces are marked *D* in the figure, and the lowest member of the frame is marked *E*. The piece *E*

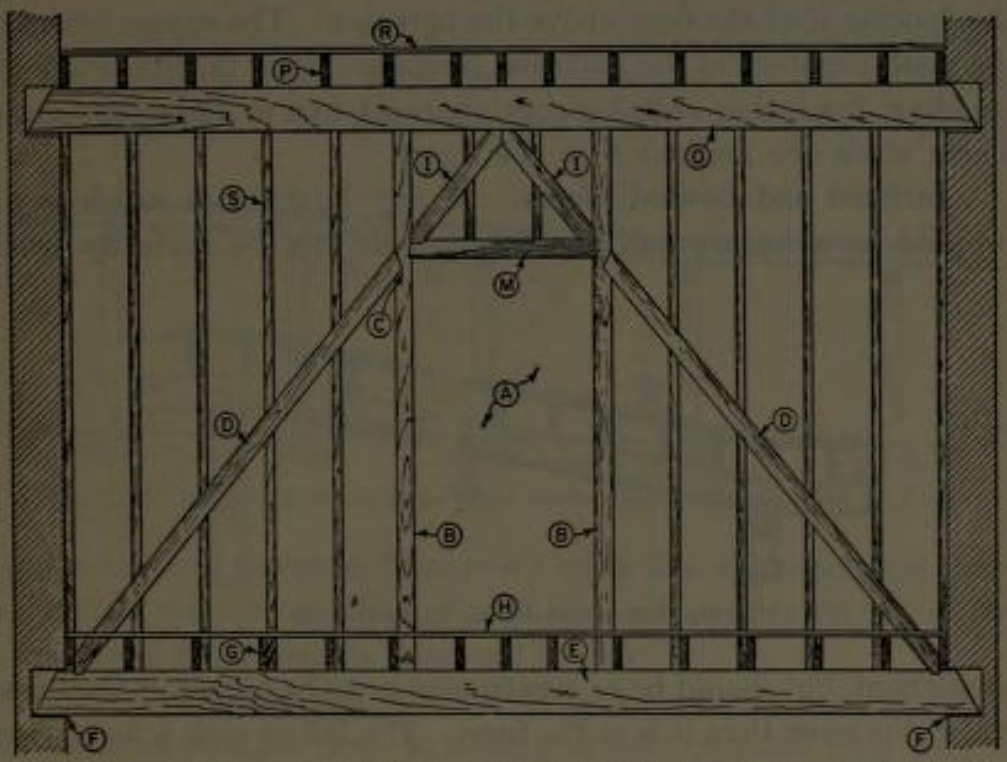


Fig. 321. Trussed Partition Spanning Space between Two Brick Walls

goes across from wall to wall and should run well into each wall as shown, so as to obtain a good bearing on the masonry and there should be a bearing plate or template of some kind under each end of it, as shown in the figure at the points *F*, to distribute the weight of the partition over a large surface of the masonry. For this purpose a thin iron plate will answer very well, or a large flat stone may be used. The piece *E* strengthens the floor construction and helps support the partition; the joists *G* rest on top of the piece *E*, or are notched over it, and the flooring *H* rests on these joists.

Above the door opening *A* there are two diagonal pieces *I* which come together at the top of the partition, forming a small truss over the opening and completing the trussing of the partition. The diagonal pieces *I* meet the uprights on each side of the door opening at the point where the horizontal lintel piece *M* meets the uprights, and they should be notched into either one or the other or both. The topmost member of the trussed partition frame is marked *O* in the figure, and on top of it rest the joists of the floor above, which either rest directly on it or are notched over it according to circumstances. These joists are marked *P* in the figure. They support the flooring *R* of the floor above the partition. The spaces between the main members of the partition frame are filled in with ordinary studding, 2x4 inches or 2x3 inches, spaced 1 foot or 16 inches apart. These studs are marked *S* in the figure.

Inclined and Bowled Floors. In any large room which is to be used as a lecture hall the floor should not be perfectly level

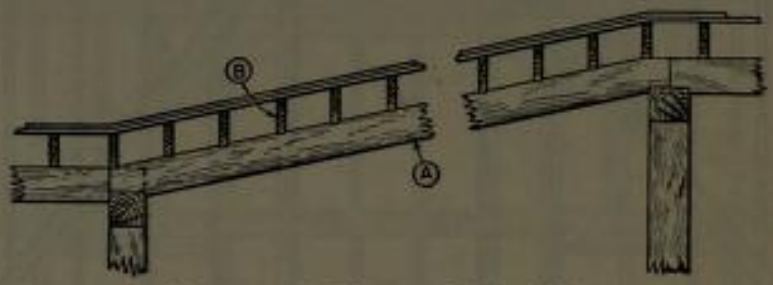


Fig. 322. Building an Inclined Floor

throughout, but should be so constructed as to be higher at the back end of the room than it is at the front. The fall of such a floor from back to front should be not more than ¾ of an inch in 1 foot, and a fall of ½ an inch in 1 foot is much better. If the floor has a greater slope than this it becomes very noticeable when anyone attempts to walk over it.

The simplest way to arrange for the slope is to construct what is known as an "inclined" floor, which rises steadily from front to back, so that a line drawn across it from side to side, parallel to the front or rear wall of the room, will be level from end to end. There are two methods of building an inclined floor, the difference between them being in the arrangement of the girders and floor joists. The two methods are shown in Figs. 322 and 323.

Fig. 322 shows the arrangement when it is necessary to have the girders run from the back to the front of the room, parallel to the slope of the floor. In this case the girders *A* are set up on an incline and the joists *B* resting on top of them are level from end to end. Each line of joists is at a different elevation from the lines of joists on each side of it. The floor laid on top of the joists will then have the required inclination. The slope of the girders must be the same as the slope required for the finished floor.

Fig. 323 shows the arrangement when it is desired that the girders shall run from side to side of the room, at right angles in the direction of the slope of the floor. The joists *A* will then be parallel to the direction of the slope, and are inclined to the horizontal, while the girders *B* are level from end to end. Each line of girders

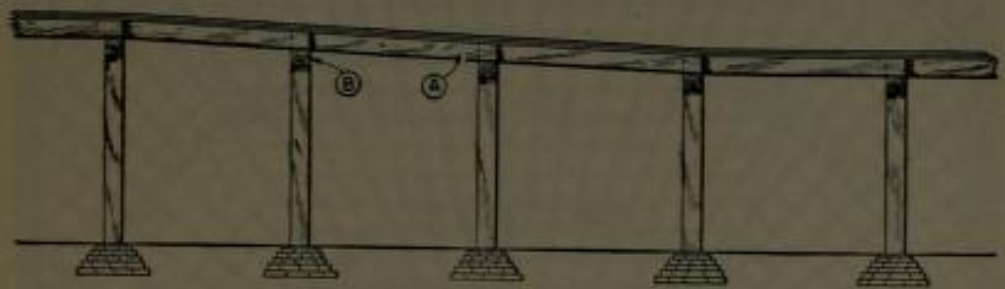


Fig. 323. Building Inclined Floor When Girders Run at Right Angles of Slope

is at a different elevation from every other line of girders, and these elevations must be so adjusted that the joists resting on top of the girders will slope steadily from end to end.

When a simple inclined floor is employed, the seats must be arranged in straight rows, extending across the room from side to side, so that each line of seats may be level from end to end. This arrangement is not always desirable, however, and it is often much better to have the seats arranged in rings facing the speaker's platform. In this case a bowled floor must be built. A bowled floor is so constructed that an arc, drawn on the floor from a center in the front of the room, on or near the speaker's platform, will be perfectly level throughout its length. This means that the floor must pitch upward in all directions from the speaker's platform, or, in other words, it must be bowled. There are two methods of constructing a floor of this kind. The simplest way is to build first an ordinary inclined floor, which slopes from the front to the back

of the room, and then to build up the bowled floor with furring pieces. This method should always be followed when it is necessary to keep the space beneath the lecture hall free from posts or columns.

The second method is to arrange girders, as shown in the framing plan of a bowled floor in Fig. 324. These girders *A* are tangent to concentric circles which have their center at the speaker's platform, and each line of girders is at a different elevation. The elevations of the different lines of girders are so adjusted that the floor joists *B*

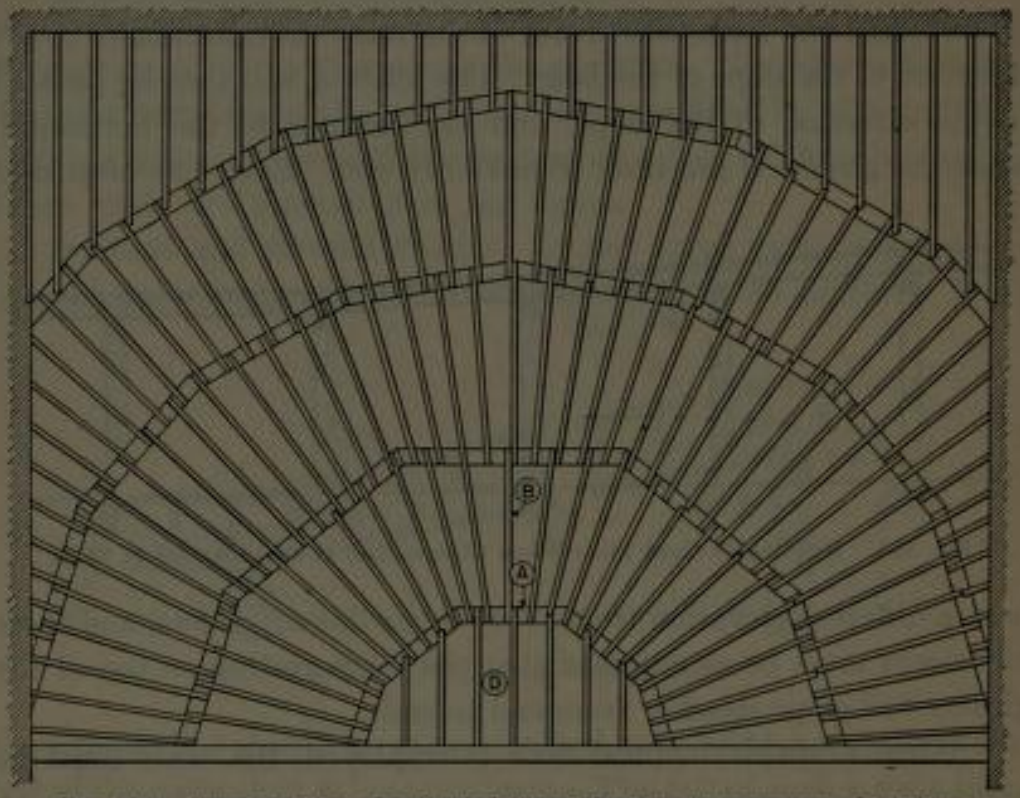


Fig. 324. Framing Plan of a Bowled Floor Showing Arrangement of Girders

which rest on them, will slope steadily upward as they recede from the platform. The girders may be supported on posts beneath the floor of the hall, and if the space under the floor is not to be used for another room, this is a very good method to employ.

Immediately around the platform there will be a space *D*, the floor of which will be level, and the slope will start several feet away from the platform.

If the floor is framed in this way it means that there will have to be a large number of posts in the space immediately beneath the floor, so many in fact as to make it practically impossible to make

use of this space for another purpose. It would be necessary to put a post at each intersection of the girders which are arranged in concentric rings about the speaker's platform, so that the posts in

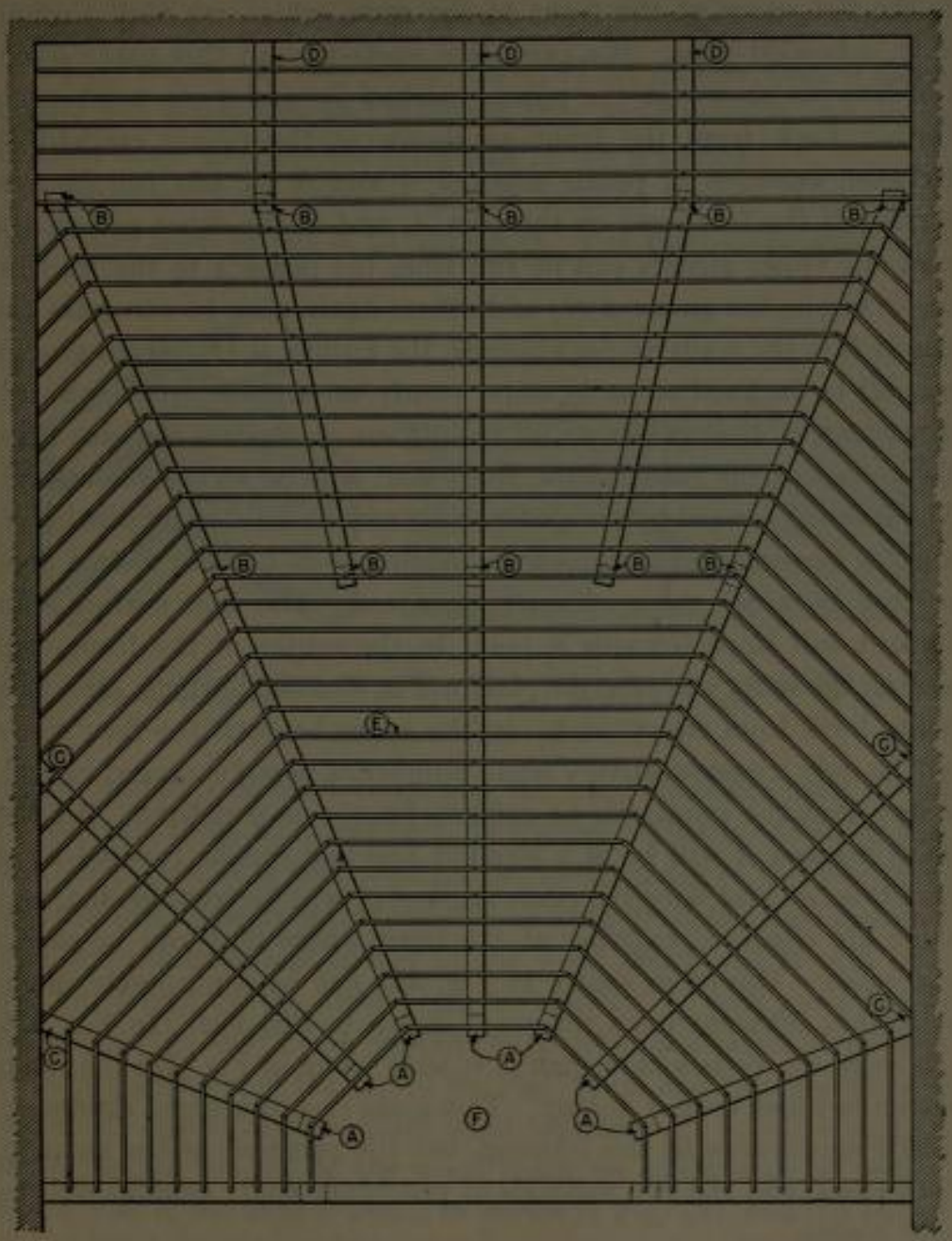


Fig. 325. Framing Plan for Bowled Floor of Longer Type than Fig. 324

the space below would also appear in rings parallel to each other and only a comparatively small distance apart. It is not possible to do away with absolutely all of these posts except as explained

above, by building up on top of a plain inclined floor surface, but it is possible to do away with a large number of them if necessary, as will be explained. In Fig. 325 suppose that the space marked *F* is the flat space at the front of the room which we wish to floor with a bowled floor. We can place posts around this space under the floor as shown at the points marked *A*, and some more posts farther back from the front as shown at the points marked *B*. Between each set of points marked *A* and *B* we can run girders, resting at the front end on the post *A*, and at the other end on the post *B*. Other girders can be run from the posts *A* to the wall as, for example, the girder *A C;* and others again may be run from the points *B* to the walls as, for example, the girders *B D*. These girders can all be inclined so as to slope evenly toward the front from all directions, so that points on all the girders at a given distance from the center of the room at the front wall will be at the same level. The framing formed by the girders may now be filled in by joisting *E*, and the flooring laid on top of the joisting so as to form a solid floor surface on which the seats may be placed. The floor surface thus formed will slope towards a point in the center of the front wall and all the seats will face the platform in concentric rings, each ring being level from end to end. In the space beneath the floor there will be only a comparatively small number of posts, arranged in such a way that the space can be utilized for rooms if desired. All the posts marked *B* will be in a straight line and can be covered by a partition, so that only the posts marked *A* will be troublesome, and these are clustered together at the front where they can be easily concealed. The room shown in Fig. 325 has been purposely made somewhat different from the room shown in Fig. 324. In Fig. 325 the room shown is longer than it is wide while in Fig. 324 the room shown is wider than it is long. This gives rise to a slight difference in the appearance of the framing, but the principle is the same in both cases, and the two methods of procedure apply equally well to both rooms.

Heavy Beams and Girders. For ordinary framed buildings there will be no difficulty in obtaining timbers large enough for every purpose, but in large structures, or in any building where heavy loads must be carried, it is often impossible to get a single piece which is strong enough to do the work. In this case it becomes

necessary to use either a steel beam or a trussed girder of wood, or to build up a compound wood girder out of a number of single pieces, fastened together in such a way that they will act like a single piece.

Steel beams are very often employed for girders when a single timber will not suffice, and although they are expensive, the saving in labor helps to offset the extra cost of the material.

Wherever wood joists or girders come in contact with a steel beam they must be cut to fit against it. The steel shape most com-

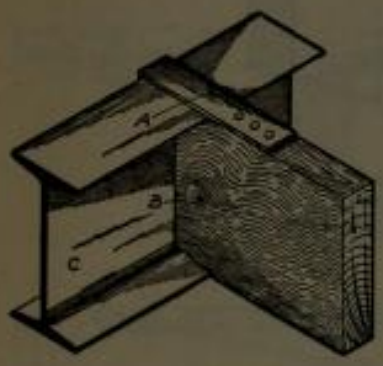


Fig. 326. Cutting Girders to Fit Steel Beams

Fig. 327. Fitting Girders to Steel Beams by Means of Angles

monly employed is the I-beam and the wood members must be cut at the ends so as to fit between its flanges. This is shown in Fig. 326. The joist *B* is supported on the lower flange of the I-beam *C* and the strap *A* prevents it from falling away from the steel member. The strap is bolted or spiked to the wood beam and is bent over the top flange of the steel beam as shown. If two wood beams frame into the steel beam opposite each other, a straight strap may be used passing over the top of the steel beam and fastened to both the wood beams, thus holding them together. If a better support is desired for the end of the wood beam, an angle may be riveted to the web of the steel I-beam, as shown in Fig. 327, and the end of the wood joist may be supported on the angle. This is an expensive detail, however, and it is seldom necessary.

Figure 328 illustrates the use of a patented steel chair or seat bolted to a steel I-beam for the support of wood joists 4 inches or more above the lower flange and Fig. 329 shows the use of a steel hanger for a wood joist or beam which frames into a steel beam of

equal depth. In each case chairs or hangers are bolted to the steel beam.

If a timber is not strong enough to carry its load, and if it is not desirable to replace it with a steel beam, it may be strengthened by trussing. There are two methods of trussing beams: by the ad-

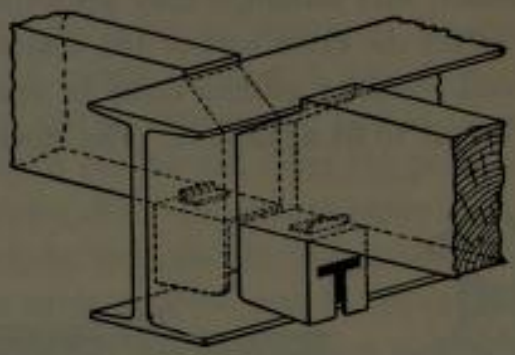


Fig. 328. Illustrating Use of a Steel Chair or Seat in Connection with I-Beam
Courtesy of Duplex Hanger Company

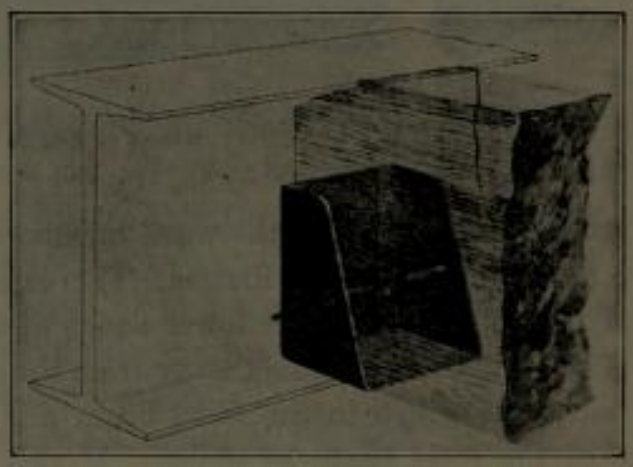


Fig. 329. Illustrating a Steel Hanger for Joists or Beams
Courtesy of Duplex Hanger Company

dition of compression members above the beam, and by the addition of tension members below it. The first method should be employed whenever, for any reason, it is desired that there be no projection below the bottom of the beam itself. The second method is the one most commonly used, especially in warehouses, stables, and other buildings where the appearance is not an important consideration.

In Fig. 330 is shown a beam which is trussed by the first method

with compression pieces A above the beam. All the parts are of wood excepting the rods B, which may be of steel. The beam itself is best made in two parts $E\,E$ placed side by side, as shown in the section at A. This section is taken on the line $C\,D$. The depth of the girder may be varied to suit the conditions of each case. In general the deeper it is made the stronger it becomes, provided that the joists are made sufficiently strong. Usually girders of this kind are made shallow enough so that the compression member will be contained in the thickness of the floor and will not project above it.

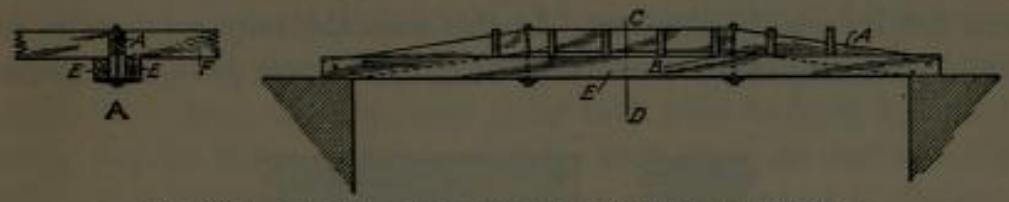


Fig. 330. Trussing a Girder by Use of Compression Members

Fig. 331. Trussing Girder by Use of Tension Member—King-Post Trussed Beam

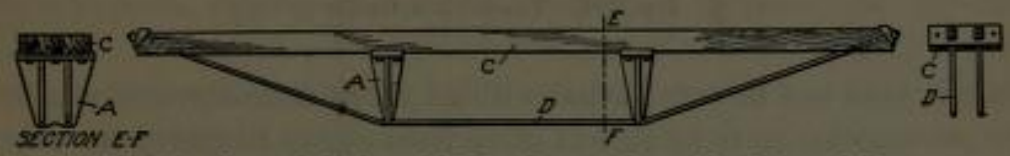


Fig. 332. Trussed Girder with Two Struts—Queen-Post Trussed Beam

A slight projection below the ceiling is not a serious disadvantage. The floor joists F may be supported on the pieces E, as shown at A, Fig. 330.

In Figs. 331 and 332 are shown examples of girders which are trussed by the second method with tension rods D below beam. These rods are of wrought iron or steel, and the struts A are of cast iron. The struts may be made of wood if they are short, or if the loads to be carried are not heavy. Sometimes the girders are made very shallow and the struts A are then merely wood blocks placed between the beams C and the rod D to keep them apart. The girder shown in Fig. 331 is known as a king-post trussed beam, while the

one shown in Fig. 332, with two struts instead of one, is known as a queen-post trussed beam. The beam itself, *C*, may be made in two or three pieces side by side with the rods and the struts fitting in between them, or it may be a single piece, and the rods may be made in pairs, passing one on each side of the beam. The struts bear against the bottom of the beam, being fastened to it by bolts or spikes, as shown in the illustrations, so that they will not slip sidewise.

It sometimes happens that a heavy girder is required in a situation where trussing can not be resorted to, and where steel beams can not be readily obtained. In this case the only resource is to build up a compound beam from two or more single pieces. A girder

Fig. 333. Construction of Compound Beam

Fig. 334. Flitch-Plate Girder

of this kind can be constructed without much difficulty, and can be so put together as to be able to carry from eighty to ninety per cent of the load which a solid piece of the same dimensions will bear. There are many ways of combining the single timbers to form compound beams, some of the most common of which will be described.

The most simple combination is that shown in Fig. 333. The two single timbers are bolted together side by side, with sometimes a small space between them. The bolts should be spaced about 2 feet apart and staggered as shown, so that two will not come side by side. Usually bolts three-quarters of an inch in diameter are used.

In Fig. 334 is shown a modification of this girder known as a "flitch-plate" girder. It has a plate of wrought iron or steel, inserted between the two timbers, and the whole is held firmly together by bolts. The size of the plate should be in proportion to the size of the

timbers, so as to make the most economical combination. In general the thickness of the iron plate should be about one-twelfth of the combined thickness of the timbers.

Fig. 335. Action of Compound Girder under Tension

If we have two pieces of timber out of which we wish to make a compound girder, it is always possible to get a stronger combination by placing them one on top of the other, than by placing them side by side. This is because the strength of a beam varies as the square of its depth, but only directly as its width. For this reason most compound girders are composed of single pieces placed one above the other. The tendency is for each piece to bend independently, and for the two parts to slide by each other, as shown in Fig. 335. This tendency must be overcome and the parts so fastened together that they will act like a single piece. There are several methods in common use by which this object is accomplished.

Fig. 336 shows the most common method of building up a compound girder. The timbers are placed together, as shown, and narrow strips of wood are nailed firmly to both parts. The strips are placed close against each other and have a slope of about forty-five degrees, sloping in opposite directions, however, on opposite sides of the girder. It has been claimed that a built-up girder of this kind has strength ninety-five per cent as great as the strength of a solid piece of the same size but it is very doubtful whether this is true in most cases. Actual tests seem to indicate that such girders have an efficiency of only about seventy-five per cent. They usually fail by the splitting of the side strips, or the pulling out and bending of the nails, but seldom by the breaking of the main pieces. It is, therefore, essential that the strips should be very securely nailed to each of the parts which make up the girder, and that they should also be carefully selected so that only those pieces which are free from all defects may be used. These girders are liable to considerable deflection, and should not be used in situations where such deflection would be harmful.

Fig. 336. Method of Building Up Compound Girder

In Fig. 337 is shown another form of girder with the parts notched, as shown, so as to lock together. This prevents them from slipping by each other. Bolts are employed to hold the parts together, so that the surfaces will always be in close contact. While this form of girder is very easily constructed, it has many disadvantages. A great deal of timber is wasted in cutting out the notches, as these must be deep enough to prevent crushing of the wood at the bearing surfaces, and thus the full strength of the timbers is not utilized. Moreover, it is apt to deflect a good deal, and its efficiency is not so great as that of other forms. On the whole it is inferior to the form previously described.

The compound beam which is almost universally considered the best is that shown in Fig. 338. This is known as a *keyed beam*, its characteristic feature being the use of *keys* to keep the parts from sliding on each other. The strength of a keyed beam has been found by actual experiment to be nearly ninety-five per cent of the

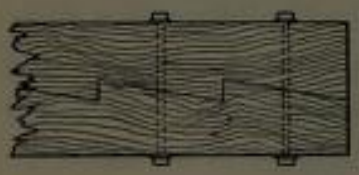


Fig. 337. Compound Girder with Notched Surfaces

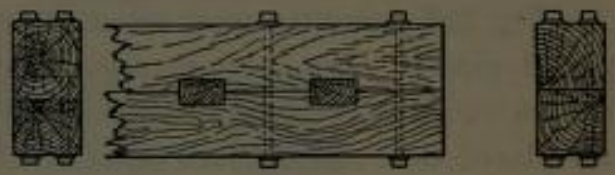


Fig. 338. Example of Keyed Beam

strength of the solid timber, while the deflection when oak keys were used was only about one-quarter more than the deflection of the solid beam. By using keys of cast iron instead of wood this excess of deflection in the built-up girder can be reduced to a very small percentage. The keys should be made in two parts, each shaped like a wedge, as explained in connection with the keys for tension splices, and should be driven from opposite sides into the holes made to receive them, so as to fit tightly. They should be spaced from 8 to 16 inches apart, center to center, according to the size of the timbers, and should be spaced more closely near the ends of the beam than near the middle. In the center of the span there should be left a space of 4 or 5 feet without any keys.

Balconies and Galleries. In churches and lecture halls it is almost always customary to have one or more balconies or galleries, extending sometimes around three sides of the main auditorium,

but more often in the rear of the room only. These galleries are supported by the wall at the back and by posts or columns in front.

Fig. 339 shows a sectional view of a gallery frame, as they are commonly constructed. There is a girder *A* in front, which rests on top of the columns *T*, and supports the lower ends of the joists *B*, forming the gallery floor. The size of these pieces will depend upon the dimensions of the gallery, the spacing of the columns which support the girders in front, and various other considerations. Usually joists 2 x 10 or 3 x 12, and girders 8 x 10 or 10 x 12 will be found to be sufficiently strong. The joists should be spaced from

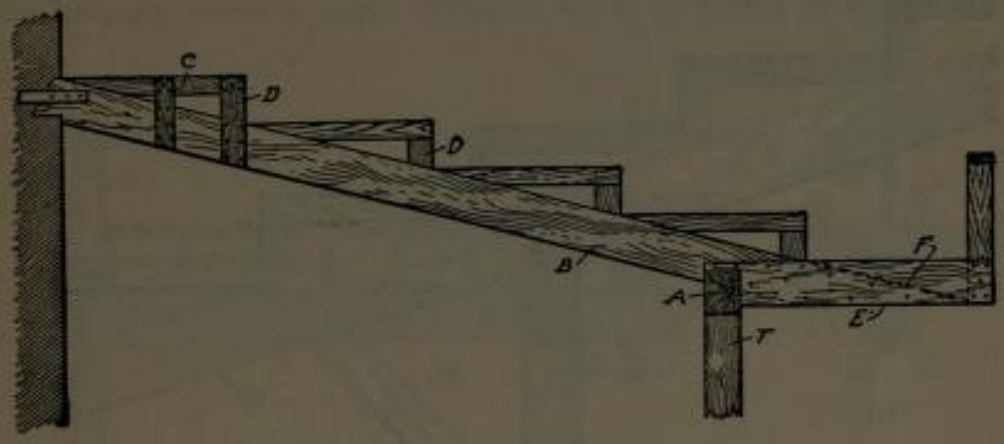


Fig. 339. Sectional View of Gallery Framing

14 to 20 inches, center to center. Very often cast-iron columns are employed to support the girders. At the top, where the joists rest on the wall, they should be cut, as shown in the figure, so that they may have a horizontal bearing on the masonry, and at least every second joist must be securely anchored to the wall, as is the one shown. Usually galleries are made with straight fronts, but if it is desired that the seats should be arranged in concentric rings, all facing the speaker, the joists may be placed so as to radiate from the center from which the seats are to be laid out.

The seats are arranged in steps, one above the other, and the framing for the steps must be built up on top of the joists, as shown in the figure. Horizontal pieces *C*, usually 2 x 4 or 3 x 4 in size, are nailed to the joists at one end, and at the other end they are supported by upright pieces *D*. The uprights are either 2 x 4 pieces resting on top of the joists, or strips of board, 1 inch to 1½ inches thick, which

are nailed to the sides of the joists and to the sides of the horizontal pieces. Both methods are shown in the figure. If boards are used, they should be placed on both sides of the joists. Great care should be taken to see that the horizontal pieces are truly horizontal.

Balconies and galleries almost always project a considerable distance beyond the line of columns which support the lower ends of the joists. This projection varies from 3 feet to 10 or 12 feet. If the overhang is not more than 5 feet, it can be supported by extending the joists beyond the girder, as is shown in Fig. 339. A strip of board *E*, about 1½ inches thick, is nailed to the side of the joist, and

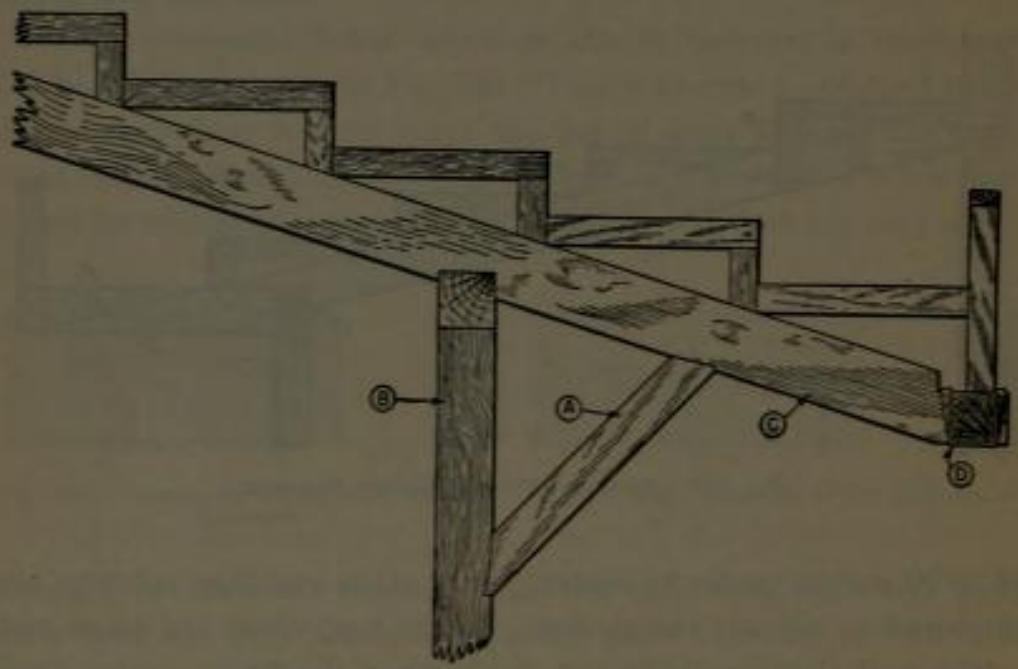


Fig. 340. Section of Gallery Framing with Overhanging Portion

a furring piece *F* is nailed on top of the joist at its lower end to make it horizontal. The railing at the front of the gallery should be about 2 feet high, and may be framed with 2x4 posts *G* having a cap *H* of the same size on top.

If the overhang of a gallery is more than 5 feet it must usually be supported by a brace, as shown in Fig. 340. The brace *A* may be nailed to the post *B* and to the overhanging joist *C*, or framed into these pieces. If the construction is very light, the braces may consist of strips of board nailed to the sides of the joists, but in heavy work they must be timbers of a good size, well framed into both the post and the joists. The braces can only be placed at

points where there are posts, and to support the ends of the joists which come between the posts there must be a girder *D*, running along the front of the gallery and supported by the braced cantilevers at the points where posts are placed.

The forms of balconies described above are all of such a sort as to require the presence of posts in the main floor below the balcony to support it, but it very often happens that such posts are very undesirable and must be avoided if it is possible to do so. In this case the balcony must be supported from above in some way, and the method most commonly employed is to hang the outer end of the main timbers from the ceiling of the main hall or room of which the balcony forms a part. Hangers made of round or square iron

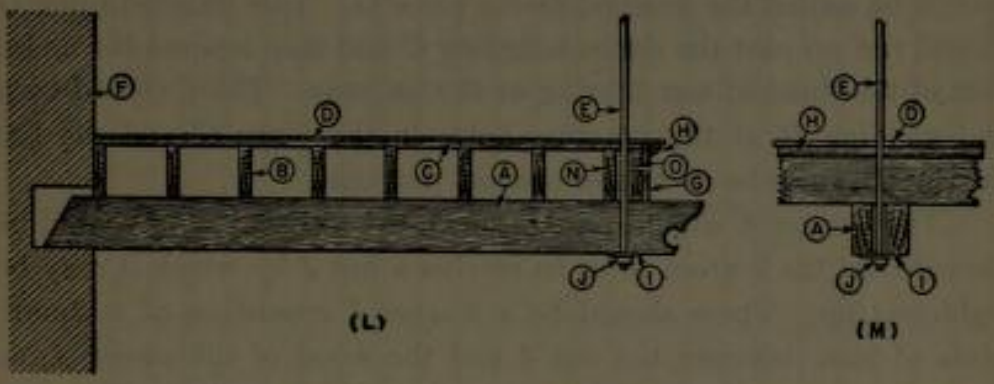


Fig. 341. Details of Balcony Construction Showing Hanger Attached to Roof

or steel rods are used, and these are fastened at the upper end to some member of the floor construction of the floor above, or to some member of the roof construction in case there is no floor above. The most common arrangement is to fasten the upper end of the hanger to the lower chord of the roof truss.

Fig. 341 shows a balcony constructed as described above. One side is supported by the masonry wall of the building, marked *F* in the figure, and the other side is hung from the roof or ceiling by means of the hangers marked *E*. At *L* is shown a section through the balcony from the wall to the inside edge, while at *M* is shown a view looking at the edge of the balcony from the inside of the hall or room in which the balcony is situated. The principal supporting members of the construction are the pieces marked *A* which run well into the wall so as to obtain a sufficient support at this end.

These pieces are made double or in pairs, as shown in the end view *M*, and are separated a little so as to allow the hanger rod to pass between the two pieces as shown. *E* is the hanger, which is a round or a square rod about 1 inch in diameter. The pieces *A* should continue a short distance beyond the point where the rod passes between them, and the ends may be cut to any shape desired in order to give them a pleasing appearance, as shown. They should be spaced 7 or 8 feet apart and on top of them may be placed ordinary joists of small size, marked *B* in the figure, which are spaced about 12 or 14 inches apart. On top of the joists *B* is laid a rough floor, marked *C* in the figure, and above this again is laid the finished flooring of the balcony *D*. A joist should be placed on each side of the hanger *E*, as shown at *N* and *O*, and against the joist marked *O* should be nailed the finished fascia piece *G*. This finished piece *G* should run up past the under boarding *C* and stop against the under side of the finished top flooring of the balcony. There should be a bed molding *H* at the juncture between the piece *G* and the top flooring *D*, so as to cover and conceal the joint.

The hanger *E* should pass between the pieces *A*, and should be threaded at the bottom so as to receive a nut *J* by which it may be tightened up. There should be a washer *I* consisting of a square plate of iron, between the nut *J* and the wood of the pieces *A*, so the wood will not be crushed and so that the nut will not sink into the wood.

The under side of the balcony seen from the floor of the main hall may be treated in any one of a variety of ways. The joists may be furred and lathed and plastered on the under side so that a plastered surface will be presented, or the under side of the joists may be covered with sheathing, V-jointed or beaded, or the joists may be more carefully chosen and left exposed to view from below.

TIMBER TRUSSES

In the discussion of roofs and roof framing which has already been given here, only those roofs have been considered which were of so short a span that they could easily be covered with a framework of ordinary rafters, spaced from 1 to 2 feet apart, between centers, but it is very often necessary to build roofs of larger span, for which ordinary rafters, even if supported by dwarf walls and

collar beams, are not sufficiently strong. In this case a different method of framing must be employed.

Instead of a number of rafters spaced fairly close together, and all of equal strength, we will have a few heavy "trusses," placed at intervals of 10 or more feet, and spanning the entire distance between the two side walls. On top of the trusses are laid "purlins," running parallel to the walls, which in their turn support the common rafters, running perpendicular to the side walls, as in the case of simple rafters in an ordinary roof. There may be one or more purlins in

Fig. 342. Roof Plan Showing Use of Heavy Trussed Purlins and Common Rafters

each slope of the roof, depending upon the size of the span, since the purlins must be spaced near enough together so that a small rafter can span the distance between them. Usually there will be a purlin at each point of the truss and the joints will be determined by the safe span for the rafters.

This arrangement is shown in plan in Fig. 342, in which *A* are trusses, *B* are the purlins, *C* are the common rafters, and *D* is the ridge. Fig. 344 shows a section taken through a roof of this kind.

There are many different kinds of trusses in common use for various kinds of buildings, which differ from each other chiefly in

the arrangement of the tension and compression pieces of which every truss is built up. Some trusses are built entirely of timber, while in others timber is employed only for the compression pieces, and wrought iron and steel for the tension pieces.

King-Post Truss. Fig. 343 shows what is known as a *king-post truss*. Its distinguishing feature is the member *A* called a *king-post*, *B* are the purlins, and *E* are the rafters resting on them. As will be seen by a study of the figure, the members of the truss are so arranged as to divide it up into a series of triangles, or rather into a series of triangular open spaces, bounded by the various members of the framework. This is an essential characteristic of a good and efficient truss. Such a framework may fail by overloading in such

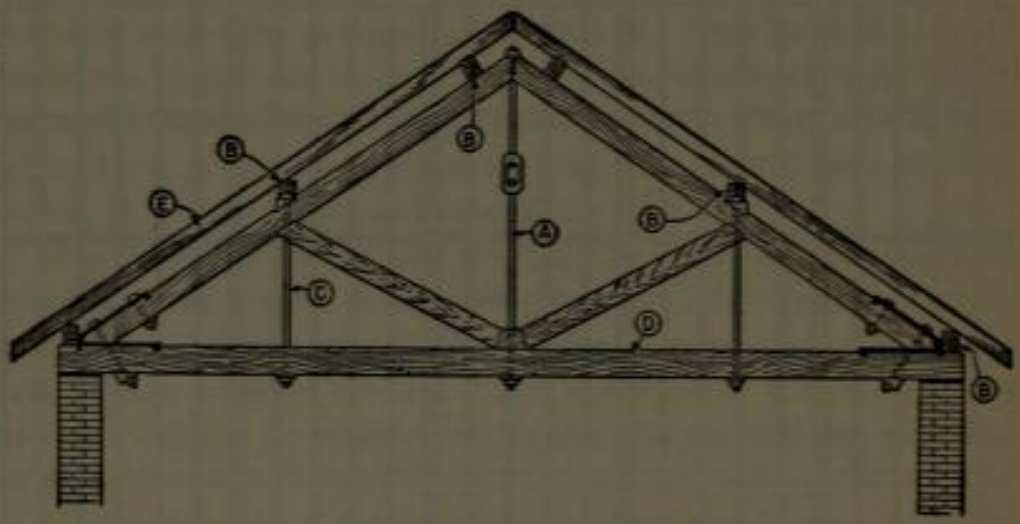


Fig. 343. Section Showing Design of King-Post Truss

a way as to be crushed or broken, but it cannot be distorted, that is, none of the triangular spaces can change their shape without some member of the truss being either lengthened or shortened, which means that some member of the framework must fail by either tension or compression before the truss can be distorted, or can fail to carry its load by reason of the failure of the joints. This principle does not hold true for a framework composed of spaces in the form of rectangles, of which the members of the framework form the sides, because it is possible for a rectangular framework to become distorted without any side being either lengthened or shortened, by the simple failure of some of the joints and the movement of the members around the joints. For this reason the first thing to con-

sider in designing a truss is the arrangement of the members and the position of the joints so all of the open spaces will be in the form of triangles.

In Fig. 343 are shown two different methods of placing the purlins. As will be readily seen, some of them are set so that their

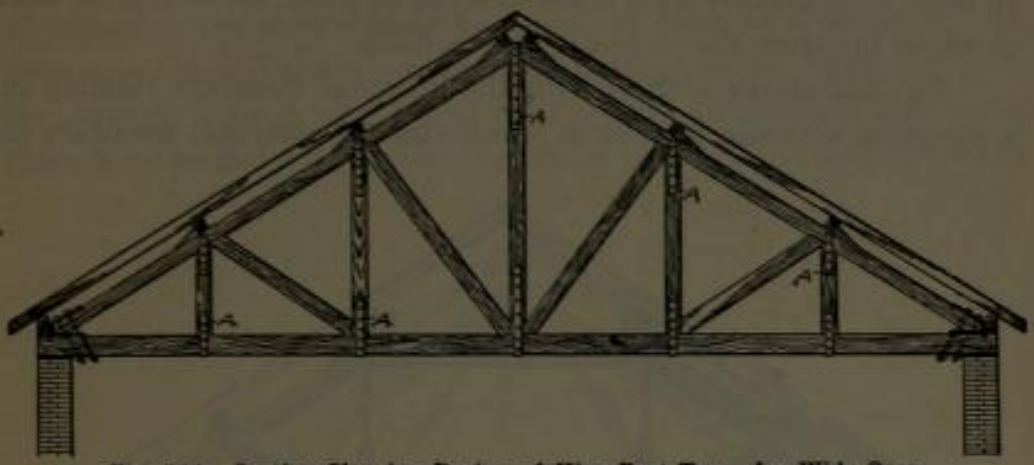


Fig. 344. Section Showing Design of King-Post Truss for Wide Span

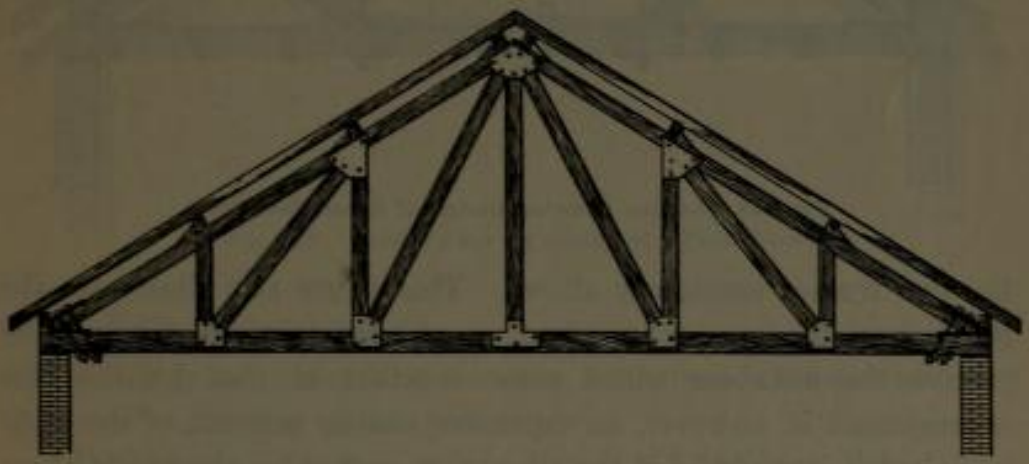


Fig. 345. Section Showing Design of Trussed Roof Using Iron Castings at Joints

longer dimension in cross section is vertical, while others are set so that their longer dimension is at right angles to the rafters. Both of these methods are commonly employed. The tension members *C* are merely for the support of the lower chord or *tie-beam D*, and could be omitted.

Fig. 344 shows a truss of the same general form as the one shown in Fig. 343, but of larger span. This truss is of such a span and has its joints and purlins arranged in such a way that it is similar to the trusses shown in plan in Fig. 342 and there marked *A*. In this truss

also the vertical members are not iron rods, as in Fig. 343, but are composed of timber. The stresses in these members are, however, still tension stresses just the same as in Fig. 343, and for this reason it is a common practice to fasten them to the chords of the truss by means of iron straps, as shown at the points marked *A* in Fig. 344. In other respects this truss is constructed in a manner similar to that in which the truss shown in Fig. 343 is built.

Fig. 345 shows a truss with the diagonal members running in a direction opposite to that in which run the diagonal members in

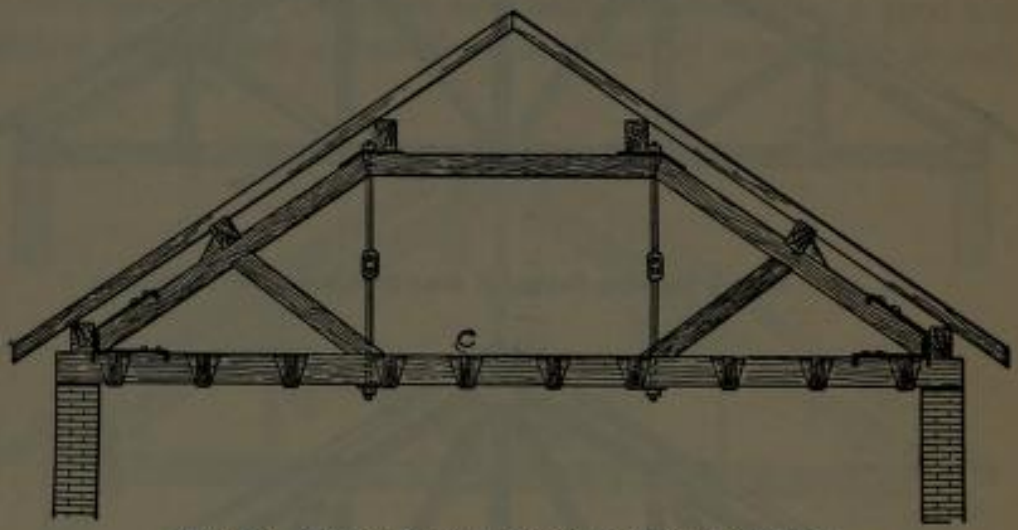


Fig. 346. Section Showing Design of Queen-Post Truss

the two trusses previously shown. This figure also illustrates the practice of placing an iron casting at each joint of the truss to receive the members which come together at that joint. This arrangement is, however, an expensive one on account of the castings, and it is doubtful if the advantage gained by the use of them is sufficient to warrant the additional cost. Usually the castings can not be kept in stock and must be made to order for each truss.

Queen-Post Truss. Fig. 346 shows a modification of the king-post truss, which is called the queen-post truss. Here there are two queen-posts instead of the single king-post. The queen-post truss is somewhat more popular in building work than is the king-post truss, but both are frequently employed in halls, warehouses, and stables, where an ornamental truss is not required, and also in churches and audience rooms, where they are to be concealed by other finish. Fig. 346 also shows how a floor or ceiling may be

supported on the lower chord or *tie-beam* of the truss. The joists *C* are hung from the chord by means of stirrup irons or patent hangers. This arrangement makes the tie-beam act as a beam as well as a tie and in this case it must be made sufficiently strong to carry the load from the joists without sagging.

The queen-post truss, as will be seen, is not entirely composed of triangles, the center panel being in the form of a rectangle. In most cases this is not a serious disadvantage, since, when the truss is uniformly loaded, as it would be if it were an ordinary roof truss, there is no tendency to distort the center panel. It is almost always

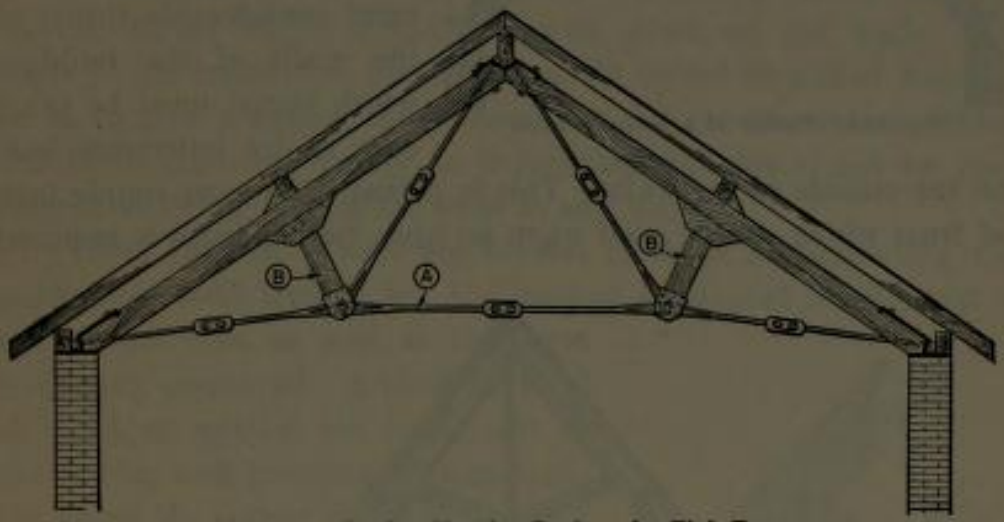


Fig. 347. Section Showing Design of a Fink Truss

better, however, to introduce an additional diagonal member into this panel so as to divide it into two triangles. This obviates any danger of distortion of this panel.

Fink Truss. In Fig. 347 is shown a Fink truss, which is a very popular form, especially for trusses built of steel. It has neither king-post nor queen-posts, and the tie-beam *A* is of iron or steel instead of timber. This is a simple and cheap form of truss for any situation where there is no floor or ceiling to be carried by the lower chord. The struts *B* may be of wood or of cast iron. It will be seen that the truss consists essentially of two trussed rafters set up against each other, with a tie-rod *A* to take up the horizontal thrust.

Open Timber Trusses. Besides the forms of trusses described above, there are other forms which are used in churches and chapels,

as well as in halls where open timber work is required, and where the trusses will not be concealed by other finish, but will be made ornamental in themselves. Among these the most common forms are the so-called scissors truss and the hammer beam truss.

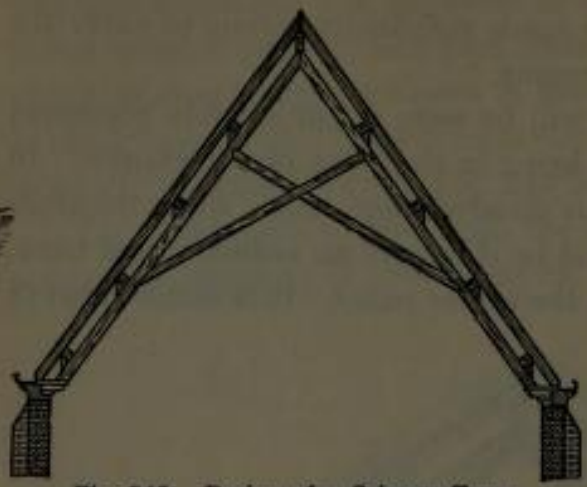


Fig. 348. Design of a Scissors Truss

Scissors Truss. The scissors truss is shown in Fig. 348. It has no tie-beam and, therefore, it will exert considerable thrust on the walls of the building, which thrust must be taken care of by buttresses built on the outside of the walls. This is perhaps the most simple form of truss which can be used when an open timber truss is required.

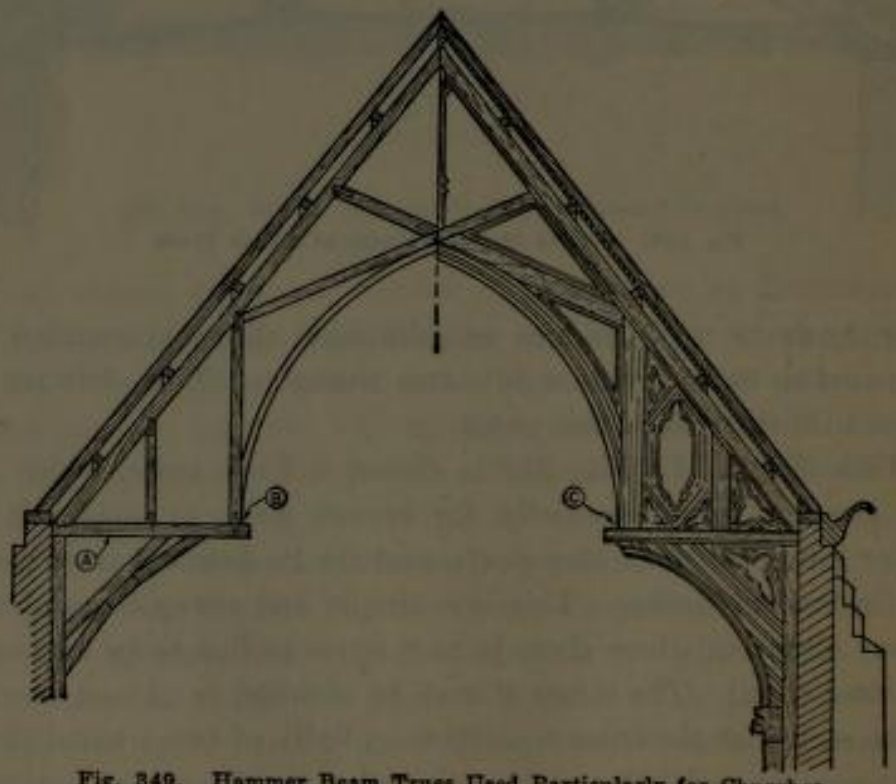


Fig. 349. Hammer Beam Truss Used Particularly for Churches

All the parts are of wood. If desired, an iron tie rod may be inserted between the two wall bearings of the truss, so as to elimi-

nate the thrust on the walls, and this rod need not detract seriously from the appearance of the open timber work.

Hammer Beam Truss. A very popular form of truss for use in churches is the hammer beam truss mentioned above. This is shown in Fig. 349. On the left is shown the framework for the truss, while on the right is shown the way in which it may be finished. Its characteristic feature is the hammer beam *A*. The sizes of the pieces can only be determined by calculation or experience, and depend entirely upon the span of the truss and the loads to be carried, which are different for different locations. It is common practice to insert a tie rod between the points *B* and *C* to take up the thrust which would otherwise come on the walls. All parts of the framework must be securely bolted or spiked together so as to give a strong, rigid foundation for the decoration, which should be regarded merely as decoration and should not be considered as strengthening the truss in any way.

Truss Details. There are several methods of supporting the purlins on wood trusses, but the method illustrated in Fig. 350 is one of the best as well as the most frequently employed. A block of wood *A* is set up against the lower side of the purlin, and prevents it from turning about the corner *B*, which it has a tendency to do. The block is set into the chord of the truss to a depth sufficient to keep the purlin from sliding downward as it receives the weight from the rafters *E*. This figure also shows the most simple method of framing a strut into the chord of a truss. The strut *C* is set into the chord *D* far enough to hold the strut in place. If it is perpendicular to the chord, it need not be so set into it, if the pieces are well nailed together, because in this case there is no tendency for the strut to slide along the chord. Care should be taken not to weaken the chord too much in cutting these mortises.

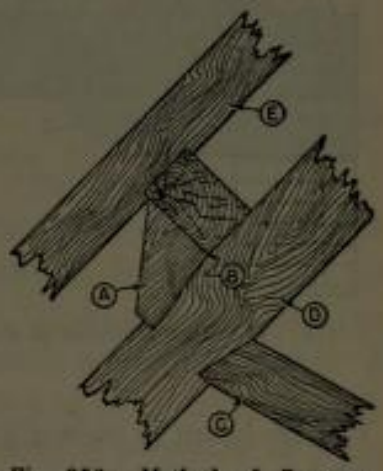


Fig. 350. Method of Supporting the Purlins on Wood Trusses

In Fig. 351 are shown the most common methods of forming the joint between the top chord and the tie-beam of a truss. The

connection shown at *A* depends upon the bolts for its strength, while that shown at *B* depends upon the wrought-iron straps *E*, which are bent so as to engage notches cut in the tie-beam *F*. The piece *C* is very often added beneath the tie-beam, at the bearing, to strengthen it at this point, where the beam is subject to considerable bending stress. The block *D* is merely for filling and to protect the bolts where they pass between the chord and the tie-beam. It may be omitted in many cases. The plate *G* is placed between the nuts or bolt heads and the wood to prevent the crushing of the latter. Washers should be used with all bolts for this purpose.

Fig. 352 shows how the joint at the center of the tie-beam of a king-post truss, or any joint between two struts, may be formed.

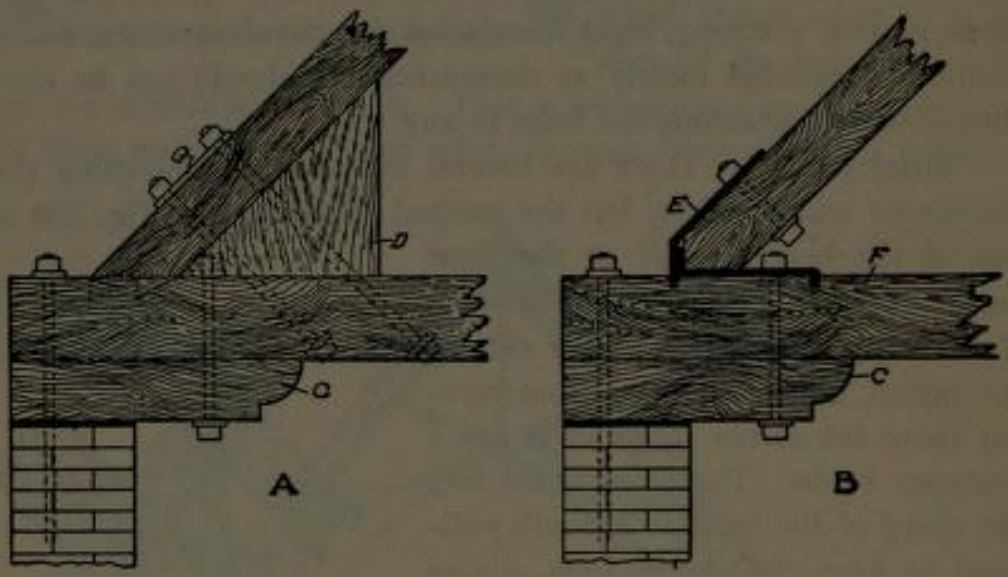


Fig. 351. Two Methods of Forming a Joint between Bottom Chord and Tie-Beam of a Truss

The tie-beam is shown at *A*, and *B* are the struts. The blocks *C*, set between the struts, receive the thrust from them. They should be notched into the tie-beam *A* deep enough to take care of any inequality between the thrusts from the two struts, which have a tendency to balance each other. The block is often made of cast iron. It may be omitted altogether, in which case the struts will come close together and bear against each other. The rod *D* is the king-post which supports the tie-beam *A* at this point. It is often made of wood and sometimes the struts *B* are framed into it instead of being framed into the tie-beam *A*.

Fig. 353 shows a form of connection for the peak of a truss, where the two top chords or principal rafters come together. The plate *A* acts as a tie to keep these members in place, as does the bent plate *B*, also. The plate *B*, moreover, prevents the crushing of the timber by the nut of the king-post tie rod. The purlin *C* supports the rafters and is hollowed out at the bottom to admit the nut *D*. The two principal rafters bear against each other and must be cut so that the bearing area between them will be sufficient to prevent the crushing of the timber. In light trusses the king-post *E* is often made of wood and is carried up between the principal rafters so that these members bear against it on each side. If this construction is adopted it must be remembered that the post is a tension member, and is held up by the principal rafters, and these pieces must be mortised into it in such a way as to accomplish this result.

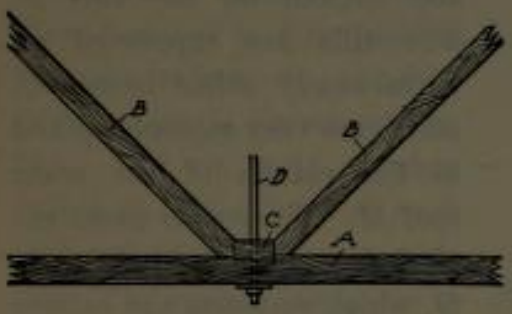


Fig. 352. Method of Forming Joint at Center of Tie-Beam in King-Post Truss

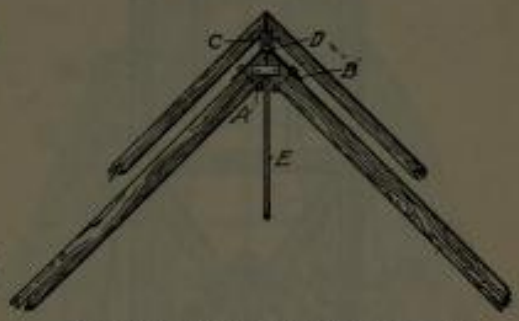


Fig. 353. Construction of the Peak Connection of a Truss

There are a great many different ways of arranging the details for wood trusses, each case usually requiring details peculiar to itself and unlike those for any other case. There are, therefore, no hard and fast rules which can be laid down to govern the design of these connections. A perfect understanding of the action of each piece and its relation to all of the other pieces is necessary in order to insure an economical and appropriate design. The aim should always be to arrange the details so that there will be as little cutting of the pieces as possible, and so that the stresses may pass from one piece to another without overstraining any part of the truss.

TOWERS AND STEEPLES

Towers are a very common feature in building construction, ranging in size from the small cupola used on barns to the high tapering spire which is the distinguishing mark of churches.

They have roofs of various shapes, some in the form of pyramids, with four, eight, or twelve sides, some of conical form, and others bell-shaped or having a slightly concave surface.

The construction of all these forms of towers is much the same, consisting of an arrangement of posts and braces, which becomes more elaborate as the tower or steeple becomes larger. The bracing is the most important consideration, because the towers will be exposed to the full force of the wind and must be designed to resist great strain.

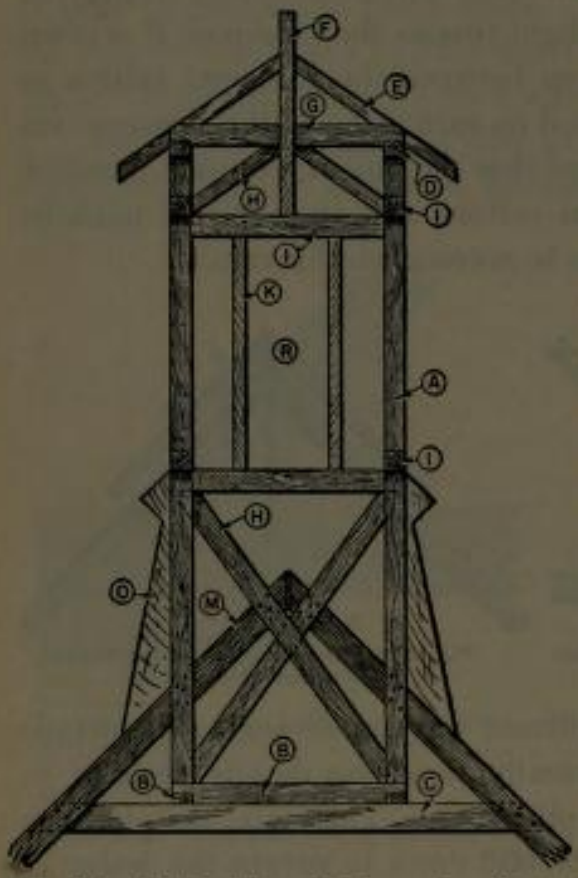


Fig. 354. Section Through Frame of a Simple Cupola

Cupola. Fig. 354 shows a section through the frame of a simple cupola. It has posts *A* at each corner, which rest at the bottom on the sills *B*. The sills are supported on extra heavy collar beams *C*, which are very securely spiked to the rafters of the main roof *M*. The corner posts extend clear up to the main plate *D*, which supports the rafters *E* of the cupola. There are hip rafters at the corner of the roof, which bear at the top against a piece *F* placed in the center of the roof. This scantling extends above the roof surface far enough to receive some kind of metal finial which forms the finish at the extreme top of the cupola; and at the bottom it is firmly fastened to the tie *G*, which is cut in between the plates. The braces *H* stiffen the frames against the wind. Girts *I* are cut in between the corner posts and form the top and bottom of the slat frame opening *R*, besides tying the posts together. The sides of the opening for the slat frame are formed by the vertical studs *K*. The rafters of the main roof *M* are placed close up against the corner posts on the outside, and the posts may be spiked to them. The pieces *O* are of

plank 2 inches thick, and are simply furring pieces placed at intervals of 1½ to 2 feet all around the cupola to give the desired shape to the bottom part. The size of the pieces will depend on the size of the cupola. The posts may be 4x4 inches or 6x6 inches, and the braces, girts, and intermediate studding may be 3x4 inches or 4x6 inches.

Miscellaneous Towers. Other towers are framed in a manner similar to that described for a cupola. There is always a base or *drum*, with posts at the corners and with the walls filled in with studding, which supports a plate at the top. The rafters forming the tower roof rest at the foot on this plate, and at the top they bear against a piece of scantling which is carried down into the body of the tower for a considerable distance and is there fastened to a tie passing between rafters on opposite sides. This is shown in Fig. 355. The tie *A* is securely nailed to the rafters at each end, and to a post in the middle. The post is cut so as to have as many faces as the roof has sides, four for a square hip roof, eight for an octagon roof, and so on. Each face receives one of the hip rafters and the intermediate rafters are framed in between them. If the roof is conical or bell shape, as shown in the figure, the post at the top may be cylindrical in form. Although the roof shown is bell shaped the rafters are not cut to fit the curve. They are made straight and are filled out by furring pieces *B*. Pieces of plank *C* are cut in between the furring pieces, as shown, so as to give a nailing for the boarding, and they are cut to the shape of segments of circles, so as to form complete circles around the tower when they have been put in place. If a tower of this shape is to be built, having a number of faces and hips, the curve of the hip rafters will not be the same as the curve shown by a section through one of the faces of the tower. In order to find the true curve for the hip rafter, the same method is followed

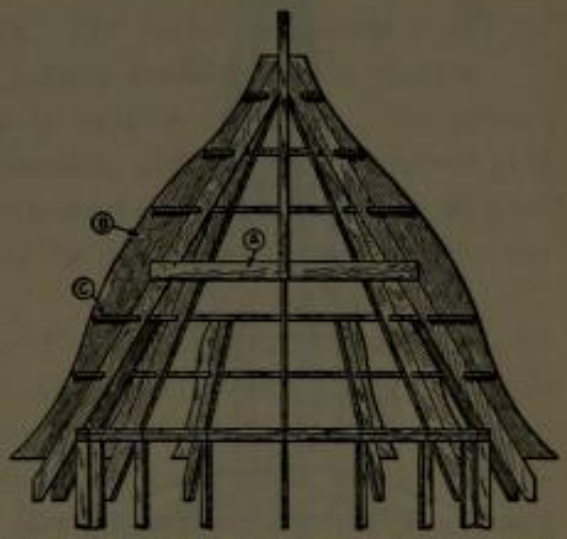


Fig. 355. Section Showing Frame Construction of Small Tower

as was explained for hip rafters in an ogee roof over a bay window, using the principle that any line drawn in the roof surface parallel to the plate is horizontal throughout its length. By this means any number of points in the curve of the hip rafter may be obtained and the curve for the hip may be drawn through them. Thus a pattern for the hip rafter may be obtained.

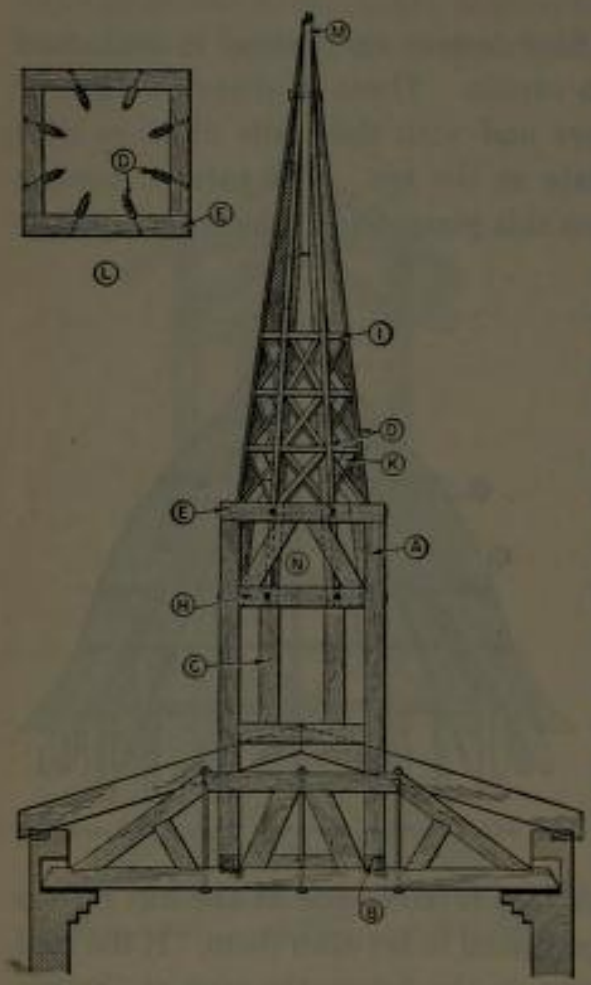


Fig. 356. Section Showing Construction of Church Spire

Church Spire. Fig. 356 shows the method of framing a church spire, or other high tapering tower. The base of the drum *N* is square and is supported by the posts *A*, one at each corner, which rest on the sills *B*. The sills are supported by the roof trusses of the main roof. The corner posts extend the full height of the drum and are strongly braced in all four faces, with intermediate vertical studding *C* between them to form the framework for these faces. The spire itself may rest on top of this square drum or there may be another eight- or twelve-sided drum constructed on the top of the first drum, on which the spire may rest. This depends upon the design of the spire. The hip rafters *D* do not rest directly on top of the drum, however, as this arrangement would not give sufficient anchorage for the spire. They are made so as to pass close inside the plate *E* at the top of the drum and are securely bolted to this plate with strong bolts. This is shown at *L*, which is a plan of the top of the drum, showing the hip rafters in place. The plate is shown at *E*, and the hip rafters at *D*. The rafters extend down into the body of the drum as far as the girts *H* (shown in the elevation) to

which they are again securely spiked or bolted, being cut out at the foot so as to fit against the girt. In this way a strong anchorage for the spire is obtained.

Horizontal pieces *I* are cut in between the hip rafters at intervals throughout the height of the spire, and braces *K*, halved together at the center where they cross each other, are firmly nailed to the rafters at each end. These braces are needed only in lofty spires, which are likely to be exposed to high winds. At the top the hip rafters bear against a post *M*, the same as in the other towers. If a conical spire is called for in the design, the horizontal pieces *I* must be cut to the shape of segments of circles, and in this case the rafters are no longer hip rafters. The horizontal pieces *I* will receive the boarding, which will form a smooth conical surface.

The spire above the drum is usually framed on the ground before being raised to its final position. It then may be raised part way and supported by temporary staging while the top is finished and painted, after which it may be placed in position on the top of the drum.

Slow-Burning Construction. For the construction of the floors and interior supports for buildings several stories high, where the enclosed spaces are not cut up by partitions but are left open, such as will be found in the case of warehouses and mills, wood construction is often employed since it is cheaper than reinforced concrete or steel. A steel structure would be seriously damaged by fire unless it were completely covered with some fireproof material which would add to its cost. The concrete, though cheaper than the steel is not so cheap as the wood and is less easily altered in case additions or changes are required. The ordinary wood structure, of course is not fireproof but a type of wooden building has been developed which will resist the attacks of the flames for a long time and which is regarded favorably by the insurance companies. This construction is usually called "slow-burning" or "mill" construction.

The principle upon which it is based is the well-known fact that wooden members such as posts and beams, if of large size, will not be seriously affected by a fire unless the fire is very hot and is allowed to burn on for a long time with a quantity of inflammable material to feed upon, whereas wooden members of small

dimensions such as joists and scantlings will be completely destroyed and will in addition provide highly inflammable fuel for the flames. Consequently, in slow-burning construction, there are no joists or scantlings. The exterior walls and any interior partitions are of masonry but the floors are of wood supported on wooden posts spaced about 8 feet apart one way and about 20 feet apart in the other direction. These wood posts are never made smaller than

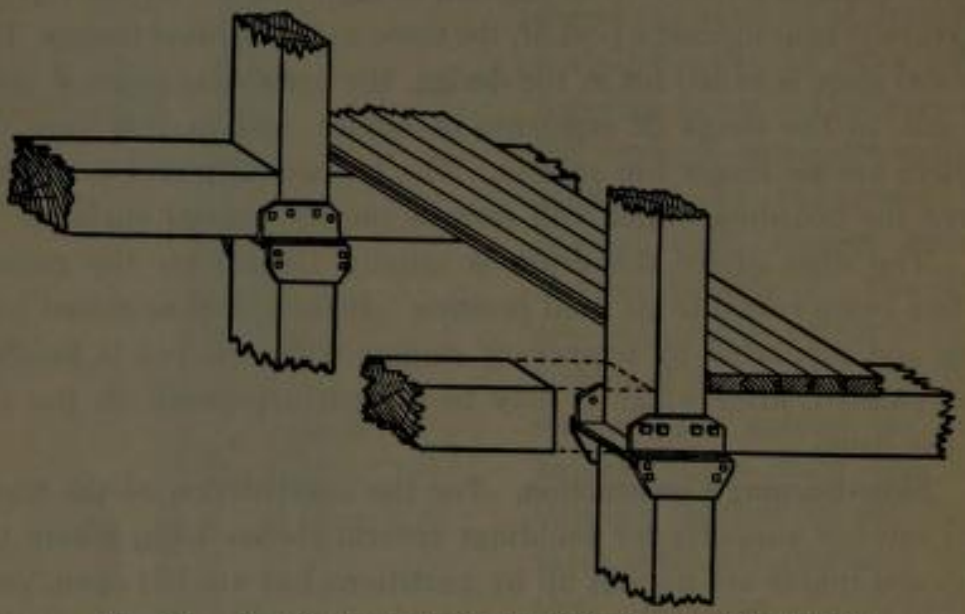


Fig. 357. Framing Details for Mill or Slow-Burning Construction

8 inches x 8 inches, whether that size is required to carry the load or not, so as to keep these important members of substantial dimensions in all cases. The posts support girders running in one direction only, so as to be spaced about 8 feet apart. On the girders and spanning across the 8 foot spaces are laid planks not less than 3 inches thick and not more than 8 inches wide which take the place of the joists used in ordinary floor construction, but which, being laid flat on their sides, with edges close together, form a solid continuous ceiling for the story below. The planks are grooved along both edges and are secured together with hard wood splines, each about 1½ inches wide x ¾ of an inch thick. See Fig. 357. On the top of this solid plank floor is placed an under-flooring of ⅞-inch thick hemlock or fir boards laid diagonally and a finished flooring or wearing surface of hardwood is laid on top. Sometimes the under-flooring is omitted, although it greatly stiffens the floor construction.

Where the girders, which may be about 10 inches x 12 inches in size or larger, rest on top of the posts or columns, there is installed a steel post cap of a sort manufactured by several different companies and so made that it will furnish an adequate seat or bear-

Fig. 358. Post Cap
Courtesy of Duplex Hanger Company

Fig. 359. Cast-Iron Column or Post Base
Courtesy of Duplex Hanger Company

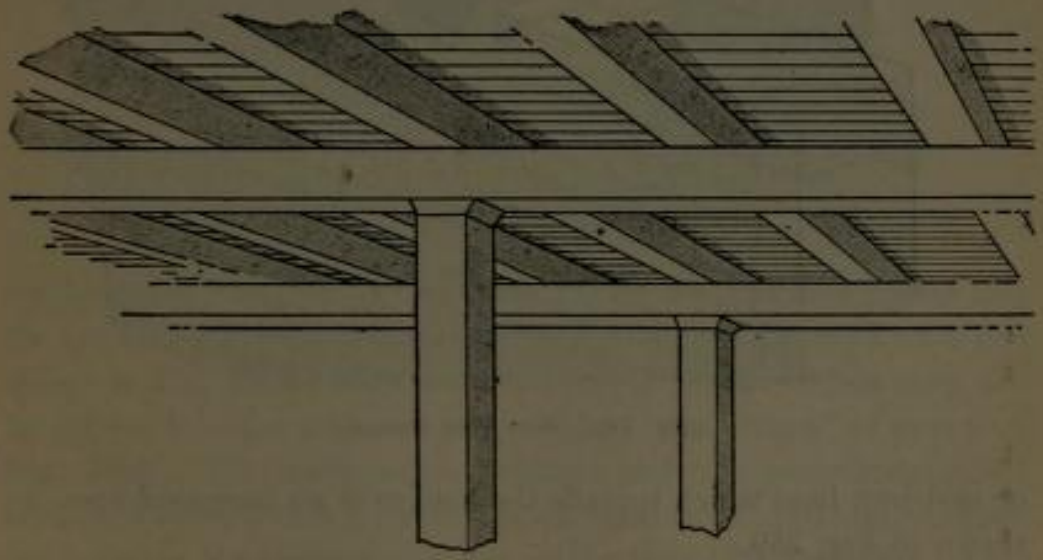


Fig. 360. Detail Showing Beams Resting Directly on Top of Girders

ing surface for each of the girders, and allow the upper post to rest on a steel plate directly on top of the post below. This is illustrated in Fig. 357 as well as in Fig. 358. These caps are especially valuable when the width of the post or column is less than

the width of the girder resting on it. In a situation of this nature, the steel cap acts as a bearing plate and prevents the post from being forced up into the girder.

At the lowest floor level, the lowest post of all rests on a steel

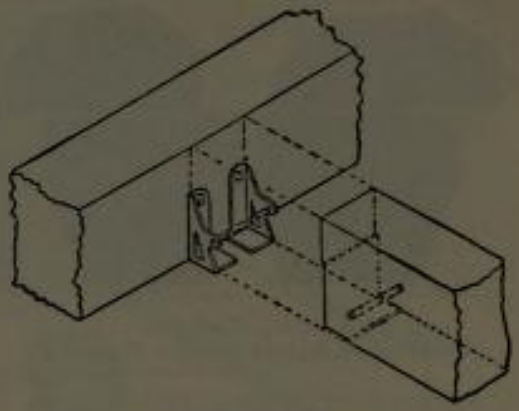


Fig. 361. Steel Hanger
Courtesy of Duplex Hanger Company

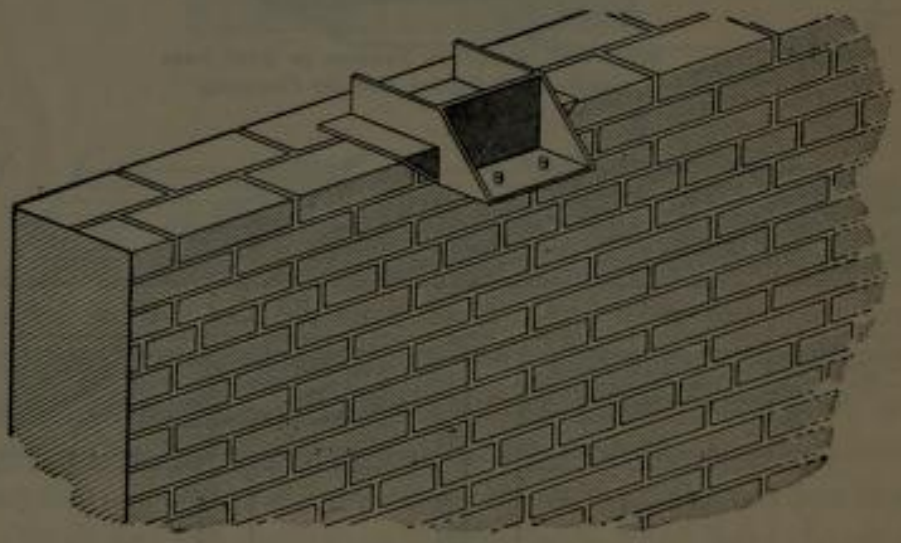


Fig. 362. Steel Wall Hanger

or cast-iron base which spreads the load over an increased area, as shown in Fig. 359.

Another method of construction employed, when it is desirable to keep the columns farther apart, is to run the girders, as described above, supported by the columns on post caps but to space them at a much greater distance apart and make them support beams which in turn carry the plank flooring. The beams can rest directly

on the top of the girders as shown in Fig. 360, but if for any reason it is found advisable to keep the girders up higher with relation to the beams, it is possible to carry the ends of the beams from the sides or top of the girders in steel hangers as shown in Fig. 361. There are several different kinds of these hangers manufactured, some of which are hooked over the tops of the girders while others

Fig. 362A. Steel Wall Hanger
Courtesy of Duplex Hanger Company

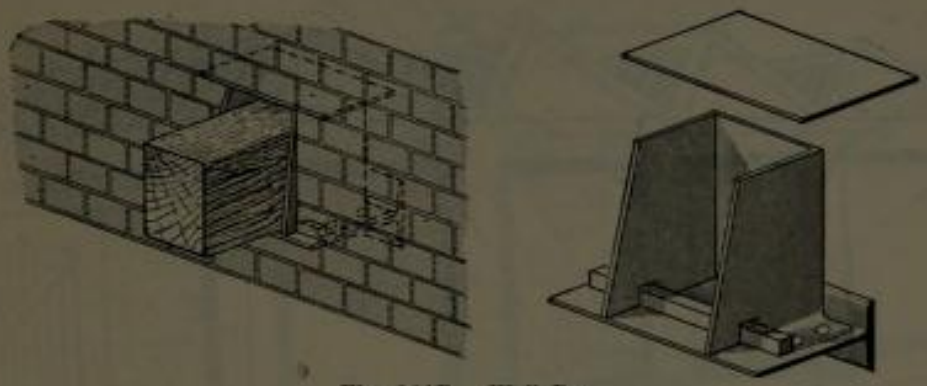


Fig. 362B. Wall Box
Courtesy of Duplex Hanger Company

are bolted to the sides of the girders. At the wall the beams and the girders as well can be carried by steel wall hangers like the one shown in Fig. 362 or 362A, and if they carry heavy loads they can be carried into the wall and supported in "wall boxes" as shown in Fig. 362B. The construction outlined above is sometimes called semi-mill construction because it is not considered to be quite so good for resisting the ravages of a fire as the type first described. Frequently the beams will be so arranged that a beam will occur directly in line with a post which already carries girders running in the other direction. In this case what is known as a "four-way" post cap is used as shown in Fig. 362C.

The flooring is not always composed of planks. Frequently

it is made by taking scantlings, 2 x 3 inches, 2 x 4 inches, or larger, dressing them on all sides and laying them on the top of the beams or girders on edge and close together so as to make a solid floor as thick as the depth of the scantlings. These pieces are spiked tightly together. Such a floor is called a "laminated floor."

Fig. 362C. "Four-Way" Post Cap
Courtesy of Duplex Hanger Company

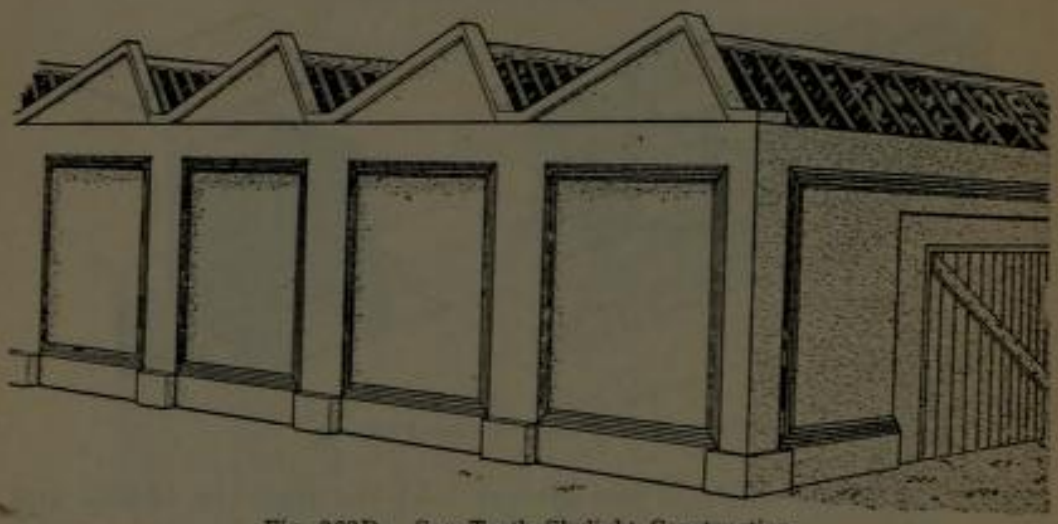


Fig. 362D. Saw-Tooth Skylight Construction

Saw-Tooth Skylights. When a mill or factory building is only one story high and the manufacturing conditions are such as to permit of the building having a low, flat roof, it frequently happens that the building covers so large an area that the interior cannot be lighted in a satisfactory way by means of windows in the exterior walls only, and that it is necessary to resort to the use of some form of skylight. A type very frequently employed is known as the "saw-tooth" skylight because of its appearance when looking at the side of such a building. See Fig. 362D.

The advantage of this construction is that the glazed sash

can be put into the sloping part of the skylight which faces most nearly towards the north and can thus transmit to the interior of the building a lot of reflected light from the sky without any of the glare which would result from placing the windows in such a position that the sun would shine directly into them. The sloping part

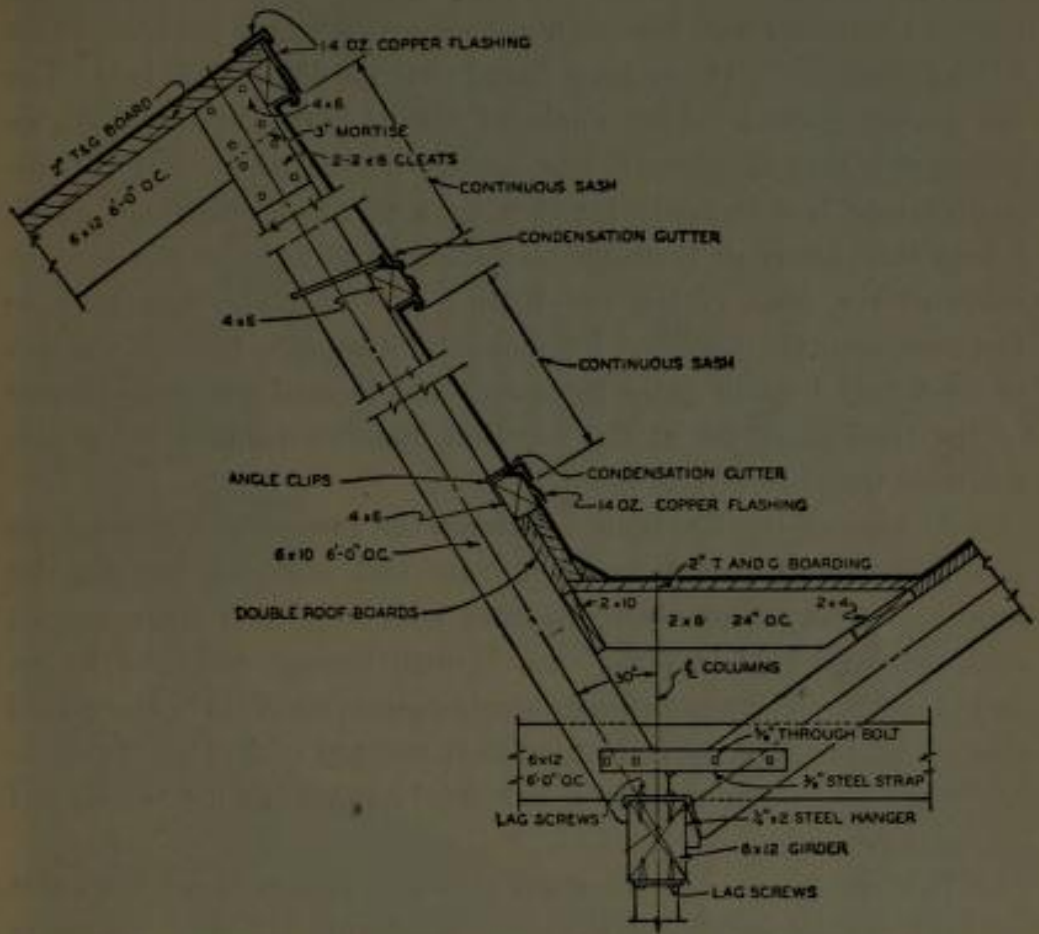


Fig. 362E. Illustrating How the Truss Members, at All Low Points in Saw-Tooth Roof, Are Held Together by Steel Straps and Held in Place by Through Bolts

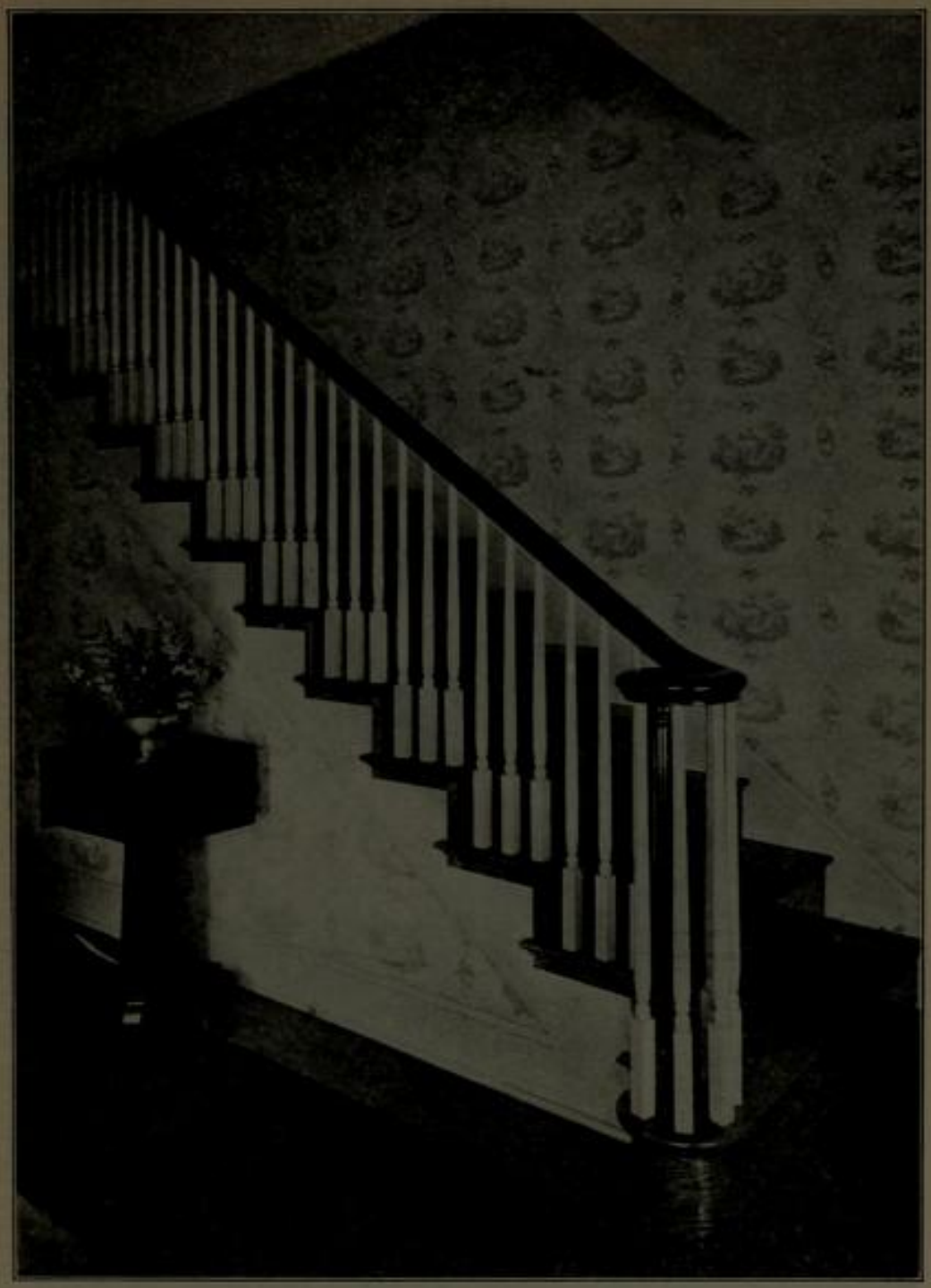
of the skylight, which faces towards the south, as no glazed sashes in it, but is roofed over the same as any other sloping roof surface.

When a roof of this kind is framed up in wood, the carpenter has to deal with a series of sloping roofs very much like the ordinary pitched or gable roof. The low parts corresponding to the eaves do not rest on the exterior walls but on girders and columns, and the rafters are replaced by heavier members corresponding to the beams in mill construction which may be 6 x 12 inches or 10 x 12 inches in size and may be spaced 6 feet or more apart. As these heavy

rafters slope against each other each set forms a sort of truss which is completed by a tie rod at the bottom between the lines of roof girders. The function of the tie rod is to take up any thrust which may be exerted by the rafters. The span of such a truss may be as much as 20 feet and the columns may be spaced a similar distance apart in the other direction making the girders some 20 feet long between supports and the column-spacing 20 feet x 20 feet, which is very desirable. It has been found that the lighting is best when the glazed slope is at an angle of about sixty degrees with the horizontal, that is, when it has a sixty-degree pitch, and the opposite slope is commonly made with a thirty-degree pitch which brings the rafters or truss members nearly at right angles to each other at the peak of the saw-tooth. At this point they may be fastened securely together by means of two 2 x 10-inch wooden cleats firmly held in place by spikes and located one on each side of the truss members at the junction, the two timbers being also mortised together at this point.

At each of the low points between the saw-teeth the two truss members are supported by the girder and are held together by means of steel straps about 3 inches wide x $\frac{3}{8}$ inch thick one on each side and held in place with $\frac{5}{8}$-inch through-bolts, as shown in Fig. 362E. The more steeply sloping piece, which is in the glazed portion of the roof, is framed against the top of the girder while the other member is supported in a steel hanger against the side of the girder.

In order to avoid the creation of a deep pocket at the low point between the slopes of the skylights, a narrow flat roof surface is formed at these places by framing 2 x 8-inch joists at 2 feet centers in between the framing for the two sloping roof surfaces, purlins being put in between the truss members to carry these joists. At the peaks of the sloping roofs, heavy purlins about 4 x 6 inches in size are carried across between the trusses to hold them in place and thus the framework is completed. Other purlins of the same size are put in at what will be the sills of the windows and then the whole roof surface is covered with 2-inch plank which can span across the 6 feet or so between the trusses. This completes the roof except for the window sashes which are similar to any other skylight sashes.



THE BEAUTY OF THIS STAIRWAY IS A RESULT OF CORRECT DESIGN AND PROPORTION OF THE SEVERAL PARTS

Courtesy of Curtis Companies, Incorporated, Manufacturers of Curtis Woodwork, Clinton, Iowa

DOUBLE COURSING OF SHINGLES DEEPENS HORIZONTAL SHADOW LINES—DRAWS HOUSE CLOSER TO GROUND

Courtesy of Red Cedar Shingle Bureau

CARPENTRY

PART IV

EXTERIOR AND INTERIOR FINISH

In the preceding pages we have considered the most important of the methods in use for the construction of the rough framework of buildings. We will now take up the general subject of finish, both outside and inside.

OUTSIDE WALL FINISH

There are two things which the outside finish of a building is intended to do: first, to protect the vital part of the structure—the framework; and second, to decorate this framework and to make it as pleasing in appearance as may be possible. Both of these purposes must be borne in mind when designing or erecting any outside finish, as both are equally important and neither should be neglected.

Material. The material used for the finish varies under different conditions and in different parts of the country. Of course, it must first of all be durable when exposed to the weather, and it must be a wood which can be easily worked. The best kinds of wood for the purpose are white pine and cypress, and one of these woods is generally used. Spruce and Georgia pine are sometimes used on cheap work, but they are much inferior to white pine. Poplar is very good but scarce. Pine should be employed wherever it is obtainable.

Redwood, Douglas fir, and western soft pine are often used on the Pacific Coast but not elsewhere to any great extent.

Sheathing. The first operation in connection with the finish is that of covering the framework with sheathing, Fig. 363, which should be about 1 inch in thickness, and for the best work, dressed on one side. The sheathing should be placed diagonally

across the studding when the frame is of the "balloon" variety, but in case of a braced frame the boards need not be so placed. With the braced frame, the boarding may be started at any time, but with the balloon frame it is necessary to wait until all of the studding has been placed in the outside walls. The sheathing should be laid

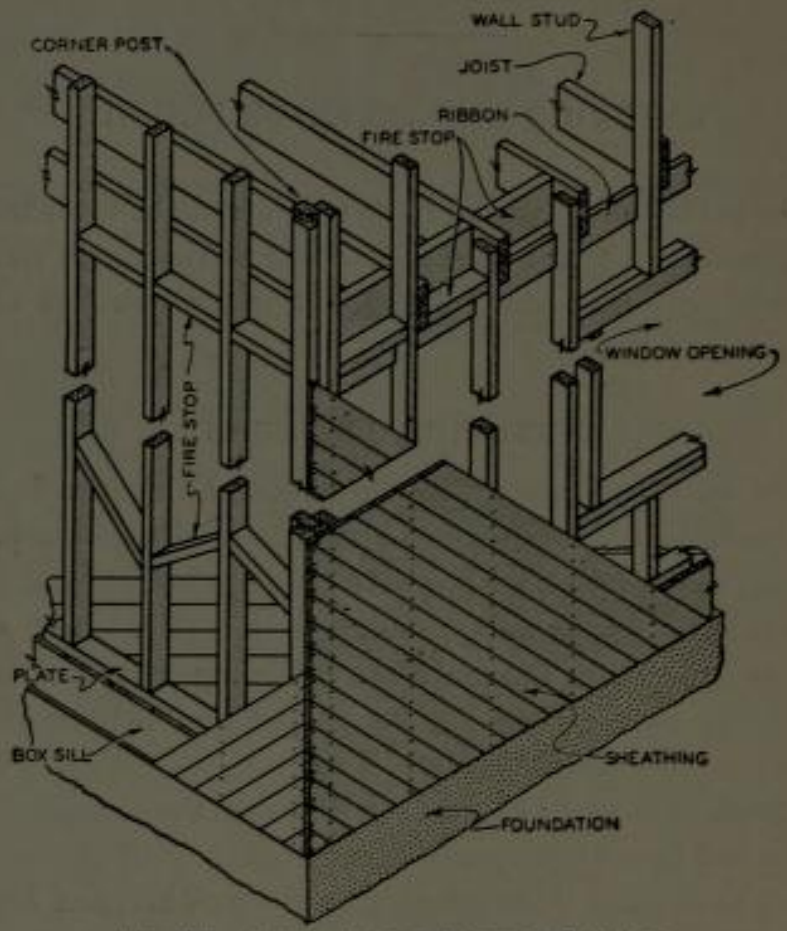


Fig. 363. Detail Showing Diagonal Sheathing
Courtesy of Weyerhaeuser Forest Products

close, but need not be matched, and the boards should be fairly wide, say 8 to 10 inches, or even more. The most common material for this work is yellow pine free from loose knots. Douglas fir, redwood, and western white pine are used on the Pacific Coast.

There is some disagreement among authorities as to the advisability of placing the sheathing diagonally across the studs. It is argued by some that the shrinkage of the sheathing boards in the direction of their width, which is bound to take place, will cause such a pull in a diagonal direction across the studding that an excessive tendency towards distortion of the frame will result and

that this more than offsets any advantage in the way of extra bracing effect which may have been gained by placing the sheathing diagonally. Tests made by the Bureau of Standards in 1915 and 1916 seem to support this argument and to show that when stucco finish is placed over the sheathing it is much more liable to show cracks when the sheathing is placed diagonally than when it is placed horizontally. The American Concrete Institute has recommended that sheathing under stucco should be placed horizontally and that the boards should not be wider than 8 inches. If this argument is correct, and if this recommendation is worthy of being followed, the unavoidable conclusion must be that it is better to brace the frame properly against the distorting action of the winds and then to cover it with horizontal sheathing or with one of the manufactured sheathing boards, especially when the exterior finish of the wall is to be stucco.

The roof sheathing is nailed on at right angles to the rafters but the boards are narrower. The width is usually 4 inches but 6 inches works well also. They are laid with spaces between them for the passage of air. These spaces are from 2 to 3 inches wide and are left for the ventilation of the shingling or other roof covering, and for the cheapening of the rough boarding.

For buildings in the northern part of the country or where the spaces under the roof are to be used for rooms, full sheathing would be laid on the roof surfaces the same as on the walls. In extremely cold climates, it is good practice to put the full roof sheathing on the rafters and then to cover this sheathing with 2-inch x 1-inch furring strips laid flat about 2 feet apart over the entire roof surface and then to cover these surfaces with a second layer of sheathing laid on top of the furring strips so as to leave an air space between the two layers of sheathing. This retards the leakage of heat through the roof and also prevents to some extent the formation of ice at the eaves. If the roof surfaces are shingled, a good plan is to first cover them with full sheathing and then lay on top of the sheathing similar furring strips called "shingle lath" spaced far enough apart to suit the "weathering" of the shingles and then to nail the shingles to the furring leaving an air space underneath the shingles.

Some curved work, such as round towers and bay windows, is boarded diagonally, when it is impossible to place the boards in any

other way. Each piece should be well nailed to each stud or rafter with large nails, ten-penny or eight-penny, and no serious defects such as large knots should be allowed in the sheathing.

In many parts of the country, it is becoming the common practice to make use of one of the many kinds of wall board such as

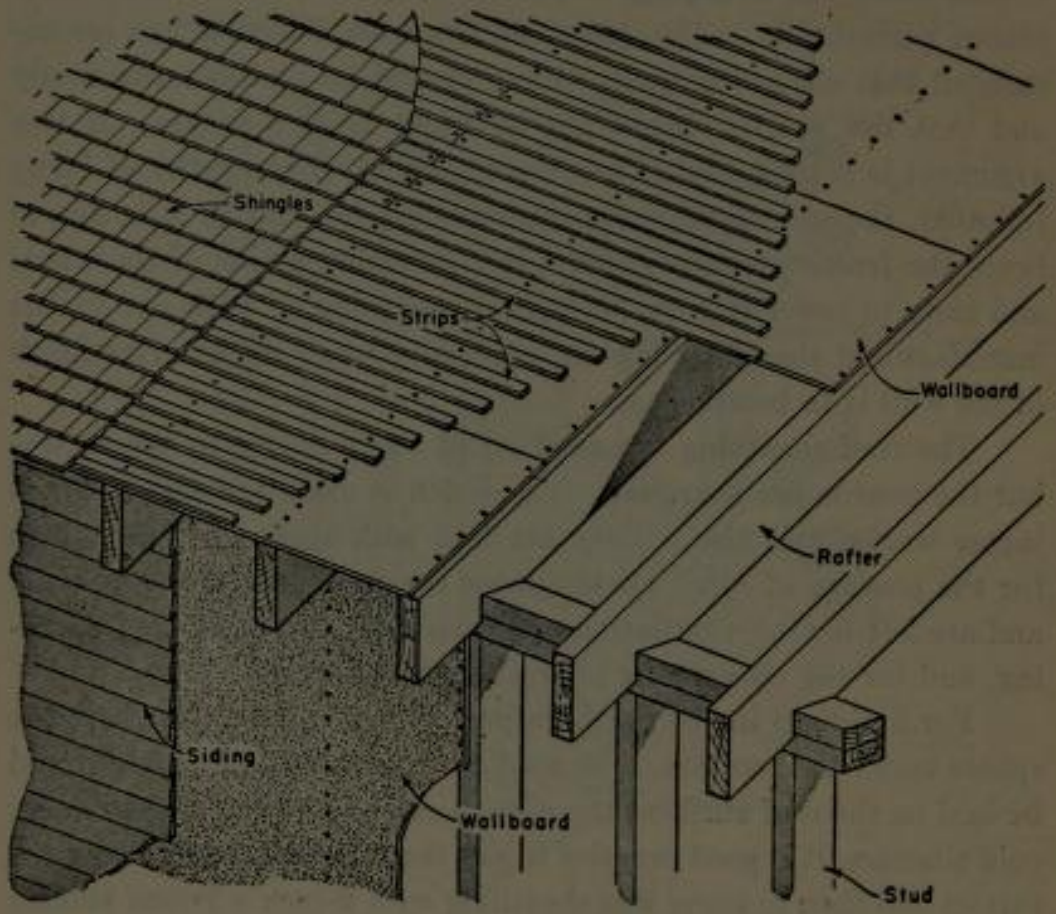


Fig. 364. Method of Applying Wallboard to Roofs under Wood Shingles and to Side Walls under Siding

Courtesy of National Gypsum Company

"Celotex," "Maftex" or "Beaver" for sheathing the outside walls and roofs instead of the ordinary boarding. As this manufactured material comes in large sheets 4 feet wide x 12 feet long and of light weight there is a saving in the cost of putting it in place on the wall. Although these sheets are only about ½ inch thick many of them have an insulation value much greater than that of the ordinary boarding. Some of the manufacturers have had tests made which seem to indicate that a frame building sheathed with this wall board will be as rigid and strong as one covered with the ordinary boarding laid

diagonally. Fig. 364 illustrates the use of such wall board in place of the usual wood sheathing.

Building Paper. Building or sheathing paper is now placed over the sheathing to keep out the weather and to cover more completely the joints in the boarding. This paper must be tough and strong as well as waterproof, and must be easy to handle and put in place. It must not be easily broken as any hole in it is an opening

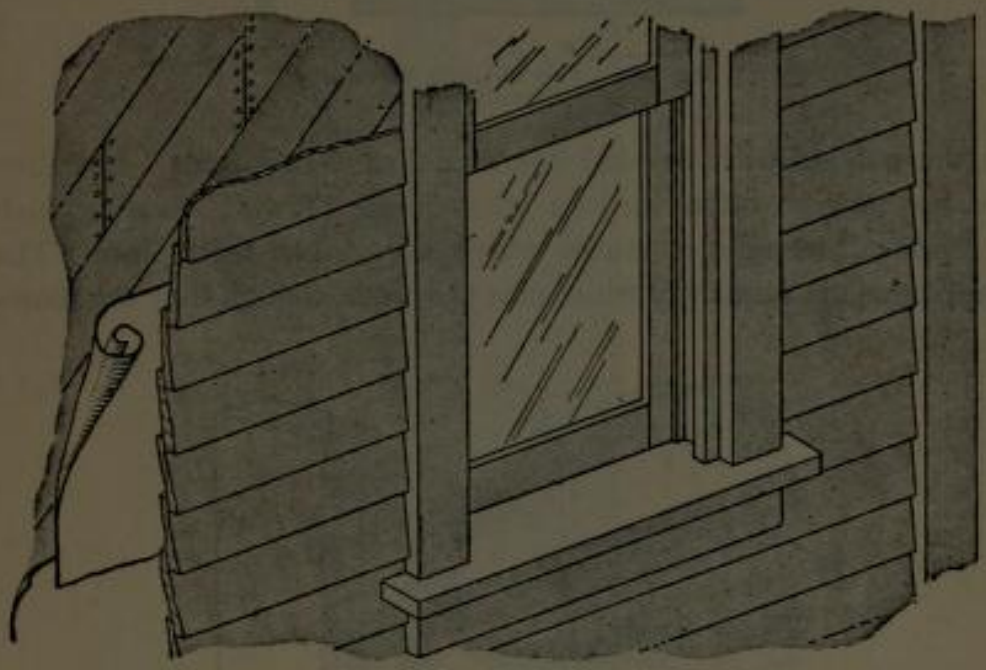


Fig. 365. Insulating Paper Applied Over Outside Sheathing
Courtesy of Johns-Manville Company

through which the weather will surely find its way. There are a number of different kinds of building paper on the market, prepared with various chemicals to render them as nearly waterproof as possible. Tar is sometimes used for this purpose. The paper should always be laid with a good lap.

There has recently been put on the market a building paper coated on one or both sides with a bright aluminum surface which is said to reflect heat in much the same way as a mirror reflects light and thus it prevents the leakage of heat from a heated building. Tests show that this paper has an insulating value nearly equal to that of ¾ inch thick insulating board or cork.

Insulating papers such as hair felt or a composition of cattle hair compressed between two layers of waterproof paper are also

used for this purpose. Fig. 365 shows the paper applied over the outside sheathing.

Clapboards for Wall Covering. In the New England States, the walls of frame buildings were formerly almost always covered

Fig. 366. Side and End Views of a Clapboard

on the outside with beveled boards called "clapboards," but they are not now so often used as other forms of wall covering such as "siding," shingles or stucco which have taken their place. The clapboards are usually of white pine or spruce, though they are some-

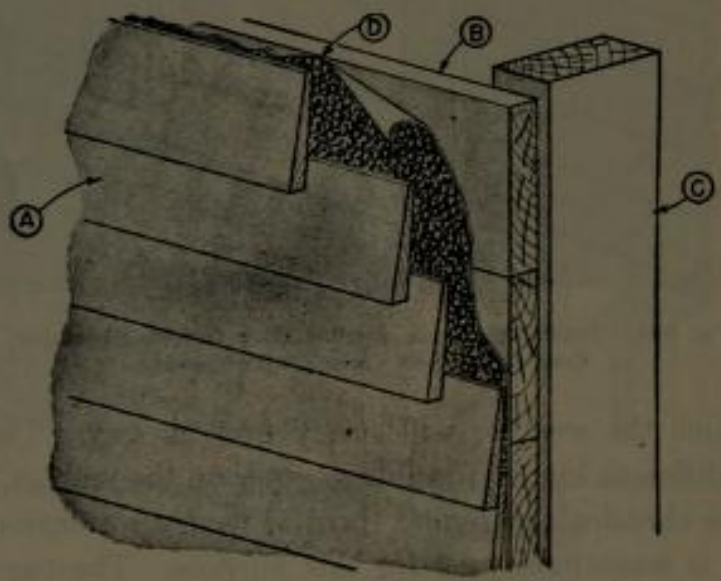


Fig. 367. Section Showing Method of Laying Clapboards

times made from a cheaper timber such as hemlock or fir. They are about 5 or 6 inches wide and about 4 feet long and are thicker on one side or edge than on the other. The thicker edge measures about ½ inch while the thin edge is only about ⅛ inch thick. Each clapboard, therefore, is as shown in Fig. 366, where *A* is an elevation and *B* is a section of the board. The tapering section is obtained by sawing the boards from a log, cutting each time from the circum-

ference inward. The boards are thus all quarter sawed and shrink evenly, if at all, when they are exposed. When laid up on the side of a building, the clapboards should lap over each other at least 1½ inches, as shown in Fig. 367. Here, *A* is the clapboarding, *B* is the sheathing, and *C* is the studding. As will be seen, the clapboards lap over each other, leaving a certain amount of each board exposed to the weather. This term "to the weather" is made use of in many

Fig. 368. Section Showing Method of Laying Siding

specifications to indicate the amount of board which is to be exposed. Thus, "4 inches to the weather" means that 4 inches will be exposed. Building paper should be placed between the clapboarding and the sheathing, as shown at *D*, to keep out the weather.

Siding. The only difference between common siding, often called "bevel" siding, and clapboards is in the length of the pieces, the siding coming in lengths of from 6 to 16 feet, while the clapboards are in short lengths as explained above. Common siding is put on in the same way as clapboards, but there is manufactured a rabbeted siding which is laid up as shown in Fig. 368. Here the rabbet takes the place of the lap, and is made about ⅝ inch deep. This siding is also furnished molded to a number of other patterns besides the simple beveled pattern, and is of various widths up to about 12 inches. Sometimes it is nailed directly to the studding, no building paper

or outside boarding being used, but this construction, although it is cheap, is not suitable for any but temporary buildings. Fig. 365 shows siding or clapboards being applied to the wall of a building over the building paper and sheathing.

Shingles. Instead of clapboards, shingles may be used for covering the walls of a building, though this method is more expensive than the other. The advantages are in the appearance of the work, the variety of effects which may be obtained, and also in the fact that the shingles may be more easily dipped in some stain and

Fig. 369. Section of Shingled Wall

a greater variety of colors thus obtained. Wall shingles should be laid with not more than 6 inches to the weather, and an exposure of 5 inches is better, but even if 6 inches are exposed, there will be a greater thickness of wood covering any particular spot of the wall with the shingling than there is with the clapboarding, and thus a greater protection from the weather is obtained. The arrangement of shingling on a wall is shown in Fig. 369. It will be seen that the shingles are in all cases two layers and in some cases even three layers thick. The width of ordinary shingles varies from about 3 inches to about 12 inches, and for rough work these widths may be used at random, but shingles which are called "dimension shingles," and are cut to a uniform width of 6 inches, may be had and these

should be used for any careful work. Also shingles may be obtained which have their lower ends cut to a great variety of special and stock patterns, which may be worked into the wall so as to yield any desired effect. A shingled wall is shown in elevation in Fig. 378. Building paper should be used under shingles in the same way as under siding.

Shingles are usually 16 inches long but there has been quite

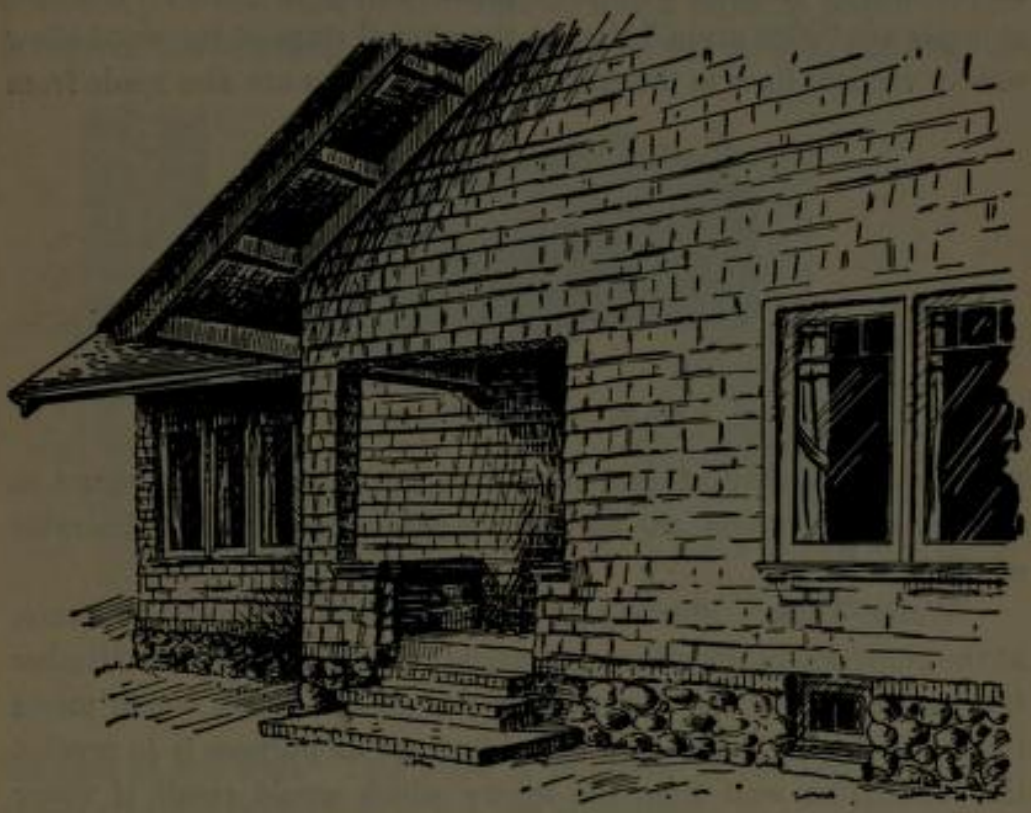


Fig. 370. Shingled Exterior Wall

an extensive employment of longer shingles, 18 inches and even up to 24 inches in length laid so as to show 9 to 10 inches to the weather on vertical walls. Sometimes the courses are not all laid with the same lap but every second course is laid so as to show only 2 inches to the weather. Fig. 370 illustrates a shingled wall of this kind.

The thickness of shingles is measured at the "butt" or thicker end. Good shingles should be thick enough so that they will not require more than five butts on top of each other to make a thickness of 2 inches. They are measured in this way because the shingles

come in bundles with the butts altogether on the outside, as shown in Fig. 371.

The better grades of shingles, and those most frequently used, are manufactured from red cedar in the North Western Pacific Coast States and from cypress in the Southern States. Redwood is also very frequently used for shingles. At least one company sells large quantities of shingles which have been already dipped at the mill in creosote stain of a great variety of colors. The best shingles are "edge grain," that is, the annual rings of the wood show nearly vertical lines in the end section. Shingles are also made from

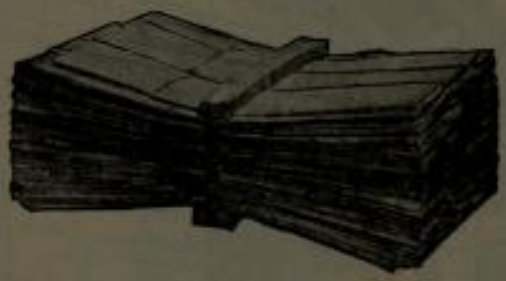


Fig. 371. Bundle of Shingles

white pine, yellow pine, and even from spruce, but these are not so durable as the others, the spruce shingles being the least desirable of all.

Water Table. Starting at the bottom of a wood structure, at the point where the masonry foundation wall stops and the timber framework begins, the first part of the outside finish which meets the eye is the water table, so called because its purpose is to protect the foundation wall from the injury which would result if water were allowed to run down the side of the building directly onto the masonry. The water table, therefore, must be so constructed as to direct the water away from the top of the foundation wall. This may be accomplished in several ways, some of which will be described and illustrated.

Fig. 372 shows the simplest form which can be used for a building which is to be covered with clapboards (this covering will be discussed later). *A* is the foundation wall, which may be stone, brick, or concrete. *B* is the sill, which may be in one or two pieces and which has already been described at length. *C* is the boarding or sheathing, which in this case is flush with the outside of the foundation wall, the sill being set back about 1 inch from this face. The

board *D* is located so as to cover the joint between the top of the foundation wall and the sheathing, and on the top of it is placed the water table *E*, which is inclined downward and outward so as to shed the water. The piece *F* is inserted to set out the first and lowest piece of siding *G*.

Fig. 373 shows another way of constructing a water table for a building with clapboards. In this case the sill *B* is set back about 4 inches from the face of the wall *A*, and a block is nailed to the bottom of the boarding, as at *C*, so as to set the piece *D* out clear of

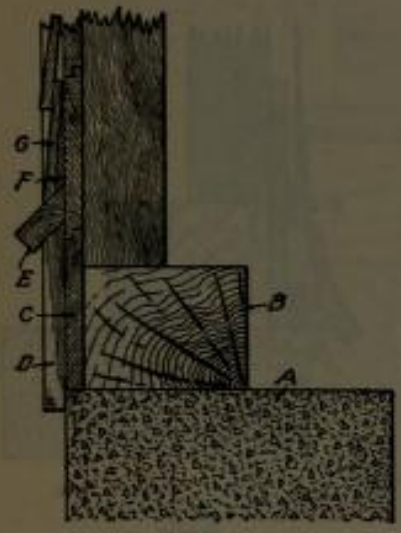


Fig. 372. Simple Form of Water Table

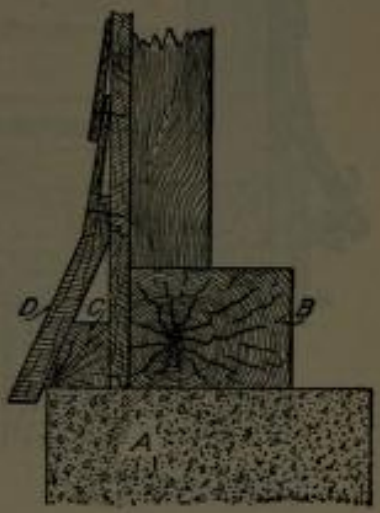


Fig. 373. Type of Water Table with Rabbeted Table Board

the face of the wall. This piece is rabbeted at the top as shown, so as to take in the bottom of the last clapboard.

Another method is shown in Fig. 374. In this case the board *D* is again made use of to cover the joint between the sheathing and the foundation wall, and it is nailed directly to the boarding as before, but the piece *E* is much larger and is blocked out by means of the addition of the piece *G*, so as to throw the water well away from the masonry. In many respects this detail is the best of the three, as the joint is well covered and at the same time there is provided a very good wash for the rain water. There are many other ways of building this part of the finish. One will be shown for use when the walls are to be covered with shingles. Fig. 375 shows how this should be done. Two or even three blocks, as at *F*, are nailed to the boarding and the shingles *G* are bent over them so as to

shed the water free of the masonry without further help. They may be finished at the bottom with a molded piece *D* to hide the joint.

The water table is sometimes omitted entirely and the clapboarding is started directly from the foundation wall, but this is not considered good practice and will surely be found to be unsatisfactory.

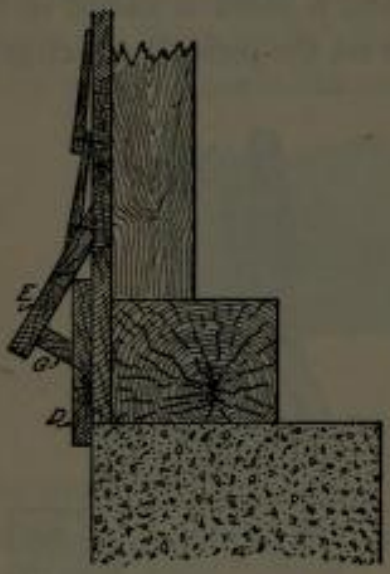


Fig. 374. Water Table of Simple Construction

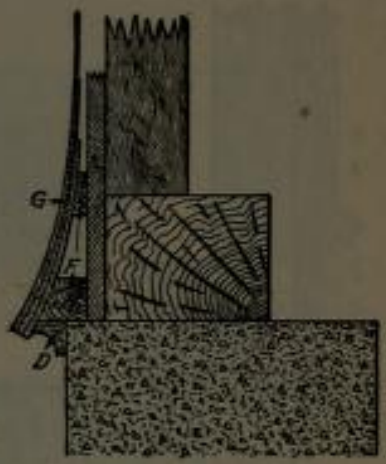


Fig. 375. Water Table Used with Shingled Walls

Corner Boards. It is customary, whenever the walls of a building are covered with siding, to make a special finish at the corners. This finish usually takes the form of two boards, one about 5 inches wide, the other $3\frac{7}{8}$ inches wide by about $1\frac{1}{8}$ inches thick, placed vertically at each side of the corner so as to project $1\frac{1}{8}$ inches—the thickness of the board—beyond the face of the sheathing. Thus they form something for the siding to be fitted against. The corner boards may be mitered at the corner, but this is not desirable, as it is hard to make such a joint so that it will not open up under the influence of the weather. The corner boards are, therefore, usually finished at the corner with a simple butt joint, the two pieces being securely nailed together. In some styles of work it may be well to give the corner boards a special character, and this can be done by crowning them at the top with a capital, so that they will form a sort of pilaster at each corner of the house. A base may also

be added if desired, though it is hard to make a base finish well on top of the water table. Fig. 376 shows a view of a simple corner board in place on the outside corner of a house. *A* is the corner board, *B* is the clapboarding, *C* is the water table, and *D* is the foun-

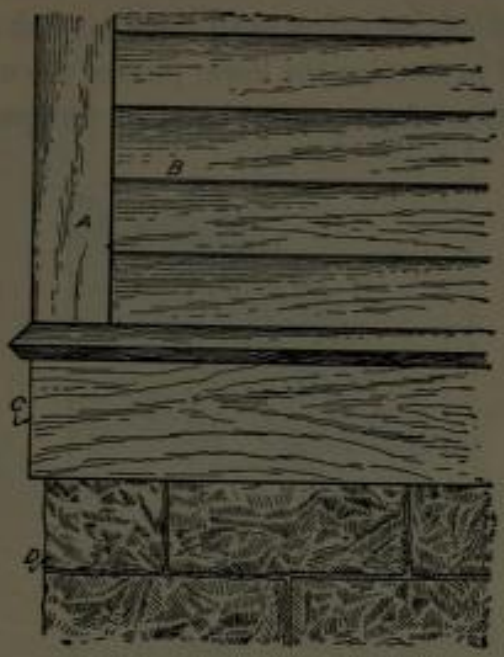


Fig. 376. Simple Corner Board in Place

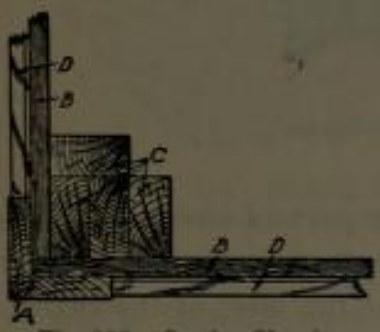


Fig. 377. Section Showing Corner Board Construction

Fig. 378. Shingled Wall Requires No Corner Board

dation wall. Fig. 377 shows a section taken horizontally through the corner of a building with corner boards and clapboards, showing how the corner boards are applied to the outside boarding. In this figure, *A* is one of the corner boards, *B* is the outside sheathing, *C* is the studding at the corner built up of 2 x 4-inch pieces, and *D* are the clapboards. The width of the boards may, of course, be varied to suit the taste of the designer.

When the walls of the building are to be covered with shingles it is not necessary to have corner boards, as the shingles can be brought together at the corner and made to finish nicely against each other. The usual method is to allow the shingles on the adjacent sides to lap over each other alternately as shown at *A* in Fig. 378.

Belt Courses. It is often desirable, for the sake of effect or for the purpose of protecting the lower part of the walls of a building, to arrange a horizontal projecting band or "course," as it is called,

Fig. 379. Details of Belt Course

which will slightly overhang the lower part of the wall. This is called a "belt course" and usually occurs at or near a floor level or across the gable end of a building at the level of the eaves. A belt course is formed by placing blocks or brackets at intervals against the face of the outside boarding, these blocks being cut to the required shape to support thin pieces of molding. This arrangement is shown in section in Fig. 379. Here, *A* is the studding, *B* is the boarding, *C* is the block or bracket, *D* is the finish under the block, *E* is the wall siding, *F* shows where the shingles come down over the belt course and the furring *G* supports the finish and provides nailing surface for the first course of shingles. A similar belt course may be placed on a building with any other kind of wall cov-

ering, the principle being the same in every case, and the purpose being always to form a projecting ridge from which the water will drip without injuring the wall surface beneath. Sometimes the wall covering is not brought out over the top of the belt course, but is stopped immediately above it, and in this case care must be taken to see that the top of the course is well flashed with galvanized iron

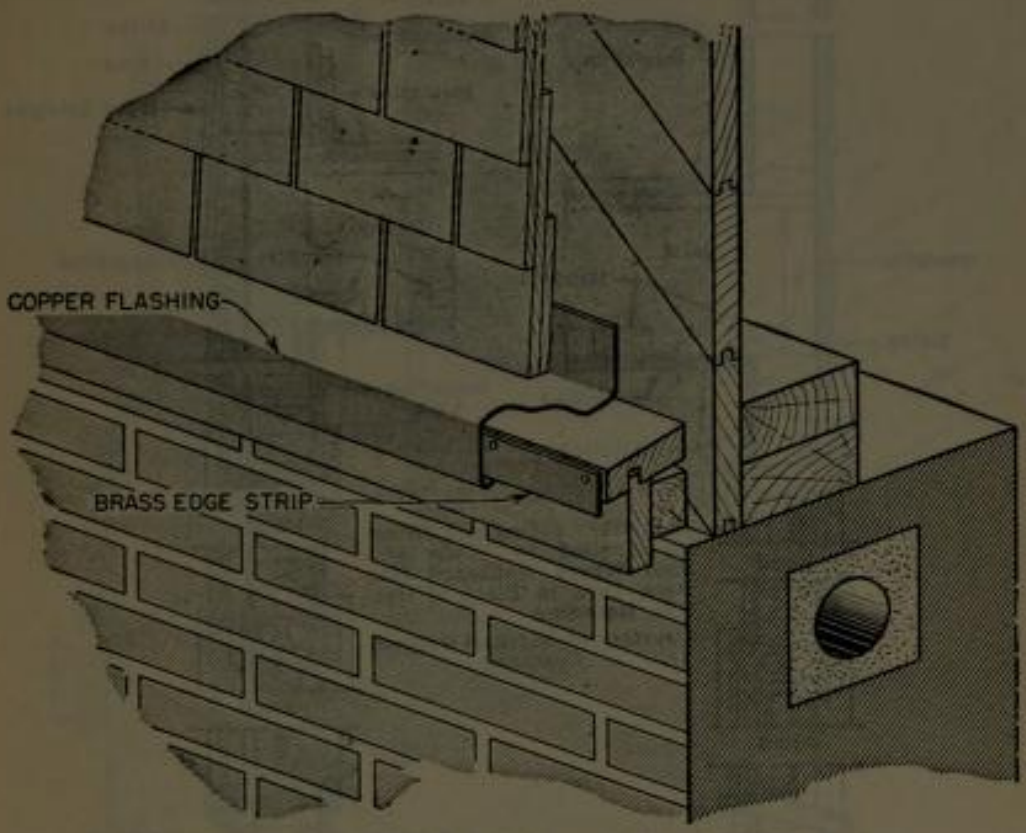


Fig. 380. Flashing for Wood Water Table or Belt Course
Courtesy of Copper and Brass Research Association

or copper so that the water cannot get through the wall around it. It is best to cover the entire top of the belt course with the flashing and to run it up onto the vertical wall 4 or 5 inches with counter flashing over it.

Belt courses are now used much less frequently than they formerly were. Years ago it was the custom to cover the lower part of a wall with one kind of siding as, for instance, drop siding and the upper part of the wall with a different kind of siding such as, for instance, bevel siding or with shingles. In such a case a molded belt course was placed on the wall between the two kinds of siding.

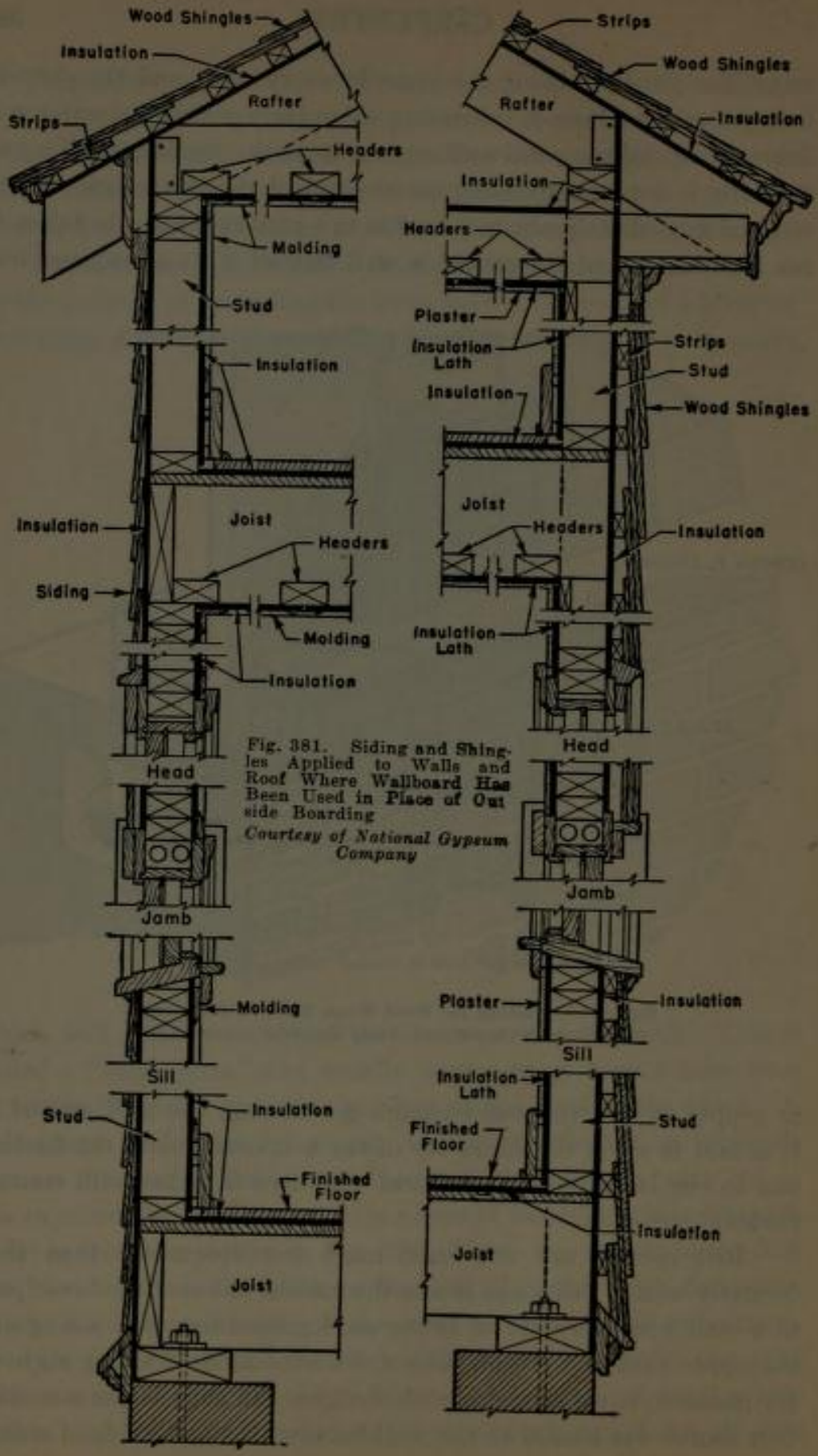


Fig. 381. Siding and Shingles Applied to Walls and Roof Where Wallboard Has Been Used in Place of Outside Boarding

Courtesy of National Gypsum Company

Fig. 379 shows a wall of this kind covered with bevel siding below the belt course and with shingles above the belt course. Today this is very seldom done as the modern tendency is towards simplicity and the entire surface of the wall is usually finished the same. Occasionally a wall is finished with brick for the lower part of the wall and with

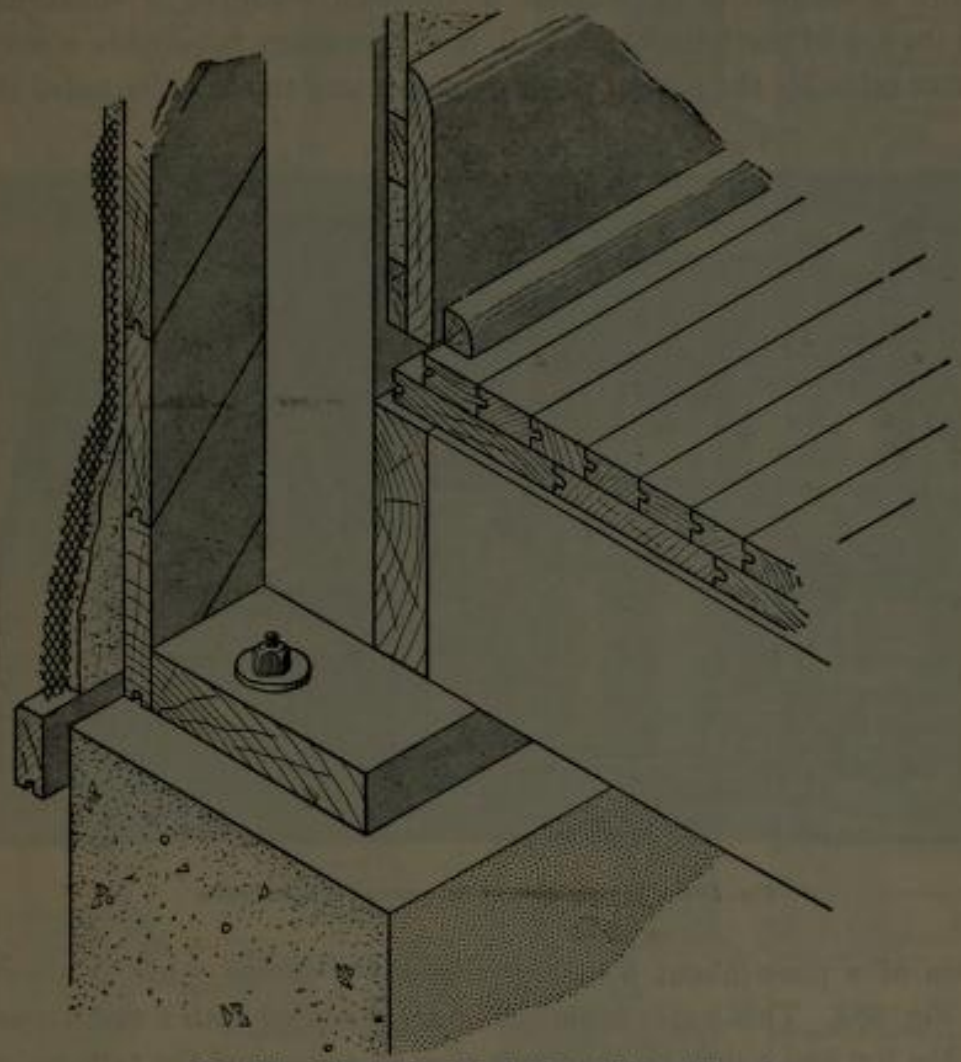


Fig. 382. Illustrating Wood Water Table at Top of Foundation in Stucco Construction

shingles for the upper part, with a horizontal belt course between them. Fig. 380 shows a belt course of this kind and also illustrates the proper method of flashing the top surface of such a belt course or water table.

Outside finish such as water tables, corner boards, belt courses, and window or door trim are put in place before the siding or wall shingling can be applied.

Fig. 381 illustrates siding and shingles applied to walls and roofs where wall board has been used in place of outside boarding.

Stucco Wall Finish. The exterior walls of frame buildings are often finished with a coating of cement plaster which is called "stucco," this material being applied on expanded metal or wire lath which is secured to the outside of the wall boarding or sheathing. At the top of the foundation wall, it is customary to provide a wood water table for the plaster to stop against and this usually takes the

Fig. 383. Combination of Stucco and Wood Panels

form of a piece about 5 inches wide x 1¾ inches thick as shown in Fig. 382. This water table is slightly moulded with a small wash at the top and a drip on the lower edge so as to shed the rain water. It is placed so as to cover the joint between the outside boarding and the masonry or concrete foundation wall. A form of "ribbed" metal lath should be used which has ribs on the back so as to set the lath itself out from the wall boarding and leave a space behind the lath so that the stucco can get a chance to go through the lath and key itself on the back of it.

The stucco exterior finish is sometimes combined with woodwork to give an effect such as that illustrated by Fig. 383. This is

called "half-timber" work and is an imitation of similar exterior finish seen on many of the large country houses in England dating from the time of Queen Elizabeth. In the old work, the timbers

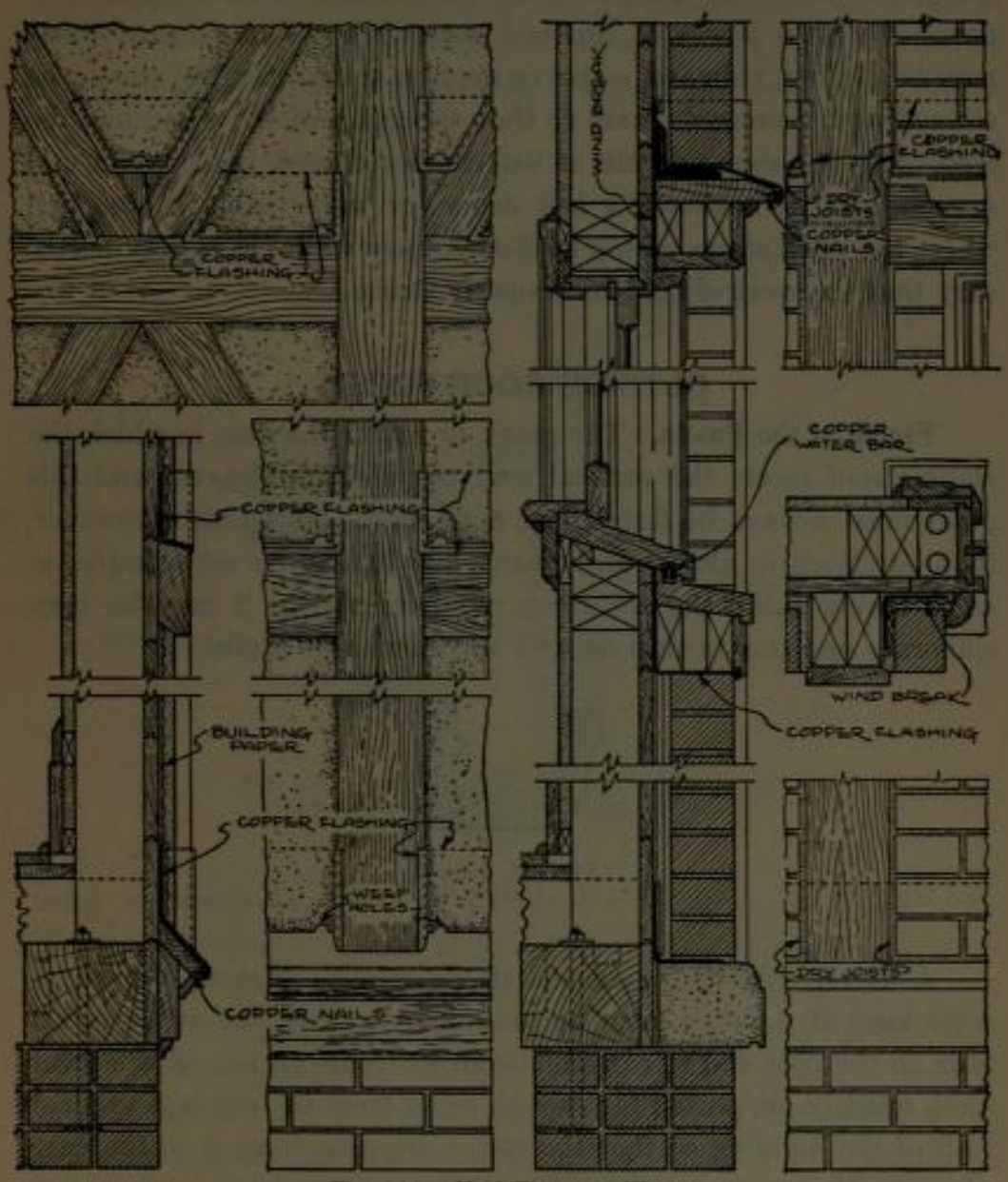


Fig. 384. Half Timbered Work
Courtesy of Copper and Brass Research Association

formed the actual framework for the wall but in modern work they are merely nailed onto the outside of the outside boarding and have a thickness of only about 3 inches. The spaces between these false timbers are covered with stucco on metal lath. Occasionally these

spaces are filled in with brickwork instead of stucco making a brick veneered wall. In this case the timbers must be about 5 inches thick but are often built up with blocking of rough scantlings with only the parts which can be seen from the exterior covered with comparatively thin pieces of finished woodwork. The finished parts may be of pine, redwood, cedar or cypress and preferably should be stained with a creosote stain so that the grain of the wood may be seen. Fig. 384 shows details of half-timbered work in elevation and section. At *A*, is shown a belt course or water table at the line where the work starts on top of the masonry wall. It is very necessary that the work should be properly flashed.

OUTSIDE ROOF FINISH

Finish at the Eaves. The point, or rather the line, in which the sloping roof meets the vertical wall is called the "eaves" and this point must always be finished in some way. This finish, however, may be varied to almost any extent, and it may be very simple, so as to barely fulfill the necessary requirements, or it may be very elaborate and ornamental as well as practically useful.

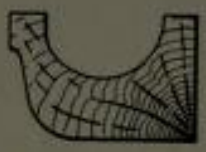


Fig. 385. Simple Gutter

Gutters. Practical considerations require that at the eaves some kind of a gutter must be provided, to catch the water which falls on the roof and streams off from it. This gutter, of whatever kind, must be supported far enough away from the straight vertical wall of the building so that the water dripping from it in the case of a possible overflow will fall free of the walls and not injure them. Usually, the gutter ought not to be nearer to the wall than one foot.

There are a number of different kinds of gutters in use, and perhaps it will be as well to describe some of them at this time, as they form a part of the eave finish. The simplest kind is made of wood, and is generally kept in stock in several different sizes by lumber dealers. It is of the general shape shown in section in Fig. 385, and

the most common sizes are 4 x 6, 5 x 7, and 5 x 8 inches. They are usually made of white pine, but may better be made of cypress or redwood. Spruce is hardly durable enough for use as a material for gutters. Besides the wood gutter just described, there are in use a number of different forms of metal gutters, some of which are carried in stock by dealers in roof supplies and others which

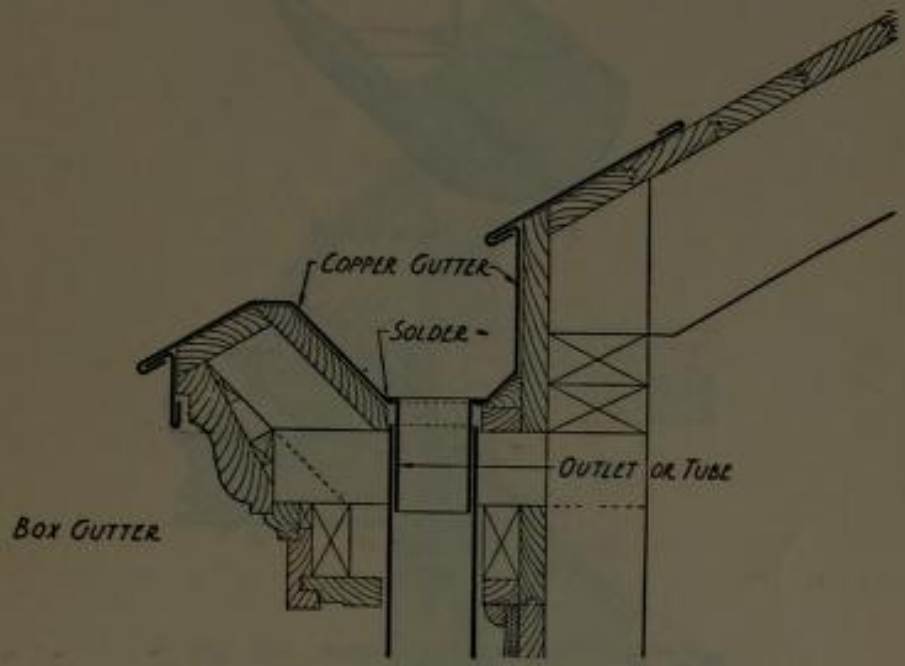


Fig. 386. Wooden Gutter Form Lined with Copper
Courtesy of Copper and Brass Research Association

must be made to order by the roofer for each particular job. The metal gutters are made of galvanized iron, copper, or of a metal lining in a wood form. Fig. 386 shows how a wooden form for a gutter may be built up and lined with metal. Any wood gutter may be improved by lining it with galvanized iron or copper or tin, and there should always be a piece of one of these metals used to cover the joint between the two pieces of a wood gutter where they meet. Wood gutters can be had only in lengths of about 16 feet at the most, so usually there must be some joints to be covered with metal. The simplest metal gutter takes the form of a trough, as shown in Fig. 387, and is fastened in place by hangers placed at frequent intervals or by brackets which answer the same purpose. Either the hangers or the brackets may be spiked to the ends of the rafters, and thus a cheap and simple gutter may be obtained.

Open Cornice. The most simple way of supporting the gutter is to let the main rafters of the roof framing extend out over the wall as far as necessary and cut a rabbet in the end of each of them into which the gutter will fit. In this case the wood gutter may be used. It is fastened into the notches left in the ends of the rafters,

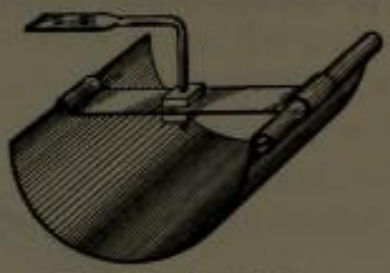


Fig. 387. Metal Gutter

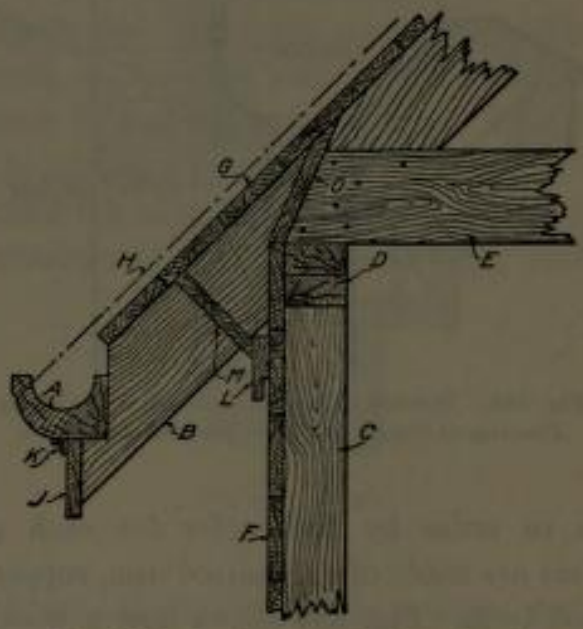


Fig. 388. Section Showing Open Cornice Construction

as shown in Fig. 388. In this figure, *A* is the gutter, *B* is the rafter, *C* is the studding of the building, *D* is the plate with the rafters cut over it and the ceiling joists *E* resting on top of it, *F* is the outside boarding, which may be covered with siding or shingles, and *G* is the roof boarding, which may be covered with shingles or slates. In one respect the construction shown in this figure is faulty, because with the gutter placed in the position shown, snow sliding off the roof would catch the outer edge of it and perhaps tear it off. The gutter should, wherever posible, be placed low enough so that the

line of the finished roof, *H* in the figure, will clear the edge of it. In order to improve the appearance of the eaves it is well to place a board *J* along the edge of the rafters so as to hide them and present a plain surface to the eye and to finish the joint between this board and the under side of the gutter with a small bed molding *K*. Underneath the rafters where they cross the plate and come through the outside boarding is placed a board *L* which forms a stop for the sid-

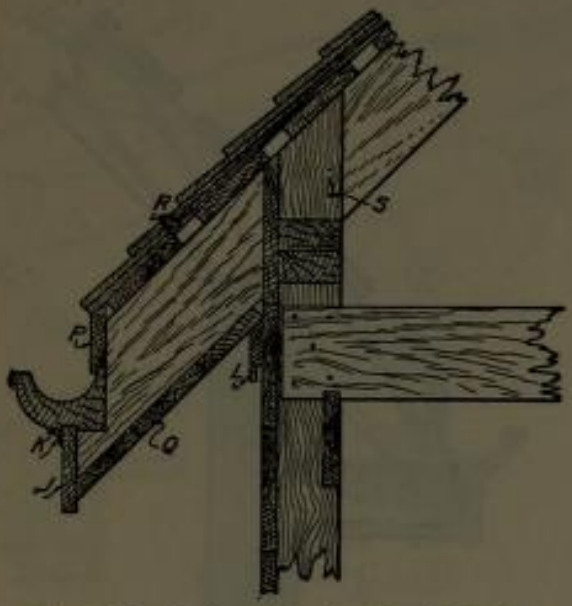


Fig. 389. Section Showing Boxed Cornice Construction

ing or shingles, and another board should be inserted between this and the under side of the roof boarding, as shown at *M*. It is also a good plan to cover the ends of the ceiling joists with a strip of boarding to keep the wind out of the roof space. This is shown at *O*. The finish shown in Fig. 388 is of the simplest and barest kind and can be used only for buildings of an unimportant character such as stables and outhouses or for cheap country houses.

Boxed Cornice. A better finished form of cornice is shown in Fig. 389. Here an extra piece *P* is placed just above the gutter so as to cover the spaces between the rafters, and the entire under side of the rafters outside of the wall of the building is covered with boarding as at Q, so that the rafters will not be seen at all. The piece *L* must still be used, however, to stop the wall covering. This figure also shows the roof shingling at R. This should be laid about 4 to 4½ inches to the weather. It is laid closer than the wall shingling

because it is nearer flat and the water will stand on it longer than it will stay on the wall. The water thus has a greater chance to leak through and the shingling must be laid closer and thicker on the roof. It is wise to insert blocks on top of the plate as shown at *S*, and to continue the side sheathing up to the roof sheathing so as to make everything tight. All of the boarding used for the boxing in of the rafters at *Q*, together with the pieces *L* and *J*, may

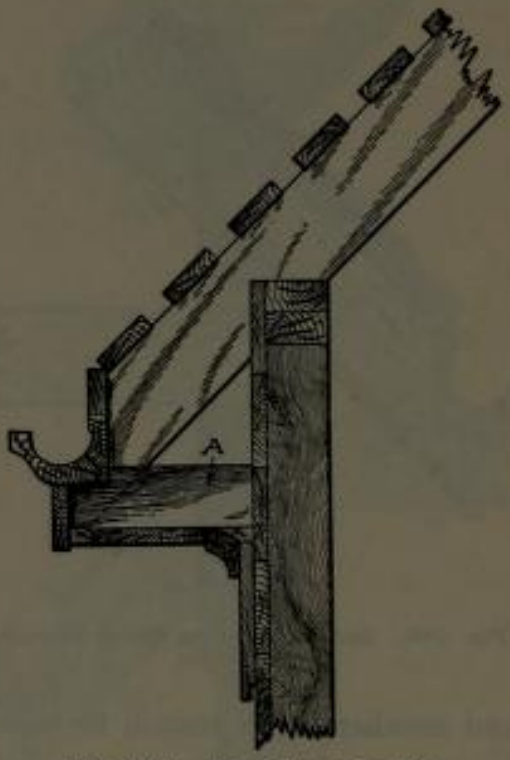


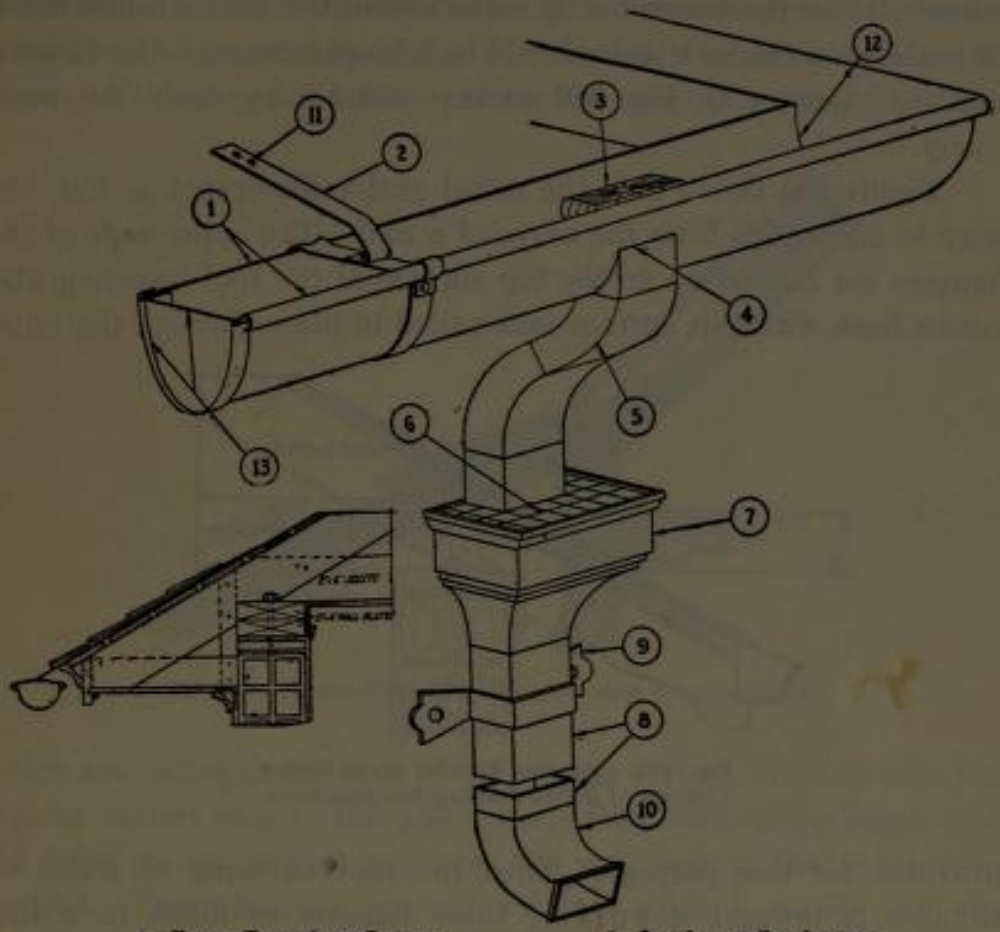
Fig. 390. Boxed Cornice with Horizontal Planceer

be of ⅞-inch stuff. The piece *P* should usually be of 1⅛-inch stuff so as to allow of rabbeting it to receive the gutter. The piece *K* may be molded as desired by the designer of the building. *J* is called the *fascia* and *Q* is called the *planceer*.

The principal objection to the boxed cornice is that, if snow melts in the gutter and freezes afterward so as to fill up the gutter during the winter, it is very likely to work its way up under the shingles when it finally melts in the spring, and in this way finds its way into the attic. In the case of the open cornice there is little chance of this happening, as the water can get away at the back of the gutter between the rafters.

Sometimes it is desired to place the planceer in such a position

that it will be horizontal instead of following up along the under side of the rafters. This is accomplished by nailing a piece of furring to the end of the rafter and to the wall in such a way that the bottom of it will be horizontal, and spacing these pieces 12 or



1. Eaves Trough or Gutter
2. Gutter Hanger
3. Basket Strainer
4. Gutter Outlet
5. Elbow
6. Screen
7. Leader Head
8. Leader or Conductor
9. Leader Strap
10. Shoe
11. Nails
12. Mitre
13. Cap

Fig. 391. Showing How Metal Gutter Illustrated in Fig. 387 May Be Hung from Roof

Courtesy of Copper and Brass Research Association

16 inches apart all around the eaves of the building. To this furring can be nailed the planceer which will box in the cornice and be in a horizontal position. The gutter can still be fastened to the end of the rafters as before. This construction is shown in Fig. 390. The pieces of furring referred to are shown at *A*. They are called "look-outs."

The lookouts should be cut with a slight bevel on the ends so

that when they are in place they will not set exactly level but so that the planceer will slope just a little downward and outward. This is in order that any water or melting snow which may find its way into the boxed-in space at the eaves may drain to the outside. It is recommended by some authorities that a small crack or space about ½ inch wide should be left open between the fascia *J* and the planceer *Q*, Fig. 389 so that water may drain out more easily.

Figure 391 shows how the metal gutter illustrated in Fig. 386 may be suspended from the eaves of a roof. The upper ends of the hangers are carried up on the top surface of the roof boarding and cut-in flush with this surface and nailed in place through the holes

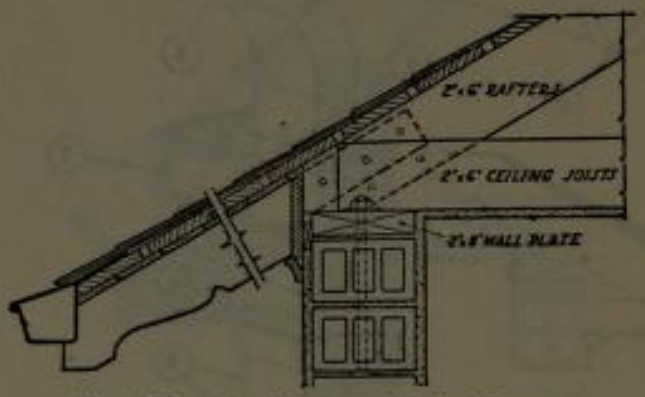


Fig. 392. Another Form of Metal Gutter
Courtesy of Hollow Building Tile Association

provided for this purpose. Then the roof covering of slates or shingles is brought down over these hangers to finish in a line directly over the hanging gutter and thus discharge the rain water into it. Fig. 392 shows another kind of metal gutter which is formed up out of copper or galvanized iron so as to set into a notch or seat fashioned in the overhanging ends of the rafters just as was done with the wooden gutter in the open cornice construction illustrated in Fig. 388. The eave finish shown in Fig. 392 is also a type of open cornice applicable to a building with brick or tile walls and stucco exterior finish. The exposed rafters are molded and the roof boarding, where it overhangs the wall and is thus exposed on the underside, is usually covered with matched boarding or "ceiling" which may be of white pine or Douglas fir or some equally durable wood suitable for outside finish such as redwood or cypress. The molded rafter ends should be of similar material and are, therefore,

made as false rafters, since they cannot well be of spruce or hemlock like the main rafters and it is not economical to make the main rafters from the more expensive wood.

False Rafter Construction. It is often desirable, for the sake of architectural effect, to break the surface of the roof just above the eave line, and in order to do this it is necessary to make use of small pieces of rafters, called false rafters, or sometimes "jack" rafters,

Fig. 393. False Rafter Construction with Shallow Gutter

which are nailed to the ends of the regular rafters. In this case the regular rafters stop at the point where they rest on the plate, and the false rafters project out over the wall line as far as may be desired. These false rafters are cut into various shapes and are usually left exposed on the under side, being in this case made of a better class of wood than that used for the regular rafters. The gutter may be placed on the ends of these false rafters if desired, but it is more usual to make use of a construction such as is shown in Fig. 393. Here it will be seen that the gutter is merely formed up on top of the roof shingling by a piece *A* which is held in place by the bracket *B*. The brackets occur at intervals of about 2 feet, while the piece *A* is continuous. The shingles which cover the roof are stopped on the strip *C* and the inside of the gutter thus built up is covered with galvanized iron, or copper, to make it water-tight. The ends of the rafters may be finished with a fascia as shown at *D*, and the space between the false rafters along the wall may be finished as shown at *E*. In place of the wood piece *A* which forms the out-

side member of the gutter, a piece of metal may be used to accomplish the same purpose, and this is often done.

Fig. 394 illustrates a similar gutter formed on top of the roof boarding with the shingling stopped above and below the gutter, which is formed up out of sheet copper. This figure shows how the sheet copper is fastened to the roof boards by means of metal cleats and straps and how the sheet metal flashing is applied under the shingles above the gutter and over the shingles below the gutter.

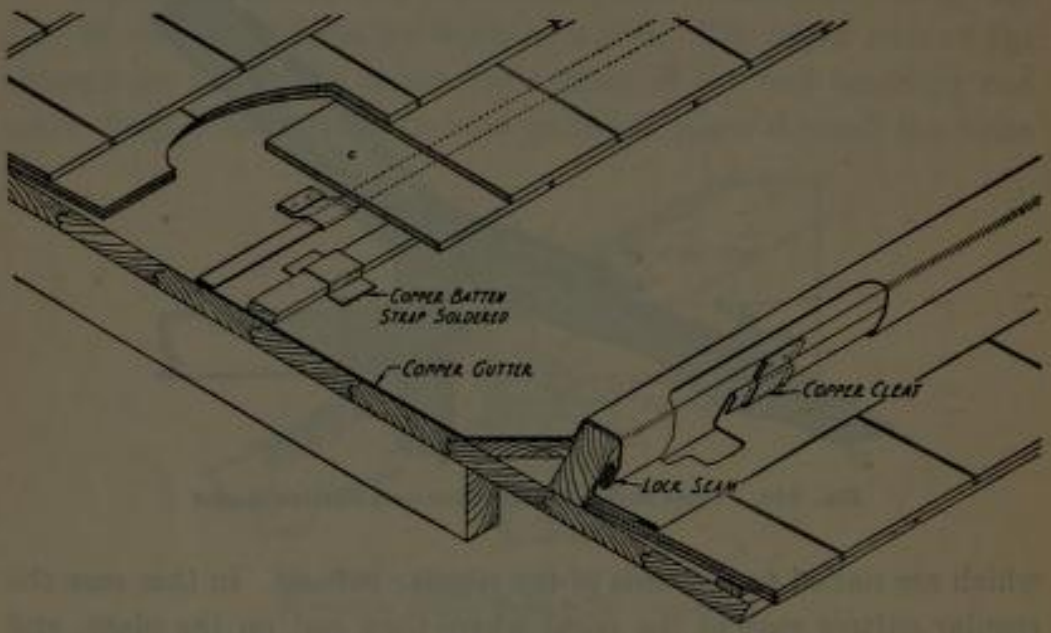


Fig. 394. Metal Gutter Similar to Fig. 393 Showing Forming of Copper and Shingle Positions

Courtesy of Copper and Brass Research Association

Concealed Gutters. Another common form of eave finish provides a concealed gutter. In this construction the ceiling joists may be extended out over the wall plate to form a support for the eave finish as shown in Fig. 395, if they are located in such a position with relation to the outside wall cornice as to make this possible. When this can be done, a secondary plate of 2 x 4-inch stuff is placed on top of the ceiling joists and the rafters are cut to set on this secondary plate as shown. The studding is shown at S and on the plate P the joists C extend over beyond the outside wall face from 8 to 14 inches, depending upon the effect desired. Around the overhanging joists the planceer Q, the fascia J, the bed mold N, and the crown molding M, are fixed. A notch O is cut in the top of each joist near the outside overhanging end and $\frac{7}{8}$-inch boards are nailed to the top

of the joists in this notch forming a sort of box open at the top. Tin or galvanized iron or copper is used as a lining for the gutter.

Fig. 395. Cornice Construction for Concealed Gutter

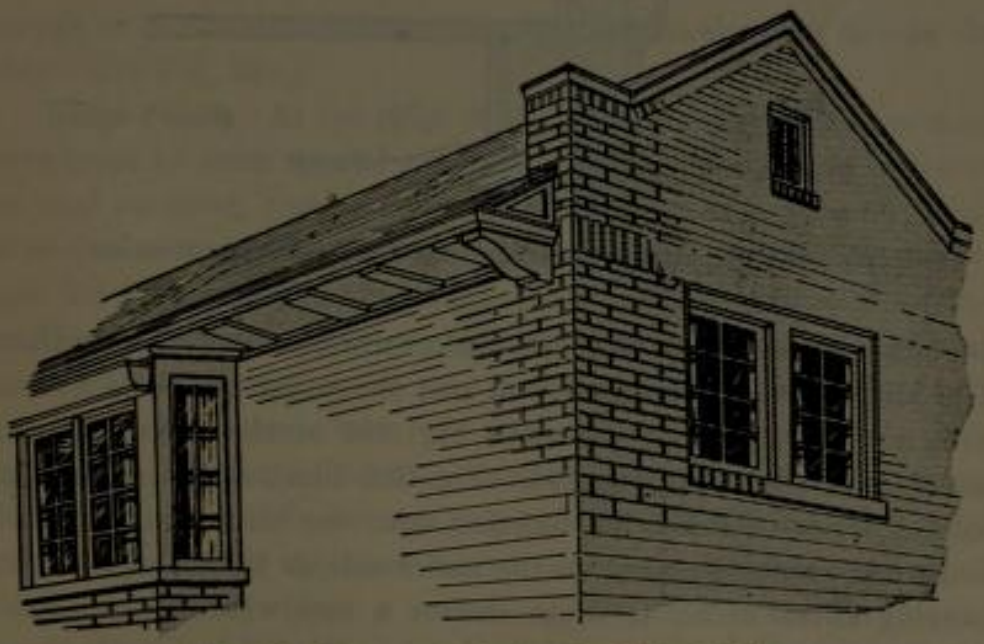


Fig. 396. Ornamental Cornice for Brick Building

The sheet metal should be nailed to the top of the crown moulding and should be run 8 or 10 inches above the shingle line. Because the ceiling joists are usually not more than 8 inches deep, this

construction can provide only a very shallow gutter. A much better method of forming such a gutter is shown in Fig. 387.

Finish for Brick Walls. Any of the forms of eave finish described above may be used equally well in cases where the wall is of brick or of hollow tile instead of wood. In this case a wood plate is placed on top of the brick wall and the rafters are brought down over it, and

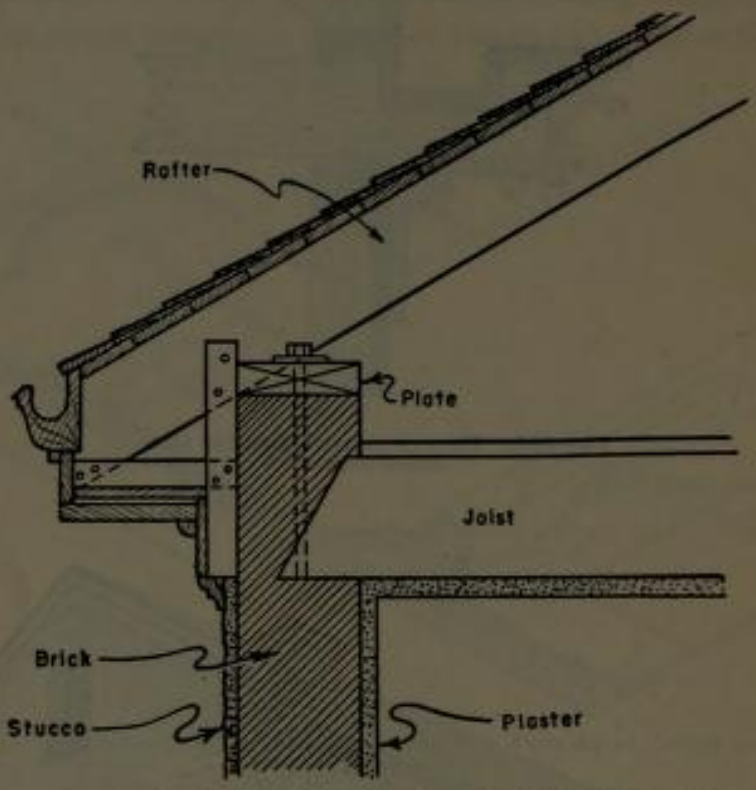


Fig. 397. Cornice for Use in Connection with Brick Wall and Stucco

are either extended out over the wall or are fitted with false rafters. The joint between the brick wall and the wood rafters is finished with a wood frieze, as shown in Fig. 392 or the rafter ends are boxed-in as shown in Fig. 391. Fig. 396 illustrates a more ornamental cornice for a brick building with the rafter ends boxed-in and wood brackets placed on the under side or "soffit" of the overhanging eaves which serve to shelter a bay window. A section through a similar cornice for a brick wall finished with stucco is shown in Fig. 397.

Cornices may be much more elaborate than any of those illustrated above, but the principles of construction are the same in all cases, the difference being in the amount of ornament applied to

the building. The ornament takes the form of molded pieces of timber which are supported by rougher furring pieces placed behind them. Economy demands that the finished pieces be so arranged as to be cut out of boarding of medium thickness, and as much space as posible should be occupied by the rough, concealed furring. As a rule, all of the eave finish can be taken out of ⅞-inch stuff. Care must be taken always to give the gutters the proper slope to the outlets called "downspouts" and they should be made large

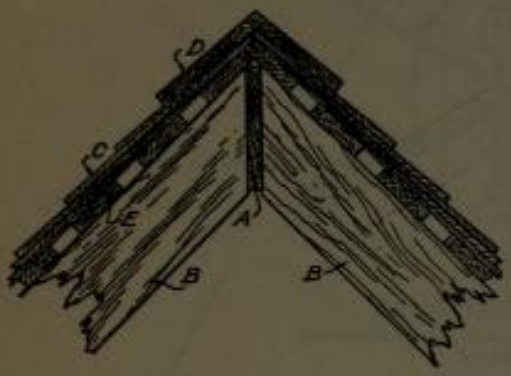


Fig. 398. Simple Ridge Finish

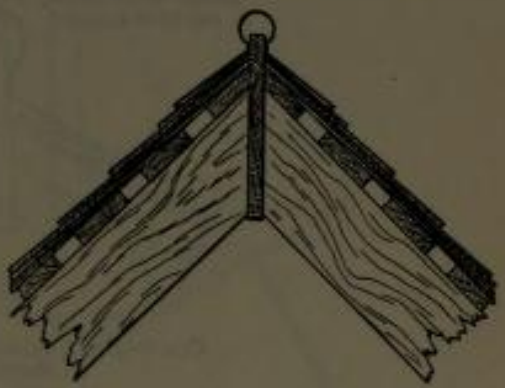


Fig. 399. Galvanized Iron Ridge Finish

enough so as not to overflow. A gutter should slope ⅜ inch to the foot. (See Fig. 391.)

Ridge Finish. At the ridge of a roof where the two slopes meet there must be some special provision made for the proper finish of the roof covering, something for the shingling or slating to finish on as well as some adequate means of covering and making water-tight the joint which occurs at this place. There is usually a ridge board, or ridgepole, which receives the rafters, and this piece may be cut off just at the ridge so that the rough roof boarding goes over it, or it may be made wider and may project up above the roof boarding, so that this boarding stops against it instead of going over it. The two different methods call for different kinds of ridge finish. The first is the most simple, and may be taken care of as shown in Fig. 398. Here, *A* is the ridge board, *B B* are the rafters, *E* is the roof boarding, *C* is the shingling, and *D* is the finish at the ridge, consisting of two pieces of board about 6 or 8 inches wide and ⅞ inch thick, which are nailed on top of the shingling to form a finish. In case the ridge board is carried up above the roof boarding, it is customary to make the ridge finish of galvanized iron or of

copper or other metal. This may be done very simply, as shown in Figs. 399 and 400. Here the ridge board is extended above the roof boarding and around it is shaped a strip of galvanized iron or copper or zinc, which is continued down over the shingles of the roof so as to form a flashing. This makes a good ridge finish and one which is water-tight if it is properly put on. The galvanized iron should be flashed down over the shingles for a distance of at

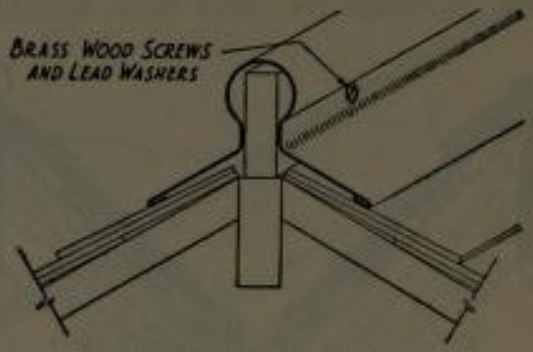


Fig. 400. Ridge Finish
Courtesy of Copper and Brass Research Association

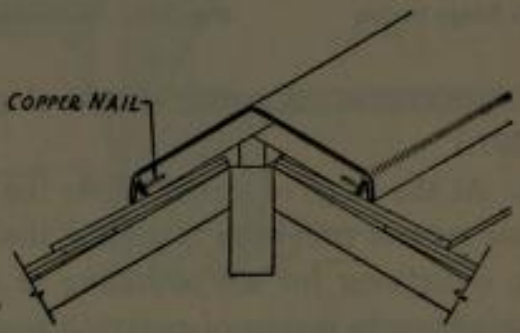


Fig. 401. Ridge Finish
Courtesy of Copper and Brass Research Association

least 6 inches. It is not necessary that the ridge board should be extended above the roof boarding. The same result may be accomplished by nailing a separate piece of scantling to the top of the shingles, running lengthwise of the roof, to form a ridge over which the metal may be shaped. It is best in every case to cover the "saddle boards" (*D*, Fig. 398) with sheet metal flashing which should cover the entire upper surface of these boards and be carried around their lower edges.

This can be done as shown in Fig. 401 which illustrates the ridge of a flatter roof than the one in Fig. 398. The sheet metal is

doubled over at the ends and nailed to the edges of the saddle boards with brass nails and then bent down over the edges of the saddle boards to rest on top of the shingles.

Hip Finish. The best method of finishing the hips of a shingled roof is to form a saddle over them composed of shingles fitted against each other along the hip line. On top of the hip

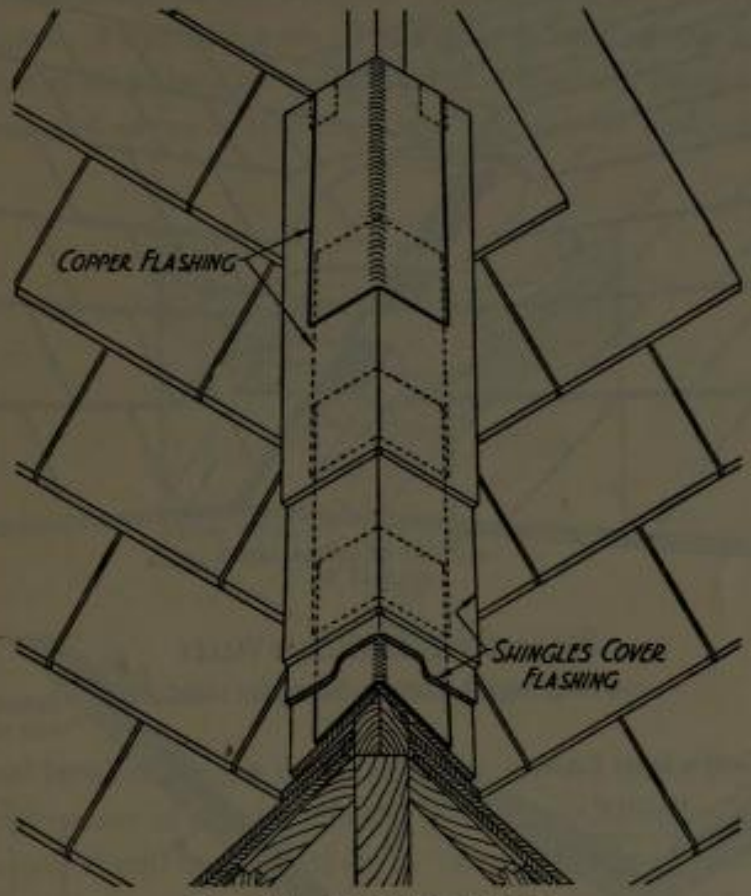


Fig. 402. Saddle Hip Flashing
Courtesy of Copper and Brass Research Association

rafter (which is not "backed") are placed separate pieces of scantling cut to the shape of the hip as shown in Fig. 402. The shingling of the two roofs is fitted against this hip piece and the saddle is formed over it. In the best work the saddle is then flashed with sheet metal as shown and a finishing saddle composed of shingles is fitted over the flashing as illustrated in Fig. 402.

Valley Finish. The proper arrangement of the roof covering at the valleys is a matter of the greatest importance as the valleys constitute the weakest points of the roof and are the source of most

of the trouble which is caused by leaks. Whereas the ridges and the hips form outstanding angles in the roof surfaces which will naturally shed water, the valleys form depressions in these surfaces

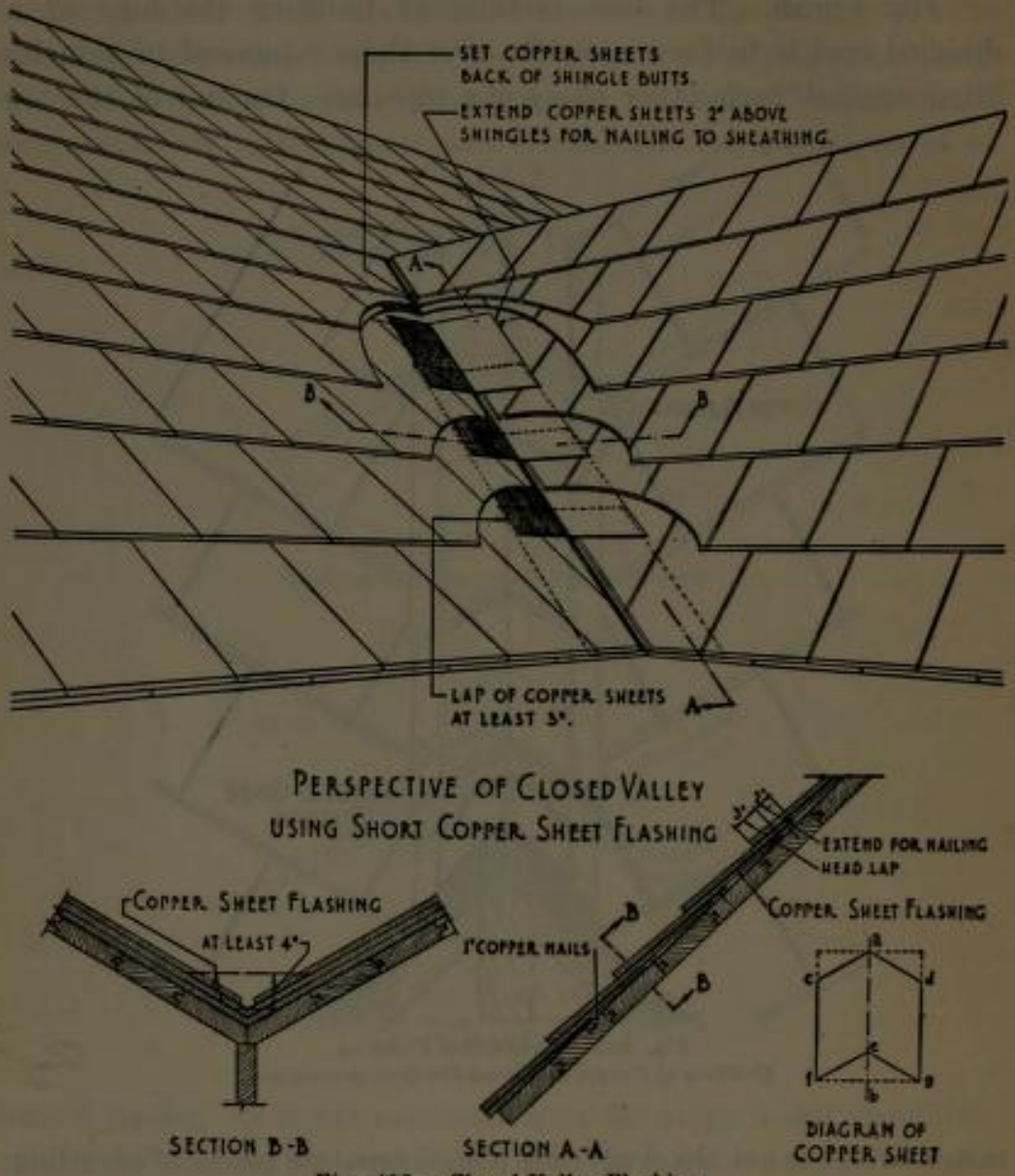


Fig. 403. Closed Valley Flashing
Courtesy of Copper and Brass Research Association

towards which large quantities of water are drained and in which snow will lodge and ice will form resulting in the damming up of the rain water. In its effort to escape, the water will find its way through weak points in the roof covering unless this covering is put on with the greatest care and is properly flashed. If the covering is wood shingles, they should be carefully fitted against each other

where they meet and the joint between them should be thoroughly flashed with sheet metal, preferably with copper.

Fig. 403 illustrates at a large scale a valley such as is shown in plan in Fig. 300, Part III, and indicates the proper method of flashing where the sheet metal is to be entirely covered up by the shingles. The sheet metal is cut into small sheets which are laid in place in courses, as the shingles are laid and are worked in with the shingles. First, a course of shingles is laid at the eaves. On top of this is laid the first metal sheet. Then the second course of shingles at the eaves is laid over the first course making a double

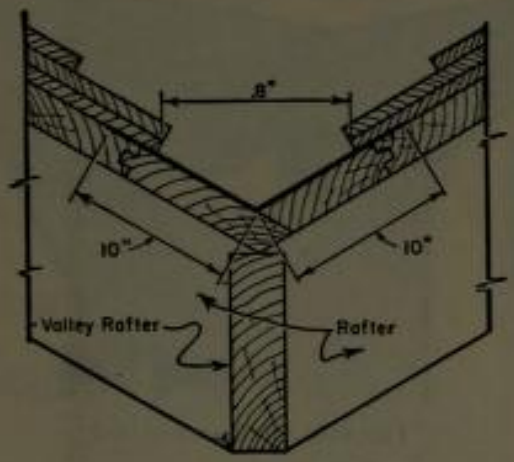


Fig. 404. Vertical Section through Open Valley

course at the eaves and completely covering the sheet metal. Then the second course of the sheet metal is laid over the shingles in such a position that it will be covered up by the next course of shingles after which the third course of shingles is laid, to be followed by alternate courses of sheet metal and shingles. In this way the entire length of the valley is covered by the metal sheets. This is called a "closed" valley because the shingles on the two slopes come together in the valley and cover up the sheet metal flashing. There is another type of valley often used where the shingles on the two slopes are not brought together in the valley but are stopped on each side of the valley line and some 6 inches or more away from the valley line. This leaves an open space of 8 inches or more wide for the full length of the valley which is called an "open valley" and which is completely covered over with sheet metal which is carried up under the shingles on each side of the valley line at least 4 inches and

preferably more than this. Fig. 404 shows a section taken vertically through an open valley.

The usual covering for the outside of sloping roof surfaces of frame buildings where they are not required to be fireproof is wood shingles. These are similar in every way to the shingles described for the outside wall covering. They should not be used more than 9 inches wide and they should be well soaked before they are laid, because they swell when they are wet and if laid dry they will press against each other at the joints and buckle as soon as they

Fig. 405. A Thatched Roof

are wet by the rain. If they cannot be wet, they must be laid with ⅛-inch wide open joints. It is best to stain them before laying and if this is done they should be dipped (not soaked) in the stain for ⅔ of their length and then allowed to dry in a loose pile. The staining will prevent the swelling and buckling. A good creosote stain is best. In laying, first lay them double thickness at the eaves projecting 1½ to 2 inches. They should also project 1 inch at the gable ends. Always use galvanized nails or copper nails as plain steel nails very soon rust away and allow the shingles to become loosened.

An unusual development in connection with the use of shingles for roof coverings is the so-called "thatched roof effect" which has become quite popular. It is an attempt to obtain with wood shingles something of the charming appearance of the thatched roofed cottages which are to be seen in England. Fig. 405 illustrates a roof of this kind. In the best examples of this type of roof, the

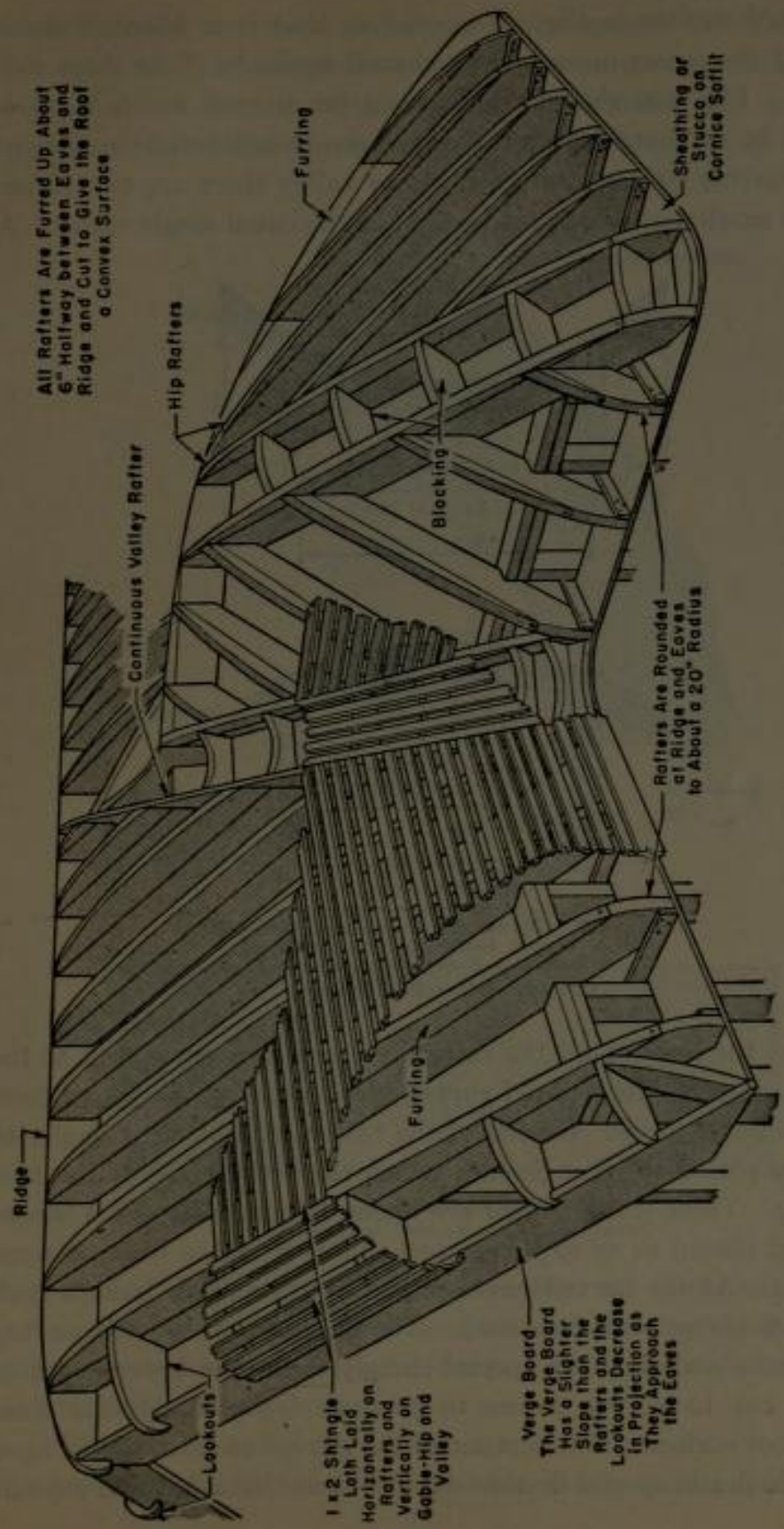


Fig. 406. Framing Details for a Thatched Roof
Courtesy of Creo-Dipt Company

entire roof surface is slightly curved so that it is about 6 inches higher at the center of each slope than it would be if the slope were straight. Fig. 406 shows the framing for a roof which is to be shingled in a "thatched effect." On top of each rafter is added a curved furring strip and at each hip or valley there are two rafters placed a small distance apart instead of the usual single rafter. At

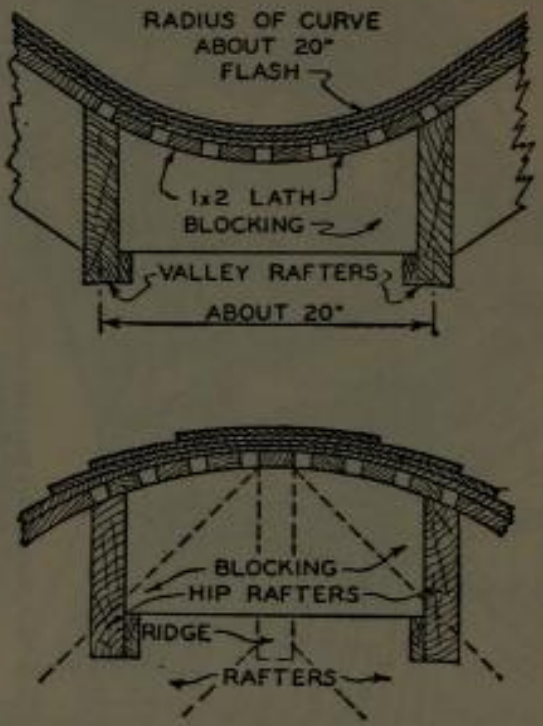


Fig. 407. Illustrating Frame and Shingles for a Typical Section of Thatched Roof Taken through a Valley and through a Hip
Courtesy of Creo-Dipt Company

the eaves the ends of all the rafters are cut to a curve and at the gable ends there are inserted curved "look-outs" or blocks to form a curved gable finish. On top of the rafters and at right angles to them are placed the shingle-lath which takes the place of the roof boarding. These shingle-laths are about 1 inch thick and 4 inches wide and placed so as to leave open spaces 3 inches wide between the laths. At the curved eaves, valleys, and gables, laths 1 inch thick x 2 inches wide are used. The shingles are placed on top of the laths and they are special shingles with the lower edges or "butts" cut to curves so as to produce wavy horizontal lines on the roof surfaces. On account of the curved eaves, valleys, hips, and gable finish, special flexible shingles made from felt and asphalt

are often used but wood shingles may be soaked or steamed and thus made flexible enough to be bent to these curves. Shingles are sold which are already bent to the proper curves. Fig. 407 shows typical sections taken through a valley and through a hip illustrat-

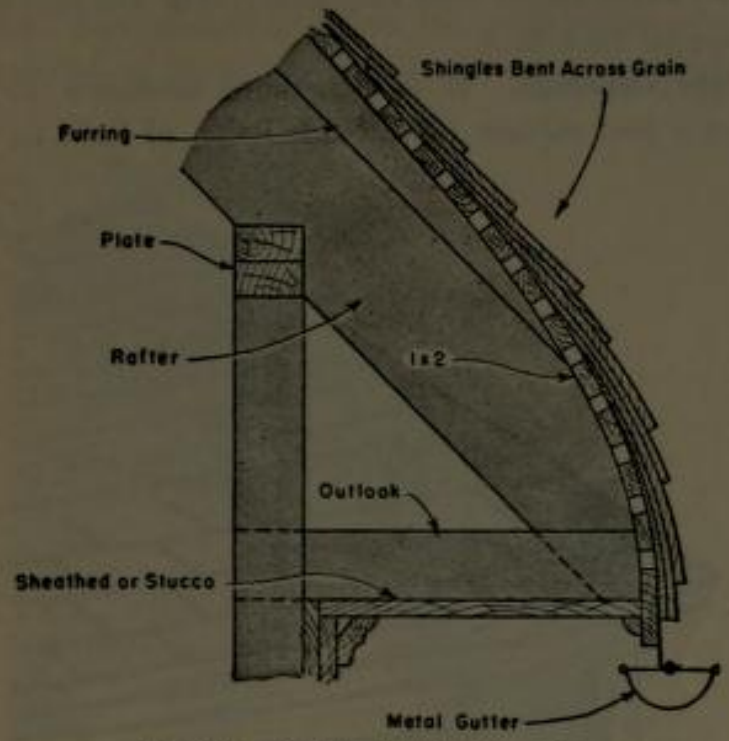


Fig. 408. Section through Eaves of a Thatched Roof
Courtesy of Creo-Dipt Company

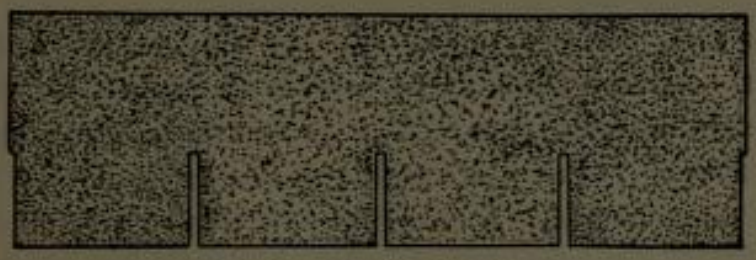


Fig. 409. An Asphalt Shingle
Courtesy of Johns-Manville Company

ing the framing and the shingles. In Fig. 408 is shown a section taken through the eaves of a thatched roof showing the gutter and the overhanging rafters and the furring. The gable ends are finished in much the same way as are the eaves.

Shingles are not always made of wood but are obtainable manufactured from asphalt and felt which are often covered on the exposed

surfaces with a coating of powdered slate. Similar asphalt shingles are now made which are coated with a thin sheet of copper. Shingles are also made from asbestos and these are fireproof. The asphalt shingles are made in strips of from two to four shingles (as shown in Fig. 409) which makes them easy to lay. Fig. 410 shows how these shingles appear on a roof.

Skylight Openings. It is sometimes necessary to make an opening in a roof surface for the admission of light to the rooms

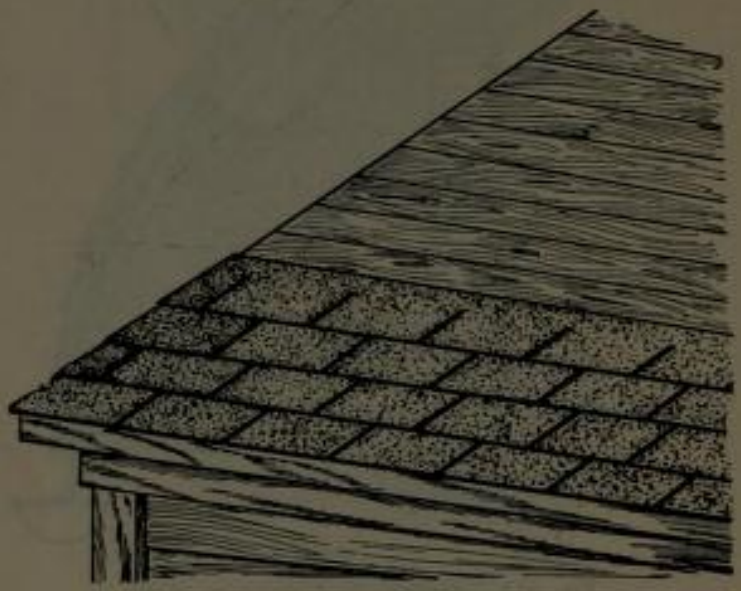


Fig. 410. Asphalt Shingle in Place on a Roof
Courtesy of Johns-Manville Company

under the roof. This is usually done by the formation of what is known as a dormer window, the method of framing for which has been already described, but often it is desired to admit light when the attic space is not of sufficient importance to justify the introduction of a dormer window in the roof. In this case recourse is had to a skylight. A skylight may be obtained by the use of glass in the roof surface in place of other roof covering such as roof boarding and shingles, but it is almost always necessary to provide some sort of frame for this glass, and the glass surface is usually raised about 6 or 8 inches above the shingled roof surface so as to keep the glass as free as possible from snow and to separate it from the general roof surface. The first thing to be done is to frame an opening, in the rough, between the rafters, by introducing trimmer pieces just above and below the place where the opening is to be. This

completes the rough framing for the skylight. The finished opening may be formed in a number of ways, one of which is shown in Fig. 411. Here, *A A* are the pieces referred to above, which frame between the rafters *B B* and form the rough opening. *D* is the roof boarding which is brought up to the edge of the opening as framed, and sawed off flush with it as shown. *C C* are pieces of rough stuff which are nailed on top of the boarding to raise the skylight above

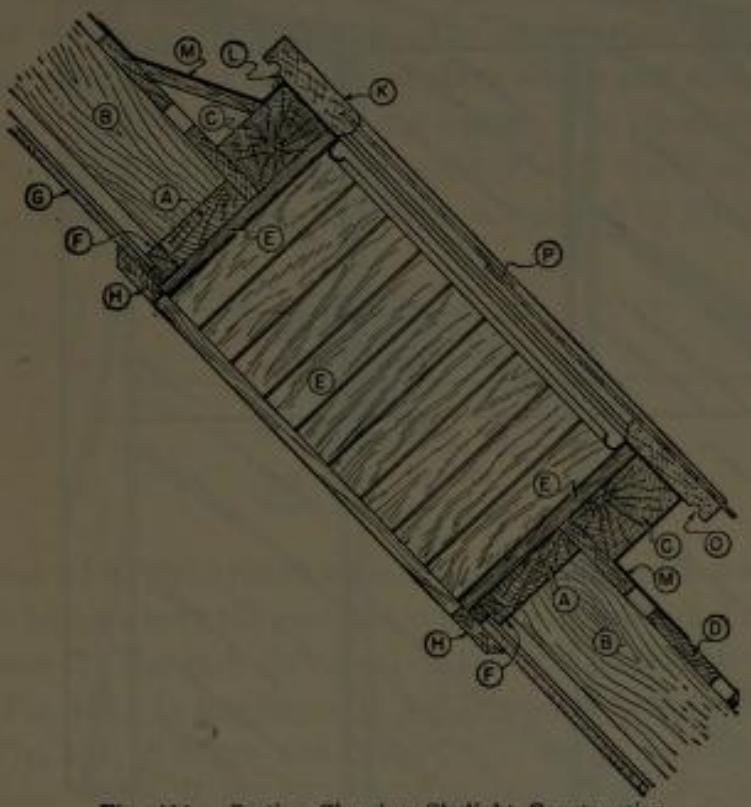


Fig. 411. Section Showing Skylight Construction

the roof surface. They may be of any size desired, but in this case they are 4 x 6 inches. *E E* is sheathing about 7/8 inch thick which forms a finish for the inside of the skylight opening. It is continued to the top of the pieces *C C* and down to the plaster line inside under the roof so as to cover up all the joints. This sheathing may be V-jointed or beaded if desired. *F F* is furring on the under sides of the rafters, and *G* is the plastering under the roof. *H H* are finishing pieces covering the joint between the sheathing and the plaster. These pieces are called casing. *M M* is flashing of some kind of metal, which should be carried well under the shingles or other roof covering all around the skylight, and is carried inside to form a little gutter around the inside of the skylight just under the

glass as shown, in order to catch drippings from the glass. *K* is the sash which holds the glass. It should be hinged to open at the top at the point marked *L* and should project an inch or two beyond the frame all around and have a drip cut in it as shown at *O*. Fig. 412 shows an elevation and a section through a sash suitable for use in a skylight. *A A* is the top rail which is ploughed to receive the

Fig. 412. Plan and Section of Skylight Window

glass as shown at *B*. The bottom rail *C C* is made thinner than the top rail so that the glass can pass over it and project beyond it as shown at *D*. *E E* are divisions called "muntins" running lengthwise of the skylight, their distance apart and the number of them required depending upon the width of the sheets of glass used. The muntins support the sheets of glass at the sides, as shown in Fig. 413, which is a section through a single muntin. In this figure, *A* is the wood muntin itself, *B B* is the glass on each side, and *C C* is the putty which is used to hold the glass in place and to make the joint tight. In a skylight sash there should be muntins running lengthwise of the sash only, and the glass should be supported only at the

side. If the sash is so long that a single sheet of glass will not cover it, two or more pieces should be used and should be lapped on each other at the ends as shown at *P* in Fig. 411 and at *F* in Fig. 412. This lap should be from 1½ to 2 inches. The side pieces of the skylight sash, *G G* in Fig. 412, should be cut similar to the muntins to receive the glass.

There are a number of other methods of constructing skylights besides the one shown in Fig. 411. The construction of the sash, however, is always about the same as there shown and as described, the difference being in the form of the frame. The pieces marked *C* in Fig. 411 are sometimes omitted entirely, and the sheathing *E*, which is only about ⅞ inch in thickness, is replaced by planking 1½

Fig. 413. Cross Section of Muntins

to 2½ inches thick. Such planking is stiff enough to be allowed to project 6 or 8 inches above the roof boarding and it thus takes the place of the pieces *C*. The sash then rests on the ends of this planking, as shown in Fig. 414. In this figure, *A A* is the rough framing similar to that in Fig. 411, *B B* are the rafters, *C C* is the planking mentioned above, which, it will be noticed, does not extend down to the plaster line on the inside, but is stopped about 3 inches above it and is pieced out with a strip of ⅞-inch stuff, *D D* the joint between the two pieces being covered and eased off by a molding *E E*. The architrave *H H* is made use of in this instance also. Other openings in the roof surface, which are parallel with that surface, and which are for other purposes than the admission of light, such as scuttles, trap doors, etc., may be framed and finished in a manner similar to that just described for skylight openings.

Dormer Windows. When it is desired to obtain the admission of light to the space under the roof surface in a way more elaborate and satisfactory than is possible with a simple skylight such as has just been described, recourse is had to dormer windows. They are so called probably because in early times nearly all of the sleeping-

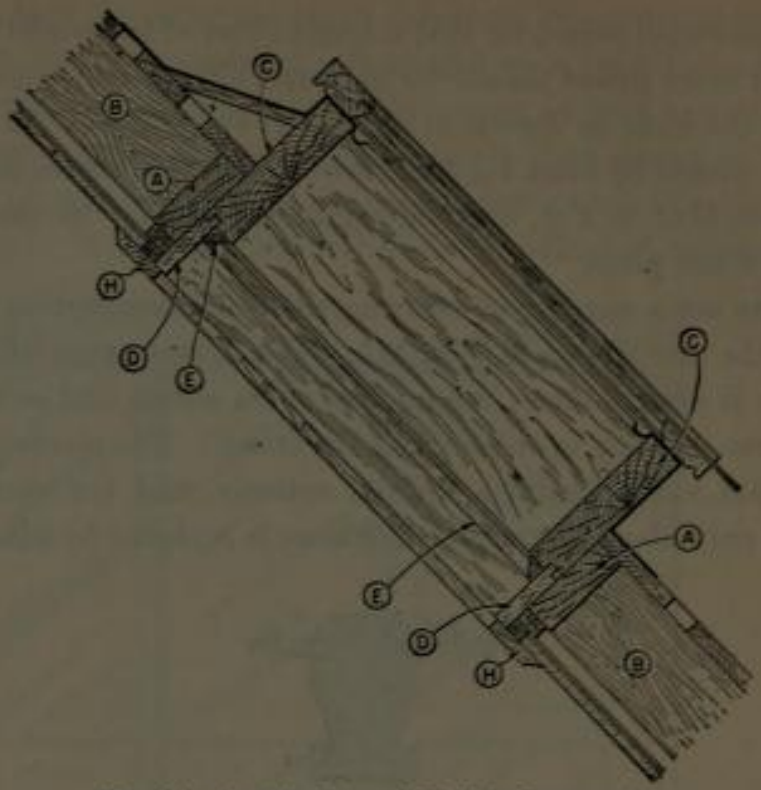


Fig. 414. Another Form of Skylight Construction

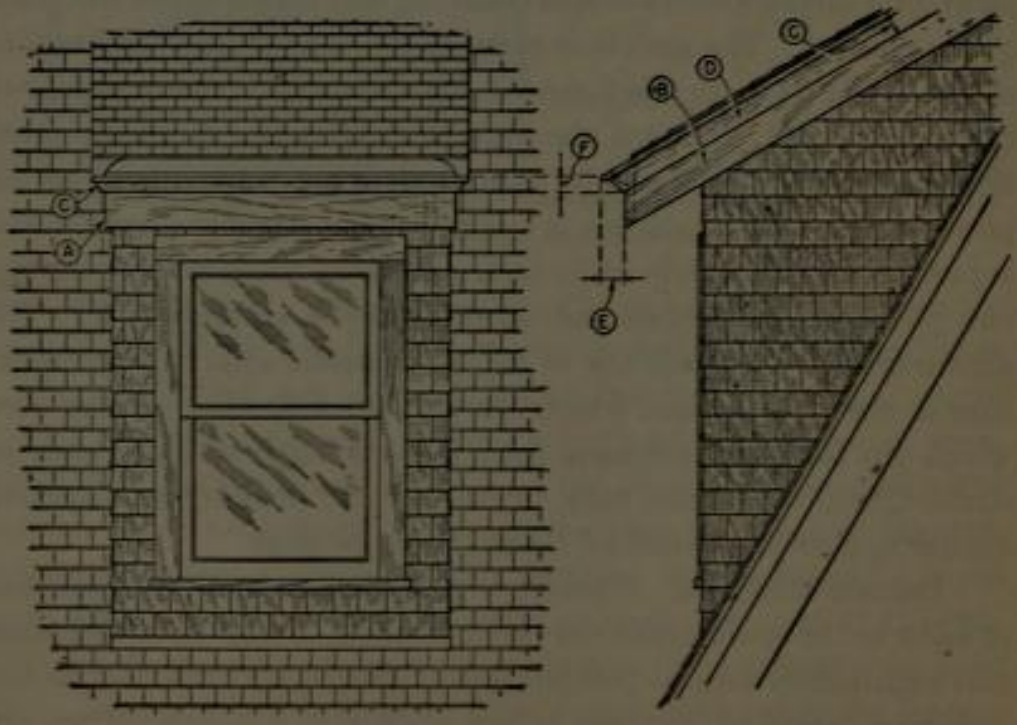


Fig. 415. Front and Side View of Simple Dormer Window

rooms of the houses were under the roofs and were lighted by means of such windows. They are formed by framing an opening in the roof surface in the same way as described for skylights, but on the rafters and on this framing are built up vertical walls of a height sufficient to take a small window set in vertically. The method of building the rough framework has been already described. The walls of dormer windows are treated in the same way as the walls of the main building, being covered with shingles or siding or,

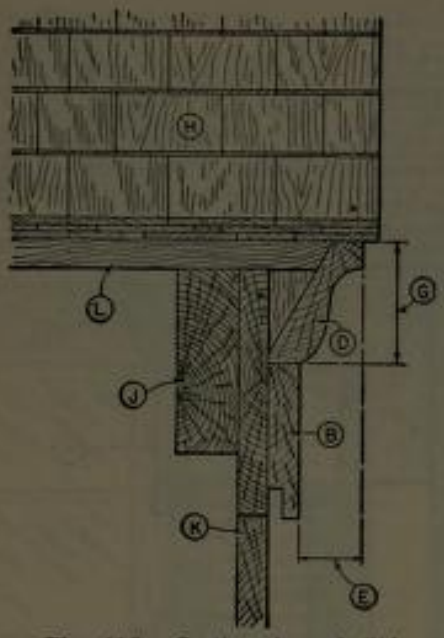


Fig. 416. Section through Side Wall Dormer Window

in some cases, with slates. Fig. 415 shows the most simple form of dormer-window roof. This is a simple roof with a pitch in one direction only, less steep than the pitch of the main roof so as to allow of enough vertical wall in the front part of the dormer to accommodate the window, and uniting with the main roof at a point farther up on this roof. The sides of the dormer are covered solid with shingles or whatever other covering is used, the front only containing an opening. This arrangement is the same for all dormer windows, there being no advantage in putting openings in the sides. The roof, shown in Fig. 415, sheds water onto the main roof in front of the dormer window and, therefore, there should be a gutter along this front and here the eaves should project somewhat over the wall, as shown. At the sides there need be no projecting eaves. A section through the gutter would be similar to that shown

in Fig. 389, though the gutter itself may be a little smaller and the rafters are of course smaller. The piece marked *A* in Fig. 415 serves as a fascia to cover the ends of the rafters and this fascia should be continued up on the sides of the dormer as shown at *B* in Figs. 415 and 416. (Fig. 416 is a section to a larger scale through the side wall of the dormer window near the roof.) This fascia is cut out as shown, to receive the shingles which cover the side walls. The gutter marked *C* runs along the front of the dormer and should

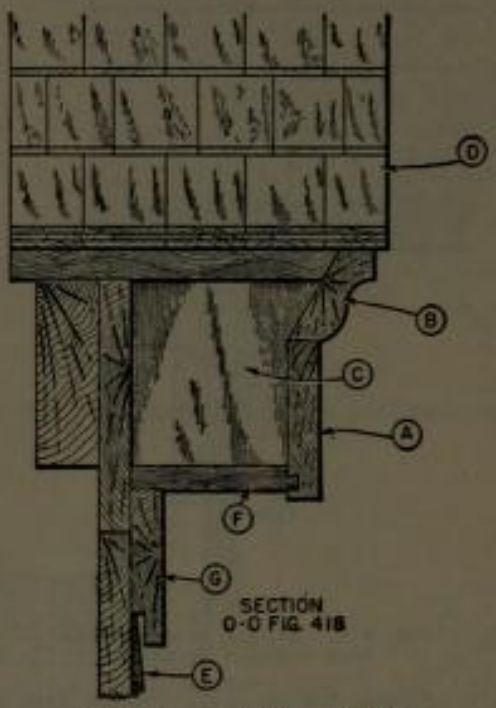


Fig. 417. Section of Dormer Side Wall Showing Boxed Construction

be made to miter at the end with a molded board marked *D*, which runs up on the side. A section through this molded board is shown in Fig. 416. The distance *E* in this figure must be the same as the distance *E* in Fig. 415, but as the distance *G* is not the same as the distance *F* (both in Fig. 415), the profile of the molded board *D* will not be the same as that of the gutter *C*. This is a principle which will often be met with in gable finish. In Fig. 416, *H* is the roof surface of the dormer, *J* is the end rafter, *K* is the boarding on the wall, and *L* is the boarding on the roof. If it is desired that the eaves shall project beyond the walls on the sides as well as on the front for the sake of effect or to better protect these side walls, this

result may be accomplished, as shown in Fig. 417, by blocking out the fascia and the molded board as far as necessary. In this figure *A* is the fascia, *B* is the molded board, *C* is the blocking, and *D* is the roof surface of the dormer, *E* is the side wall of the dormer. The blocking *C* should consist of pieces of 2-inch stuff cut to the required shape and spaced 1½ feet to 2 feet apart along the line of the eaves to receive the finished pieces *A* and *B*. *F* is a soffit piece added to

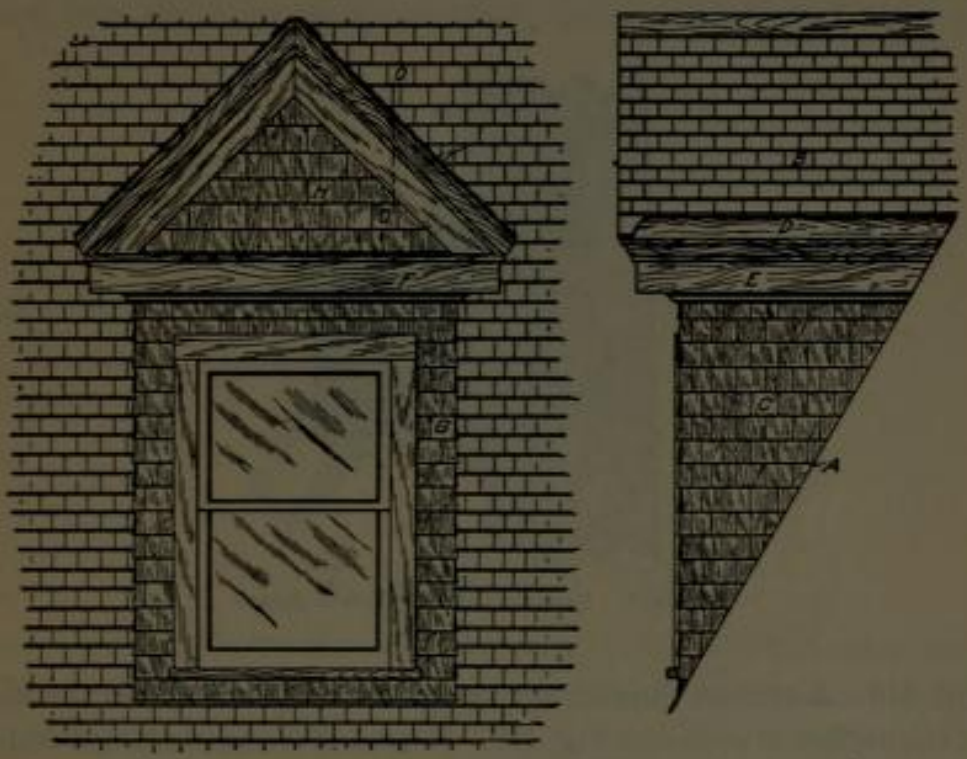


Fig. 418. Dormer Window Construction with Gutters on Side of Dormer Roof

box in the eaves and *G* is a secondary fascia added to receive the shingles or other covering, on the side wall of the dormer.

The type of dormer roof just described throws the water forward onto the main roof of the building, but this arrangement may be varied by allowing the roof to drain sideways like an ordinary double-pitched gable roof. In this case there will be gutters on the eaves at the sides of the dormer window and a gable on the front. Such a window is shown in Fig. 418, in which *A* represents the line of the finished roof surface, while *B* is the roof of the dormer window shown in side elevation, *C* being the side wall of the dormer itself. *D* is the gutter at the eaves. A section through the eaves at *D*

would be very much like that shown in Fig. 390. *E* is a fascia covering the ends of the rafters and the eaves may be either open or boxed in. The fascia *E* is usually continued around the front of the dormer window as shown at *F*, projecting as far as may be desired beyond the front wall *G*. A molded board, cut in such a way as to miter with the gutter, is carried up the side of the gable end, and this piece is generally known as a "raking molding," or a "raking mold." It is similar in shape to the molded board shown at *D* in

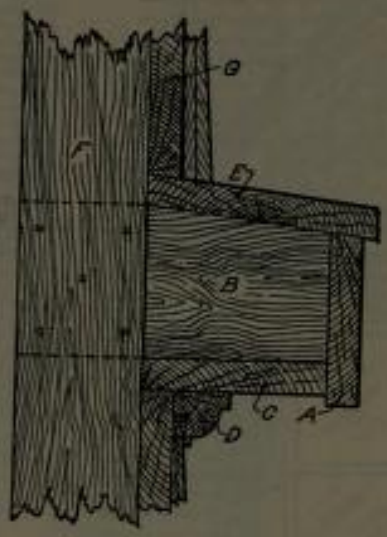


Fig. 419. Section Through Fascia Board

Fig. 416. A section through the fascia where it runs across the face of the dormer is shown in Fig. 419. Here *A* is the fascia board which is nailed to the ends of pieces called "lookouts," about 2 inches thick and spaced from 1 to 2 feet apart, as shown at *B*. The lookouts may be nailed to the studs as shown in the figure or they may be merely nailed to the outside boarding, but the method shown is the better one, as it gives the lookouts a very much firmer support. The under side of the lookouts should be sheathed with $\frac{7}{8}$-inch stuff as shown at *C*, with a piece *D* to receive the shingles. The upper surfaces should be covered also with sheathing and on top of this a covering of galvanized iron, copper, or tin to shed water. Besides this the tops of the lookouts should be cut with a pitch outward, as shown at *E*, to facilitate the shedding of water. In this figure, *F* is the studding of the front wall of the dormer and *G* is the outside boarding which comes in the triangular space marked *H* in Fig.

418. A section through the raking molding *K*, in Fig. 418, is similar to that shown in Fig. 417.

The gutter *D*, at the eaves in Fig. 418, is really unnecessary as the rain water drains from it directly onto the main roof and does not stream down in front of a window since there are no windows in the side walls of the dormer. This gutter may, therefore, very well be omitted.

Although the two types of dormer windows described are the basis from which all other types have been developed, still there are

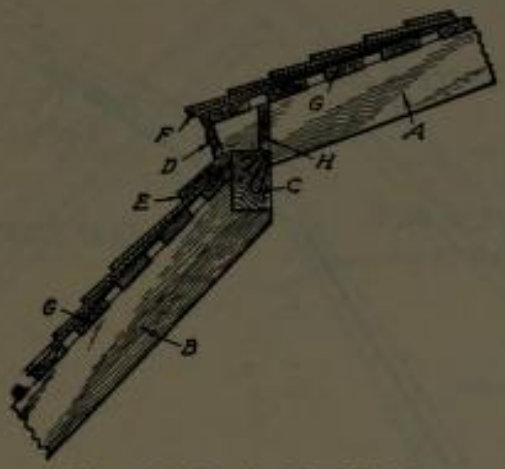


Fig. 420. Gambrel Roof Finish

many kinds of dormers which have quite a different appearance. They are all, however, similar in construction to the two types shown, the difference being in the way in which the wall covering is applied and in variations in the proportion and in the shape of the windows. The ones shown are the simplest of their respective kinds, but they serve to illustrate the manner in which all should be constructed.

Gambrel Roof Finish. The kind of roof known as a "gambrel roof" has already been described so far as the framing of the roof is concerned, but at the point where the steeper part of the roof meets the flatter part, there is a little finish which may well be described and illustrated while considering the roof finish. The rafters *B*, in Fig. 420, stop at the top against a framing piece *C* and the roof boards *G* are nailed to them, but the ends of the rafters of the flatter portion *A* rest on top of the piece *C* and the lower end would be left exposed if it were not covered by the finishing piece *D*. This is of $\frac{7}{8}$-inch stuff and runs continuously across the ends of all the

rafters, covering the spaces between them. It is well, however, to take the additional precaution of putting in the piece *H* so as to make the space under the roof less accessible to the weather. The shingles or other roof covering on the flatter portion of the roof should project over the piece *D* far enough to form a sufficient drip over it, as shown at *F*, and the piece *E* should be inserted to catch the drippings and shed them onto the shingling of the steeper roof.

A form of finish similar to that described above may be used

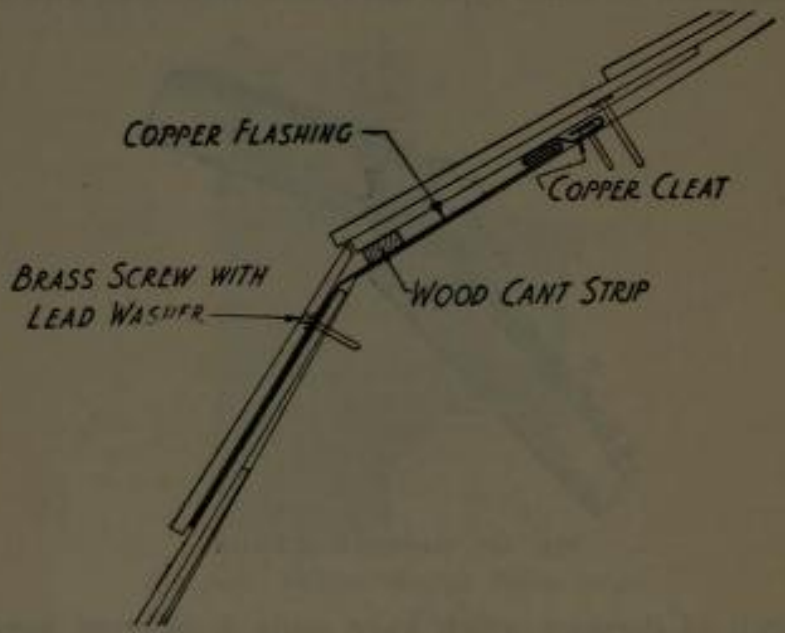


Fig. 421. Concealed Flashing-Mitred Joint
Courtesy of Copper and Brass Research Association

in the case of a deck roof at the point where the flat deck meets the inclined roof surface. The only difference between the deck roof and the gambrel roof finish shown in Fig. 420 is that the rafters *A* will be nearly flat instead of inclined, but this will not affect the application of the finish.

The flat deck of course would not be covered with shingles but would have full sheathing and would be finished with sheet metal or a composition roofing of tar and gravel.

In the better class of work the piece *E* should be well and thoroughly covered with sheet metal flashing in the same way as was described in connection with the saddle boards at the ridge of a roof. (See Fig. 401). Very often the member *D*, Fig. 420 is just a plain board and is covered with sheet metal flashing. Some-

times the gambrel roof is framed up in such a way that at the junction of the two sloping surfaces there is no need for the finishing piece, *D*, Fig. 420, because the two roof slopes meet in a line at this point. It is then necessary to flash very carefully with sheet metal all along this line. Fig. 421 illustrates how this can be done without exposing the sheet metal flashing, which is entirely covered up by the shingles.

The eaves of a gambrel roof which usually occur at or near

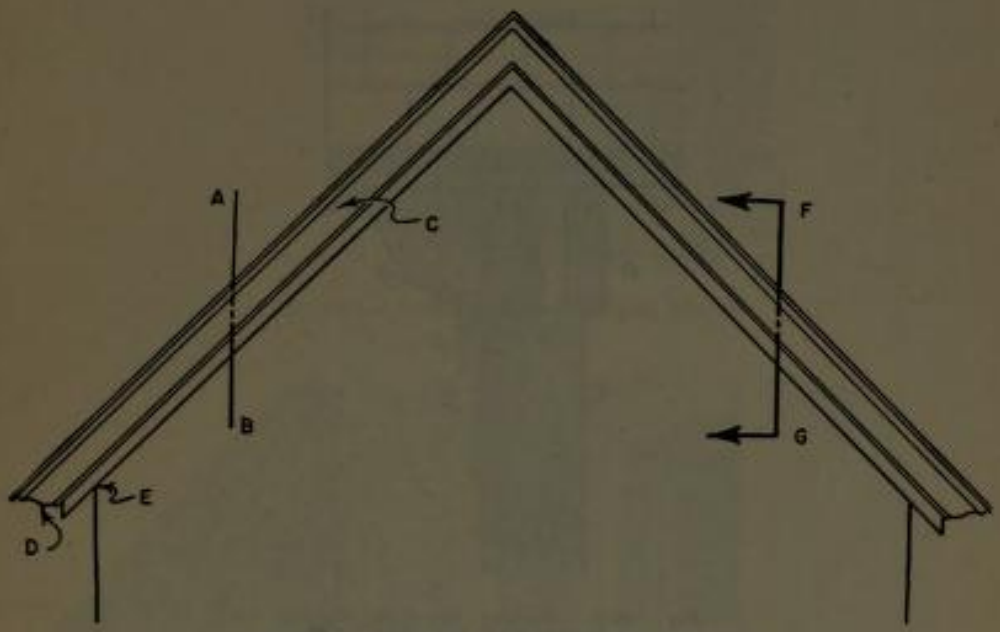


Fig. 422. Diagram of Simple Gable End of a Building

the level of the first floor ceiling are finished as a rule in much the same way as the eaves of any of the sloping roofs already described. In most cases there will be a boxed cornice and gutter provided at this point.

Gable Finish. We have seen that when a dormer window is designed with two sloping roof surfaces, there is thus formed on the front of the dormer a triangular-shaped surface which must be decorated in some way and which calls for a certain amount of finish. The same thing is true of the main roof when this is designed as a gable roof, the triangular surfaces at the ends of the building being known as "gables." The problem which presents itself here is to treat the lines in which the roof surfaces meet the vertical wall surfaces at the ends of the building, and to cover up the rough lumber

of both the wall and the roof. The most simple way of doing this is to miter the gutters at the sides of the building at the line of the eaves with a raking molding which will follow the line of intersection between the roof surfaces and the gable wall. In the plainest work this raking molding will not project much beyond the wall line, only far enough to miter properly with the gutter. Fig. 422 shows a very simple gable end of a building with no finish except the raking molding, referred to above, mitering with the gutter at the eaves. In

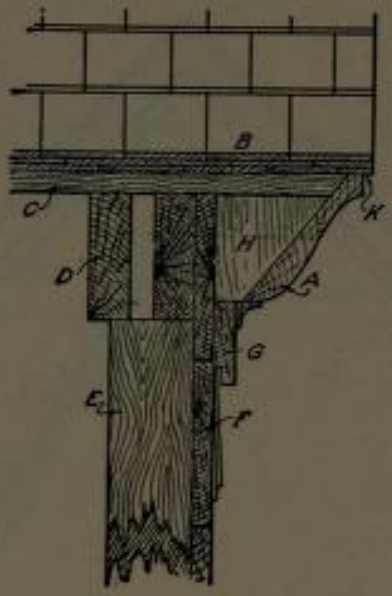


Fig. 423. Section through Raking Molding of Fig. 422.

this figure, *C* is the raking molding, *D* is the gutter. In Fig. 423 is shown a large-scale section taken through the raking molding on the line marked *A-B* in Fig. 422. In Fig. 423, *A* is the raking molding, *B* is the roof shingling, *C* is the roof boarding, *D* the rafters, *E* the end wall studding, *F* the outside boarding on the end wall of the building, and *G* the fascia below the raking molding. The molding is so arranged that the roof boarding stops against it and the roof shingling passes over it and projects a little beyond it so as to form a drip as shown at *K* in Fig. 423. In the space marked *H* is blocking consisting of rough pieces spaced 2 to 3 feet apart and shaped to take the back of the molding.

There is an awkward place at the point marked *E* in Fig. 422, where the line of the gable meets the vertical line of the corner of the building, and some finish is usually placed here to overcome this

awkwardness. In the small gable on the end of the dormer shown in Fig. 418 the fascia is carried across the face of the gable as well

Fig. 424. Common Type of Gable Finish

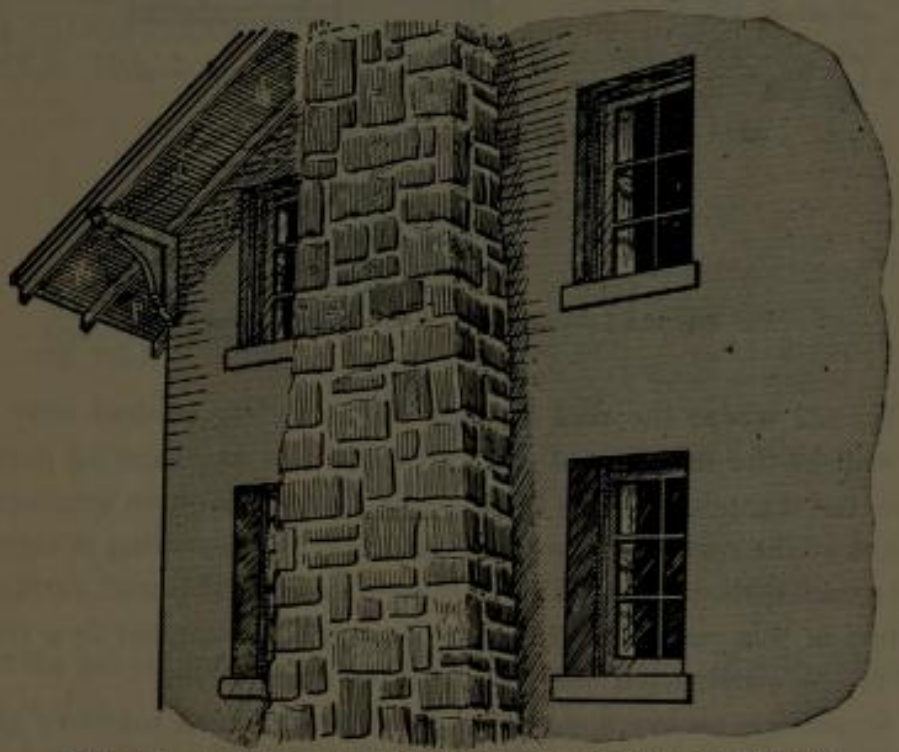


Fig. 425. Another Type of Finish for Point Marked E in Fig. 422

as along the raking line of the roof, and this arrangement is sometimes adopted on larger gable ends, but a more common practice is only to start the fascia across the gable end wall and then return it

on itself a foot or two from the corner marked *E* in Fig.422, stopping the raking fascia on top of it. This is shown in Fig. 424. A better result is obtained by returning the gutter molding as well as the fascia. The top of the return marked *A* in the figure should be sloped outward slightly so as to shed water. *B* and *C* are additional fascia boards which are added to give additional width to the raking moldings.

Figure 425 shows another type of finish for the point marked *E*

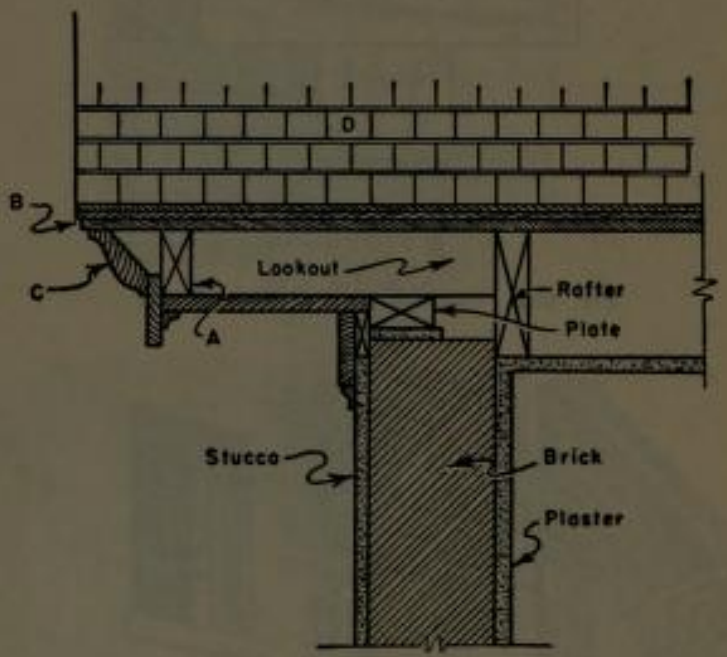


Fig. 426. Section Taken through Gable End

in Fig. 422 where the roof surface is allowed to project over the end wall of the building at the gable and the overhanging portion of the roof is supported on a finishing rafter resting on an ornamental bracket at the corner of the building. The roof boarding is exposed on the underside and would have to be dressed. The wall surface is finished in this case with stucco which might be applied to a frame wall or one constructed of brick or of terra cotta tile.

Sometimes an overhanging roof of this kind on a masonry gable end wall is cased in with outside finish which is supported by "look-outs" which are cantilevered out over a plate resting on the sloping upper surface of the brick or terra cotta tile wall. Fig. 426 shows a section taken through such a gable end on the line *F G*, Fig. 422. The brick wall is shown finished with stucco on the outside and with

plaster on the inside. There is a rafter, close against the wall on the inside. The lookouts may be about 2 inches x 4 inches spaced 16 to 24 inches apart and they support a small sloping rafter, *A*, at their outside ends. In this case, the roof boarding *B* projects out

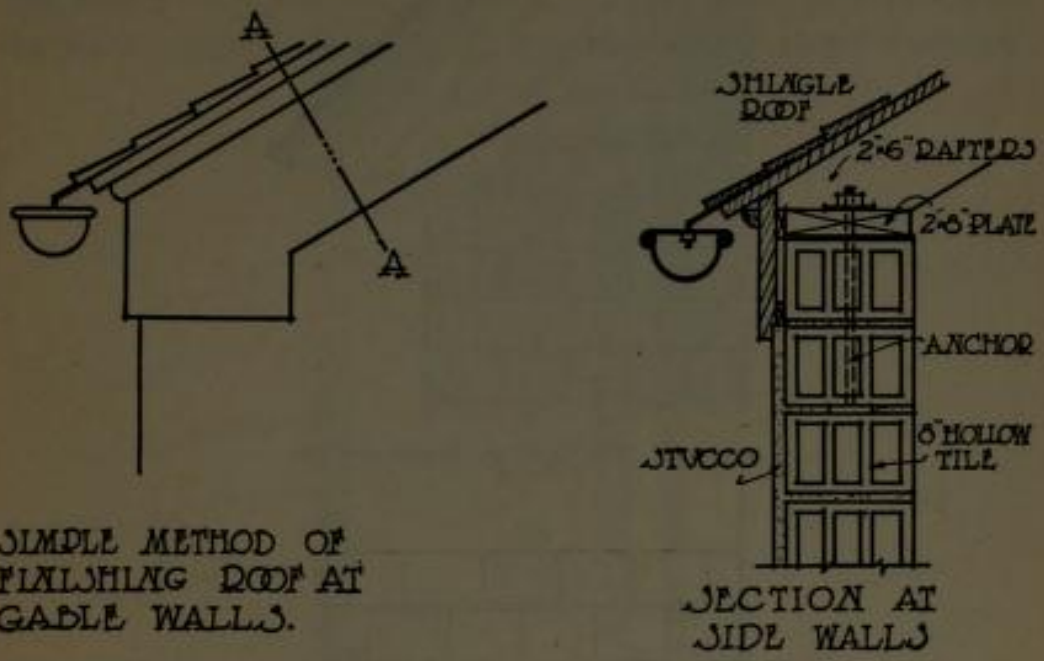


Fig. 427. Typical Side Construction with Flush Eave

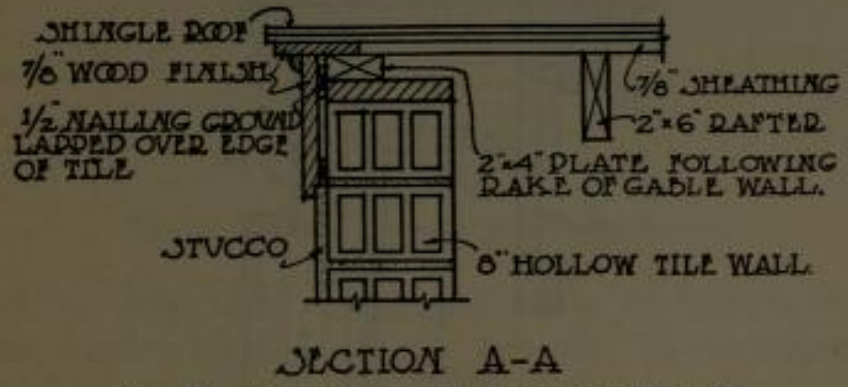


Fig. 428. Typical Side Construction with Flush Gable

over the raking moulding *C* and must be dressed. *D* is the shingled roof surface.

At times the masonry wall is carried straight up above the roof surface and the roof stops against it as shown in Fig. 396.

Often the gable end finish is kept close against the end wall of the building with very little over-hang. This is illustrated in Fig. 427, which shows the end view of the corner and also a section

through the side wall. Both walls are constructed of terra cotta tile finished on the outside with stucco. Fig. 428 shows a section through the end wall on the line *A A*. In this case, there is no rafter

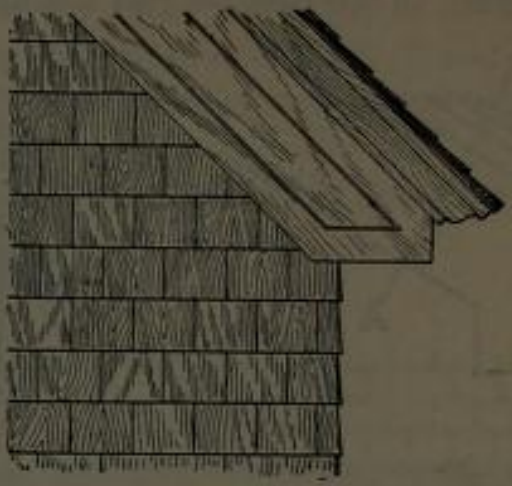


Fig. 429. Use of Verge Board as Gable Finish

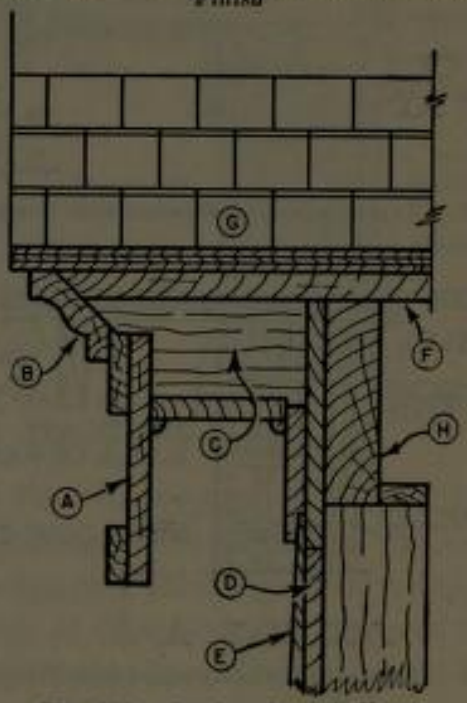


Fig. 430. Section through Verge Board and End Wall

close up against the end wall but the plate on the sloping upper surface of the wall serves to support the ends of the roof boarding.

Verge Boards. It is a common practice to use what are called "verge boards" for the finish of the gable ends of buildings. These are a kind of ornamental rafter which follows up the rake of the roof, not along the wall but some distance from it, being held in place

by lookouts which are nailed to the studding or to the boarding and placed at the proper distances apart. The verge board forms a stop for the gutter and furnishes a very suitable finish for the gable. It is usually crowned with a raking molding of some sort and is, therefore, only a big fascia. Fig. 429 shows a verge board in elevation at the point where it joins the eaves, and Fig. 430 shows a section

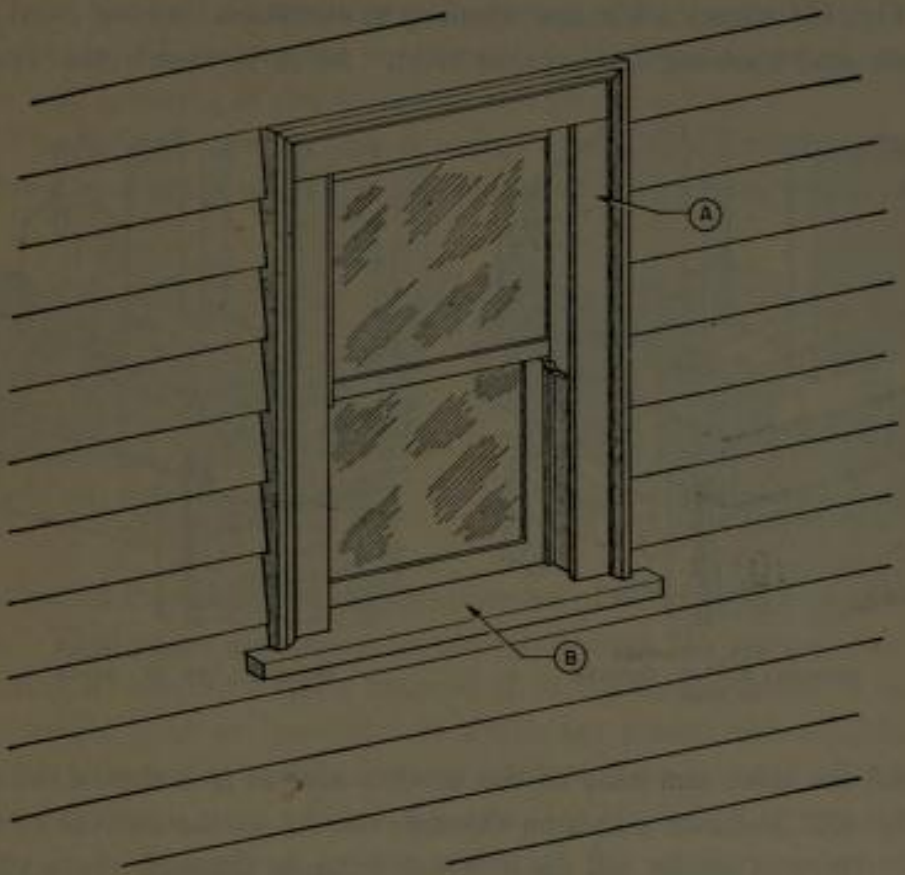


Fig. 431. A Window Opening in Elevation Showing Outside Trim

through the verge board and the end wall of the building showing how the board is supported by the lookouts. In this figure, *A* is the verge board, *B* is the raking molding, *C* is the blocking which forms the lookout, *D* is the outside boarding of the wall, and *E* is the wall shingling, *F* is the roof boarding, *G* is the roof shingling, and *H* is one of the rafters.

WINDOW AND DOOR FINISH

Outside Finish Around Windows. Wherever there is an opening in the wall of a wood building, such as a window or a door, the outside finish, consisting of shingling, siding, or other covering, has

to be stopped, and if no special provision were made for the finish around the opening there would be as a result a very ragged appearance. In order to avoid this it is customary to place all around the window opening pieces of finished lumber which are known as *outside trim*, *outside architrave*, or *outside casing*. These pieces form a stop for the wall covering.

Fig. 431 shows a window opening in elevation looking from the outside and showing the outside trim. At *A* is shown the casing

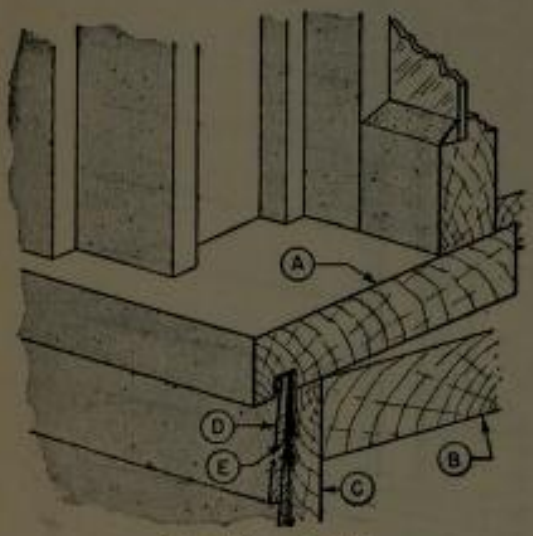


Fig. 432. Section through Sill at Outside of Wall

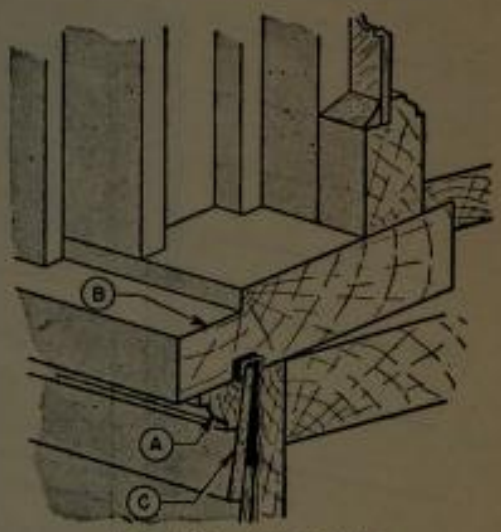


Fig. 433. Sill Details Showing Use of Apron

around the sides and head of the window and at *B* is shown the sill. In Fig. 432 is shown a section through the sill at the outside of the wall. Here, *A* is the sill itself which extends through the wall to the inside and receives the sash as will be explained later; *B* is the rough framing for the opening and this piece goes between the vertical studding at the sides of the rough opening; *C* is the outside boarding attached to the studding; *D* is the wall covering of shingles or clapboards; and *E* is building paper which must be placed between the outside boarding and the wall covering. It will be noticed that the under side of the sill is ploughed to receive the shingles or clapboards and that it projects out over the wall line a distance of about 1 inch, so as to let rainwater drip to the ground without touching the wall. This figure shows the simplest sort of sill, such as would be used only for very cheap work. In more important work it is customary to add another piece, called an "apron," under the pro-

jecting part of the sill, as shown in Fig. 433, where *A* is the apron, *B* is the sill, and *C* is the wall covering. The purpose of the apron *A* is to cover the joint between the wall covering and the sill and to give it a finished appearance. Fig. 434 shows a section taken through the side or jamb of the window shown in Fig. 431. Here, *A* is a section through the vertical studding at the sides of the rough opening, *B* is the outside architrave or casing with the molding *C* attached to it, *F* is the outside boarding, *G* is the building paper, and *E* is the wall covering of clapboards or shingles or siding.

The outside architrave *B* is nailed at one side directly into the studding, and at the other side it is ploughed so as to join into another

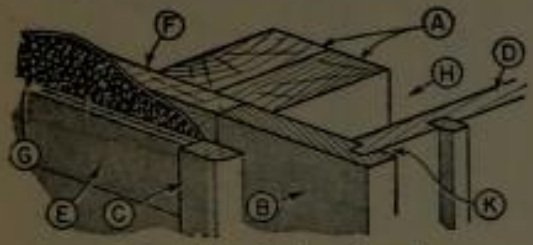


Fig. 434. Section through Window Jamb

Fig. 435. Another Form of Window Jamb Construction

piece called the "pulley stile," the purpose of which will be explained later. This pulley stile must be placed at least 2¼ inches from the studding *A*, leaving a space marked *H* in the figure, which is called the "weight box" or "pocket," in which are placed the weights for operating the window. The arrangement of these weights will be explained in detail later. It will be seen that the width of the outside casing *B* is determined by the width of the weight box which it has to cover. It will also be seen that the casing *B* projects beyond the pulley stile *D* by a small amount at the point marked *K* in the figure. This projection is usually about ½ inch and is for the accommodation of the sashes. The purpose of the molding *C* is to form a projection against which the shingling or the clapboards can be stopped. The building paper *G* should be carried around as shown and the wall covering placed over it, so as to thoroughly cover the joint between the outside boarding and the molding *C*. This is to keep the weather from entering the building through this joint. If more room is required in the weight box this may be obtained by setting the outside casing *B* outside of the outside boarding, as shown in Fig. 435. The molding *C* may then be dispensed with if

desired, since it is no longer required as a stop for the wall covering, which can stop against the edge of the outside architrave *B*.

In Fig. 435 the weight box is shown narrower. This is possible because special weights are now manufactured which do not require a wide weight box.

Fig. 436. Window with Blinds in Wide Open Position

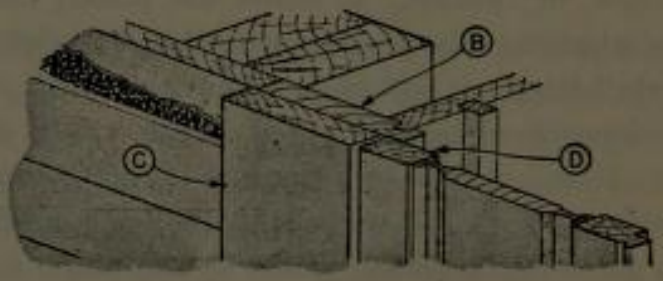


Fig. 437. Section Shows How Blind Fits into Recess Formed by Outside Casing

Although the moulding on the outside architrave is not required as a stop for the wall covering when the architrave or outside casing is placed outside of the outside boarding, some sort of moulding is very useful in this location for the purpose of forming a hanging stile to receive the hinges or butts for the outside blinds or shutters when these are used. Fig. 436 shows a window with these blinds in a wide open position while Fig. 437 shows in section how the blind *D*

fits into the recess formed by the outside casing *B* and the piece *C*.

In the more northerly parts of the country, where the summer sunshine is less strong, blinds or shutters, though often used are not so necessary as they are in the south, but the cold of the winters makes it essential to have an extra sash or set of sashes outside of the regular window sash to retard the escape of heat from the building through and around the windows and to keep out the cold winds. Such "outside" sash or "winter" sash or "storm" sash is similar to

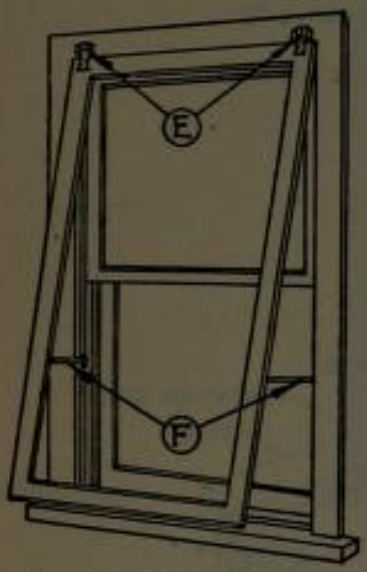


Fig. 438. Modern Manner of Hanging Winter Sash and Blinds
Courtesy of The Stanley Works

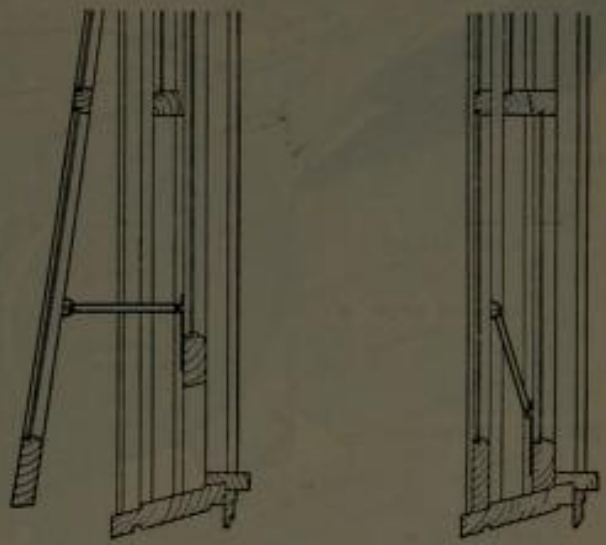


Fig. 439. Section Showing a Double Hung Window Frame with Storm Sash
Courtesy of Andersen Frame Corporation

the blinds or shutters except that it has its panels glazed so as not to obstruct the passage of light. This sash is frequently hung in the same recess which accommodates the blind *D* in Fig. 437 and such storm sashes were formerly hinged at the sides, as a rule, just as in the case of the shutters. The more modern way of hanging both winter sash and blinds, however, is to hinge them at the top to swing outward and this is for many reasons a great improvement over the older method. Winter sash hung in this way may be seen in Fig. 438. At *E* are shown the hinges and at *F* are shown "fasteners" for holding the sash open or closed. Fig. 439 shows in section a double hung window frame with storm sash hung in this way and fitted with special patented hardware in the form of operators which automatically open the storm sash whenever the lower sash

of the window is opened for ventilation, but holds it in such a position as to keep out most of the wind and rain. Whenever the inside sash is closed, the storm sash is automatically closed also.

Pulley Stile. In Fig. 434 we have seen that the piece *D*, called

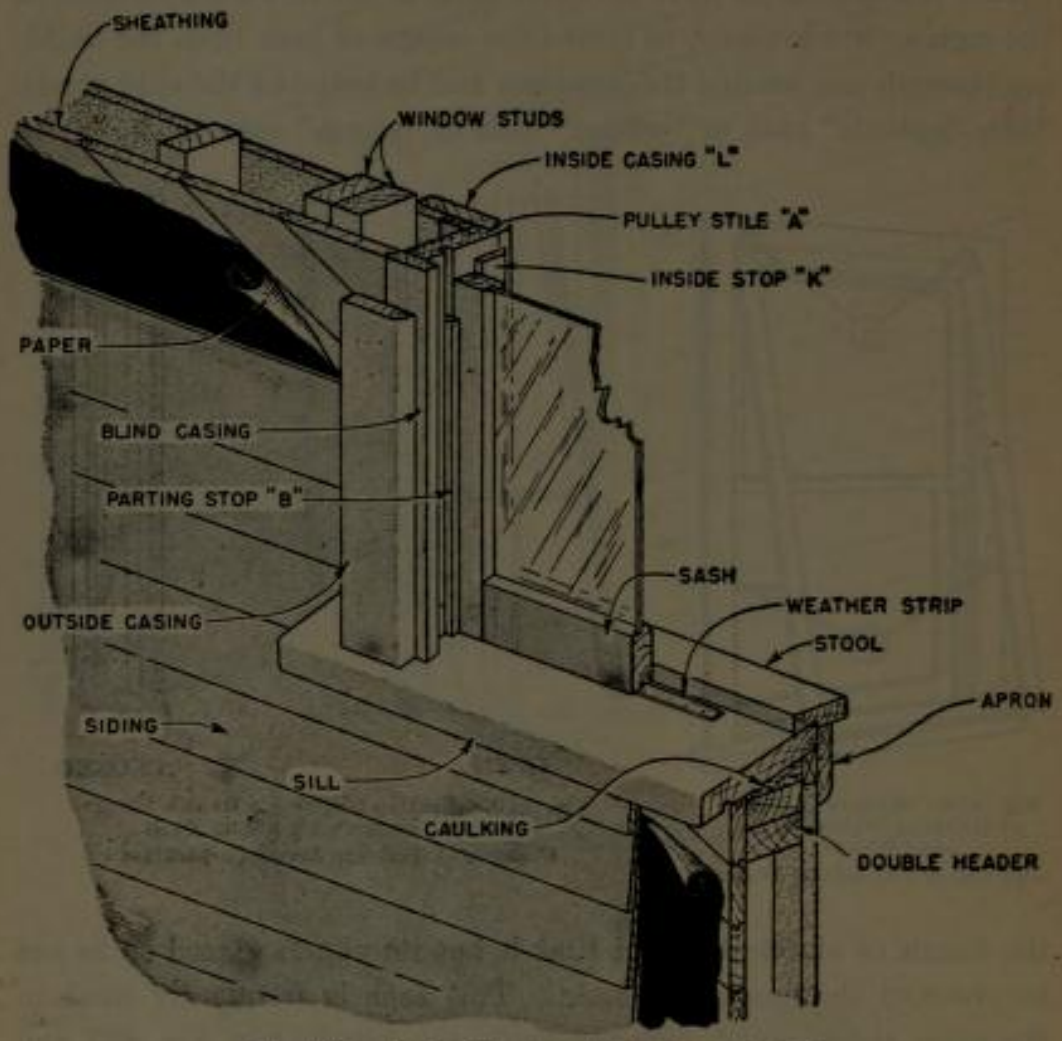


Fig. 440. Section Showing Window Frame and Casing

Courtesy of Weyerhaeuser Forest Products

the pulley stile, forms one side of the box where the weights for the window sashes are concealed, and that it is fastened to the outside architrave by a tongued and grooved joint. Besides forming one side of the box for the weights, the pulley stile acts as a guide for the sashes, which slide up and down in grooves formed by the outside architrave, the parting strip, and the stop bead, as is shown in Fig. 440. In this figure, which is a section taken horizontally through the

window jamb, *A* is the pulley stile, which should be 1⅛ inches thick but may be made ⅞ inch thick if the windows are not large. *B* is the "parting strip," so called because it comes between the sashes and separates them from each other. It is let into the pulley stile as shown, and is usually ⅜ inch thick and about 1 inch wide. It must extend the full height of the pulley stile. *K* is the "stop bead," so called because it comes in front of the inside sash and holds it in place, forming one side of the groove in which the sash slides. The

Fig. 441. Sash Cord Pulley

Courtesy of American Pulley Company

other side of the groove is formed by the parting strip, as shown in the figure. The stop bead is really a part of the inside finish, and is usually made of hard wood. It is screwed in place so that it can be easily removed, and when it has been taken out the sashes themselves can be removed also. The stop bead must be wide enough to go a little past the edge of the pulley stile and lap over onto the piece *L*, which is a part of the inside finish called the "inside casing." The stop bead thus covers the joint between the outside and the inside finish. In Fig. 440 it will be seen that the outside casing, the parting strip *B*, the stop bead *K*, and the pulley stile *A*, together form a sort of pocket about the edges of the sashes, in which they

slide up and down freely but out of which they can not fall either toward the inside or toward the outside of the building. Figure 439 shows a section through a window sill and shows the pulley stile, parting strip, and stop bead or inside stop in elevation. The upper and lower sashes are shown side by side in the grooves on

Fig. 442. Window Frame Complete with Sash Cord Pulleys
Courtesy of Andersen Frame Corporation

each side of the parting strip where the lower sash can slide up and the upper sash can slide down. Near the top of the pulley stile there are cut in it two mortises and in the mortises are placed pulleys about two inches in diameter made especially for the purpose. Fig. 441 illustrates one of these pulleys and Fig. 442 shows a window frame ready to be put into the wall of a building with the pulleys in place.

A stout cord about ¼ inch in diameter or chain such as those shown in Fig. 443 is attached to the side of the sash and passes over the pulley into the weight box, where it is attached to a weight made of cast iron or lead which serves to balance the window sash and make it work more easily. There are two pulleys in the top of the pulley stile, one for each of the sashes. In Fig. 444, which is a

Fig. 443. Sash Chain and Cord

Fig. 444. View of Upper Part of Pulley Stile

view of the upper part of the pulley stile looking at its edge from the outside, one of the pulleys is shown at *A*. This figure also shows the top of the pulley stile *C* let into the yoke *G* about ½ inch. This is shown at *B*. It is the usual method of fastening the pulley stile at the top. In the figure *F* are the upright studs at the sides of the rough window opening, and *E* are the rough pieces which form the top of the rough opening. *D* is the parting strip which occurs at both the side and the top of the window opening.

In Fig. 445 is shown a section taken vertically through the top of a window frame of this type. *A* is the yoke, sometimes called the "head-jamb," which should be 1⅛ inches to 2 inches in thickness; as explained above, it should be long enough to pass over the top of the pulley stile on both sides and allow this member to be let into it. The space *K* between the yoke and the rough framing *E E* is filled with rough blocking. *F* is an outside casing similar in all respects to that which occurs at the sides of the opening. It is ploughed to receive the yoke, as shown. *B* is the parting strip, the

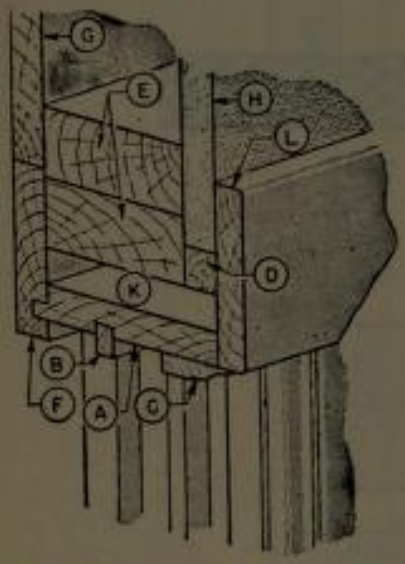


Fig. 445. Vertical Section of Top of Window Frame

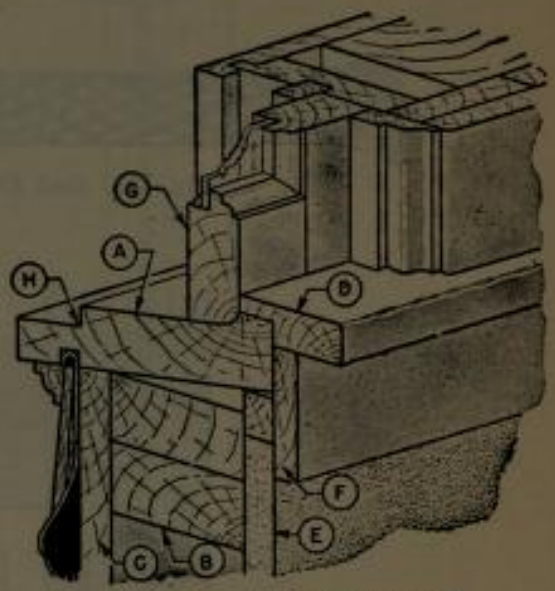


Fig. 446. Section Showing Sill Construction

same size as that on the pulley stile described above, and *C* is the stop bead. *L* is the inside architrave or "inside casing." *E E* is the rough framing which runs over the top of the opening between the vertical studding at the sides of the opening, *G* is the outside boarding, and *H* is the plastering inside, *D* being what is known as a "ground," to which the inside casing, *L*, is nailed.

Sill. In Fig. 446 is shown a section taken vertically through a window sill, showing the sill complete. Here *A* is the sill itself, which will be seen to extend through the wall far enough to receive the inside sash *G*. The top of the sill is cut with a slope downward and outward, which is known as a "wash," and the purpose of which is to carry off the rain water which may be driven against the glass of the window and drip down from there to the sill. This slope or

"wash" is often made as much as three inches to the foot. *C* is the outside boarding, *B* is the rough framing, and *E* is the plaster. *D* is a part of the inside finish called the "stool" and *F* is another piece called the "apron," which together cover up the edge of the sill on the inside. The pulley stile is let into the sill about ½ inch in a manner similar to that in which it is let into the yoke at the top, and the sill is made long enough to extend a little beyond the back of the pulley stile on both sides just as is the yoke. Thus the two pulley stiles at the sides and the yoke at the top, together with the sill at

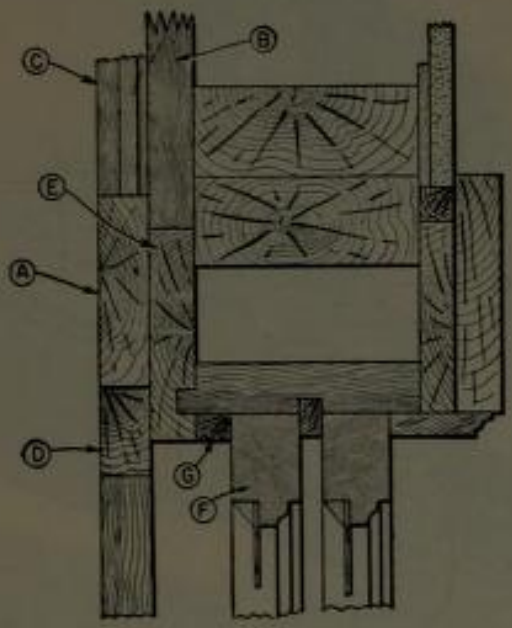


Fig. 447. Horizontal Section through Window Jamb

the bottom, form a complete frame called the "window frame," which is usually made up at the mill and taken to the building in one piece, where it is set up in place inside of the rough-framed opening. Fig. 442 shows such a frame without the yoke. In Fig. 446 the slight rabbet in the sill shown at *H* is intended for a stop for outside blinds when these are used. In this case the blinds are hung as shown in Fig. 447, which is a section taken horizontally through the window jamb. *A* is the outside architrave, which is placed in this case outside of the outside boarding *B* for the purpose of receiving the blinds. It serves at the same time as a stop for the wall covering *C*. *D* is the blind, and *E* is a piece put in to form the weight box and known as the "outside casing," also sometimes called the "outside liner" and "blind stop" or "blind casing." This figure also

shows at *G* a small block which may be inserted between the outside casing and the sash *F* in order to fill up the space and push the sash nearer the inside wall line. To this small block a strip may be nailed which will take a sliding fly screen, or this screen strip may be nailed to the edge of the blind stop, *E*. The block *G* may be made wider so as to take a screen strip which will accommodate a double

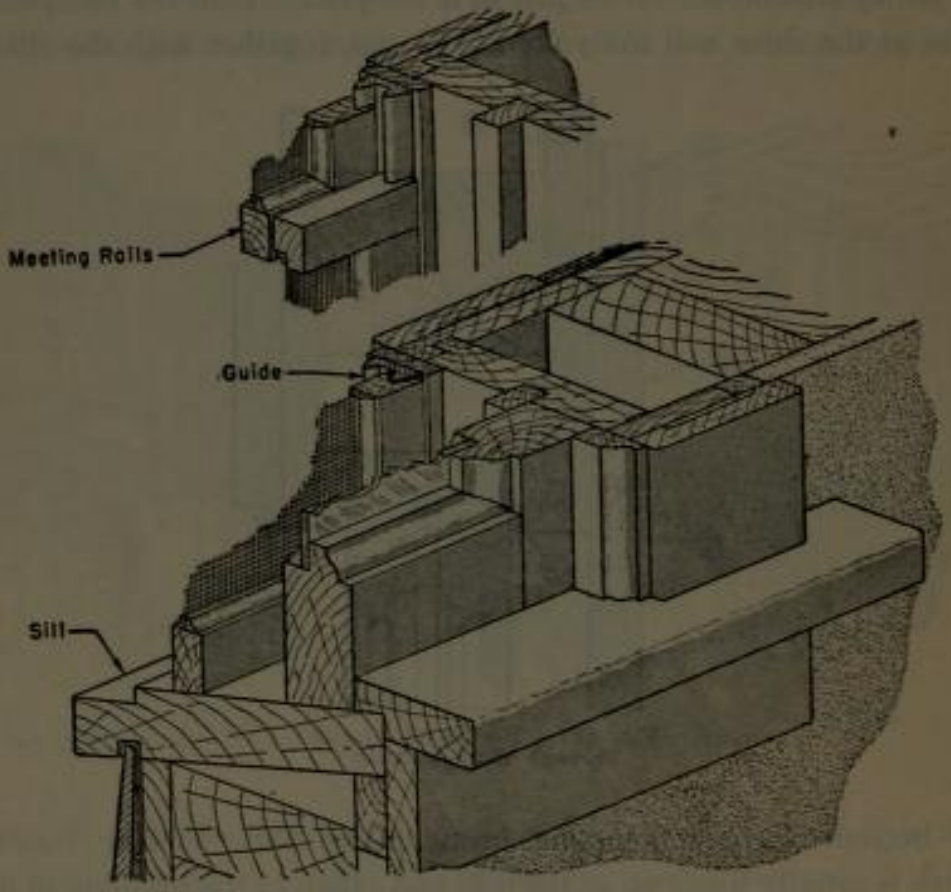


Fig. 448. Section through a Window Having a Double Hung Screen
Courtesy of International Nickel Company

hung screen with both upper and lower sections which will slide up and down on the screen strips. Fig. 448 shows a section through a window having such a double hung screen, and Fig. 436 shows how such a screen looks from the outside. When the thickness of the wall is such that there is not room for the block *G* (Fig. 447) the screen is usually made only large enough to cover the lower sash of the window and is made to slide up and down on a screen strip nailed to the edge of the blind stop. Fig. 449 shows a section through such

a window with the outside screen shown in place. This figure also shows by the dotted lines how a screen may be placed on the inside of the window sashes sliding on a guide strip attached to the stop bead.

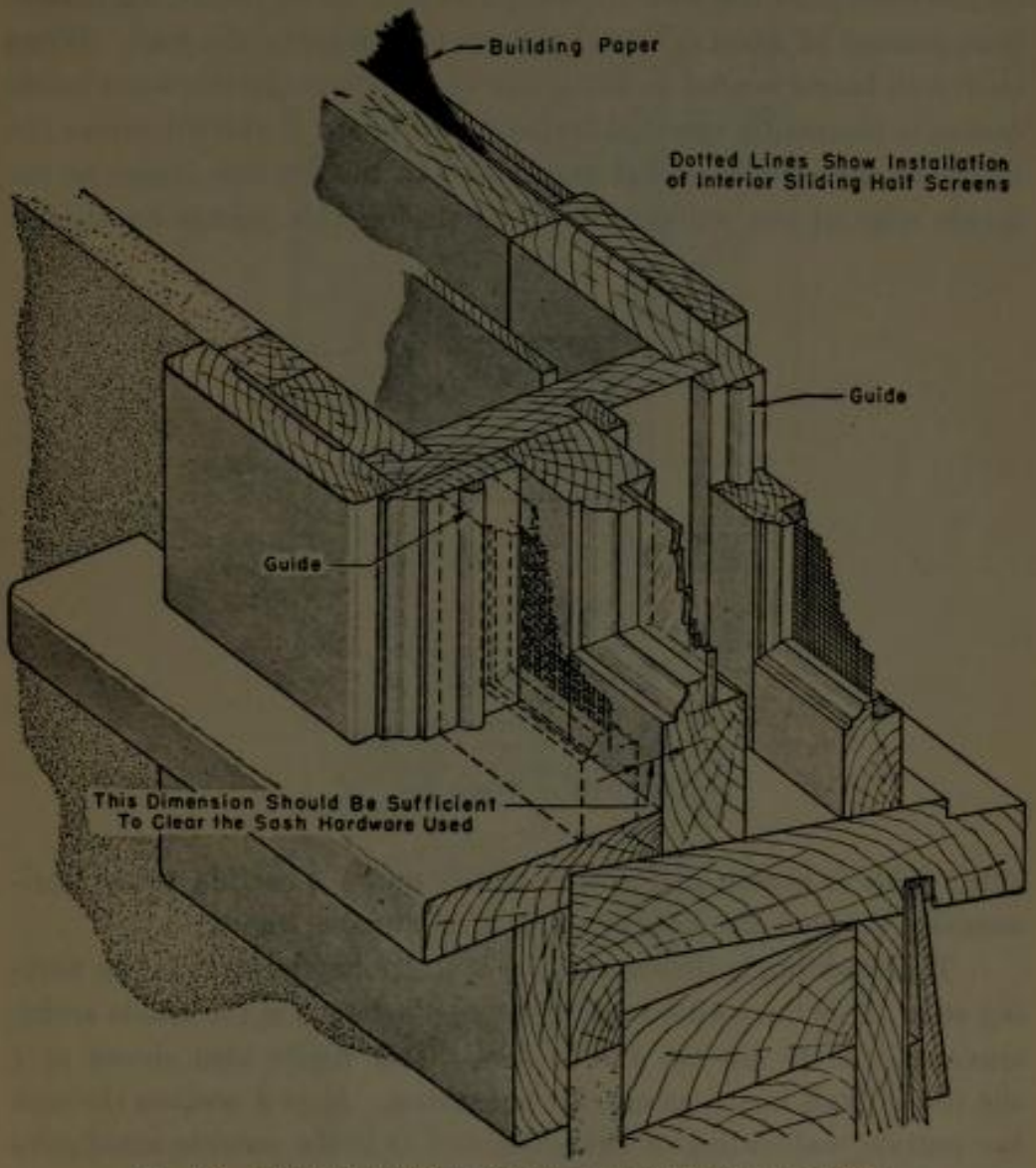


Fig. 449. Section through a Window Having an Outside Screen
Courtesy of International Nickel Company

Figure 447 also shows on the inside of the wall at the weight box an extra member *E* called the "inside casing" or "inside liner" which is frequently added underneath the inside architrave. It is especially useful in colder climates as the use of it makes the wall construction much tighter against the cold winds around the windows

than it would be with only the inside architrave to cover the inside of the weight box as is shown in Fig. 450.

It is becoming increasingly the custom to employ some form of manufactured wall board to take the place of the wood sheathing on the outside of the wall studding and also as an insulating plaster base instead of wood or metal lath on the inside of the wall. When such wall board is used on the inside of the studding, the wood inside casing is frequently omitted and the wall board is carried across the inside of the weight pocket and nailed to the window frame at the inside edge of the pulley stile, thus closing this pocket on the in-

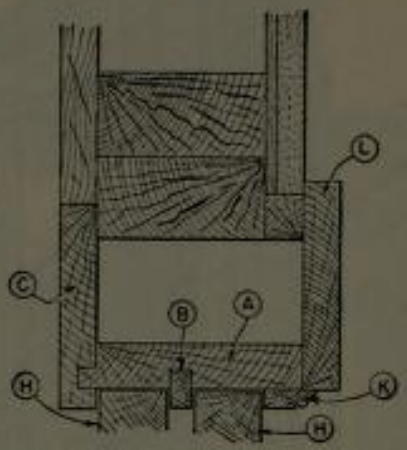


Fig. 450. Section Showing Condition Where Only the Inside Architrave Covers Inside of Weight Box

side. This is shown in Fig. 451 which shows a section taken horizontally through the side or jamb of a window frame.

The studding is shown at *E*; *A* is the pulley stile; *B* is the parting strip; *D* is the wall board; *G* is the plaster; *L* is the inside architrave and *H H* are the two sashes. This figure also shows at *I* the use of wall board as outside sheathing. *M* is a section through the outside wall siding or shingling and *O* is the outside architrave with the outside casing *C* of the window frame made wide enough to allow it to be nailed to the vertical studding at the sides of the window opening. *K* is the stop bead or inside stop.

Figure 381 illustrates the use of wall board on the inside and outside of the wall studding.

Figure 452 shows, in a similar way, how the inside surface of an outside wall may be finished with one of the many wall boards

available without plaster, and how this wall board may be carried across the inside of the weight pocket and nailed to the inner edge of the pulley stile. In this figure, *D* is the wall board and the other

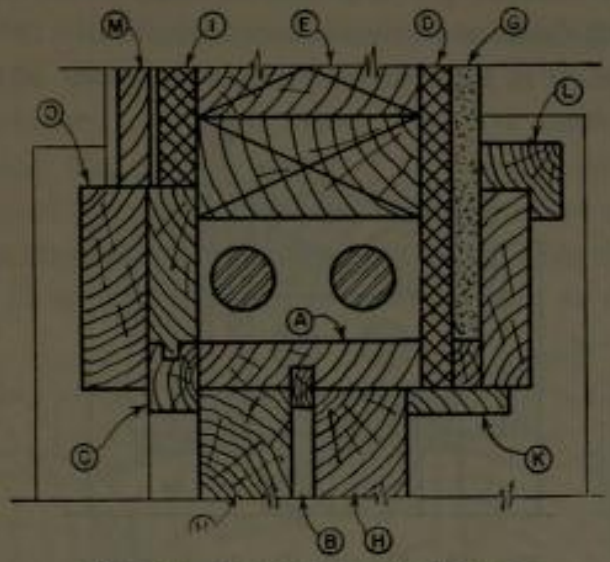


Fig. 451. Section Taken Horizontally through Jamb of Window Frame

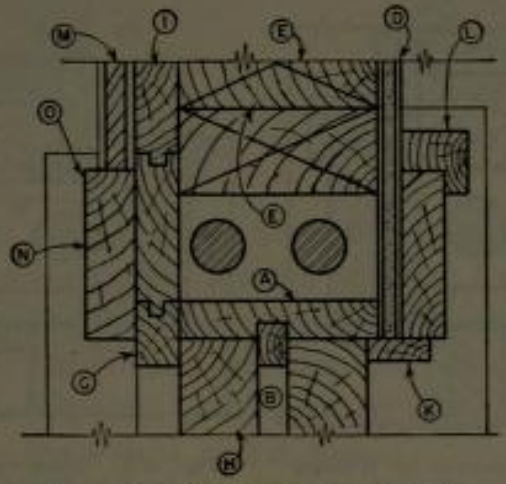


Fig. 452. Showing How the Inside Surface of an Outside Wall May Be Finished with a Wallboard

parts are designated by the same letters as were used in Fig. 451, except that there is no plastering and at *I* is indicated the use of the ordinary wooden outside boarding instead of a manufactured insulating wall board. The piece marked *N* in this figure, forming the outside casing, is frequently not furnished as a part of the window frame especially if the frame is purchased from a mill where

it will have to be shipped some distance by freight. This piece can be bought and put up as a part of the outside boarding and may be of the same kind of wood as the rest of the outside boarding which is usually of a cheaper grade of lumber than is the window frame.

Figure 453 shows a section taken horizontally through the side of a window frame in a frame wall where the inside of the wall stud-

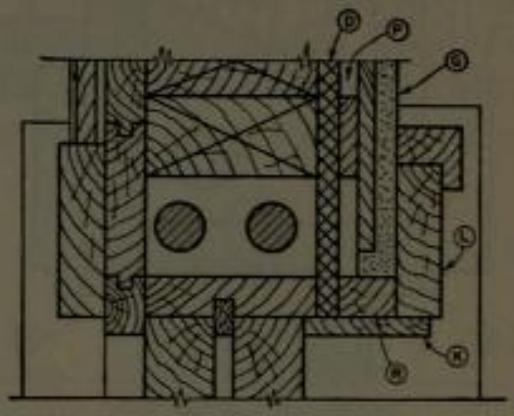


Fig. 453. Showing How Inside of Wall Studding Can Be Covered with an Insulating Board

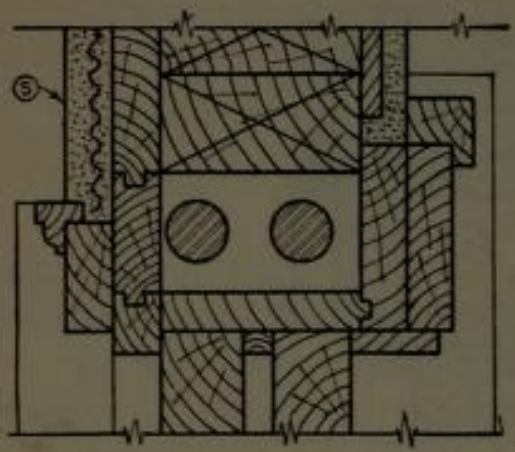


Fig. 454. Showing Section of Window Jamb in Frame Wall Finished on Outside with Stucco

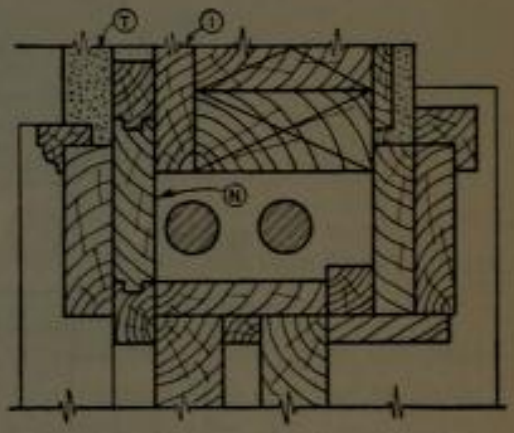


Fig. 455. Showing Section of Window Jamb in Frame Wall Finished on Outside with Stucco

ding is covered with an insulating wall board which is carried across the inside of the weight pocket to the edge of the pulley stile and then an air space is created by nailing furring strips *P* over the inside of this wall board with lathing and plastering *G* installed over the inside of the furring strips. This construction should make a very warm wall for buildings in cold climates. An extra piece *R* is required at the inside edge of the frame in line with the pulley

stile to form a ground for the plaster and for nailing the inside architrave *L* and the extra wide stop bead *K*. This enables the plastering to be carried across the inside of the weight pocket making the construction still more weather tight.

Figures 454 and 455 show cross sections through the window jamb in a frame wall finished on the outside with stucco (which is a kind of plaster) on metal lath. Fig. 454 shows the outside boarding forming the outside lining of the weight pocket and the metal lath applied directly against the outside surface of the outside boarding. The stucco is shown in section at *S*. This does not make so good a job of stucco work nor so warm a wall as does the con-

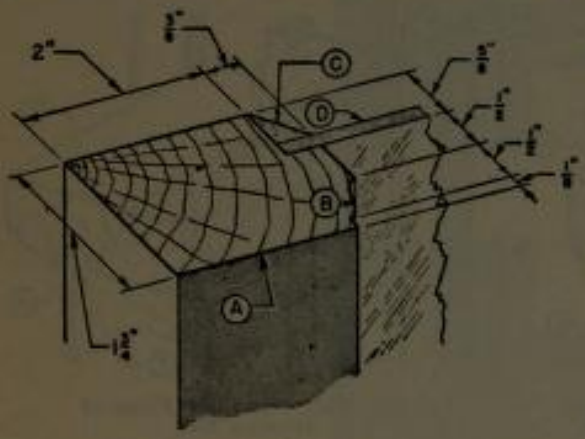


Fig. 456. Section through Window Stile

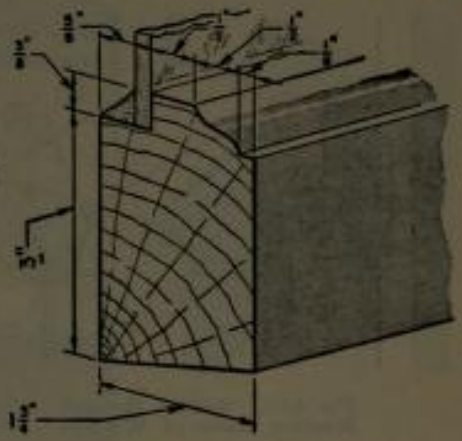


Fig. 457. Section through Bottom Rail

struction shown in Fig. 455 where the outside casing *N* of the weight pocket is placed outside of the outside boarding *I* and furring strips *T* of thickness equal to that of the outside casing are placed over the outside surface of the outside boarding over which the metal lath and stucco is installed, thus creating an air space behind the stucco as well as making the weight pocket wider.

Double-Hung Sash. In Fig. 456 is shown a large-size section through the side or stile of an ordinary window sash, such as *F* in Fig. 447, with some of the dimensions given. The same section is ordinarily used for the top rail of the sash, as for the stiles at the sides, but the bottom rail is usually made heavier. A section through the bottom rail is shown in Fig. 457 which illustrates to large scale the sash shown at *G*, in Fig. 446. In Fig. 456, *A* is the body of the stile, which for ordinary good work is made 1¾ inches thick and 2 inches wide, not counting the rabbet for the glass. This rabbet is

shown at *C* and is made 3/8 inch x 5/8 inch, which makes the entire stile 1¾ inches x 2⅜ inches. The portion shown at *B* is molded in various ways, usually as shown. The glass *D* is held in place by means of small, triangular pieces of tin driven into the sash outside of the glass, after it has been put in, and then covered up with putty as shown at *C*. The bottom rail shown in Fig. 457 differs from the stiles only in size, being usually 3⅜ inches wide instead of 2⅜ inches.

Sashes are often made thinner than 1¾ inches, but if they are at all large they are likely not to stand well but will warp and twist.

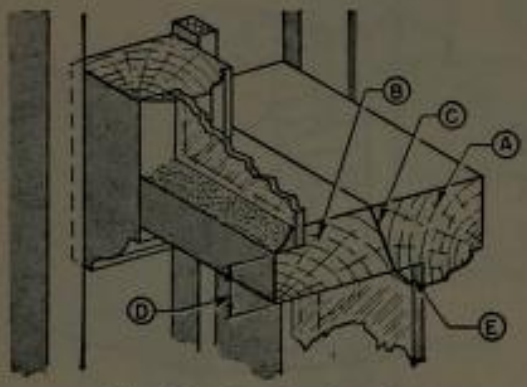


Fig. 458. Section through Meeting Rails of Window

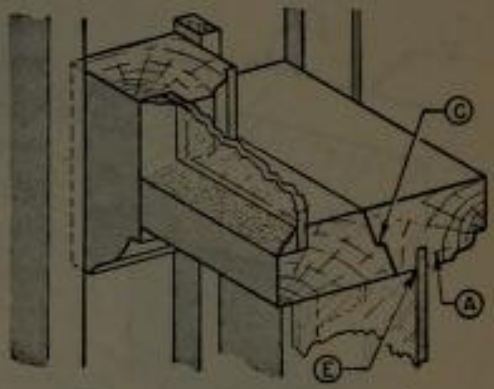


Fig. 459. Another Form of Meeting Rail

For very large windows the sashes should be made thicker still, being in this case 2 inches or even 2¼ inches thick.

Upper and Lower Sash. Double-hung sashes are divided into two parts, one called the "upper sash" and the other the "lower sash," which are so arranged as to slide by each other. They meet at the center of the window opening, and at this point, at the top of the lower sash and at the bottom of the upper sash, is a rail known as the "meeting rail." In Fig. 458 is shown a section through the meeting rails of a window. The section has been taken vertically and shows the meeting rails at a large scale. *A* is the top rail of the lower sash and slides up. *B* is the bottom rail of the upper sash and slides down, the two coming together in the inclined line marked *C*. Each rail is cut so that when they come together they will meet in this line. The thickness of the rails is determined by the fact that the distance marked *D* is 1 inch, making the entire thickness of the rail *B* 1⅜ inches and the thickness of the rail *A* 1¾ inches. The rail

A is carried down below the bottom of the rail *B* so as to allow the glass to be puttied in as shown at *E*. In Fig. 459 is shown another method of fitting the glass into the top rail of the lower sash. Here *A* is the top rail of the lower sash and at *E* is shown the method of fitting the glass. As will be seen, the rail *A* is ploughed to a depth of about ¼ inch and the glass inserted in the opening. This method allows the rail of the lower sash as well as the rail of the upper sash

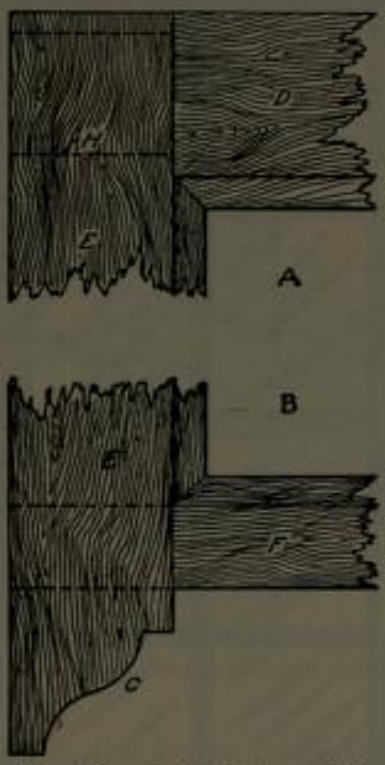


Fig. 460. Joint Between Stile and Rails

to be only 1⅜ inches thick. Fig. 459 also shows another method of constructing the meeting rails as shown at *C*. Here, instead of meeting in a straight line as in Fig. 458, there is a slight rabbet made in each rail so as to give a small extent of horizontal surface on each. The advantage of this method is that it prevents the sashes from slipping too far past each other, as they may do if cut as shown in Fig. 458, especially after they have become a little worn.

At the corners, where the horizontal rails meet the vertical stiles, they are fastened together with a mortise-and-tenon joint, the mortise being in all cases cut in the stiles and the tenon made on the ends of the rails. This is shown in Fig. 460 where at *A* is the joint

between the top rail and the stile, and at *B* the joint between the meeting rail and the stile. *D* is the top rail and *E* is the stile, while at *H* is the tenon cut in the end of *D*, fitting into a mortise in *E*. *F* is the meeting rail tenoned into the stile. It is a common practice to continue the stile some distance below the meeting rail and to cut a molding in the end of it as shown at *C*. This makes the stile

Fig. 461. Window Sash Showing Muntins

much stronger at this otherwise weak point. The joint between the bottom rail and the stile is made in a manner similar to that shown at *A*.

Muntins. When there are more than two lights in a window opening, the sashes must be subdivided and the panes of glass made smaller, and this subdivision is accomplished by means of pieces called "muntins" which are made so as to receive the glass in the same way as do the rails and stiles. In Fig. 461 is shown a window

sash divided into lights, four in each sash, and at *A* is shown a muntin. In Fig. 462 is shown a full-size section through one of these muntins showing the way in which it holds the glass. *A* is the body of the muntin, *B B* is the glass on the two sides of it, held in place by the putty *C C*. The molding *D* may be varied to suit the taste of the designer, but must be the same as on the rails and stiles.

Casement Sash and Frames. The frames and the sash before described, known as "double-hung sash" or "English sash," are those most commonly employed in the United States and Canada, but there is another kind of sash known as "casement or French" sash which is constructed on a different principle entirely. This sash

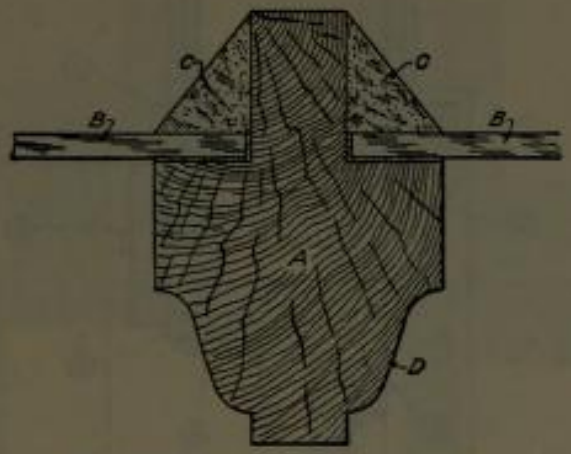


Fig. 462. Section through Muntin

is hinged at the sides to the frame so as to swing in or out. The principal objection to this arrangement is the difficulty of making such a sash water- and weather-tight. It is also impossible to use outside fly screens, if the sashes are hung to swing out, and if they are hung to swing in, the weather can penetrate through them much more readily. In Fig. 463 is shown a horizontal section through the side or jamb of a casement window in a frame wall. It will be seen that the outside architrave is similar to the one which was described in connection with the double-hung window, and in this respect there is no difference between the two. There is, however, no box for the accommodation of weights in this case, as no weights are required. The outside architrave is made in a way slightly different from any which have been illustrated before, but this method is equally well adapted for use with the other type of window. As shown at *H* it

is made in two pieces, *H* being perfectly plain and the molded piece *K* worked out of smaller stuff and fastened on to it. It will be noted that the piece *K* is rabbeted slightly and that the end of the piece *H* fits into the rabbet in such a way that the joint between the two pieces is hidden from the front, and may open a little without being noticed.

In the figure, *A A* are the studs at the sides of the opening, *I* is the outside boarding and *J* is the plastering on the inside. *B* is the frame for the casement windows, 1¾ inches in thickness, rabbeted, as shown at *E*, to receive the sash *C*. The sash itself is

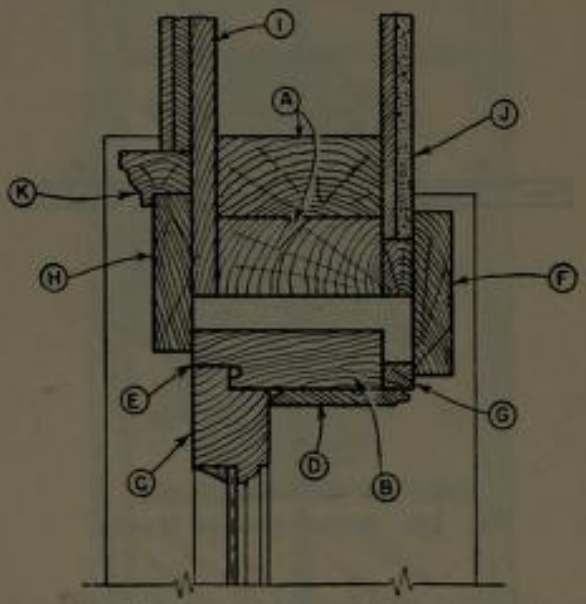


Fig. 463. Horizontal Section through Jamb of Casement Window

rabbeted and a groove is cut vertically in the frame, as shown, in order that any rain water which may penetrate the joint at *E* may be stopped and may run down the groove to the sill without getting inside. *D* is the stop bead and *G* is a block which receives the inside architrave *F*. The sash is hinged at the point *E* and swings out. In Fig. 464 is shown another method of constructing a casement window so that the sash will swing outward. The frame *B* is made wide enough to extend in to the plaster line, thus doing away with the block *G* in Fig. 463. The stop bead *D* is also omitted. The frame *B* is rabbeted near the outside edge to a depth of about ¾ inch to receive the sash *C* and an extra groove is cut in the frame to receive a

half-round molding cut in the edge of the sash. This arrangement is to keep out the weather. The sash *C* is 1¾ inches thick and 2⅜ inches wide. There are, of course, many other ways of constructing these frames and sashes which are more or less elaborate, according as the work is intended to be cheap or good. The designs shown are suitable for ordinary good work and may be simplified for cheap work.

Figure 465 shows a section taken vertically through the sill of a window of the casement type, which opens out. *A* is the rough piece, called a "header," which forms the bottom of the rough opening, *B* is the outside boarding, *C* is the plastering. *D* is the sill,

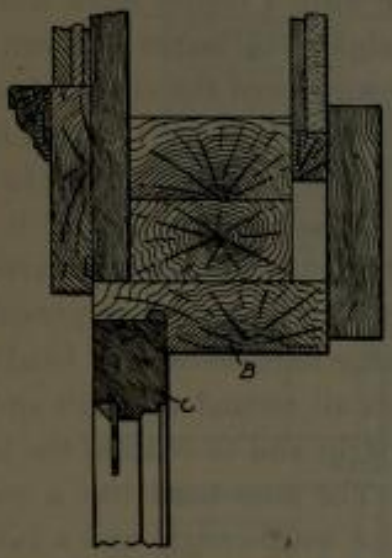


Fig. 464. Another Form of Casement Window Construction

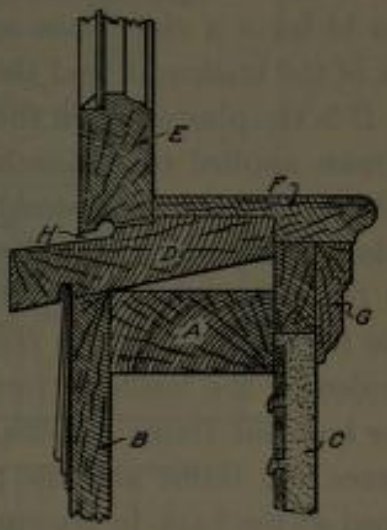


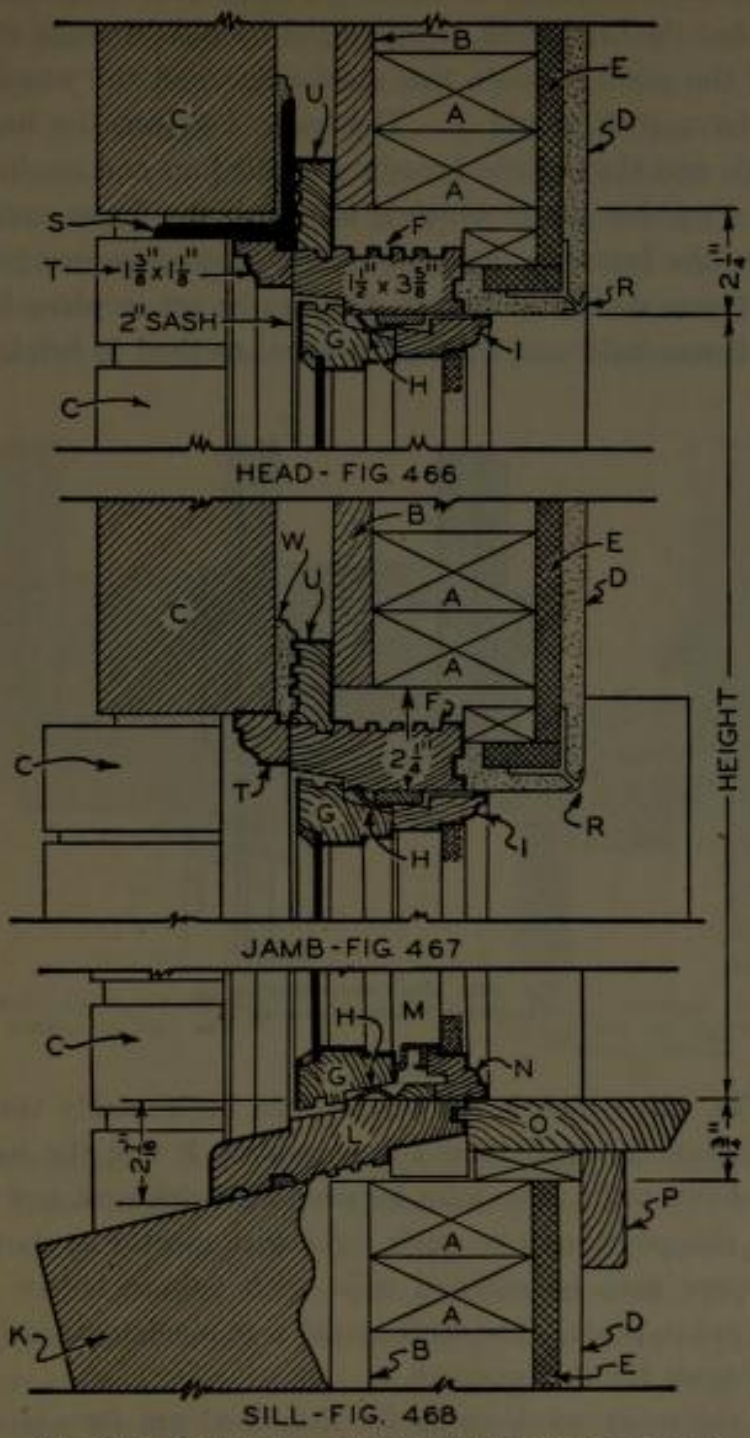
Fig. 465. Vertical Section through Sill of Casement Window

and *E* is the sash. *F* and *G* are the inside finish which cover up the rough sill *D*. It will be seen that the sill *D* is ploughed on the under side to receive shingles, as was the sill of the double-hung window. It is rabbeted on the top to receive the sash *E*, and rabbeted again under the sash so that there will be less chance that the drippings from the sash will be driven into the inside by the wind. The under edge of the sash is also ploughed as shown at *H* in order to catch these drippings if they are blown in.

With the types of out swinging casement windows described above, it is almost impossible to keep out the wind and rain even when special precautions are taken such as the grooving of the frames and the sashes. For this reason a number of specially designed

casement windows have been developed which have frames and sashes formed in such a way that they can be used in combination with metal weatherstrips. The purpose of the weatherstrips is to keep out both the cold winds and the rain and to prevent the escape of heat from the inside by tightly closing all the cracks between the sashes and the frames. Figs. 466, 467, and 468 show sections taken through the head, jamb, and sill of a casement window of this kind, equipped with weatherstrips, which is patented and sold by the Andersen Frame Corporation. These figures show a window in a brick-veneer wall. *A A* are the studs at the sides, top, and sill of the rough opening in the wall; *B* is the outside boarding; *C* is the brickwork on the outside of the wall, 4 inches thick and set so as to leave a clear open space of about 1½ inches between the back of the brickwork and the outside surface of the outside boarding; *D* is the plastering on the inside of the wall which, in this case, is shown applied to an insulating board *E* which is nailed to the inside face of the wall studding. In Figs. 466 and 467, *F* is the window frame which is rabbeted on the outside edge to receive the sash *G*. The sash is also rabbeted in such a way as to provide a space for the weatherstrip *H*, and a large hard wood stop bead *I* is provided on the inside to form a finish all around the sash and to cover both the frame and the weatherstrip and to conceal the joint between the frame and the plaster. The stop bead has a recess formed at the back to accommodate the weatherstrip and a rabbet on the inside edge in which a fly screen can be fitted.

In Fig. 468, which is a section taken vertically through the sill, there is a brick sill shown at *K* over which the wood sill *L* fits. The lower rail of the sash shown at *G* is much the same in shape as the stile and top rail shown at *G* in Figs. 466 and 467 and there is a similar weatherstrip at *H*. There is also a special metal sill piece shown at *M* against which the lower rail of the sash stops when it is closed. This is finished on the inside by the stool moulding *N*, which covers the joint between the outside sill *L* and the inside stool *O*. The inside finish is completed by the apron *P*. There is no inside architrave at the jambs and head of the window opening on the inside but the plaster is carried around a metal "corner bead" *R* to form a plaster jamb and head to the opening and finishes under the edge of the inside stop bead *I*. In Fig. 466, which is a section



Figs. 466, 467, and 468. Sections Taken through the Head, Jamb, and Sill of a Casement Window Equipped with One Kind of Weatherstrip

Courtesy of Andersen Frame Corporation

taken vertically through the head of the window opening, it will be seen that the brickwork is supported by a steel angle shown at *S* and that the joint between this steel angle and the wood frame is covered by a staff mould *T*. The space between the back of the steel angle and the outside boarding is filled up and made weather-tight by a wooden lug *U* which is a part of the frame and which is secured to the frame by means of a tongue-and-groove joint. The window frame would, of course, have to be set in place before the brickwork was built and this is the usual method in brick veneered walls.

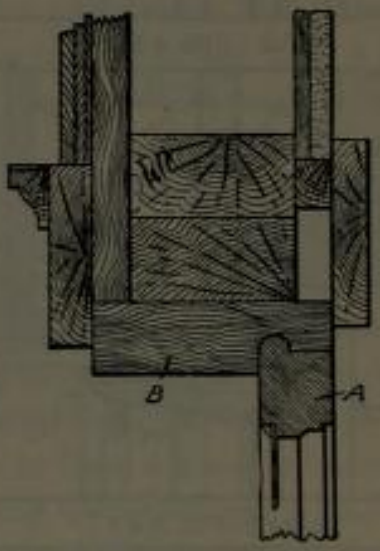


Fig. 469. Horizontal Section of Casement Window Opening In

In Fig. 467, which is a section taken horizontally through the window jamb, the staff mould is shown at *T* and the lug on the frame is shown at *U*. The joint between the brickwork and the wood frame at this point may be made tight with mortar as shown at *W*, or this space may be caulked tight with oakum before the staff mould is put in place. The staff mould is made detachable from the window frame for this purpose.

The casement windows so far described are for sashes which are made to open out, but casements are also made to open in. Fig. 469 shows a horizontal section through the jamb of such a window frame and sash. *A* is the sash with a half-round fitting into a mortise in the frame which is rabbeted as well to receive the sash. *B* is the frame, the sash being placed on the inner edge of the frame.

Another method of forming the frame is shown in Fig. 470. Here, as in Fig. 469, *A* is the sash, and *B* is the frame which is ploughed as shown at *C*. This allows the sash to be made without the tenon shown in Fig. 469 and is, therefore, cheaper and easier to make as regards the sash without being any more expensive as regards the frame. The hinges in this case come at the point marked *D* and they would come in the same position in Fig. 469. In Fig. 471 is shown a vertical section through the sill of a casement window opening in. It will be seen that the sill *B* differs but little from the other

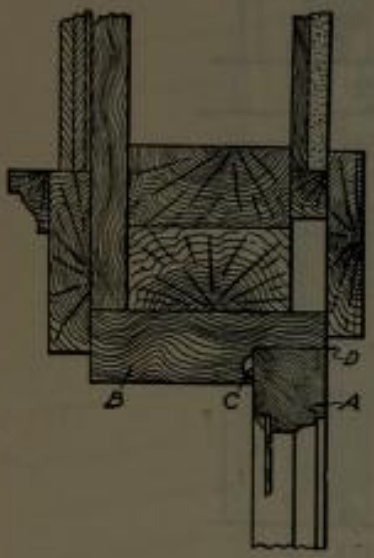
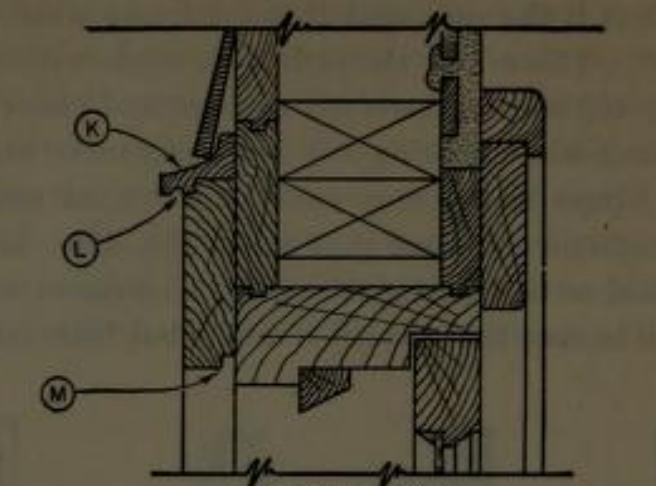


Fig. 470. Another Construction Similar to Fig. 469.

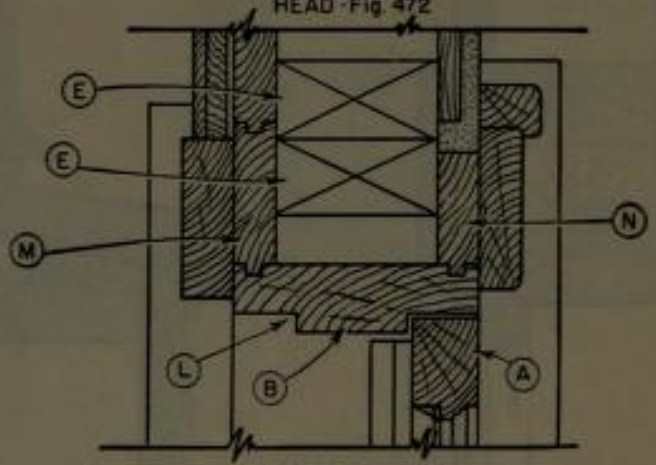
Fig. 471. Vertical Section through Sill of Casement Window Opening In

sills shown before. It is rabbeted on the inside for the reception of the sash *A*, and at *C* is shown a special drip piece which is let into the sash and which is ploughed on the bottom so as to receive any drops of water which may be blown under it by the wind. All casement sashes opening in should be provided with something of the kind.

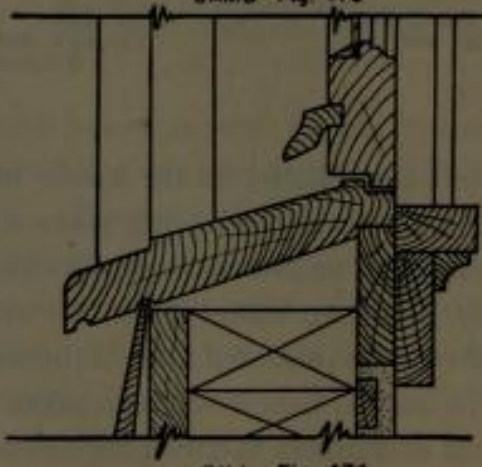
Figures 472, 473, and 474 show sections taken through the head, the jamb, and the sill of another in-swinging casement window. Fig. 472, which is a section taken vertically through the window head, shows a cap at *K* placed on top of the outside architrave, moulded in such a way that it will receive the wall siding and will shed rain water away from the wall. At the outside edge of this member is formed a recess *L* on the underside called a "drip," to prevent rain



HEAD · Fig. 472



JAMB Fig. 473



SILL · Fig. 474

Figs. 472, 473, and 474. Sections Taken through the Head, Jamb, and Sill of an In-Swinging Casement Window

water from clinging to the edge and running back against the architrave. There is also a similar drip formed on the lower edge of the outside architrave, as shown at *M*.

Figure 473, which is a section taken horizontally through the window jamb, is somewhat similar to Figs. 469 and 470 but differs slightly from them. It will be noticed that the window frame *B* is shown in Fig. 473 setting a little away from the wall studs *E E*.

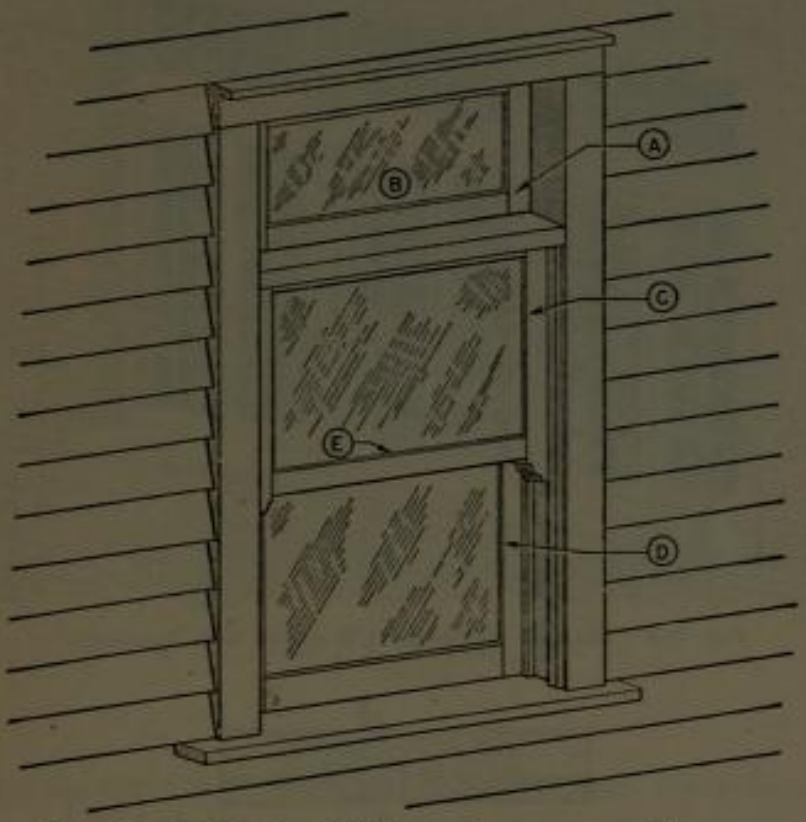


Fig. 475. Double Hung Window with Transom and Transom Sash

Figs. 469 and 470 are really incorrect in this respect as it would not be practical to set the wall studding so accurately that the window frames, when they come from the mill, will fit closely against the studding as is indicated in Figs. 469 and 470. In Fig. 473 at *L* is shown a rabbet at the outside edge of the frame into which may be fitted a "winter" or "storm" sash similar to the inside sash *A* but hinged to swing out instead of in. The frame *B* is grooved on the back to receive the lugs *M* and *N*. The inside lug, or "casing," *N* serves as a ground for the plaster and the outside one *M* forms

the start of the outside boarding. The sill shown in Fig. 474 is very similar to that shown in Fig. 471.

Transoms. An additional window above a double-hung or casement window is called a "transom." The horizontal division separating the two windows is called the transom sill or transom bar. In this case the additional sash which comes above the transom sill is in

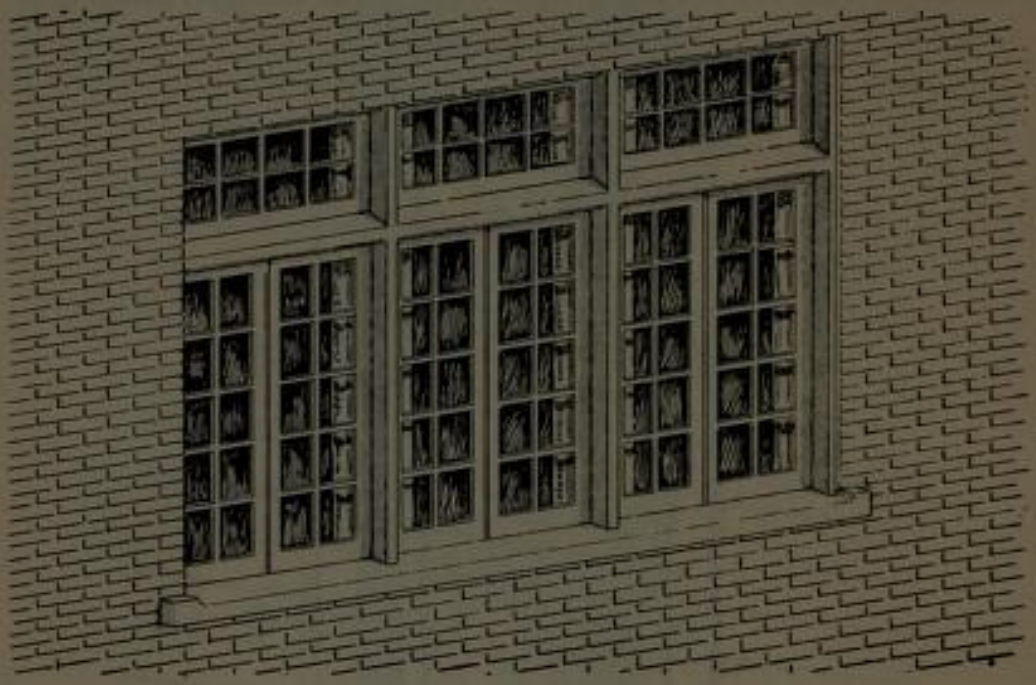


Fig. 476. Example of Casement Windows with Transoms

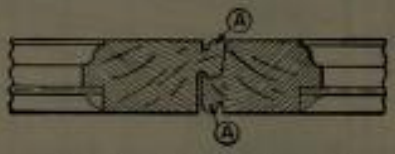


Fig. 477. Section through Casement Meeting Stiles

the nature of an extension to the window proper, and it is usually hung in a different way, sometimes being made stationary so as not to be allowed to open at all. Fig. 475 shows a double-hung window with a transom and a transom sill. *A* is the transom, *B* is the transom light, *C* is the upper sash of the window proper, *D* the lower sash, and *E* is the meeting rail. In Fig. 476 is shown a casement window with a transom. As no description of the meeting stile for casement windows has yet been given, a section through the stile is shown in Fig. 477. The bead at *A A* may be omitted if de-

sired and the stiles may be made plain. This, of course, cheapens the construction somewhat.

A transom sill for a double-hung window must combine two members, namely, a headpiece for the window proper, and a sill for the transom sash to stop against. These properties determine the construction of the transom sill. In Fig. 478 is shown a section taken vertically through the transom sill of a double-hung window, and it will be seen that two members have been provided for. *A* is the sill for the transom sash, which is shown at *C*, while *B* is the head

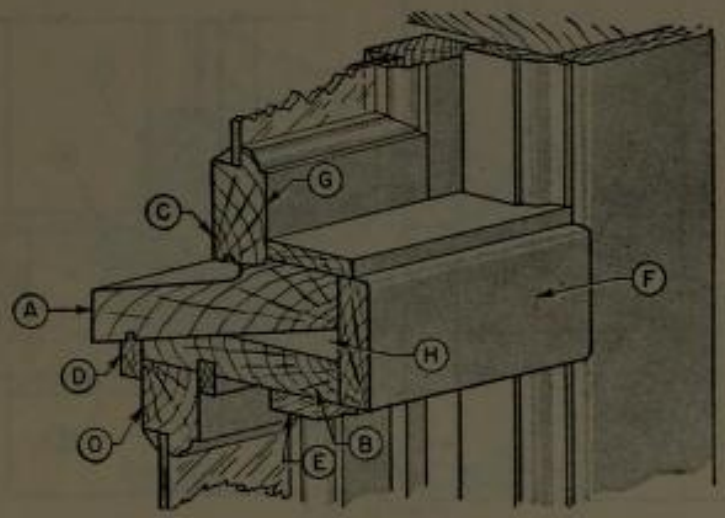


Fig. 478. Vertical Section through Sill of a Double-Hung Window

jamb for the main window frame, the upper sash being shown at *O*. The piece *D* is in line with the outside casing of the window at the jambs, and E is the stop bead which is in line with the stop bead at the sides. The space marked *H* is filled with blocking. *G* is the window stool on the inside and *F* is the finished face of the transom sill on the inside.

In Fig. 479 is shown a section taken vertically through the transom sill of a casement sash such as is shown in Fig. 476. It will be seen that this transom sill differs somewhat from the transom sill shown in Fig. 478, the head for the casement frame being quite different from the head for a double-hung window frame.

In this figure, *A* is the top rail of the lower part of the window, that is, of the casement sash itself, while *D* is the bottom rail of the

transom sash which forms the upper part of the window. This section shows a window in a comparatively thick wall.

In Fig. 480 is shown a vertical section through the transom bar of a casement window which opens out and which is in a thinner wall, say one with 2 x 4-inch studding. At *H* is shown a small groove in the top rail, which is intended to catch any water which may be driven through the opening between the sash and the frame during heavy rains. This groove should be deeper at one end of

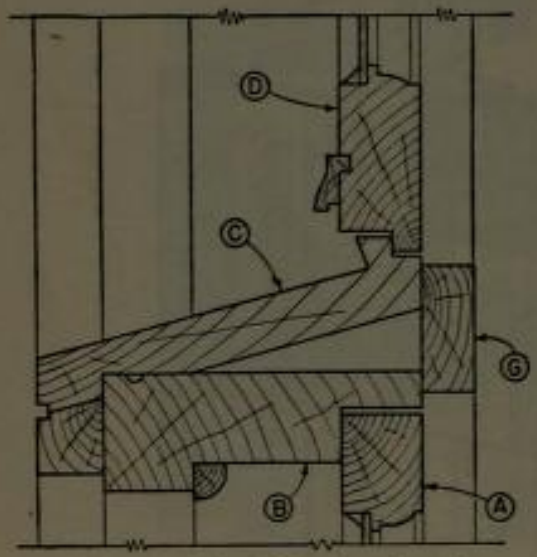


Fig. 479. Vertical Section through Transom Bar of Casement Sash

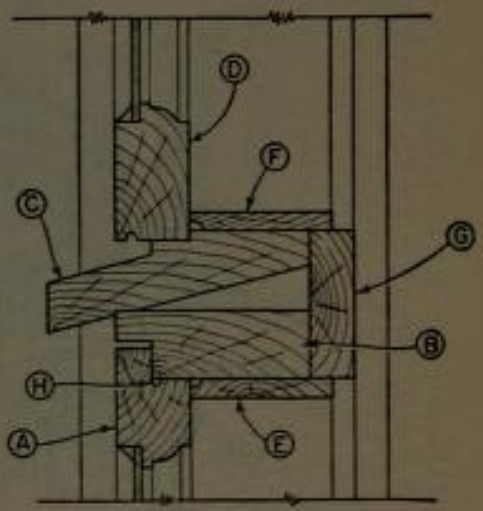


Fig. 480. Vertical Section through Transom Bar of a Casement Window

the top rail than it is at the other end, so that the water will flow away toward the side and be carried down to the sill, which will throw it outward. *E* is the stop bead immediately inside of the casement sash. *B* is the piece which forms the head of the casement frame. On top of the piece *B* is the sill *C* of the transom frame. The sill piece is made with a wash on top, the slope of which should be about 2 inches to the foot, and on top of the sill piece comes the lower rail of the transom sash *D*. The piece *F* is a stop bead carried across the frame on the inside just above the sill piece for the transom sash to stop against in case it is hinged at the top to swing outward, or to receive the hinges in case it is hinged at the bottom to swing inward. The latter arrangement is the most common one. The piece *G* forms the inside finish of the transom

bar and may be treated in any way desired. Fig. 481 shows a section taken vertically through the transom bar of the out-swinging casement window illustrated in Figs. 466, 467, and 468.

Mullions. In Fig. 482 is shown a double-hung window which is in two parts with a mullion between them. The mullion is shown at *A*. The window shown also has two transom sashes with a mullion, *C*, between the sashes *B B*. The mullions *A* and *C* are usually made 8 or 9 inches wide, so as to provide space for the weight boxes in the thickness of the mullion. Fig. 483 shows a section taken horizontally through the mullion *A*, with spaces for the weights

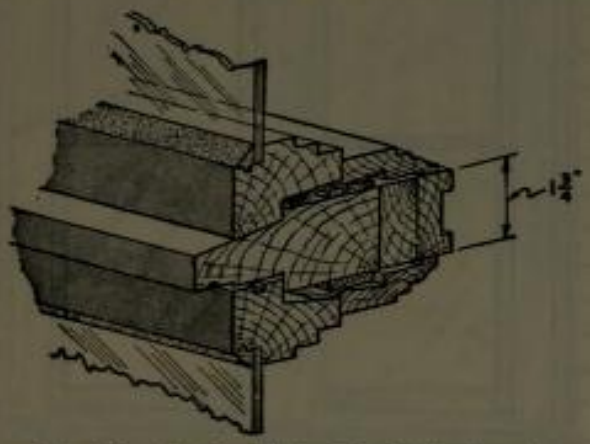


Fig. 481. Section Taken Vertically through the Transom Bar of an Out-Swinging Casement Window

at *D D* and with a strip *E* to separate the two weight boxes. *F F* are the two pulley stiles, made in the usual way as described above, with parting beads at *G G* and the sashes at *H H*. *K* is the piece which forms the outside finish of the mullion. The piece *L* forms the inside finish of the mullion and may be made very plain or very elaborate to suit the taste of the designer. It may be treated with sinkages or with raised moldings and varied to almost any extent. *M M* are the stop beads which hold in the sashes and serve also to cover the joint between the pieces *F F* and the piece *L*.

In Fig. 476 is shown a casement window with two mullions. It will be noticed that the mullions are much narrower than the mullion used in the case of the double-hung window shown in Fig. 482, the reason for this being that in the case of the casement window there are no weights to be taken care of and so there need not be any weight boxes in the thickness of the mullion.

Fig. 482. Double-Hung Window in Two Parts with Mullion Between

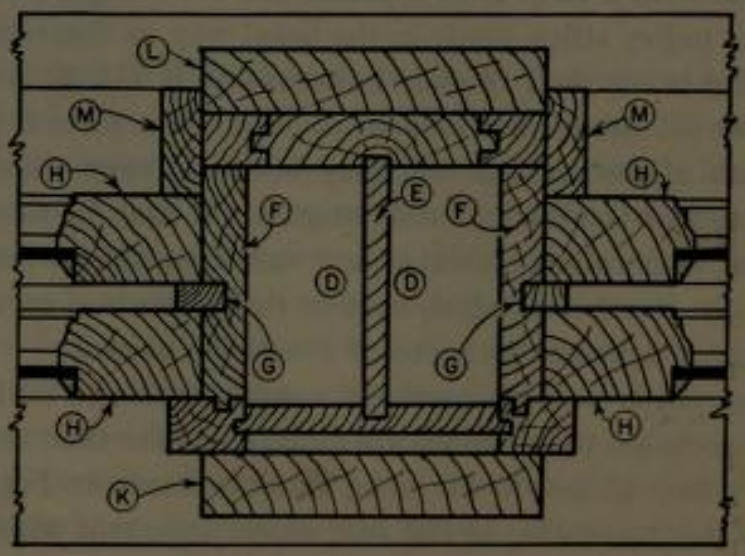


Fig. 483. Section Taken Horizontally through Mullion Showing Spaces for Weights

In Fig. 484 is shown a section taken horizontally through the mullion showing its construction. The sashes are shown at *C C*. In Fig. 485 is shown a section taken horizontally through a mullion for the outswinging casement window illustrated by Figs. 466, 467, and 468.

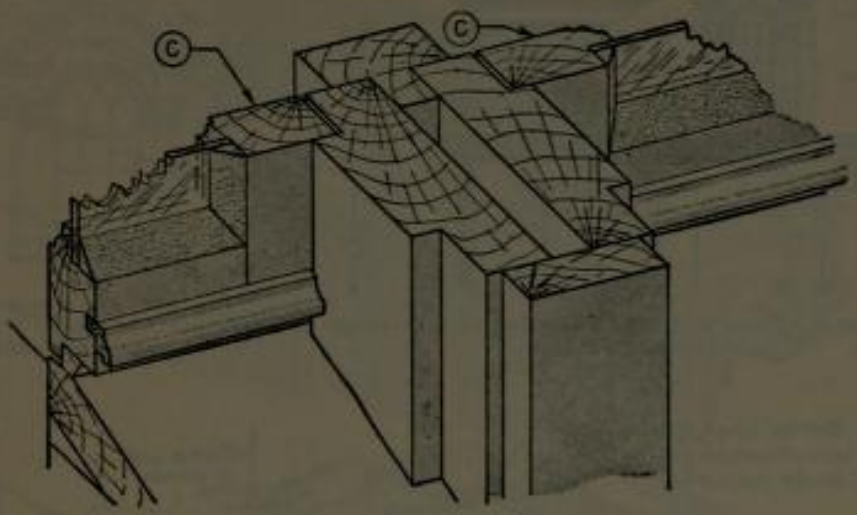


Fig. 484. Horizontal Section through Mullion Showing Its Construction

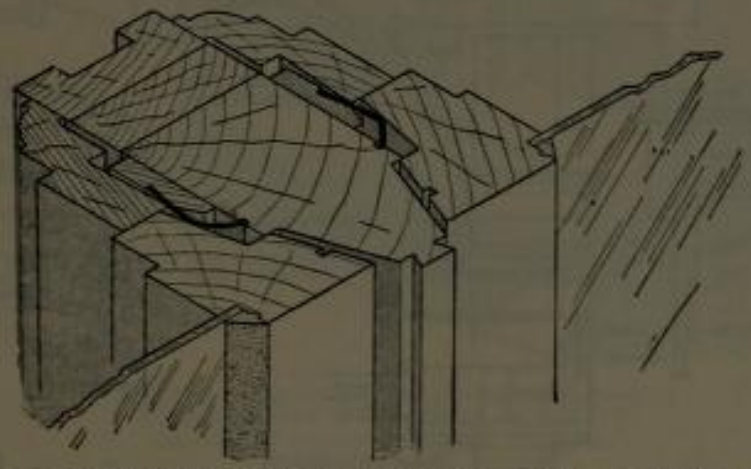


Fig. 485. A Section Taken Horizontally through a Mullion for the Outswinging Casement Window

Figure 486 shows, in front elevation and in side elevation, a circular head dormer window of Colonial type which has been treated with a considerable amount of exterior finish. This finish consists of a curved architrave moulding around the head of the window opening and pilasters with moulded caps and bases at each side of the window opening at the two front corners of the dormer.

The two pilasters have above them additional mouldings forming what is known as an entablature, and the top member of this entablature is similar to the facia mould of the eave finish of the

Fig. 486. Front and Side Elevation of a Circular Dormer Window

Fig. 487. Larger Scale Drawing of Dormer Window Shown in Fig. 486

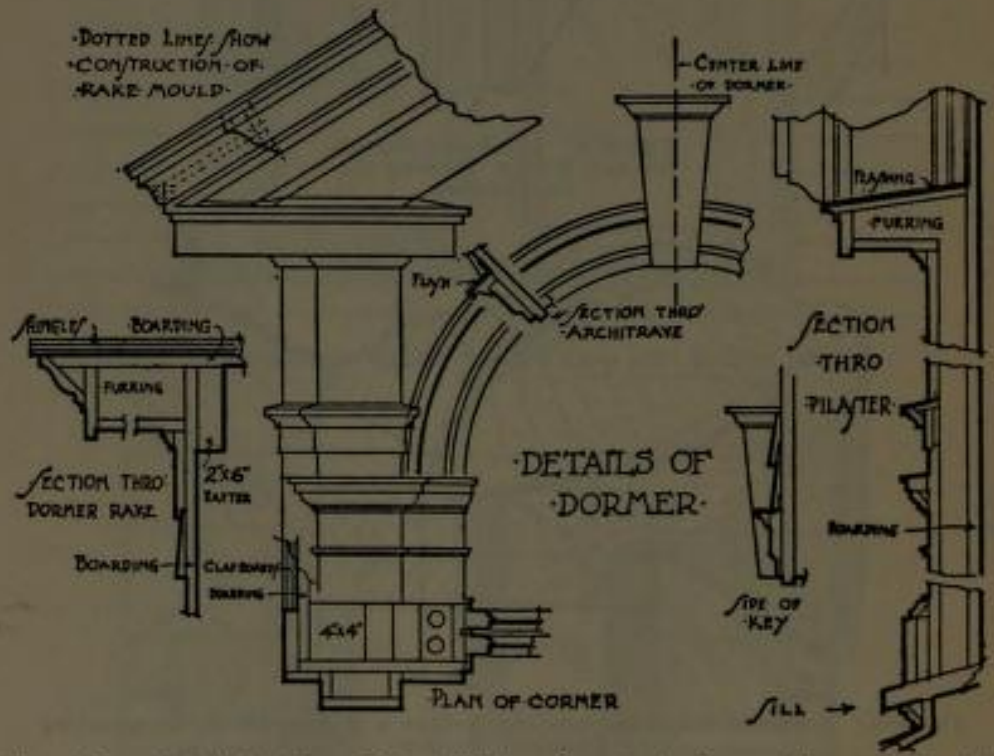


Fig. 488. Details for Upper Part of Window Opening for Dormer Shown in Fig. 486

dormer, this facia mould being thus returned for a short distance across the front of the dormer. Fig. 487 shows to a somewhat bigger scale the front elevation of this dormer so that the outside finish can be seen more clearly.

Figure 488 shows, to a much bigger scale, the upper part of the window opening and a portion of the front left-hand corner of the

dormer, at the level of the eaves. The curved architrave moulding around the head of the window opening is shown both in elevation and in section illustrating the way in which this moulding is made. The cap of the pilaster is shown in elevation and there is also a sec-

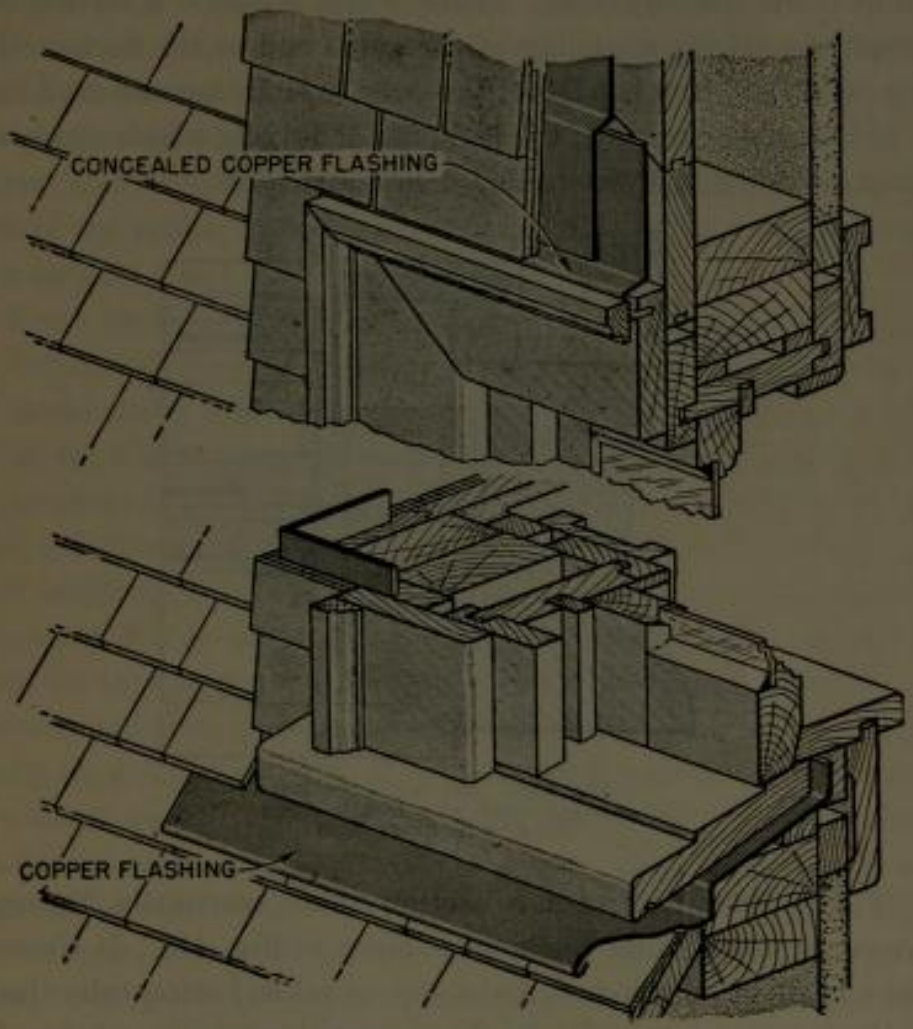


Fig. 489. Vertical Section through a Dormer Window Similar to One Shown in Fig. 418
Courtesy of Copper and Brass Research Association

tion taken vertically through this pilaster showing how it is formed and how the entablature above it is constructed out of ⅞-inch boards blocked out from the outside surface of the outside boarding. This section also shows how the mouldings, which make up the cap and base of the pilaster, are formed and how they are applied to the boards which form the face of the pilaster.

Figure 488 also shows a horizontal section taken through the

corner of the dormer in which can be seen in plan the 4 inch x 4 inch corner framing stud, the outside boarding, the pilaster, and a section through the window frame and sashes. This horizontal section or plan shows the corner boards and the clapboards on the side wall of the dormer window. There is also included a section taken through the raking moulding of the gable end of the dormer showing a rafter and roof boarding; the outside boarding and wall covering of the gable end wall; the lookouts or furring which support the raking moulding, and the raking mould and facia.

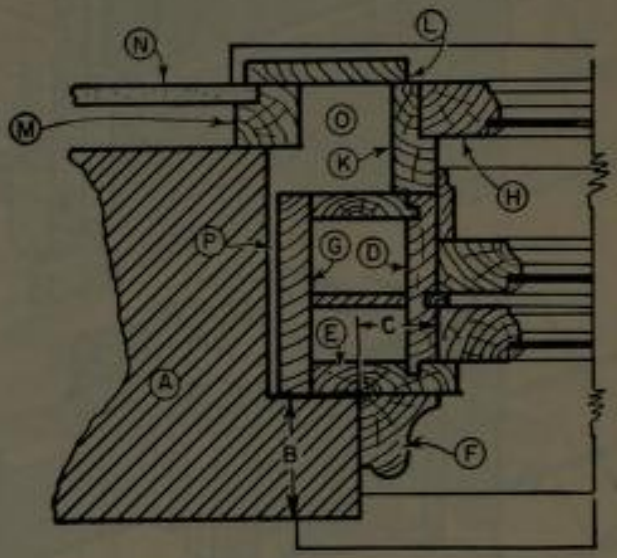


Fig. 490. Horizontal Section through Jamb of a Double-Hung Window in Brick Wall

Figure 489 illustrates a section taken vertically through a dormer window similar to the one shown in Fig. 418. It shows the head and sill of the window, and a section taken horizontally through the jamb would be similar to the section through the window head with the addition of the weight box. Note the flashing at the head and sill. This is particularly necessary in the case of dormer windows which always are in a very much exposed position. In other respects, this dormer window is very similar to the ordinary double hung windows shown elsewhere as regards both exterior and interior finish.

Windows in Brick Walls. Windows in brick or other masonry walls are in every respect similar to windows in frame walls, the only difference being in the arrangement of the jambs, heads, and sills. Figure 490 shows a section taken horizontally through the jamb of

a double-hung window in a brick wall. At *A* is shown a section through the wall itself. It will be seen that there is a sort of rabbet made in the back part of the wall in which to set the window frame, and that the front portion of the wall projects in front of the frame, as shown at *B*. This is done in order that there may be a certain amount of solid masonry which will cover the joint between the wall and the frame and prevent the wind from driving in between them through this joint. The distance *B* is called the "reveal" of the window, and is usually made 4 inches, but is sometimes 8 inches. The depth of the rabbet in which the frame sets may vary considerably, but is usually 2 to 4 inches.

From the face of the brick reveal to the face of the pulley stile *D* the distance *C* may be made anything, according to taste, but is best made about 2 inches. The pulley stile *D* is made in the same way as for windows in frame walls. *E* is the outside casing, which sets as close as possible against the brickwork, and *G* is a piece called the "back lining," which forms the back of the weight box. In all other respects the construction is the same as described for windows in frame walls. At *H* is shown an inside sash which can be put on in winter for additional protection against the cold. It is usually made as a casement sash to open in. As will be seen, it is hung on a rabbeted piece *K*, which also forms the jamb lining of the window on the inside and receives the inside architrave which is indicated at *L*. *M* is the furring on the inside of the brick wall and *N* is the plastering. The space *O* is filled with rough blocking, and the space *P* should be well caulked with oakum, or other substance, to keep out the cold. *F* is a piece called a "brick mold" or sometimes, a "staff bead," which is put in to cover up the joint, between the frame and the brick. It may be of any desired form, being sometimes made a simple square block or strip on which the window blinds are hung.

Fig. 491 shows a section taken vertically through the head of a double-hung window in a brick wall. At *A* is the masonry lintel which covers the masonry opening. It is usually of stone. The distance *B* is the same as the distance *B* in Fig. 490 and the distance *C* is also the same as the corresponding distance in Fig. 337. *D* is the yoke, the same as for a window in a frame wall, with the outside casing *E* and the staff bead *F*. At *G* are shown the steel angles

forming a steel lintel such as is usually employed to support the brickwork back of the stone lintel over the window opening. This section also shows an inside, or winter, sash at *H*, the same as in Fig.

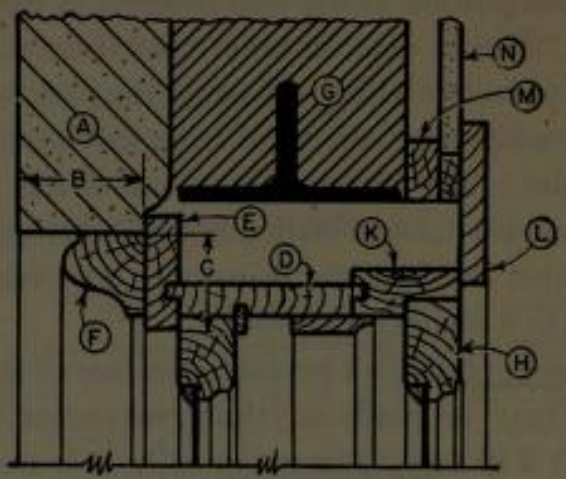


Fig. 491. Vertical Section through Head of a Double-Hung Window in Brick Wall

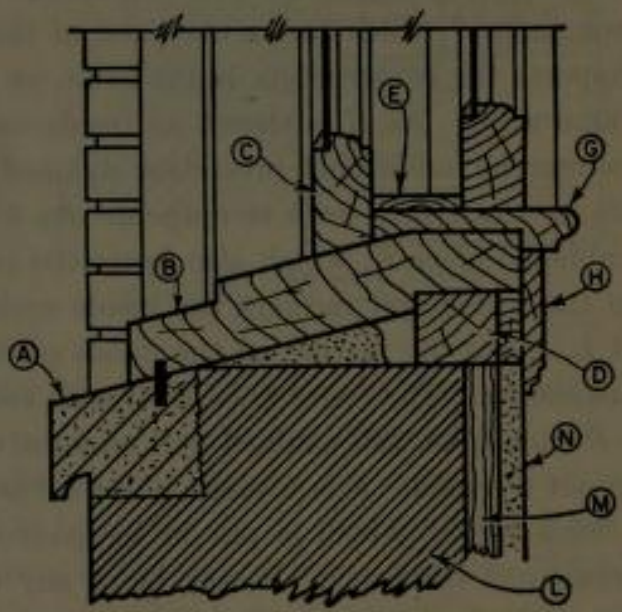
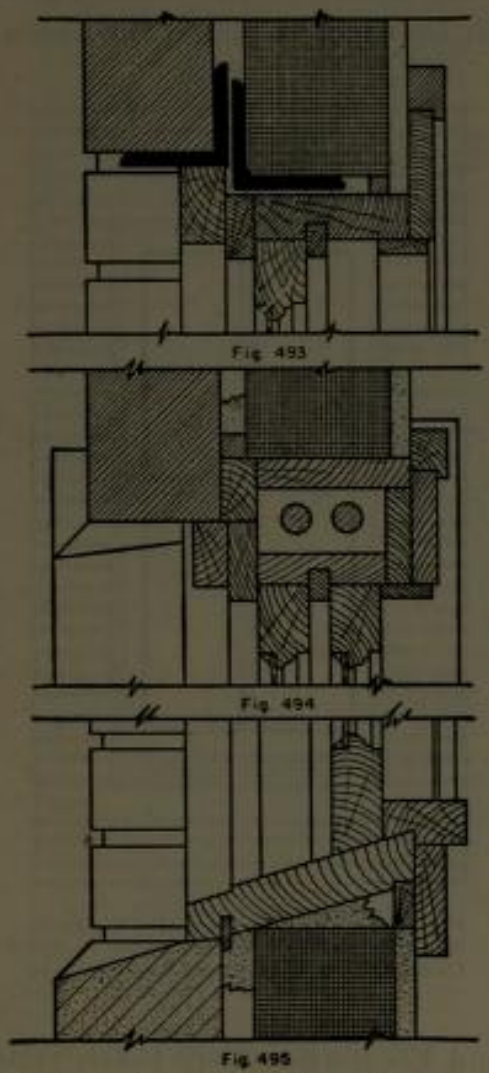


Fig. 492. Vertical Section through Sill of a Double-Hung Window in Brick Wall

490, with the piece *K* arranged to receive it and also to receive the edge of the inside architrave *L*. *M* is the furring on the masonry wall, and *N* is the lathing and plastering, the plastering being covered by the architrave *L*.

Fig. 492 shows a section taken vertically through the sill of a double-hung window in a brick wall. *A* is the stone sill in the

outside of the masonry wall, and should be wide enough to extend into the wall and under the wood sill far enough to allow the wood sill to lap over it about 2 inches. The wood sill, shown at *B*, is usually made wide enough to receive the staff bead, so that the width



Figs. 493, 495. Vertical Sections through the Head and Sill of a Double-Hung Window in a Wall of Terra Cotta Hollow Tile Blocks Faced with Bricks
Fig. 494. Horizontal Section through Same Window as Shown in Figs. 493 and 495

of the stone sill needs to be about the same as the depth of the reveal at the jambs, or the stone lintel at the head of the window. The sill *B* rests, on the inside, on a piece of rough timber built into the wall, as shown at *D* in the figure. The sill should have a "wash," or slope outward and downward, of about 3 inches to the foot. In the figure, *C* is the lower rail of the lower sash of the window, which

must stop against the sill and be made tight in some way. The piece *E* forms the finish on the inside corresponding to the stop bead at the jambs and head. *L* is the rough brick wall with the furring at *M* and the plastering and lathing at *N*, and the space between the rough sill and the plastering is covered and finished by the piece *G*, or the stool. Underneath the stool is placed the apron, as shown in the figure at *H*.

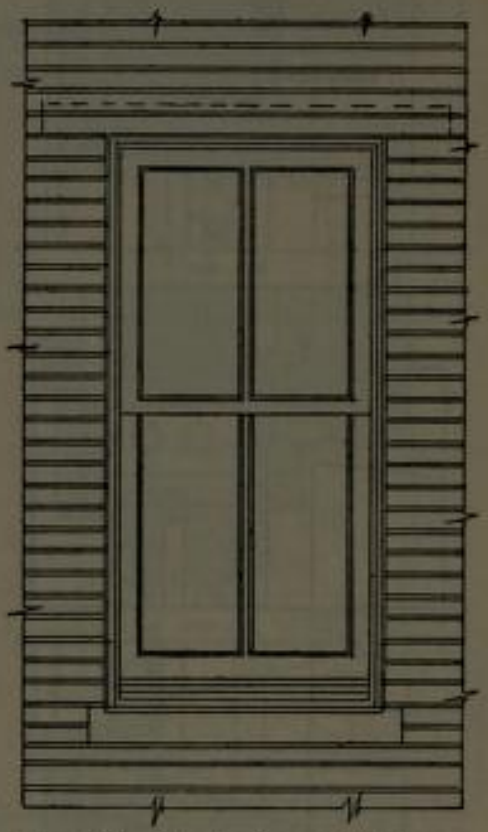


Fig. 496. Outside View of Window in Solid Brick Wall Where Same Frame Construction Was Used As Shown in Figs. 493, 494, and 495

Figures 493 and 495 show sections taken vertically through the head and sill of a double hung window in a wall formed of terra cotta hollow tile blocks faced on the outside with brick. Fig. 494 shows a section taken horizontally through the jamb of the same window. In Fig. 493, which is a section through the head of the window, a brick lintel supported by a steel angle is shown, instead of the stone lintel shown in Fig. 491, and a steel angle is shown supporting the hollow tile behind the lintel. No inside winter sash is shown or provided for in Fig. 494. These sashes are very seldom used now in masonry buildings as weather stripping of metal, of

which there are many different kinds, has been perfected. The inside winter sashes were found to be a great nuisance as they had to be taken down and stored away every spring. The weather strip

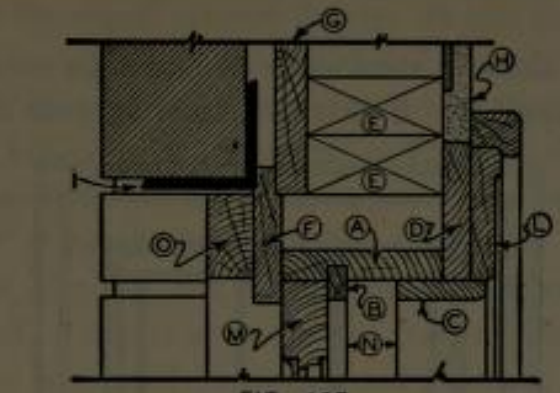


FIG. 497

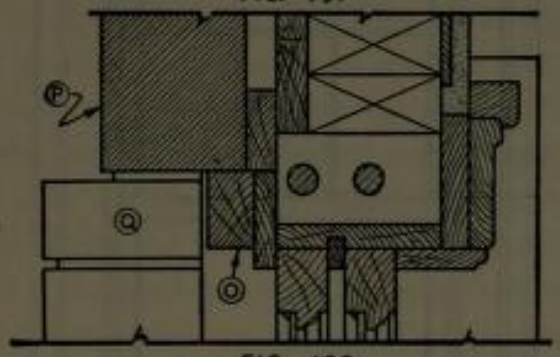


FIG. 499

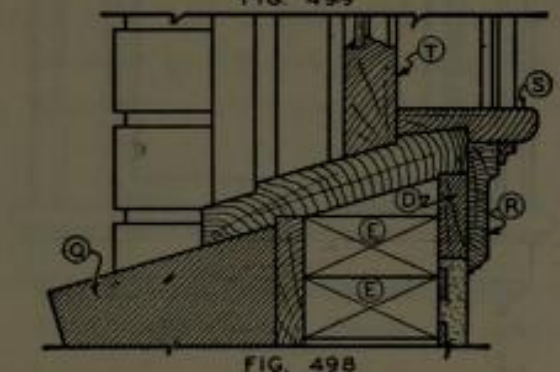


FIG. 498

Figs. 497, 498. Vertical Sections through the Head and Sill of a Double-Hung Window in a Brick-Veneered Wall
Fig. 499. Horizontal Section through Jamb of Window Shown in Figs. 497 and 498

is applied to the edges of the sashes. It is not shown in the figures. Outside winter sash could be hung on the staff bead.

The window frame construction, Figs. 493, 494, and 495, could be used equally well for a double hung window in a solid brick wall. Fig. 496 shows a view of such a window from the outside.

Figures 497 and 498 show sections taken vertically through the head and sill of a double-hung window in a brick-veneered wall

which is framed up with wood studding covered on the outside with boarding and then faced with brickwork 4 inches thick. Fig. 499 shows a section taken horizontally through the jamb of the same window.

Figure 497 shows a steel angle at *I* used to support the brickwork over the opening. *E E* is the studding over the head of the

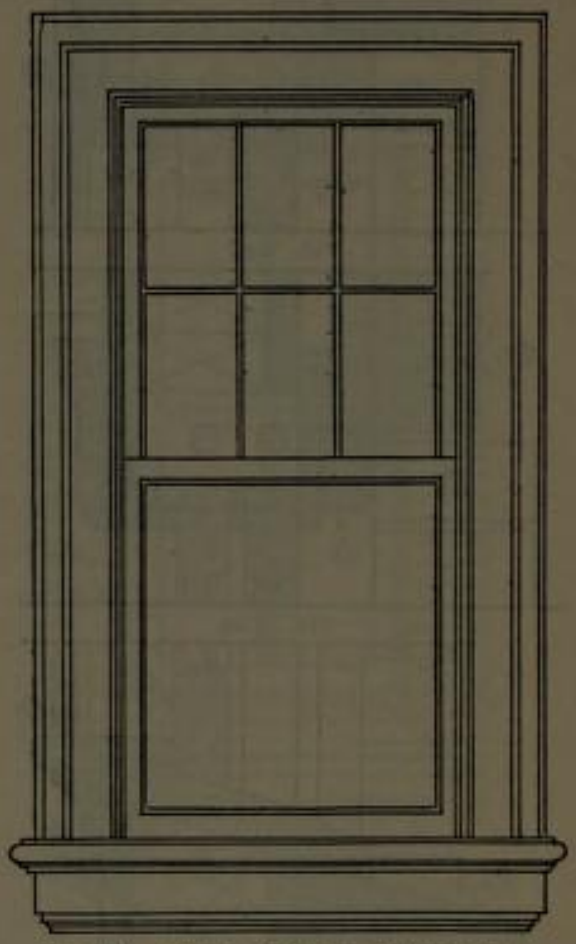


Fig. 500. Outside View of a Double-Hung Window

rough opening; *F* is the outside casing; *G* is the outside boarding; *H* is the plastering on wood lathing on the inside of the wall; *D* is the inside casing which serves also as a ground for the plastering; *A* is the yoke or head-jamb with a space between it and the rough framing *E E*; *B* is the parting strip and *C* is the stop bead. The inside architrave is shown at *L*, and is in two parts. The upper sash is shown at *M* and when the lower sash is raised it fits into the space *N*. This is all very similar to the construction shown in Fig. 445 except that the outside casing *F* is placed outside of the outside

boarding and the inside casing *D* is used in place of the ground shown in Fig. 445. There is added a member *O* on the outside of the frame which is a staff bead or brick mould to cover the joint between the brickwork and the wood window frame. It can also be used as a supporting rail for top-hung winter sash or blinds.

Figure 499, showing the horizontal section through the jamb of the window, is very similar, of course, to Fig. 447, and is also much like Fig. 440, with the addition, however, of the brick wall facing *P*. A brick sill is also indicated at *Q*. The brick sill is shown in section at *Q* in Fig. 498 and this figure also shows in section the wood window sill which is a part of the frame. The inside edge of this wood sill is supported by the ground *D* which is nailed to the wood studding *E E*. This ground and the inner edge of the sill are covered up and finished on the inside by the apron *R* and the window stool *S*. The stool is carried back on top of the window sill as far as the line of the inside of the window sash *T* and forms a rabbet into which this sash fits when it is closed, thus preventing the wind from blowing in under the lower edge of the closed sash. Fig. 500 shows a view of a double hung window looking from the inside.

Figure 501 shows a section taken vertically through a casement window in a brick wall with a stone sill. A section through the jamb would be the same as the section through the head with rabbeted frame to receive the sash and with brick mould on which winter sash hinged at top or side could be hung if it were made of a simple rectangular shape. The meeting stiles are beaded, beveled, and rabbeted as shown.

The lower rail of the sash is rabbeted and has a weather mould on the outside. The inside edge of the sill is finished with a brass plate so that the sash will not stick at this point. A metal water bar is placed partly in the underside of the wood sill and partly in the upper surface of the stone sill. This bar may be of copper or of galvanized iron.

Figure 502 shows a section taken vertically through an outswinging casement window in a frame wall which is finished on the outside with stucco on metal lath. The figure shows how the wood sill can be finished with an apron over the stucco and also shows how copper flashing can be placed under the wood sill to protect the wall from the effects of any possible leakage of water around the

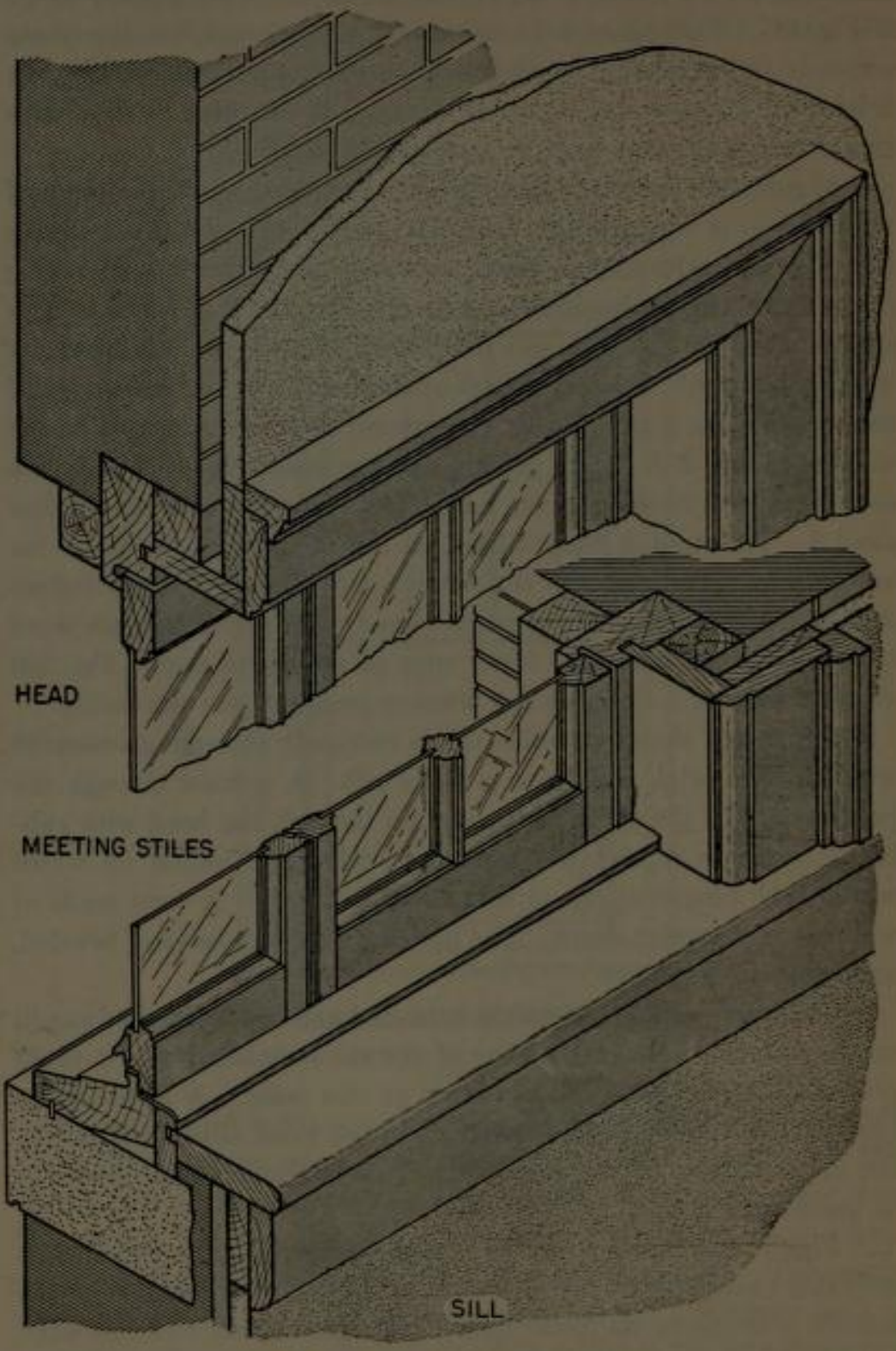


Fig. 501. Vertical Section of a Casement Window in a Brick Wall with a Stone Sill

sill. This figure also shows a section through a cornice such as might be placed over the head of a window so as to project out a short distance from the wall. The section shows rough lookouts of scantling nailed to the sides of the wall studding just above the headers over the window opening together with the rough blocking supported by these lookouts in the proper position to receive and support the facia

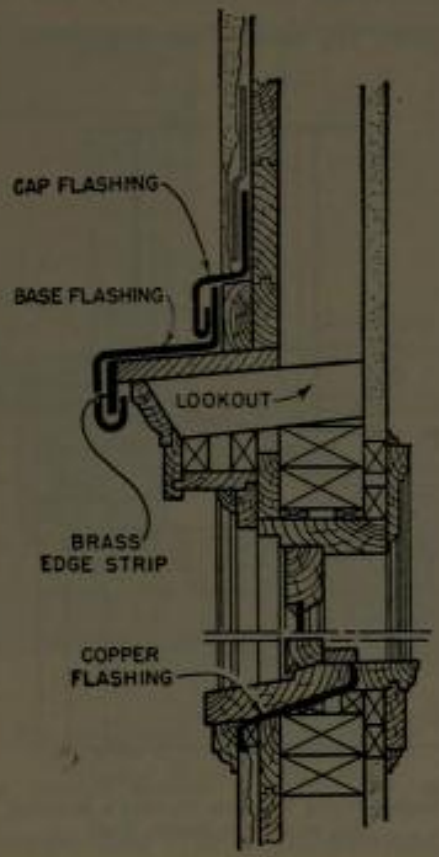


Fig. 502. Vertical Section through an Out-Swinging Casement Window in a Frame Wall

Courtesy of Copper and Brass Research Association

and the soffit of the cornice. The crown moulding is supported by the ends of the lookouts which are cut to an angle so as to receive this moulding. The top surface of any projecting cornice of this kind must be flashed with sheet metal and the figure shows such flashing of copper and also a cap flashing carried up behind the stucco wall covering above the window opening.

A double hung window in a brick wall is sometimes provided with a wood sill instead of the more usual stone sill illustrated in

Figs. 492 and 496. Fig. 503 shows a section taken vertically through such a window with a wooden sill. The brick wall is shown at *L*, while at *O* is shown a rough timber placed in the masonry wall at the outside face just under the place where the sill will come. The sill *B* is furnished and put in place as a part of the window frame as usual but the outside edge is ploughed to receive the additional piece *P* which forms the finish on the outside of the wall together with the apron *R;* these two members being nailed to the

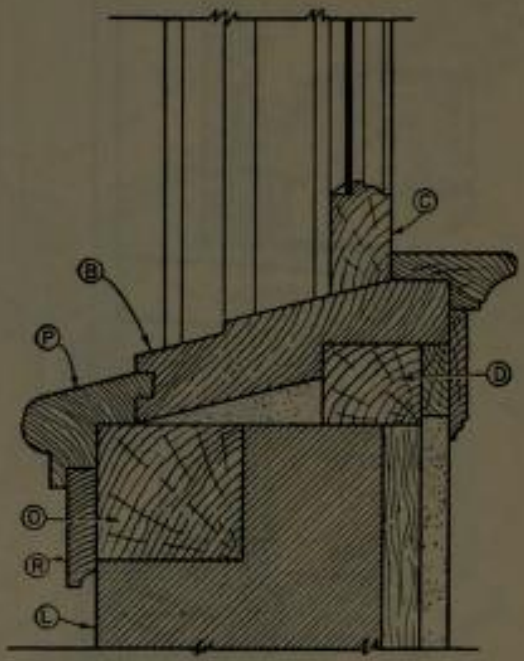


Fig. 503. Vertical Section through a Double-Hung Window Having a Wooden Sill and in a Brick Wall

rough nailing block *O*. The joint between *P* and *B* must be set in white lead as it is exposed to the weather. The two members *P* and *R* may be moulded in a great variety of ways to suit the fancy of the designer. At *D* is shown a second rough timber, set on the inside of the masonry wall to receive the sill *B*. In this window there is no inside winter sash and the lower sash of the double hung window is shown at *C*.

Figure 504 shows in elevation the lower left-hand corner of the window which is shown in section by Fig. 503 so that the appearance of the wood sill in the brick wall can be seen and the way in which it is treated at the two ends can be understood. As will be

seen in the figure the moulding is returned on itself against the brick wall.

Outside Door Frames. Outside doors are usually made heavier and thicker than inside doors, and, therefore, the frames for them must be different from the frames for inside doors even in frame buildings, and in buildings of brick or stone they are necessarily

Fig. 504. Exterior Elevation View of Lower Left-Hand Corner of Window Shown in Fig. 503

different from the inside door frames on account of being set in the masonry walls, while the inside door frames are usually set in wood walls.

The jambs and head of the frame, if in a building of wood construction, are usually made of plank from 1¾ inches to 2½ inches thick. As the doors to private houses generally open inward, the frames must be rabbeted on the inside edge to receive the door, and should also be rabbeted on the outer edge to receive a screen door in summer. The inner edge of the frame is set flush with the plaster line on the inside so as to receive an architrave, the same as in the case of a window frame.

Fig. 505 shows an outside door frame for a wood building, the section being taken horizontally through the door jamb. *A A* are

the studs which form the rough opening, *B* is the outside boarding and *C* is the lathing and plastering which is carried on the inside of the studding.

It will be seen that the frame *E* extends in width from the outside of the boarding to the inside of the plaster, and receives on its outer edge the outside casing *F*, and on its inner edge the inside architrave *G*. *D* is a ground for the plastering, and *H* is the door itself,

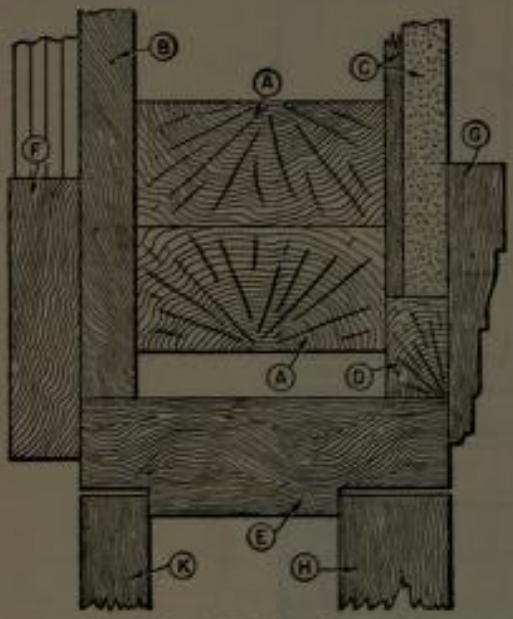


Fig. 505. Section of Outside Door Frame

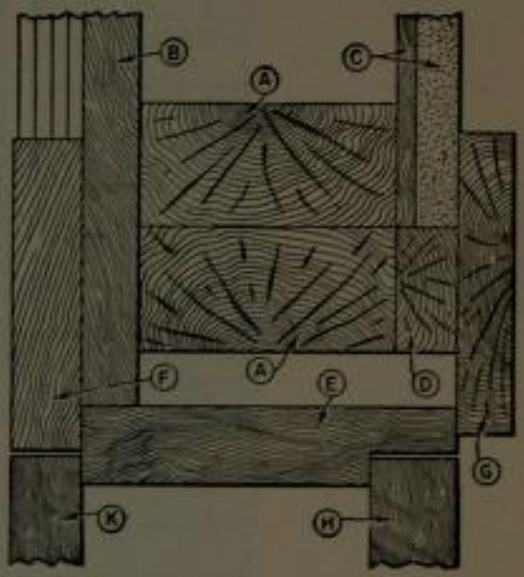


Fig. 506. Another Outside Door Frame Construction

fitting into a rabbet cut in the frame, about ½ inch deep and the thickness of the door. *K* is the screen door for which a rabbet is cut in the outside edge of the frame.

A similar arrangement is shown in Fig. 506. There is no rabbet cut in the frame shown in this figure, the screen door being designed to hang on the edge of the outside casing, as indicated, the casing being made thicker in order to receive the door. This figure is lettered the same as Fig. 505. The frame *E* is much lighter than the frame in Fig. 505.

The section taken vertically through the head of the door frame would be the same as the section through the jamb, but the section taken through the sill would be different. Fig. 507 shows such a section. Here, *A* is the sill which forms a part of the rough framing of the building, and rests on the foundation walls, receiving the

joists which are shown in the figure at *B*. *L* is the line of the outside boarding, *C* is the under flooring, and *D* is the finished flooring. On top of the under flooring is placed the door sill *E*, which is cut out of plank about 1¾ to 2½ inches thick, with a wash on the outside like a window sill, and with the top placed about ¾ inch above the finished floor so as to allow the door *F* to swing inward over any rug or carpet which may be laid on this floor. The sill is a little wider than the distance from the inside of the inside architrave, to the

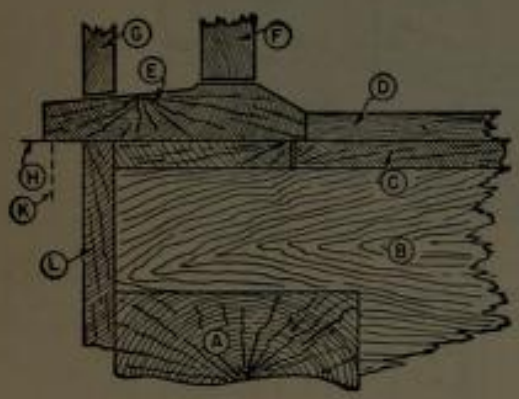


Fig. 507. Section through Sill of Door Frame

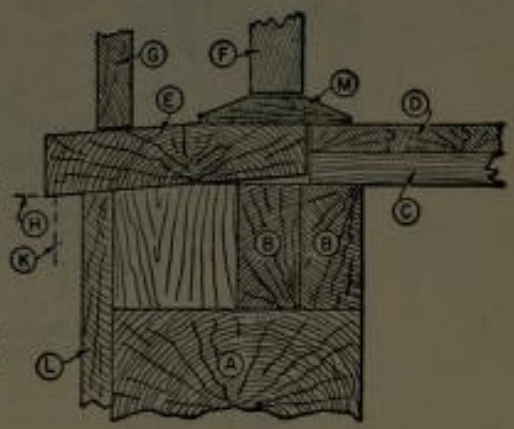


Fig. 508. Another Type of Construction for a Door Sill

outside of the outside casing. The line *H* is the line of the porch floor, if there is any porch, or there may be a step with the face as indicated by the line *K*. *G* represents a screen door.

Fig. 508 shows another type of door sill which is more simple in construction and less expensive than that shown in Fig. 507. Instead of being shaped to receive the door, as is the sill shown in Fig. 507, it is cut square, with a slight wash only, and on top of it is placed a saddle under the door. In Fig. 508 *A* is the rough sill of the framework resting on the foundation walls; *B B* are blocks to receive the ends of the flooring *C* on top of which is the finished flooring *D*. The top of the sill *E* is flush with the top of this finished flooring, and the saddle *M* covers the joint between the two, being beveled as shown at both sides. *F* is the door, and at *G* is the outside screen door. As before, *H* is the level of the veranda, if there is one, and *K* is the face of the riser of a step which may be placed under the sill on the outside. *L* is the line of the outside boarding

Figures 509 and 510 show sections taken vertically through the head and the sill of an outside door frame in a brick wall with a stone door sill. A section taken horizontally through the door

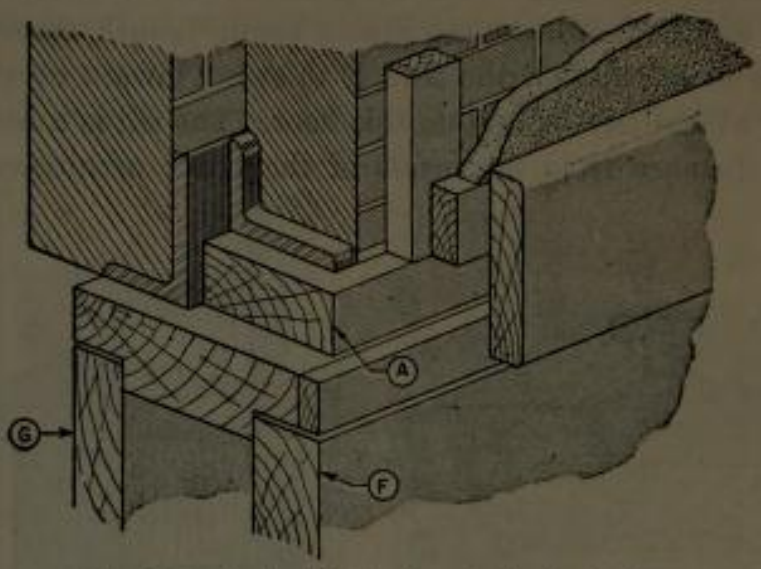


Fig. 509. Vertical Section through the Head of an Outside Door Frame in a Brick Wall

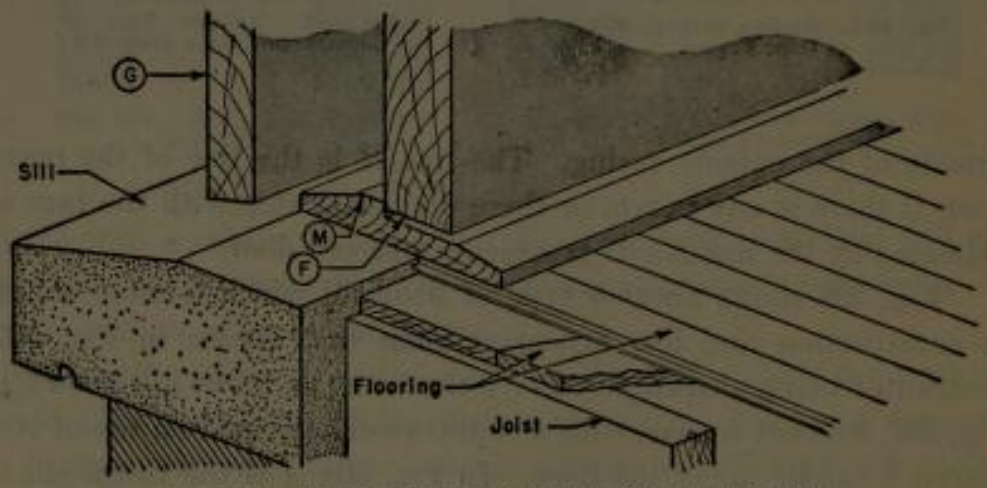


Fig. 510. Vertical Section through the Sill of an Outside Door Frame in a Brick Wall

jamb would be the same as the section through the head shown in Fig. 509, except that the steel angles forming the lintel over the door opening would be omitted leaving only the brick jamb, with the rough frame *A* embedded in it. Fig. 510 shows a rabbeted threshold at *M* which serves to prevent an open joint under the outside door *F*. *G* is the outside screen door.

An exterior doorway in a brick wall is sometimes finished with woodwork on the outside of the wall as is illustrated in Fig. 511. The parts of the wood finish which can be seen are composed of comparatively thin pieces 7/8 inch or 1 1/8 inches thick and back of them is placed wood blocking of rough scantlings to set them out

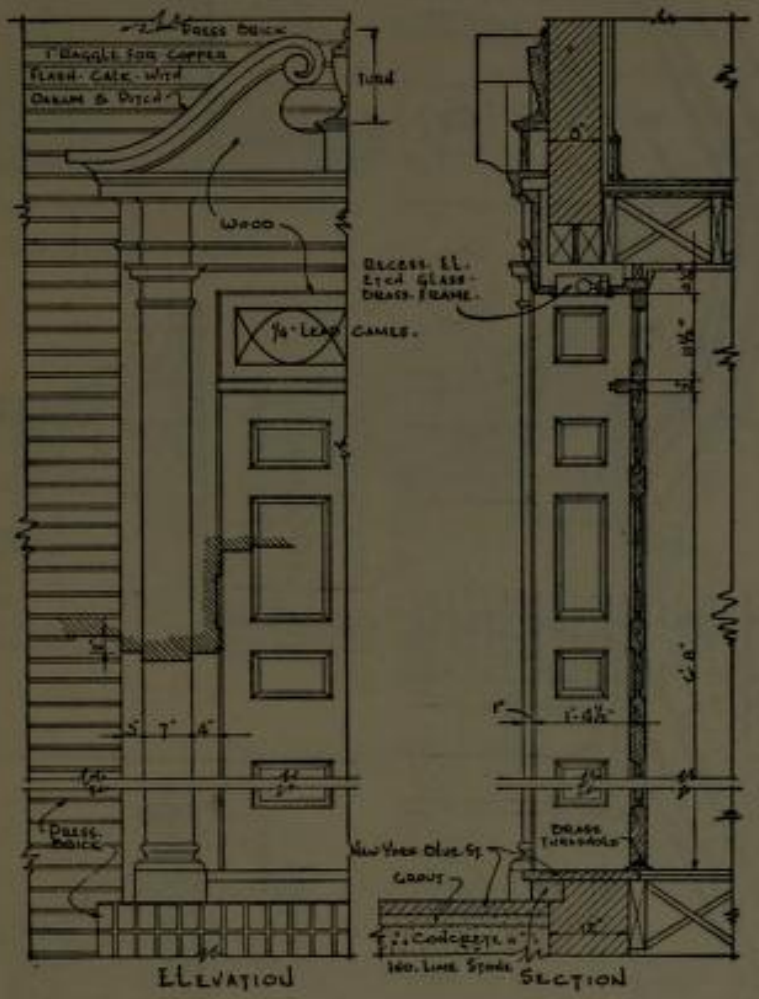


Fig. 511. Exterior View of Doorway in a Brick Wall Finished with Woodwork

from the wall and to give the effect of thickness. Fig. 512 shows a similar, but somewhat less elaborate finish over and around the heads of doorways in walls finished with brick, stucco, and shingles. Sections are shown through the overhanging or projecting hood over the doorway. The rough blocking can be seen and also the finished woodwork. The entire top surfaces of such hoods or projections of any kind should be covered with sheet metal, preferably copper, and this metal should be carried back against the wall behind the wall

Fig. 512. Flashing for Doorways
Courtesy of Copper and Brass Research Association

finish and flashed with sheet metal as shown in the figure. At *A* and *B* and at section *X X* is shown a brick wall. At *C* and at section *Y Y* is shown a stucco wall. At *D* and at section *U U* is shown a shingled wall.

Inside Door Frames. Inside door frames are in some respects similar to the outside door frames described above, but as they are intended for the lighter interior doors, they are not made so heavy as are the outside frames. Fig. 513 shows a section taken horizontally through the jamb of an interior door frame, the same section also serving for a section through the head of the frame taken vertically since the two sections will be the same. In this figure, *A A* are the studs in the partition at the side of the door opening, and

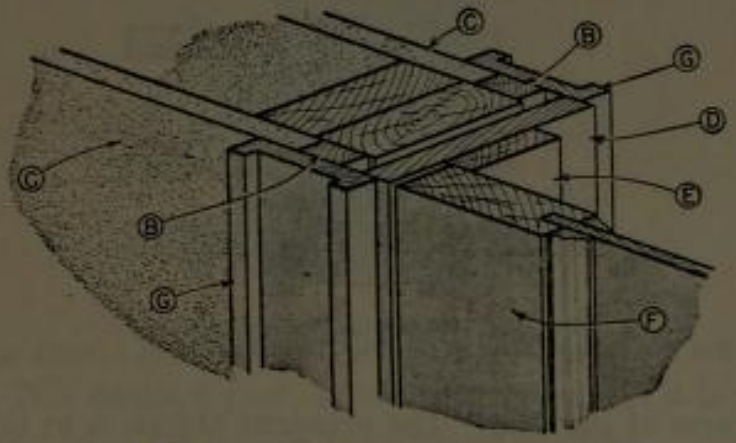


Fig. 513. Horizontal Section through Jamb of Interior Door Frame

forming the rough framing for the opening. *B B* are the grounds for the plaster *C* to stop against, and these grounds, of course, go all around the door opening, on both sides, and across the top. *D* is the finished door jamb, the head being exactly the same in section. The jambs are usually made $1\frac{1}{8}$ inches thick, but sometimes only $\frac{7}{8}$ inch. *F* is the door itself, shown $1\frac{3}{4}$ inches thick, although closet doors are frequently made of less thickness than this, and some heavy doors might be thicker. At one side of the frame the door is hinged, the hinge being fastened partly to the edge of the door, and partly to the frame, but at the other side of the frame there must be something provided to form a stop for the door. There are several methods of applying the "stop," one of which is shown at *E* in the figure. It is fastened to the jamb, but is in the form of a separate piece. The stop is carried all around the door opening,

and is usually set back from the edge of the jamb on both sides by an amount equal to the thickness of the door, so that the door can be hung at either edge of the jambs, or at either side of the partition. The final finish of the door opening is the "architrave" or "casing," which is shown at *G G*. This must be at least wide enough to extend from the edge of the jamb over onto the plaster so as to cover the joint entirely.

Another method of making the door frame is shown in Fig. 514. Here, the frame is rabbeted to form a place for the door, and there is no need of a stop. Such a frame is usually made thicker than the one shown in Fig. 513, and is rabbeted to a depth of ½ inch, and

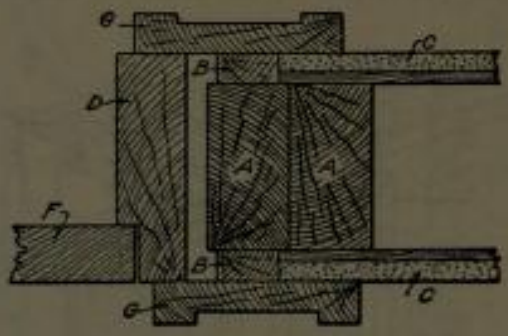


Fig. 514. Horizontal Section through Jamb of Interior Door Frame

the thickness of the door. The principal objection to this method is that at the head of the door, which is rabbeted the same as is the jamb, the part of the frame which shows above the door itself is greater on one side of the door than it is on the other. Therefore, unless all the doors in a room open into that room, or all of them out from the room, they will not line with each other at the head. For this reason it is better, to use some form of frame with a separate stop planted onto it, or a frame rabbeted on both sides.

The lettering in Fig. 514 is the same as in Fig. 513, and need not be explained again.

The only finish about a door frame with the exception of the door itself, is the architrave or the trim as it is sometimes called. It is also called casing. This is shown at *G* in Fig. 513. It may be made of any design desired, and as wide as desired, it being only necessary that it shall cover the plaster ground *B*, and project over onto the plaster *C*. The architrave is usually worked out of 1⅛-inches stuff, but may be made thicker as necessary. Its thickness is

determined by the thickness of the base or skirting in the room, which base or skirting has to stop against the architrave at each side of the door opening.

In Fig. 515, at *A*, is shown what is known as a "back band." It goes behind the architrave, as shown, and is used when for any reason it is necessary to have the architrave set out from the face of the plaster. Its purpose is to cover up the joint between the architrave and the plaster surface. Of course it may be molded as desired. It is usually made $\frac{5}{8}$ inch thick and as wide as necessary. In Fig. 515 *B* is the architrave, *C* the plaster ground, *D* the lathing and plastering, *E E* the studding in the wall, *F* the door, *G* the jamb,

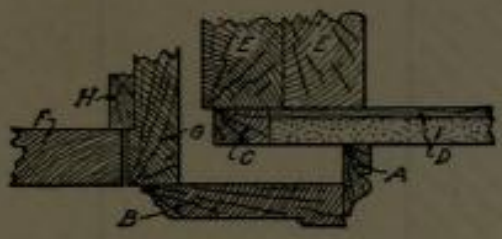


Fig. 515. Door Trim Construction Showing Back Band

and *H* the stop. It will be seen that the stop *H* is set into the jamb *G*. This makes a good, solid construction, but it is not often done on account of the trouble and expense involved.

Doors. The construction of doors is essentially the same, whether they are to be used as outside or as inside doors, the only difference being in the thickness of the door and in the finishing of it. The most simple kind of door is, of course, a single piece of board, with hinges at the side, but this is almost never satisfactory for any purpose, as it is likely to warp, crack, and shrink, and has not sufficient strength. It is customary in every case to build up a frame of comparatively heavy pieces and then to cover it over or to fill it in with lighter stuff in the form of panels. In such a framework for a door, the vertical pieces are called stiles, and the horizontal pieces are called rails. There are always at least two stiles and at least two rails, a stile at each side of the door, and a rail at top and bottom, but there may be more than two of each of these members. The stiles usually extend the full height of the door, from top to bottom, and the rails are tenoned into them. As mentioned above, the number of rails may be varied to suit the conditions, or the taste

of the designer, so that the door will have many small panels, or a few larger ones. After the frame has been built up in this way, the door may be finished as desired, that is, with sunk panels in the spaces between the rails and stiles, or with the framework covered with sheathing on one or both sides so as to present a plain surface without panels. Most of the simple, heavy doors for use in inconspicuous positions, such as doors for barns and outhouses, gates on

Fig. 516. Double-Diagonal Door Sheathing

Fig. 517. Diagonal Sheathing on Door Frame

walls, etc., are made with only one side covered with sheathing fastened to a rough frame.

The sheathing is sometimes put on vertically or horizontally, but a much stronger door is obtained if it is put on diagonally. It is possible, indeed, to make a satisfactory door by the use of sheathing alone, without any frame. The sheathing is put together in two thicknesses, and diagonally, but each thickness is made diagonal in the opposite direction to the other thickness so that all the pieces cross each other. Such a door is shown in Fig. 516. In Fig. 517 is shown a door with diagonal sheathing on the outside of a framework. Fig. 518 shows a strong type of door with a braced frame which is covered on one or both sides with vertical sheathing.

There is no difficulty in fastening together the simple doors just described, but when we come to the paneled doors, there are

some special methods in use for fastening the rails into the stiles at the corners, which must be described. There are also special ways of building up the members of which the doors are composed, to prevent warping and twisting.

In Fig. 519 is shown the most simple type of door for use in the interior of a building. It is called a "four-panel" door on account of the arrangement of the panels and their number. The stiles,

Fig. 518. Braced Door Frame with Vertical Sheathing

marked *A* in the figure, are all made not less than 4½ inches in width. The middle rail, marked *B*, is made 8 inches wide, and the top rail *C* the same as the stiles. The bottom rail, marked *D*, is made wider also, its width being about 10 inches. The panels are marked *E E*.

Figs. 520 and 521 show other arrangements of panels which may be employed. Of course, the more cross rails there are between the top rail and the bottom rail, the stronger will be the door.

The point of greatest interest in the construction of a door is the joint between the top rail *C* and the stiles *A A*. The rail is always tenoned into the stiles, the stiles continuing all the way up to the top edge of the door, and this joint is never made as a mitered joint. Fig. 522 shows the tenon by dotted lines.

It will be seen that it does not go all the way through the stile

of the door but should be stopped back about ½ inch, so as not to show on the edge of the door.

Fig. 523 shows how a door should be constructed, the figure being a section taken through the stile of the door. The entire piece is built up out of strips of pine ⅞ inch thick, and of a width equal to the thickness of the door, minus ½ inch for a veneering of

Fig. 519. Four-Panel Door

Fig. 520. Door with Horizontal Panels

Fig. 521. Another Form of Door Paneling

¼ inch thick on each side of the door. This veneering is often made only ⅛ inch thick. The strips are carefully glued together, side by side, thus forming the finished piece on which the veneering is applied. Fig. 523 also shows the proper construction of a panel at the place where it joins the stile or the rail.

A piece marked *A* in the figure is first glued into the stile or rail, and to this are glued the panel moldings, after the panel has been put in place, the panel moldings projecting out beyond the piece *A* far enough to hold the panel, which is thus left free to move as it shrinks or swells. The panel will remain as a plain surface, and will not bulge or crack. The moldings should never be fastened in any way to the panel itself. Unless the panel is absolutely free to move it is sure to crack badly.

The types of doors shown in Figs. 519 and 521 are not seen in the best modern buildings. Fig. 524 illustrates four of the more modern types of doors for interior door openings. For exterior

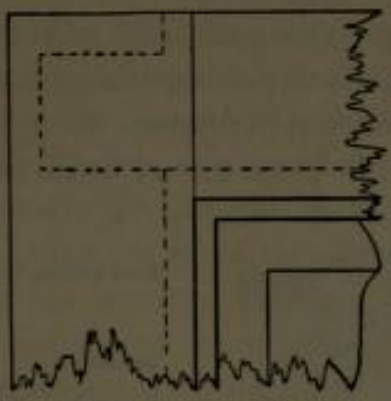


Fig. 522. Construction of Joints Between Top Rail and Door Stile

Fig. 523. Section Showing Panel Construction

Fig. 524. Interior Doors

doors one of the first three designs shown in Fig. 524 is frequently used with the panel or the upper panel glazed. Exterior doors, however, are usually made thicker and heavier than interior doors and, because they are exposed to the weather, they should never be

veneered doors as the veneering would soon become loosened. Solid doors should always be used for outside doors.

TRIM

Base or Skirting. The walls and ceilings of rooms in which there is no attempt made to give an ornamental treatment in woodwork are ordinarily finished in plaster. Even in the cheapest work, however, there should be some sort of finish at the point where the

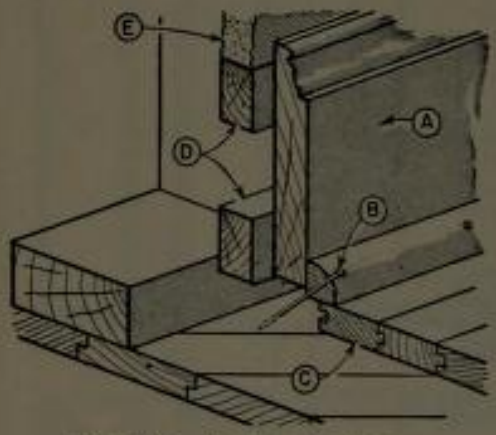


Fig. 525. Section of Base Board or Skirting

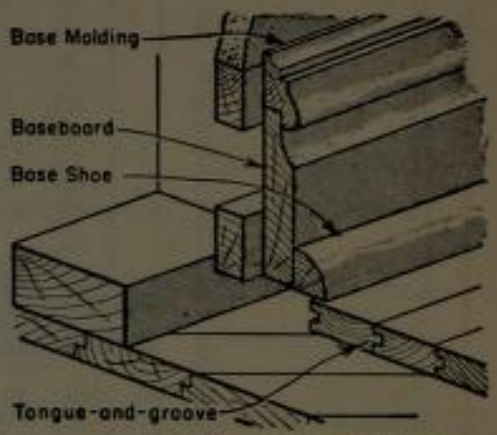


Fig. 526. Section of Three-Member Base

floor and the wall meet, in order to stop the plaster and the finished flooring. This member is called the "base" or "skirting" and is almost invariably of wood. It may be of hard wood, or of soft wood for painting, and may be very plain or very ornamental. Such a base would ordinarily be made out of stuff $\frac{7}{8}$ inch or $1\frac{1}{8}$ inches thick, and would be made from 6 to 10 inches high above the floor. The top of this member is usually molded in some way. Fig. 525 shows such a base. It is about 8 inches high, molded at the top, as shown at *A* in the figure. The finished flooring *C* passes under the base, in which case the flooring must be laid first, but the base may be set in place before the flooring is laid, and the flooring stop against it, in which case it is necessary to place a quarter-round molding, as shown at *B* in the figure, to cover the joint between the two. *E* is the plastering against which the base sets and *D D* are grounds of wood which are nailed to the studding or furring before the lathing and plastering are done, so as to provide something to which the base may be nailed. The base should not, however, be

fastened at both top and bottom, as it is likely to crack if it does not have a chance to shrink and move freely in one direction. The plastering may be carried down behind the place where the base is to go or not, as desired. If the plastering is carried down to the floor, a warmer building is obtained than would be the case if the plastering were to be stopped at the top of the base.

Fig. 526 shows how the base may be built up out of two pieces so as to save material, the upper part being taken out of thicker stuff than the lower part. If this base were made in one piece it would be necessary to take the entire member out of the thick stuff and waste material in the lower portion. In this manner it is possible to build up the base in any shape desired, and to make it of as many pieces as seems advisable. A base may be made to any height up to 12 or 14 inches, but these heights are excessive for a base. If it is necessary to protect the wall up to a greater height than can be covered by means of a base, or if an ornamental effect is desired, a wainscot is used.

Wainscoting. Whenever it is not desirable to carry the plastering down to the floor, for any reason, it is customary to make use of a wainscot, which is a covering of woodwork about 3 or 4 feet high, which either goes on top of the plaster or takes the place of the plaster on the inside of the wall. Such a covering may be made

Fig. 527. V-Shaped Sheathing

higher, up to 6 or 7 feet, and it is then known as a "dado," but the two names are very loosely used and are often confused, one with the other.

The most simple kind of wainscot is composed of matched sheathing, which may be ornamented by being beaded, or V-jointed or center beaded. Fig. 527 shows a section through a few pieces of V-shaped sheathing to illustrate the meaning of the term "V-joint." The sheathing is tongued and grooved and the narrow strips are set up vertically and matched together, but each strip has the sharp edges cut away on one side, so as to form in the finished work a V-shaped depression as shown at *A* in the figure.

Fig. 528 shows a section taken horizontally through a portion

of some beaded sheathing. This sheathing is tongued and grooved in the same way as is the other sheathing described above, but instead of being V-jointed as the other is, it has a bead worked on each piece on one edge only, as shown at *A*. This makes it more

Fig. 528. Beaded Sheathing

Fig. 529. Center-Beaded Sheathing

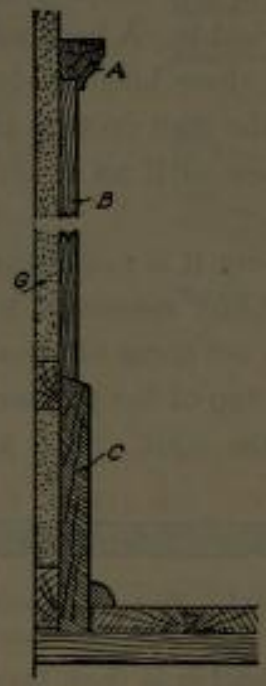


Fig. 530. Section through Simple Wainscoting

expensive than the V-jointed sheathing and much more expensive than plain tongued and grooved sheathing.

Fig. 529 shows a section through some center beaded sheathing, where, in addition to the bead *A* worked on the edge of each piece, a bead or sometimes two beads are worked in the center, as shown at *B*.

Fig. 530 shows a section taken vertically through a simple wainscot composed of matched sheathing with a base and a cap mold. The sheathing itself is shown at *B*, the plaster being at *G*,

with the sheathing placed close against the plaster surface. At *C* is the base, with the top beveled to receive the sheathing. This method of receiving the sheathing on a beveled top to the base is the best, because dust and dirt will not then collect between the joints of the sheathing at the bottom, and whatever does collect there can be easily cleaned away. At *A*, is shown the cap molding which is grooved on the bottom to allow the sheathing to fit up into it. This cap mold runs the full length of the wainscot and stops against the architraves around the windows and doors, so that its

Fig. 531. Horizontal Section through Another Kind of Wainscoting

Fig. 532. Section Showing Paneled Wainscoting

Fig. 533. Another Paneled Wainscoting

projection can not be greater than the thickness of the architrave molding, and it should be about ⅛ inch less than this thickness.

In Fig. 531 is shown another kind of wainscoting, the section being taken horizontally through a portion of it. This form of wainscoting is more expensive than simple matched or beaded sheathing, but it is not so expensive as is paneled work. It consists of pieces called "battens," as shown at *C*, with other thinner pieces grooved in between them, as shown at *B*. The battens may be ⅞ inch or 1⅛ inches in thickness, while the panels are usually made ½ inch thick. The width of the various pieces depends upon the design of the wainscoting which can be altered to suit the taste of the designer.

Fig. 532 shows the joint between the panels and the battens in simple paneled wainscoting. In this case, the battens *C* are grooved as in Fig. 531 and the panels *B* are tongued into them.

In Fig. 533 is shown a better way to fasten in the panels *B*, the piece *A* being separate from the panel and the batten, but the molding is still a part of the batten *C* itself.

Fig. 534 shows a form of paneling where both the molding *D* on the face and the piece *A* on the back are separated, and the batten

C is cut with a rabbet to receive the molding on the face so that it will not extend too far on the face of the panel B, in which case it is likely to curl up a little at the edge and become separated from the panel instead of lying flat against it. The method shown in Fig. 534 is much the best, especially in the case of raised panel moldings.

In dining rooms and in some other rooms it is customary to

Fig. 534. Still Another Form of Wainscot Paneling

Fig. 535. Vertical Section through Plate Rail

carry the wainscoting to a height of 5 or 6 feet from the floor and in this case it is usually capped with a member called a "plate rail." Fig. 535 shows a section taken vertically through such a plate rail. The wainscoting or dado A stops underneath the blocking C, and a molded piece B is planted onto the face of the blocking to form a finish. The projection of the rail from the wall is about 3½ inches.

Figure 536 illustrates another type of plate rail which is much lighter than the one shown in Fig. 535, and this is the kind of plate rail most frequently seen. It is, of course, not so strong as the other but is cheaper. When a plate rail is desired in a room with plastered walls but with no wood wainscoting, the piece A is employed to furnish a support for the plate rail. The piece C acts as a continuous bracket to hold up the top member B.

Wood Cornices. In many cases the only portion of the cornice around a room which is made of wood, is the picture molding, which

is a small molding to the top of which picture hooks may be fastened. Fig. 537 shows several forms which such a molding may take.

When it is desired to have the entire cornice in wood, it should be built up out of comparatively thin pieces, say $\frac{7}{8}$-inch stuff, and

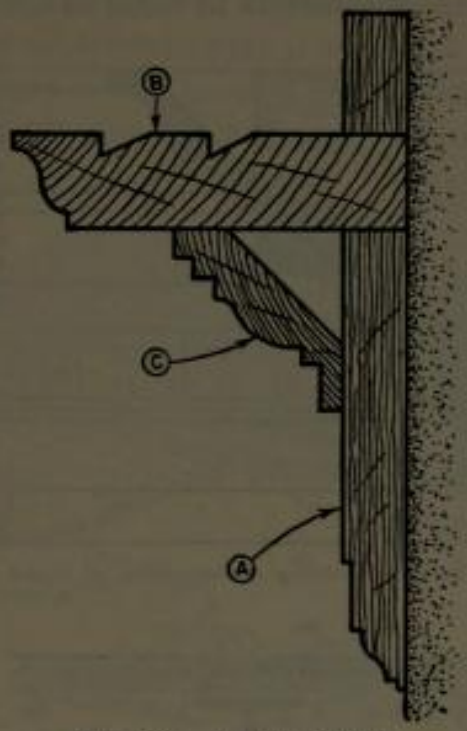


Fig. 536. Vertical Section through Plate Rail

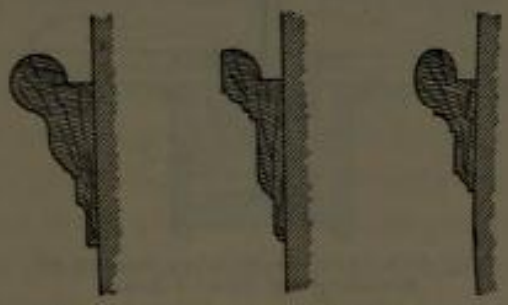


Fig. 537. Forms of Picture Molding

these thin pieces should be blocked out with rough blocking to the extent desired. In Fig. 538, *A*, *B*, and *C* are furring strips placed about 2 feet apart and the shaded portions represent the pieces out of which the cornice is built up.

Wood Ceiling Beams. It is often necessary or desirable to have beams showing in the ceiling of certain rooms, and these beams may be either true or false, that is, they may be either an ornamental

covering for beams which really exist, or they may be entirely ornamental, enclosing nothing which forms part of the real construction of the building.

Fig. 539 shows how a steel beam may be covered and ornamented so as to give a finished appearance in wood in the ceiling. *A A* are

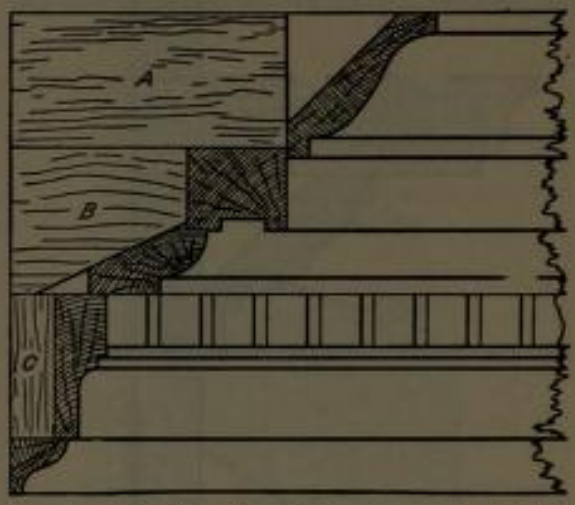


Fig. 538. Section Showing Construction of Wood Cornices

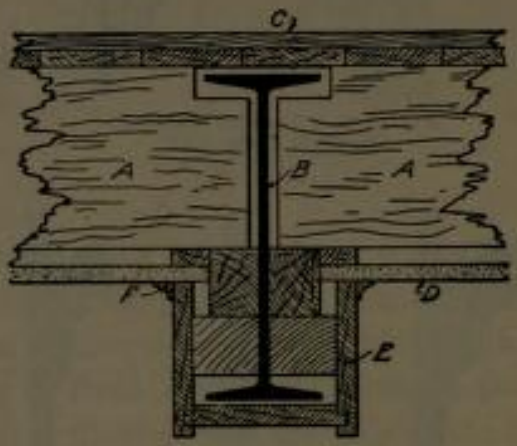


Fig. 539. Section Showing Method of Finishing Off Steel I-Beam

the floor joists, and *B* is the steel beam. *C* is the line of the finished floor above, and *D* is the line of the finished ceiling. *E* is the finish of the ceiling beam, and *F* is a little molding to cover the joint between the plaster and the wood.

In case the beams are false, they are constructed in the same way except that the shell is filled in with blocking to take the place of the real beam shown in Fig. 539.

Finished Flooring. The finished flooring may be of soft wood but

it is usually of hard wood such as Birch, Maple or Oak. It is, as a rule $^{13}/_{16}$ inches thick although $^{3}/_{8}$-inch stuff is sometimes used. The pieces of flooring should be narrow, from $1^{3}/_{4}$ inches to $2^{1}/_{2}$ inches wide, not counting the tongue which projects on one side, since the pieces are usually tongued and grooved or "matched" so that they will fit into each other and not leave an open joint if each piece should shrink a little. Fig. 540 shows the flooring in place on top of the rough flooring or "sub-floor" with building paper laid in between the two

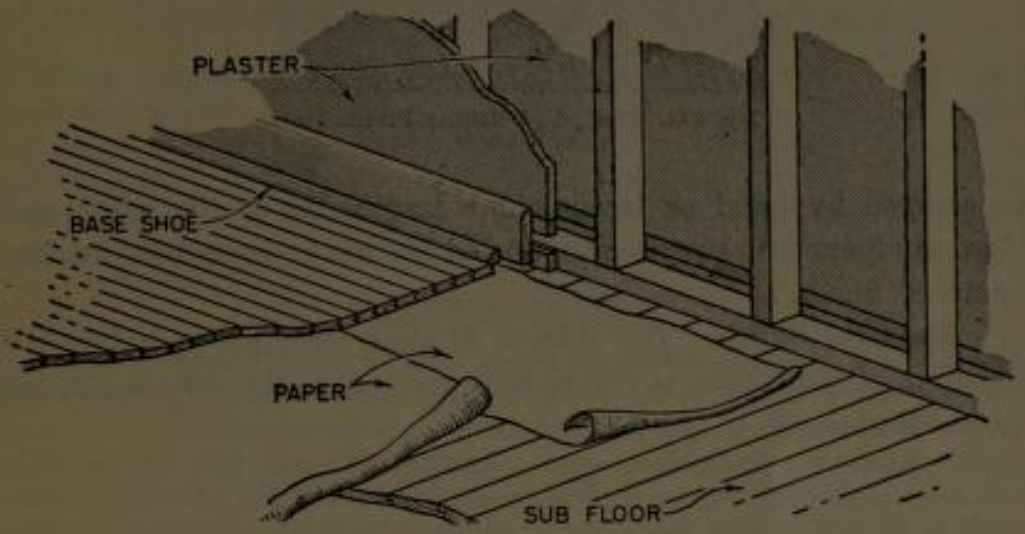


Fig. 540. Showing Finish Flooring in Place over Paper and Subfloor
Courtesy of Weyerhaeuser Forest Products

floors. The pieces of flooring are of different lengths, some long and some as short as one foot. The best and most expensive flooring has only a small percentage of short lengths while the cheapest flooring has a large percentage of these short pieces.

The pieces of flooring are nailed to the sub-floor with cut steel flooring nails, eightpenny for $^{13}/_{16}$ inch flooring and threepenny for $^{3}/_{8}$ inch flooring. Each piece of flooring has a nail every 16 inches. The nails are always driven in on the side of the flooring where the tongue is and are driven into the angle of the tongue so as not to show on the top of the flooring as shown in Fig. 541.

The pieces of flooring should not be laid close to the wall on any side of the room but should be kept about 1 inch clear of the wall all around to allow for possible swelling of the flooring. The joint will be covered by the "base-shoe" as shown in Fig. 540.

The base-shoe should not be nailed to either the base or the finished flooring but must be nailed to the sub-floor with long nails as shown at *B* in Fig. 525. This is so as to allow both the flooring and the base to shrink and swell freely while the joint between them is covered by the base-shoe. After the flooring is laid it must

Fig. 541. Method of Nailing Finish Floor to Subfloor

be scraped by hand or by machine lengthwise of the wood and then sandpapered, swept, and dusted so as to be ready for the painters' finish.

Staircase Finish. The subject of stair building, including the finishing of staircases, is completely covered in the article entitled "Stair Building."

The material in Part V, Farm Buildings, which follows immediately, has been reprinted from Fundamentals of Carpentry, Volume II, *by W. E. Durbahn.*

CARPENTRY

PART V

FARM BUILDINGS

QUESTIONS THIS CHAPTER WILL ANSWER

1. *When designing and constructing a barn, why is it important for the carpenter to understand the nature and effect of wind pressure?* 2. *What advantage does the gambrel-roof barn have over a gable-roof barn?* 3. *Can you name three farm buildings besides the house and barn?* 4. *What kind of material is used in the construction of small farm buildings?* 5. *What two types of hog houses are commonly used by farmers?*

INTRODUCTION

In this chapter you will learn many important facts about the construction of barns, hog houses, and poultry houses. Other small farm buildings also considered include sheepsheds, rabbit hutches, and granaries. Attention is called to the fact that the carpenter must understand the nature of wind pressure and the effect on buildings of different types of winds, such as the ordinary straight wind and the winds of hurricane proportions. It is likewise pointed out that among the common causes of farm-building failures are faulty foundations, insufficient anchorage of buildings, and poorly constructed joints. The responsibility of the carpenter in preventing these failures is stressed, since he must be able to anticipate and effectively prepare for the defeat of these destructive forces by learning how to build well.

You will further find in this chapter interesting as well as instructive discussions on the advantages of certain types of roofs for barns, sheds, and other farm buildings. Careful consideration is given also to the question of how to provide properly heated and ventilated shelters for livestock, in order to protect the health, not only of the horses and cattle, but also of the hogs, sheep, and hens.

You should give as careful attention to the study of this part as you did to other parts dealing with the building of a home for a family. Since the wealth and income of the farmer depend largely upon the proper storage of his farm crops and the good physical condition of his flocks and herds, it is a common saying with farmers that "a good barn will build a good house."

CONSTRUCTION OF FARM BUILDINGS

Farm buildings comprise a large field of special construction. Any book on carpentry would be incomplete without some attention being

given to the construction of barns, hog houses, sheepsheds, henhouses, implement sheds, and other important small farm buildings.

When erecting store buildings, warehouses, or other buildings necessary to carrying on his business, the city dweller relies in most cases upon the services of an architect, contractor, or a trained builder. However, the farmer usually does much of his own carpentry work, with the help of his neighbors and friends. Because of the nature of his work, the average farmer is by necessity something of a mechanic and usually can handle carpentry tools with reasonable skill. What he needs most is information concerning design and details, also training in the various methods of construction. Fortunately, such information usually is available through services provided by leading agricultural colleges, state universities, and the United States Department of Agriculture. There are also private organizations[1] and dealers in building materials that generously furnish information regarding the use of the supplies which they handle.

CAUSES OF FAILURES OF FARM BUILDINGS

Extensive investigations, study, and experiments[2] show that failures of barns and other farm structures to withstand violent winds usually may be attributed to one or more of the following causes: (1) misunderstanding of the nature and effect of wind pressure; (2) inadequate foundations; (3) insufficient anchorage of the frame to foundation; (4) lack of adequate bracing in the framework; and (5) weak joints.

Nature and Effect of Wind Pressure. In order to prevent the failure of barns and other farm buildings to withstand the pressure of violent winds, the builder should understand the nature of wind pressure and the effect such pressures exert upon frame structures. Three types of violent windstorms wreck buildings in the United States—the *cyclone*, the *tornado*, and the *hurricane*.

Cyclones. As storms of gigantic circular movements of air, *cyclones* pass across the United States as high- and low-pressure areas, usually traveling with a velocity of from 20 to 30 miles an hour. These wind-

[1] For example, Southern Pine Association, New Orleans, La., and the West Coast Lumbermen's Association, Seattle, Wash.

[2] *Design of Barns to Withstand Wind Loads*, Bulletin No. 42, published by the Kansas State College, Experiment Station, Manhattan, Kan. This is a full report of studies and experiments which furnished much basic data on wind loads.

storms, characterized by circular movements, often rotate at the rate of from 90 to 130 miles an hour. In the Northern Hemisphere these rotations move in a counterclockwise direction; in the Southern Hemisphere they move in a clockwise direction. The high-pressure currents of air in a cyclone rotate about a calm center of low atmospheric pressure. The diameters of these huge circular air movements usually vary from 50 to 900 miles. The cyclone and the hurricane both appear to be straight winds in any locality. Although the winds in a cyclone are not as strong as those of the violently whirling tornado, cyclonic winds are more widespread and do much greater total damage than the tornado. The term *cyclone* should not be applied, as it often is, to either the tornado or the twister.

Tornado. The *tornado* is an extremely violent revolving windstorm, normally occurring in association with cyclones. When fully developed, a tornado is accompanied by a funnel-shaped cloud. The funnel-shaped mass, depending from a black storm cloud above, tapering downward to the earth and advancing with a velocity of from 20 to 50 miles an hour, sometimes covers a distance of many miles as it travels over the land. Though in comparison with the diameter of the cyclone, the diameter of the funnel of a tornado is small, yet this type of storm, with its rapidly whirling air movements, is highly destructive wherever it strikes the earth. Its path may vary in width from a few feet to a mile or more. As the storm progresses it leaves behind a well-marked pathway strewn with wreckage. The tornado occurs in many localities, but is especially frequent in spring and early summer in the central Mississippi River Valley. The wind pressure in a tornado cloud is too violent to be measured and the barometric pressure falls so rapidly that wooden structures often are lifted from the ground and burst open by the pressure of the air confined within them.

Hurricanes. The *hurricanes* which occur along the southern and eastern coasts of our country are also large circular air movements of a cyclonic nature. These air movements create high-wind velocities near the center of the storm cloud and often do tremendous damage to many different kinds of structures, as well as to crops and forest trees. For example, consider the hurricane which struck Galveston in 1900; it was a cyclonic wind which blew steadily for 18 hours, reached a velocity of 135 miles an hour and resulted in the loss of 5000 lives and

property damage estimated at more than $17,000,000. However, after the storm had passed, there were some buildings in Galveston that had withstood this terrific test of their construction. The builders of these structures had understood the nature and effect of wind pressure, and also realized the importance of providing for such emergencies.

When a straight wind is blowing directly against the side of a building, the wind pressure against that particular surface varies with the velocity of the wind. In addition to this pressure on the windward side there is also a negative pressure, or *suction pressure*, as it is commonly called, on the opposite side, also on the ends, and on most of the roof. The air pressure on a gambrel-roof barn, when the wind is blowing against one side, is shown in the illustration, Fig. 1. Note the direction and amount.

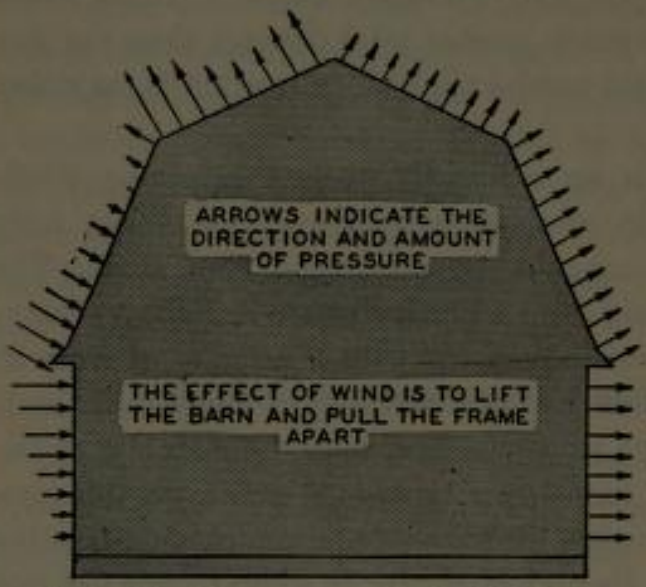


Fig. 1. Wind Pressure on a Gambrel-Roof Barn

In designing a building to withstand wind pressure we should, of course, consider, not only the pressure on the windward side but also the suction and the lifting pressure on much of the remaining surfaces of the building. In fact, the suction forces are greater in total amount than the wind forces which press in on the walls. In preceding chapters we have emphasized the ability of a building to stand up under loads, and most of the various members are designed to hold up the weights of the building or the load of materials stored in the building. When constructing barns and small buildings on the farm to withstand wind, we should lay equal or greater emphasis upon both the part that holds the building down to the foundation and that which holds the roof onto the walls. We might also give more attention to the shape of a building as it affects wind pressure. The building with streamlines such as circular roofs are less likely to be blown over and are still safe even with a lighter and cheaper construction.

WIND-RESISTANT CONSTRUCTION

An adequate foundation for anchoring a building securely to the ground is the starting point of all good wind-resistant construction. The second essential of good construction of a wooden building is anchoring the frame securely to the foundation. In wind-resistant construction,

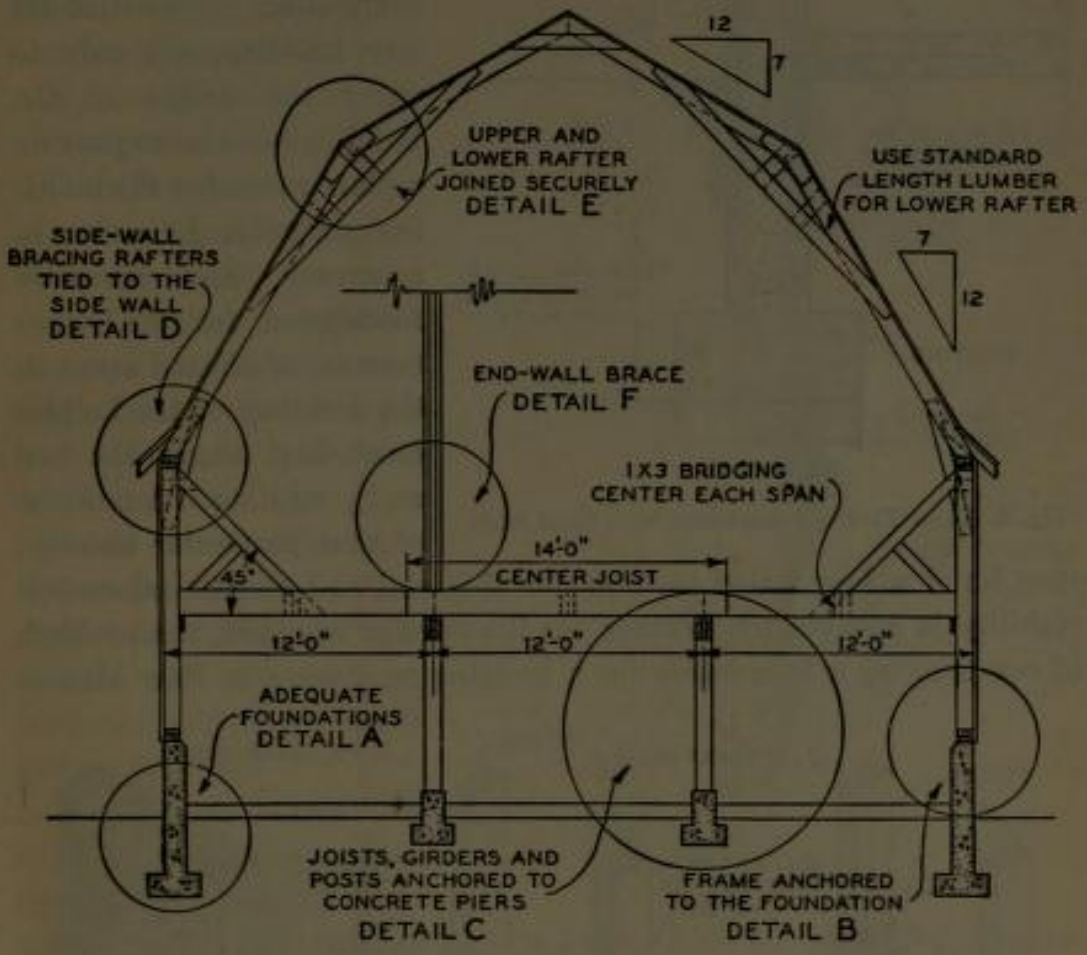


Fig. 2. Six Essentials of Wind-Resistant Construction

another important factor is anchoring the joists, girders, and posts to concrete piers, while a fourth essential is securely tying the roof rafters to the side walls. Bracing of end walls is a fifth important factor, and a sixth essential in good construction is proper fastening of broken joints, such as those of a gambrel roof. These six essentials of good wind-resistant construction are illustrated at (*A*), (*B*), (*C*), (*D*), (*E*), and (*F*), Fig. 2. Another essential, which may be called the seventh essential of good construction, is the method used in fastening joints

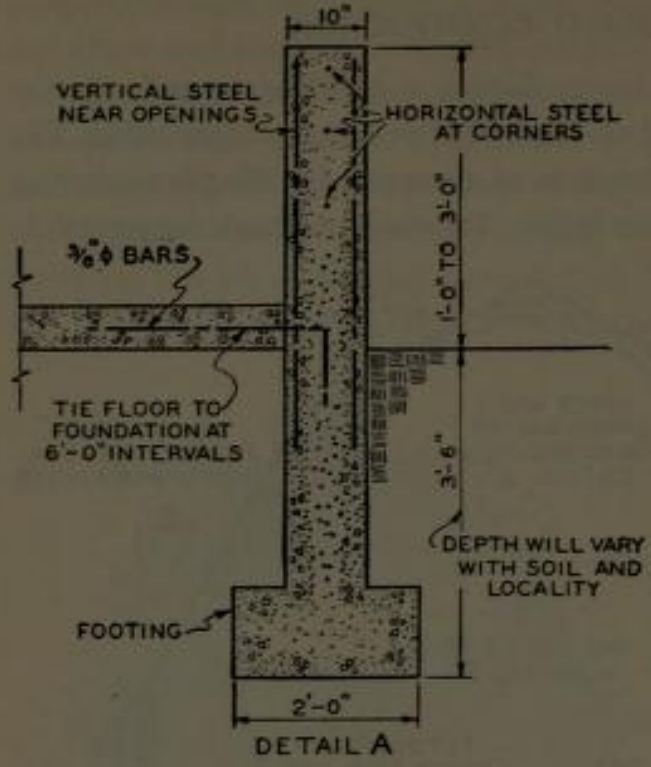


Fig. 3. Floor Tied to Foundation with Steel Rods

and materials together. A brief description in detail of each of the foregoing essentials is given in the following paragraphs.

1. Foundations. A good foundation is essential for any building, not only to carry the weight of the building but also to provide a place to anchor the building securely. In order to construct an adequate foundation for the structure to be erected upon it, the architect or the builder must first study the soil and weather conditions of that particular locality, then build a foundation suitable for that soil and climate, since soil stability is affected by weather conditions. For example, the problem of constructing a foundation for a building on a mesa in New Mexico

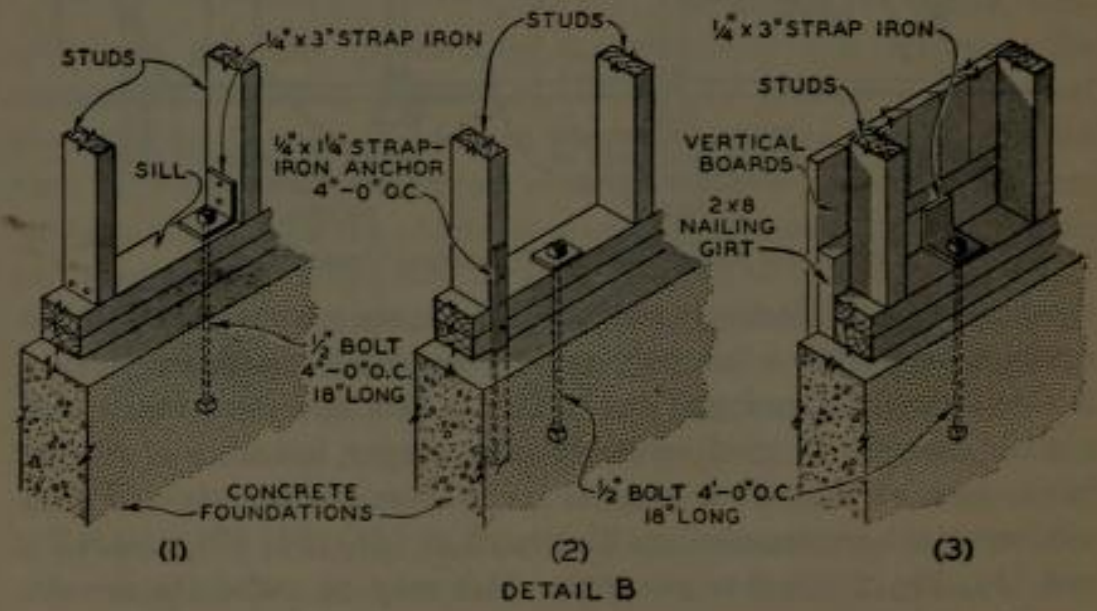


Fig. 4. Three Methods of Anchoring Walls to Foundations

is far different from that of constructing a foundation for a similar building in the Everglades of Florida. In the northern and central regions of the United States, foundations should go below the frost line, if at all possible, to prevent heaving by frost. To be satisfactory the footing must be wide enough to hold the weight of the building and its contents without settling. Steel rods in foundations are good investments and will prevent uneven settling and heaving. See (*A*), Fig. 2, and the detail drawing of this shown in Fig. 3. Note especially the steel rods. This type of construction will also hold foundations together at corners and will tie the walls and floors together. This often prevents cracks in the foundation at this point. Foundations also should be high enough to hold wooden framing members above the ground moisture.

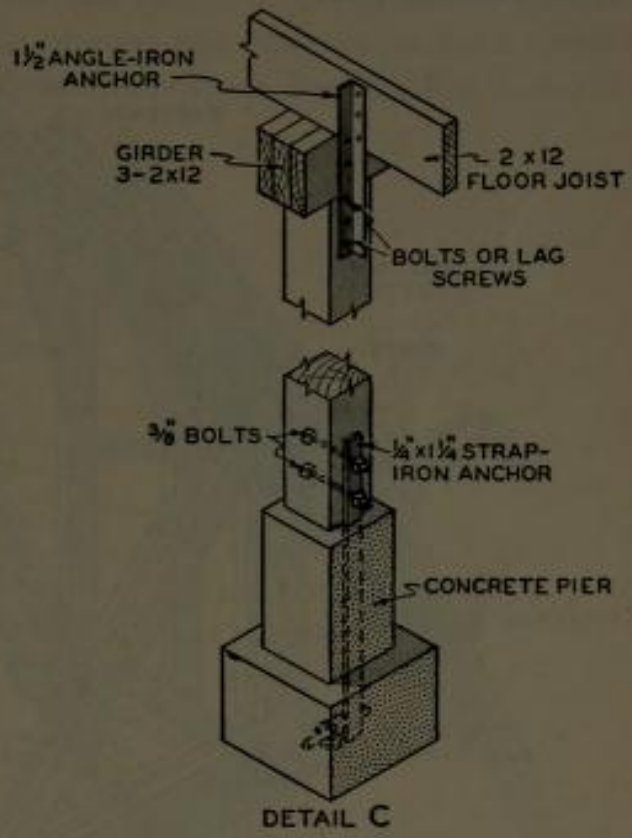


Fig. 5. Joists, Girders, and Posts Anchored to Concrete Piers

2. Wall Anchorage. All surveys of damage done by violent storms have shown that many buildings have been lifted off their foundations by wind. See (*B*), Fig. 2, and the detail drawing of this shown in Fig. 4. Note particularly the three different methods of anchoring buildings to foundations. The method illustrated at (*1*), Fig. 4, shows a heavy piece of strap iron, bent to a right angle, with one leg bolted to the foundation and the other leg bolted to the stud. This makes a simple and effective tie. Another method of using strap iron and bolts for tying the sill to the foundation is illustrated in (*2*), Fig. 4. The third method shown at (*3*), Fig. 4, is to nail vertical or diagonal sheathing directly to the sill which is then bolted to the foundation. This is also a good method.

3. Anchors for Joists, Girders, and Posts. A method of anchoring joists, girders, and posts to concrete piers is shown at (*C*), Fig. 2, and the detail drawing of this is shown in Fig. 5. Note the angle iron used to anchor the floor joist to the girder and to secure the girder to the post. Also note the use of strap iron and bolts to anchor the post to the concrete pier.

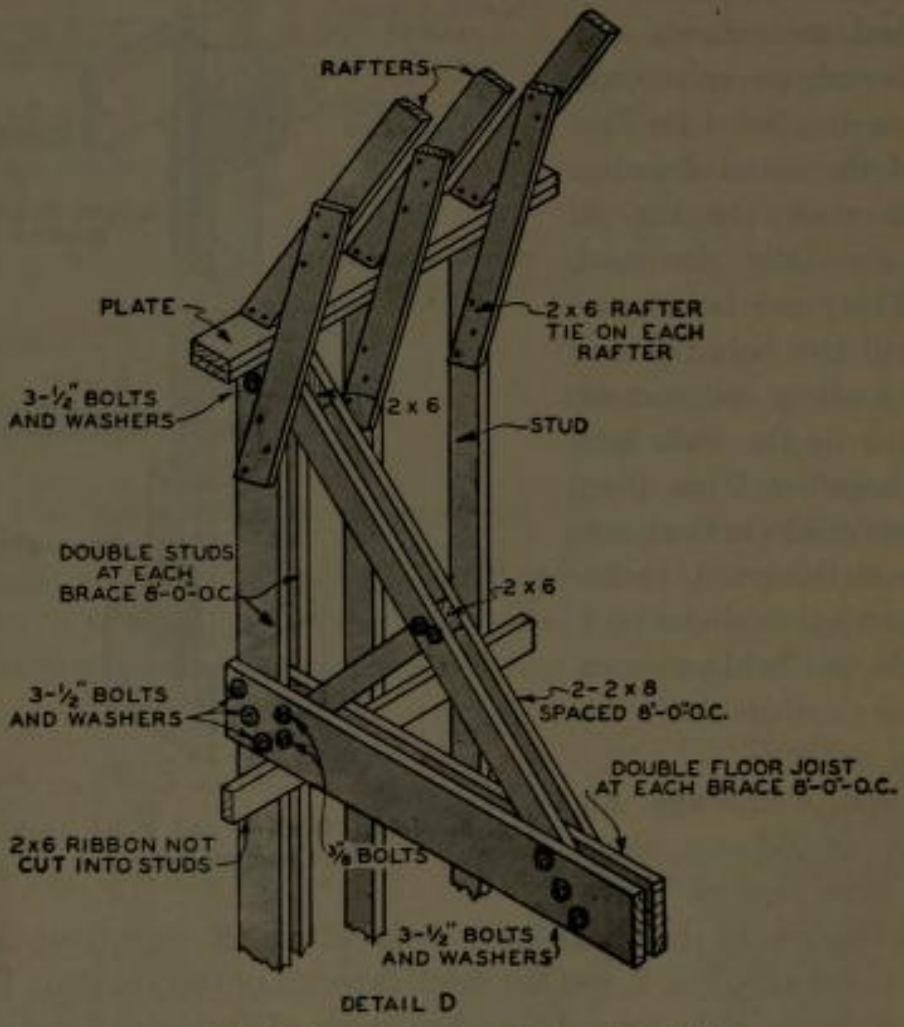


Fig. 6. Bracing Rafters Tied to Side Walls

4. Roof Anchorage. For tying side-wall bracing rafters to the side wall see (*D*), Fig. 2, and the detail drawing of this shown in Fig. 6. To anchor the roof to the walls the usual method of construction is to toenail the rafters to the rafter plate. However, a better method is the use of short pieces of 2x4 or 2x6 in addition to the toenailing. These pieces should be nailed to both rafters and studs as shown in Fig. 6,

where 2x6 rafter ties are shown nailed to each stud. Another method of solving this problem is to make the rafter and stud of one continuous member, as, for example, in the laminated rafters of the gothic-roof barn.

5. Rafter Ties. Rafters must be securely tied together where they meet at the ridge or where the two rafters of the broken or gambrel roof join. Wind suction pulls upward and outward on both leeward rafters, thus tending to pull these rafters apart. See (*E*), Fig. 2, and the

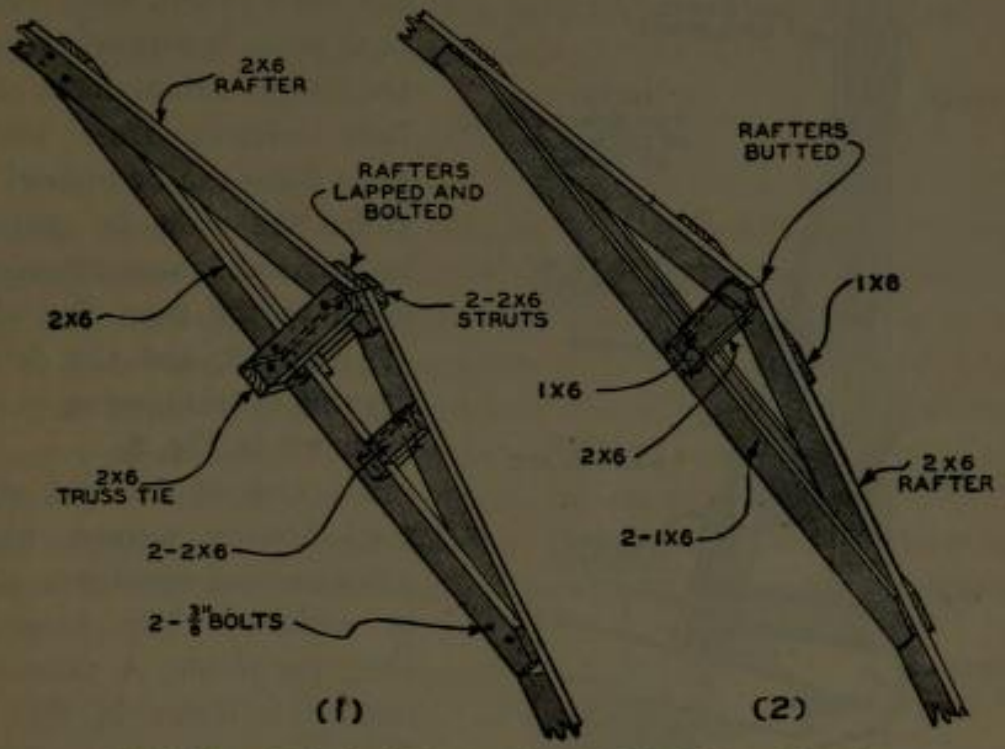


Fig. 7. Two Methods of Construction for Tying Rafters Together

detail drawing of this shown in Fig. 7. Note the two methods of construction. The better method (*1*), Fig. 7, shows the rafters lapped and bolted. Note also the truss tie and the struts. These tend to give stiffness to the member, increasing its wind resistance. The method shown at (*2*), Fig. 7, does not provide as great resistance to wind pressure since the rafters are butted instead of lapped. There are no truss ties and, instead of bolts, nails are used for fastening the materials together.

6. Braces for Side Walls and End Walls. Diagonal braces spaced 8 or 10 feet apart are needed to stiffen the frame against wind loads. In Fig. 6 side-wall braces are shown running down from the wall plates

to the floor joist. These braces are necessary and should not be omitted. Such braces do not interfere seriously with the space in the haymow and they do greatly increase the rigidity of the entire barn against wind pressures. Note the 2x6 ribbon which helps in supporting the joists. The ribbon should not be cut into the studs because this will weaken the studs at a point where they are carrying an extra load and should never be weakened by cutting. Double studs and floor joists are recommended at the point where each diagonal brace is located. Where the interior arrangement of a barn includes cross partitions, these can be utilized to stiffen the walls by putting in diagonal braces extending down to the floor. See also (*F*), Fig. 2, and the detail drawing of this bracing which is shown in Fig. 8.

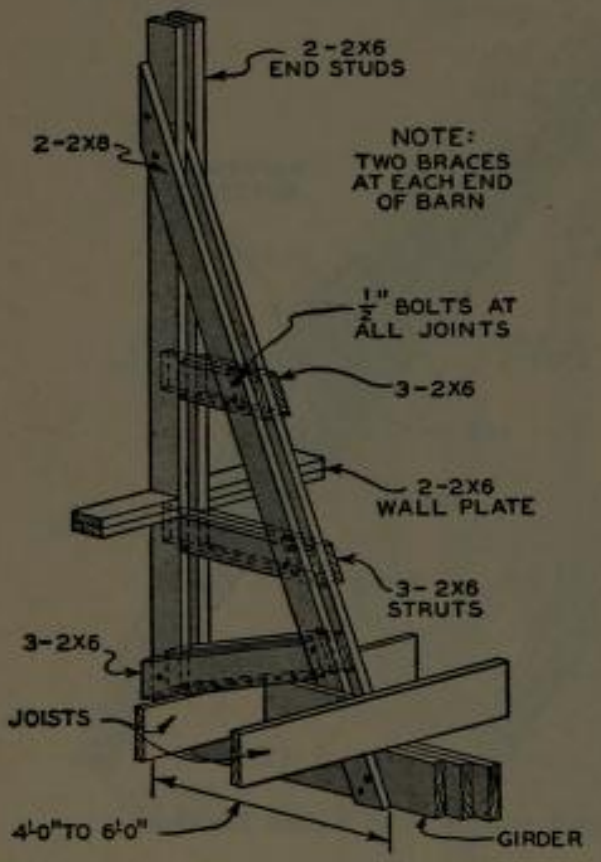


Fig. 8. Diagonal Braces Used to Stiffen Frame of Barn against Wind Pressure

The ends of the barn also need bracing against wind pressures and sometimes also to withstand hay pressure from the inside. A practical method is shown in Fig. 8. Note especially the two 2x8's extending from the double studs about 12 feet above the floor down to the rigid girder which supports the joists. A rigid end-wall brace is provided by the double or triple struts between the main members, all securely bolted together. Note especially the 2x6 struts which stiffen the brace, adding resistance to wind pressures. In the construction of barn roofs, braces are designed not only to stiffen the building to resist wind pressures but also to withstand hay pressure from within.

Fastening of Joints and Materials. A wood frame building is no stronger than its joints. Therefore, a seventh essential of good wind-

resistant construction is the need for stiff joints between the framing members. Unfortunately for the good of barn frames, the nailed joints so commonly used are the weakest of all ordinarily used methods of joining structural lumber. Better results can be obtained by using one of the following methods of securing joints: (1) glued and nailed joints; (2) bolted joints; (3) glued and bolted joints; (4) split-ring connectors with bolts; and (5) toothed-ring connector with bolt.

All of the foregoing methods for joining materials are explained in Chapter VII on "Wood Fastenings," *Fundamentals of Carpentry*, Volume I, by W. E. Durbahn.

BARNS

Next to the house, the barn probably is the chief building on the average farm. In addition to housing the livestock, the barn usually provides space for a vast amount of feed for the stock. In planning for this important farm building several factors must be considered.

1. Floor Plan. The inside arrangement, or floor plan, of a barn must meet the requirements of the livestock which the building will shelter. These requirements will depend upon the kind, number, and size of the animals; the methods used for feeding the stock; and the method to be used in removing litter and such like. The size of a barn is determined largely by the extent of its use. See Table I for size of cow stalls commonly used.

TABLE I. DIMENSIONS OF COW STALLS*

BREED	APPROXIMATE WEIGHT, LBS.	LENGTH OF STALL	WIDTH OF STALL
Ayrshire	1,000	4 feet 8 inch.	3 feet 6 inch.
Brown Swiss	1,200	5 feet 0 inch.	3 feet 8 inch.
Guernsey	1,000	4 feet 8 inch.	3 feet 6 inch.
Holstein	1,200	5 feet 0 inch.	3 feet 8 inch.
Jersey	900	4 feet 6 inch.	3 feet 5 inch.
Shorthorn	1,400	5 feet 4 inch.	4 feet 0 inch.

Courtesy, Portland Cement Association.

*These are dimensions commonly employed for average size cows. Stall lengths for large cows may be increased three inches; for small cows, decreased three inches. Heifers require stalls about three feet wide and four feet long.

2. Storage Space. Provision for the storage of grain and hay, or other roughage, is governed to a great extent by the shape and construction of the roof. The gothic type of roof, although more expensive to build, naturally allows for more storage space because of its large unobstructed haymow.

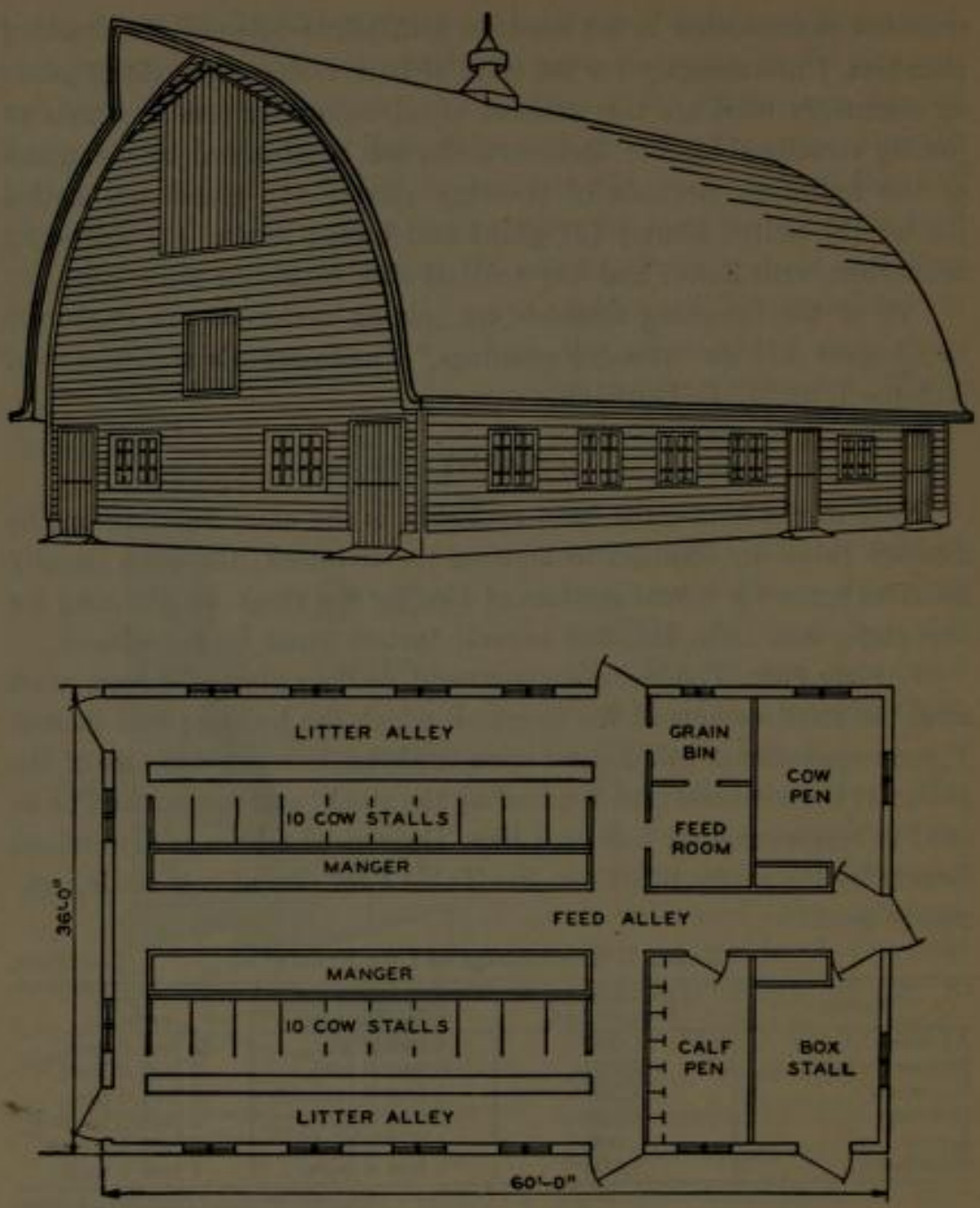


Fig. 9. Gothic-Roof Dairy Barn and Floor Plan

3. Architectural Design. Requirements of the outward appearance, or *architectural design*, of the barn must be given consideration also. The design must meet the practical needs of the owner, harmonize with the other farm buildings, and be structurally sound. The three types of barns considered in this chapter are those most common on American farms today. All three types are structurally sound and are

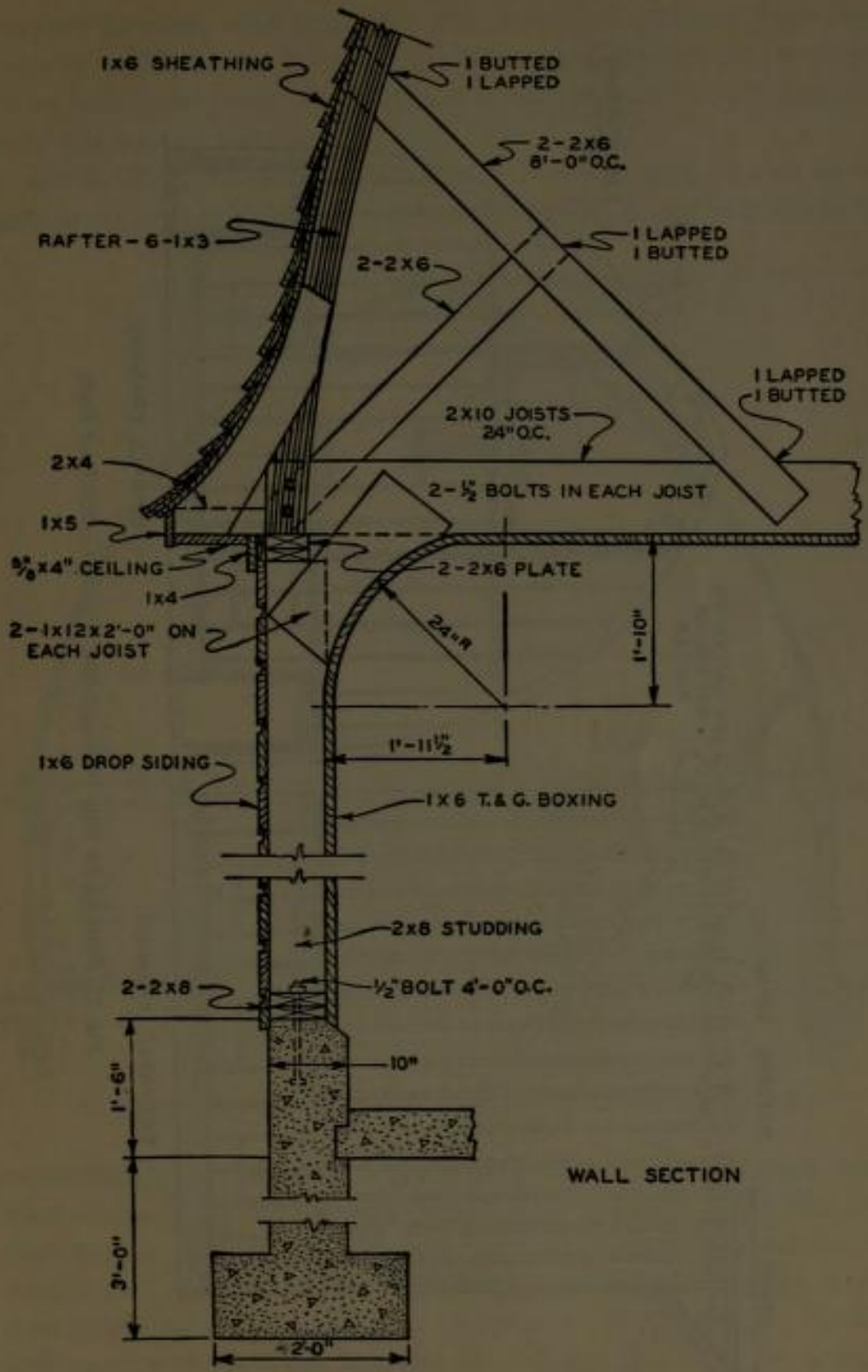


Fig. 10. Wall Section of Gothic-Roof Barn, Showing Details of Bracing Rafters

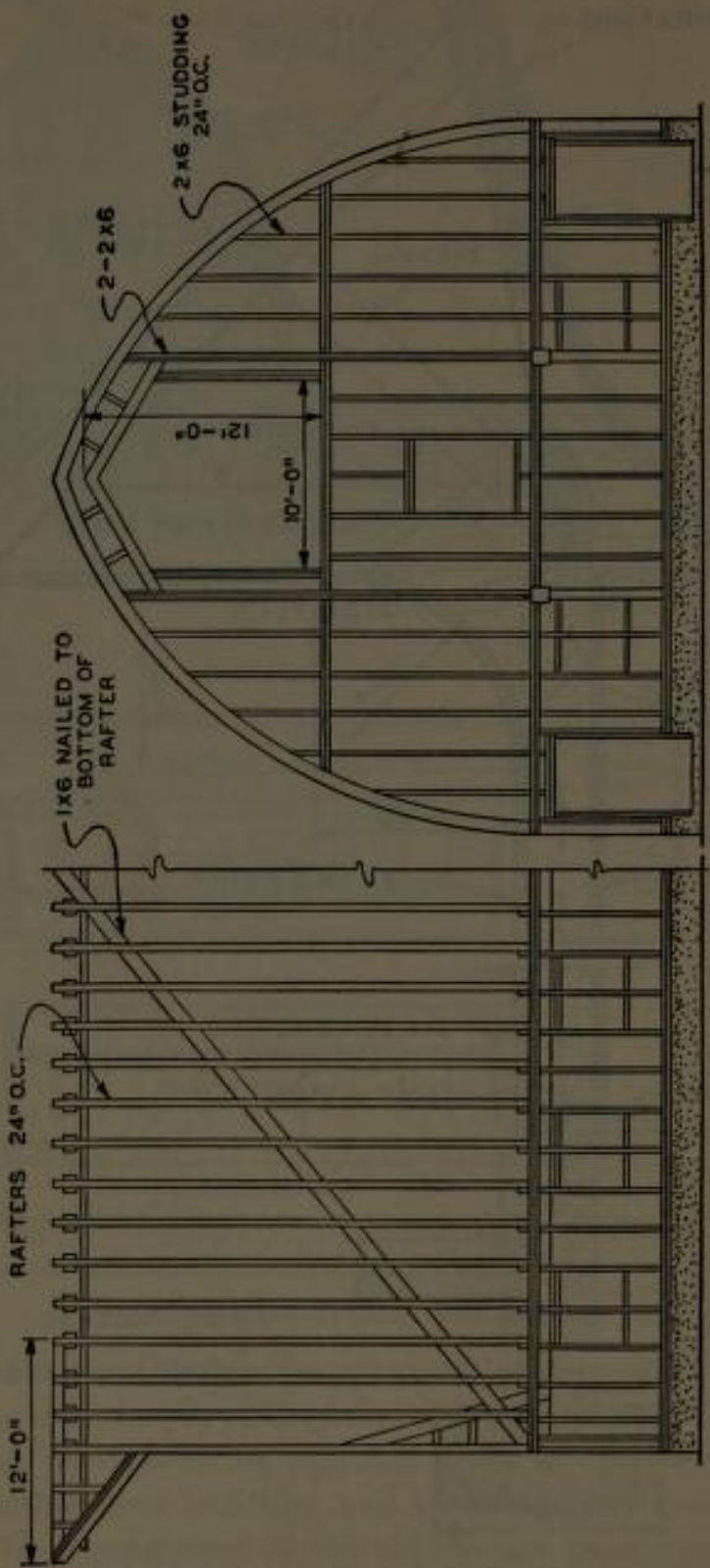


Fig. 11. Framing for Side Wall and End Wall of Gothic-Roof Barn

designed to resist wind pressures. The structural plans of these three types of buildings are intended for barns of 36 feet or less in width. Wider buildings require a different and more expensive roof design to carry the load of wind and hay pressure.

Gothic-Roof Barn. A modern design of dairy barn known as the *gothic-roof barn* is becoming extremely popular. It not only meets the

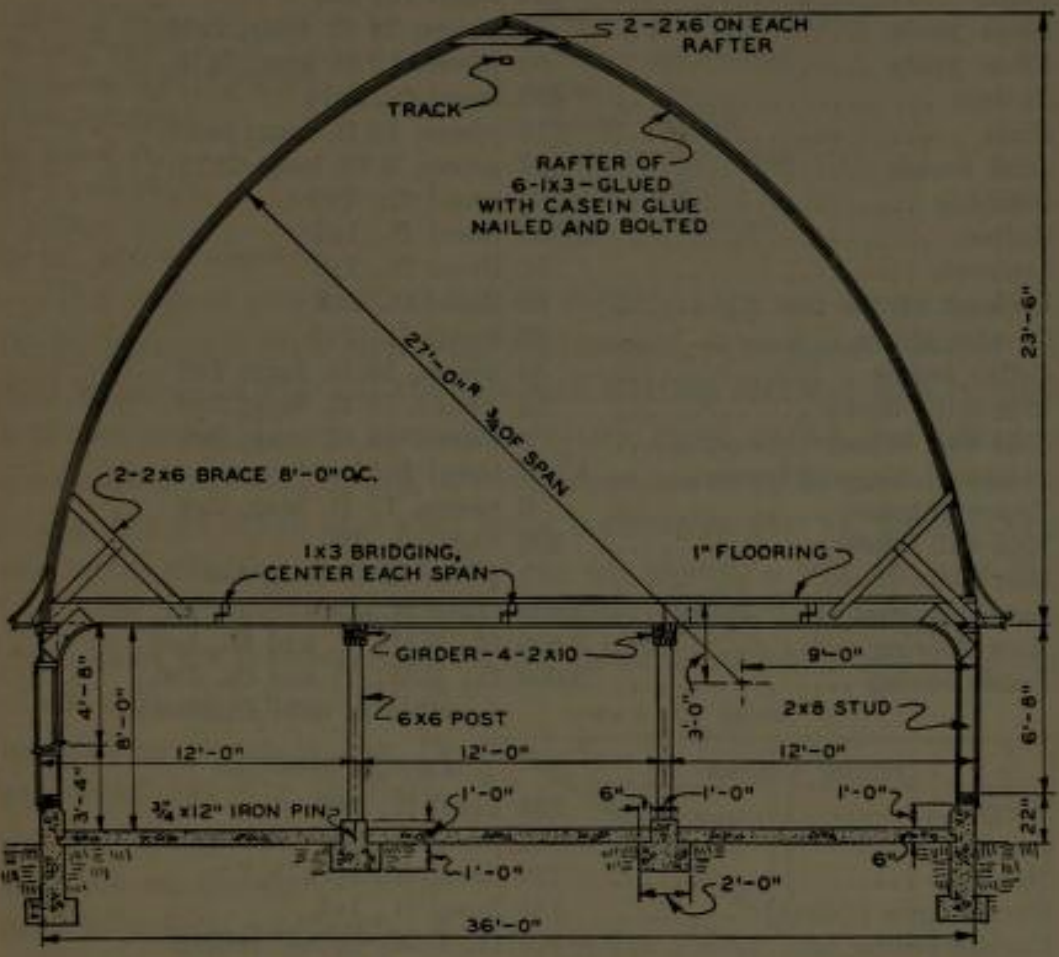


Fig. 12. Cross Section, Showing Construction Details of Gothic-Roof Barn

requirements for utility and good design but also withstands heavy wind loads. It provides comparatively large haymow space, free from obstructions, and permits of a variety of floor arrangements. The curved roof with its laminated rafters requires little bracing within, thus producing a mow with a hay capacity of 60 tons, Fig. 9. The kind and amount of materials required for building this barn are given in the following lists.

MATERIALS

FRAMING LUMBER	AMOUNT REQUIRED
Sills	384 lineal ft., 2x8
Studs, side wall	40 pieces, 14 ft. long, 2x8
Studs, end	8 pieces, 20 ft. long, 2x6
Studs, end	27 pieces, 14 ft. long, 2x6
Studs, end	24 pieces, 10 ft. long, 2x6
Studs, end	356 lineal ft., 2x6
Plates	504 lineal ft., 2x6
Floor joists	31 pieces, 14 ft. long, 2x10
Floor joists	62 pieces, 12 ft. long, 2x10
Girders	480 lineal ft., 2x10
Posts	12 pieces, 14 ft. long, 6x6
Joist braces	120 pieces, 2 ft. long, 1x12
Bridging	360 lineal ft., 1x3
Rafters	12,056 lineal ft., 1x3
Lookouts	186 lineal ft., 1x8
Lookout struts	62 lineal ft., 2x4
Cornice struts	80 lineal ft., 2x2
Collar beams	30 pieces, 10 ft. long, 2x6
Side-wall braces	12 pieces, 12 ft. long, 2x6
Side-wall braces	6 pieces, 14 ft. long, 2x6
Side-wall diagonal braces	173 lineal ft., 1x6
End-wall braces	8 pieces, 12 ft. long, 2x8
End-wall braces	108 lineal ft., 2x6
Hay beam	1 piece, 12 ft. long, 4x8
Sheathing roof	2,890 ft., B.M., 1x6
Mow flooring	2,520 ft., B.M., T. and G., 1x6
Inside boxing	3,000 ft., B.M., T. and G., 1x6 (omitted in mild climates)

FINISH LUMBER	AMOUNT REQUIRED
Verge	124 lineal ft., 1x5
Frieze	124 lineal ft., 1x6
Molding	124 lineal ft., ½"x1¼"
Cornice trim (fascia)	124 lineal ft., 1x4
Cornice ceiling	310 ft., B.M., ⅝"x4" ceiling
Doors	388 bd. ft., T. and G., 1x6
Door battens	288 lineal ft., 1x8 boards
Door battens	146 lineal ft., 1x6
Door Trim	158 lineal ft., 1x4
Track planks	2 pieces, 12 ft. long, 1x10
Shingles	40 squares (4½ inches to weather)
Drop siding	2,610 ft., B.M., 1x6 drop siding
Windows	33–6 light, 9x10 barn sash
Window trim	330 lineal ft., 1x4
Window trim	232 lineal ft., 1x6
Window trim	42 lineal ft., 1x2
Window sills	60 lineal ft., 2x12

(Continued on page 453)

MATERIALS—*Continued*

Corner boards	4 pieces, 14 ft. long, 1x4
Drip cap	100 lineal ft.

HARDWARE AND MISCELLANEOUS MATERIALS

58 pieces	26 gauge wind shield
68 lineal ft.	24 gauge, galvanized iron, ridge roll
56—⅜"x7"	Bolts—end braces
8—⅜"x9"	Bolts—end braces
128—½"x5"	Bolts—joists to rafters
48—½"x15"	Bolts—foundation
48 pieces ¼"x1¼"x10"	Strap iron
496—¼"x5½"	Bolts—rafters
66 lineal ft.	Hay carrier track
20 lineal ft.	Door track
1 only	24" Barn ventilator

32 cu. yds. of concrete

The various construction details for this barn are shown in Figs. 10–15, and need little additional explanation. A sectional view of the wall is shown in Fig. 10; the side-wall framing and end-wall framing is shown in Fig. 11; the laminated rafters, glued, nailed, and bolted in place, are illustrated in Fig. 12; the frieze sawed to fit curve is shown in Fig. 13; the detail of a wind brace is shown in Fig. 14; a detail of a sill, metal windshield, and a drip cap are shown in Fig. 15; and Fig. 16 shows the detail of a laminated rafter layout. Cold-mixed waterproof glues are recommended for the rafter bents which are made out of six 1x3's nailed and bolted together as shown in Fig. 12 and detail (*A*), Fig. 16. Rafters for the gothic roof are laid out on the floor of the mow in a form as illustrated in Fig. 16.

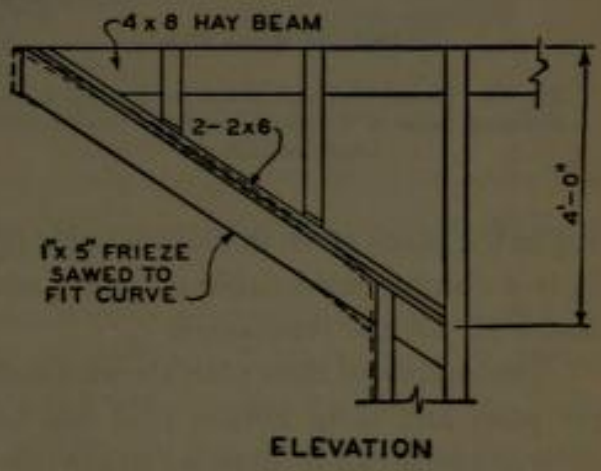


Fig. 13. Detail of a Hay Beam

The Gambrel-Roof Barn. A gambrel-roof barn adapted to general utility purposes is illustrated in Fig. 17. This sturdy, well-designed gambrel-roof barn is of the braced-rafter type. It meets all the requirements of many small farms and can be built at comparatively low cost. Short lengths of lumber can be used and no large or heavy timbers are required. When built accord-

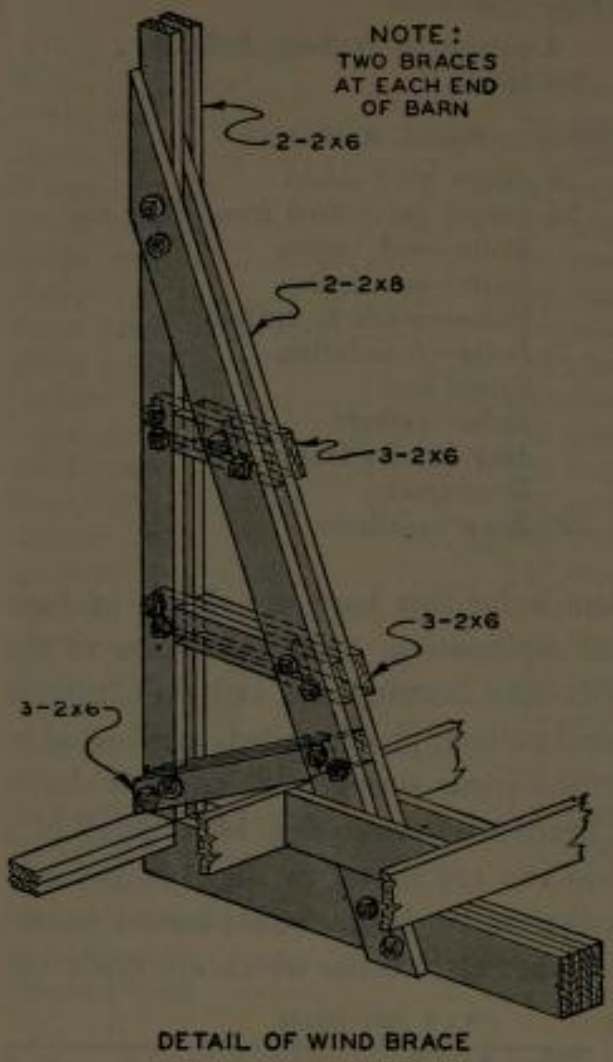


Fig. 14. Detail of Wind Brace on End of Barn Showing Sizes of Lumber Used for Braces and Location of Bolts

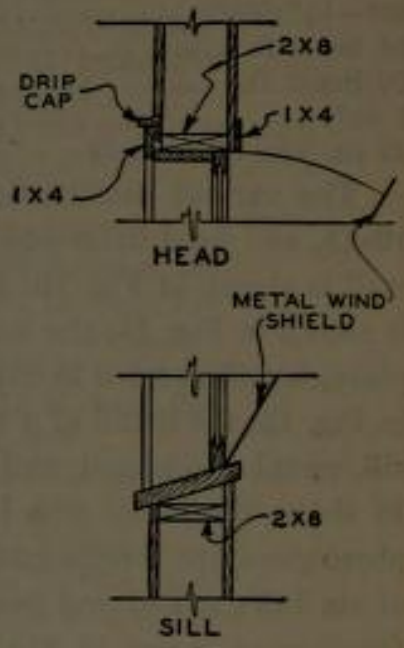


Fig. 15. Detail of Barn Window, Showing Drip Cap, Metal Wind Shields, and Sill

ing to the plans given in this text, this type of barn is easy to construct. It is a durable serviceable structure and will prove to be satisfactory under all normal conditions.

The suggested floor plan shows a compact arrangement of stalls for six cows and three horses, also one box stall and grain bins. Other arrangements can be planned to provide for cows only, for horses only, or for various combinations of cows and horses. This design can be used equally as well on a barn of larger size up to 36 feet in width. However, adapting this roof design to a wider barn will demand longer rafters and larger braces. The sizes of these members must be kept to the same

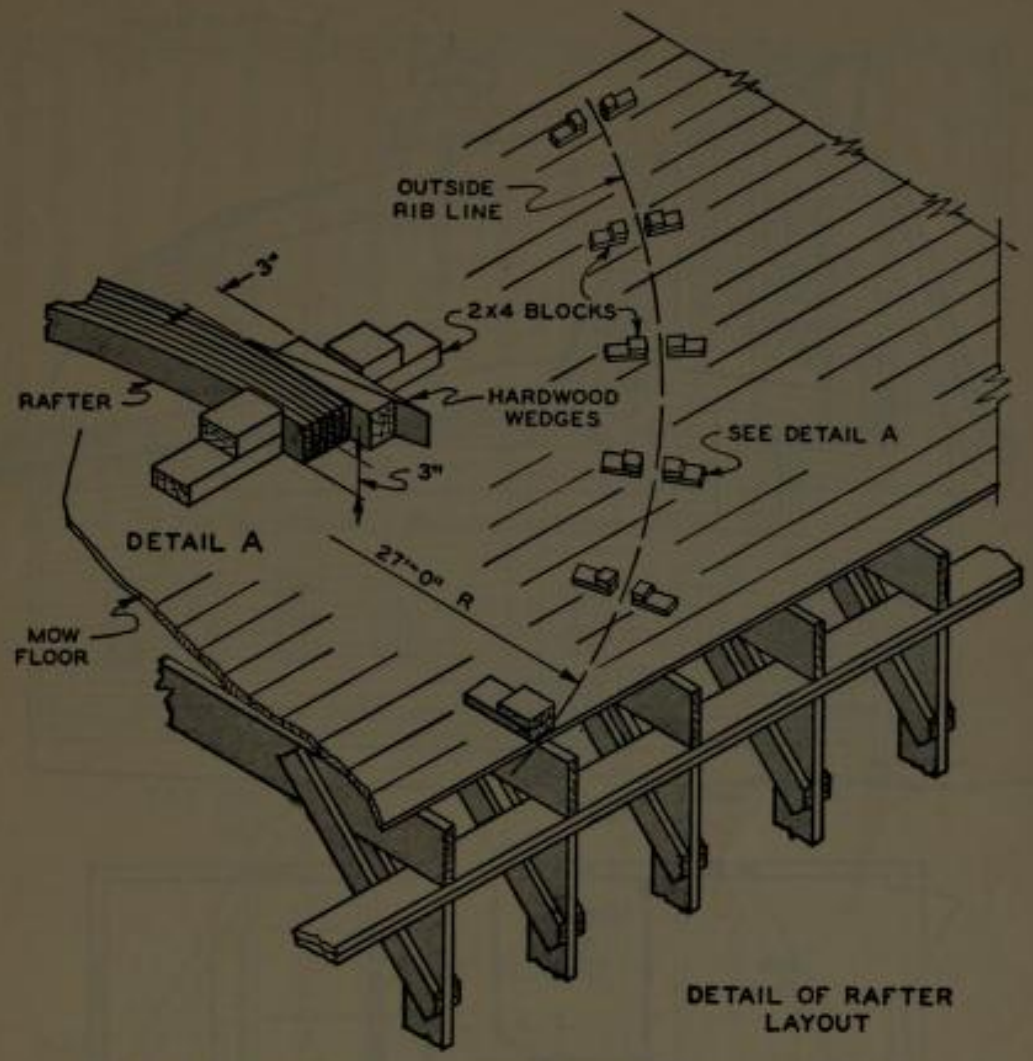


Fig. 16. Detail of Layout for Rafter Bents of Gothic-Roof Barn

proportions as those shown in the cross-section drawing (Fig. 21). The haymow in this 24x32-foot barn has a hay capacity of 15 tons of loose hay.

The framing for the side and end walls are shown in Figs. 18 and 19. The 2x4 lookouts at the eaves are nailed to each rafter at an angle great enough to carry the roof water away from the sides of the barn, Fig. 20. The rafter bents, Fig. 21, are laid out on the floor of the haymow, as shown in the detail drawing, Fig. 22. Point (*A*) represents the peak of the roof. The line (*AB*) equals 12 feet. The line (*BC*) equals 12 feet (½ the width of the barn). The line (*AD*) equals 8 feet, the length of the upper-slope rafter. The line (*DC*) equals 10 feet, the

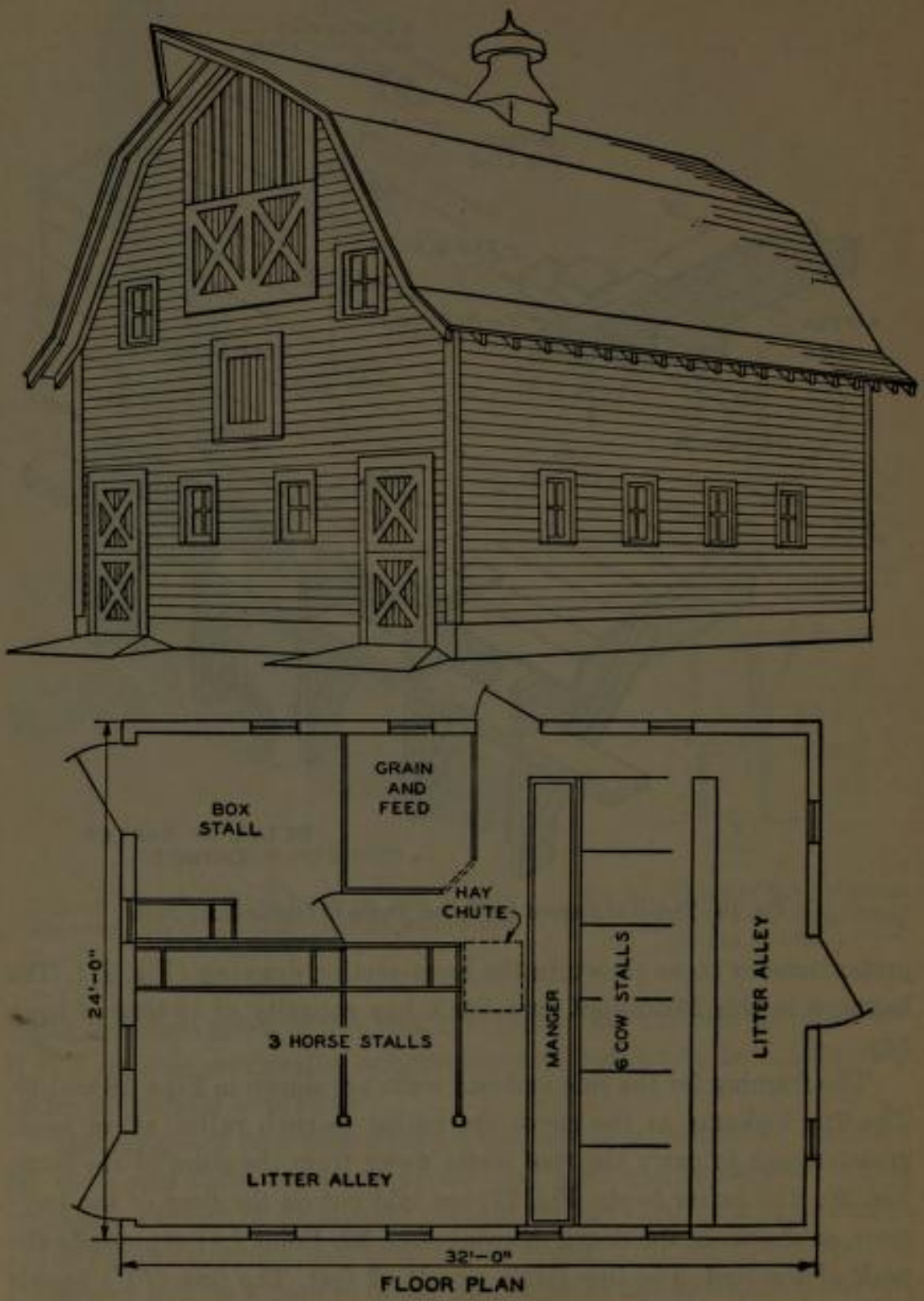


Fig. 17. Gambrel-Roof Barn and Floor Plan, for Cows and Horses

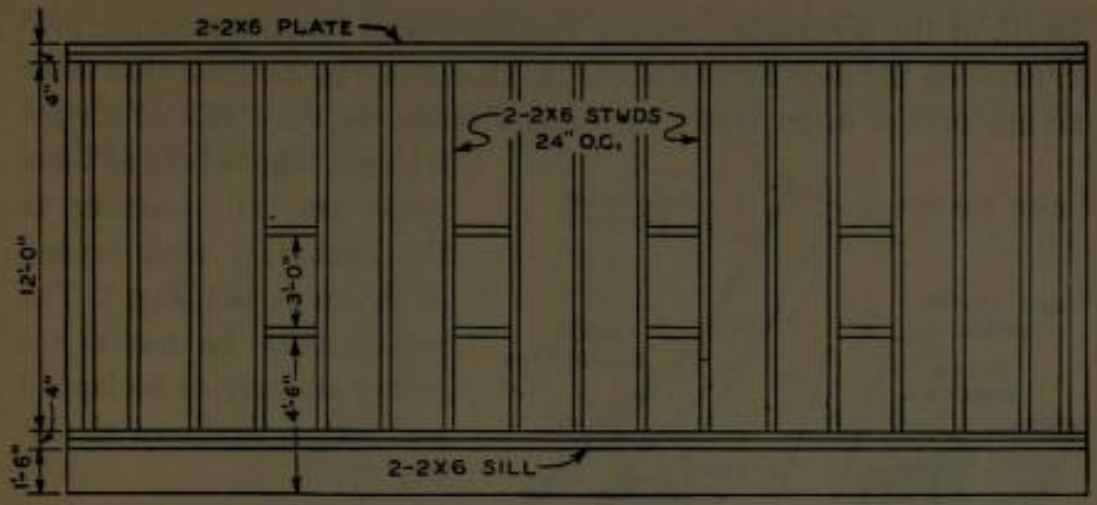


Fig. 18. Side-Wall Framing for Gambrel-Roof Barn

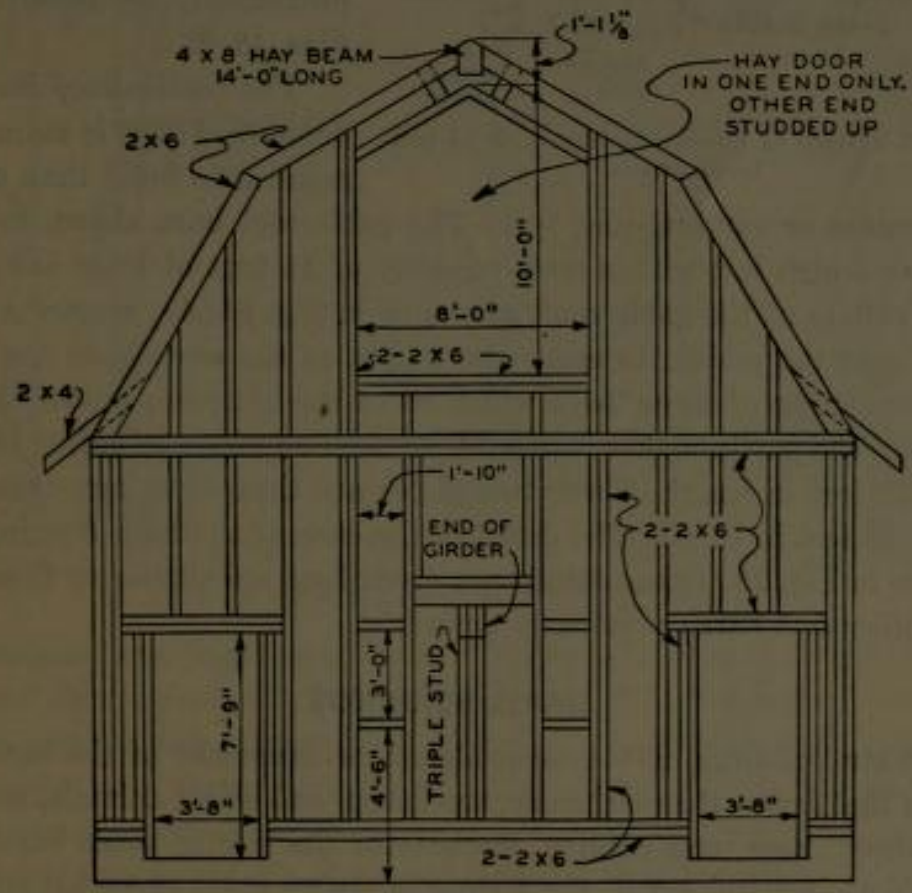


Fig. 19. End-Wall Framing for Gambrel-Roof Barn

length of the lower-slope rafter. The upper and lower rafters are held in place on the floor by 2x4 blocks, as shown in Fig. 22. Note that when laying out the rafter bents, each rafter forms the third side of a right triangle. The rafters of these bents are held together at the joint (*D*) with braces, as shown at (*E*), Fig. 2. The rafters may be nailed together securely or be lapped and bolted, as shown at (*1*), Fig. 7.

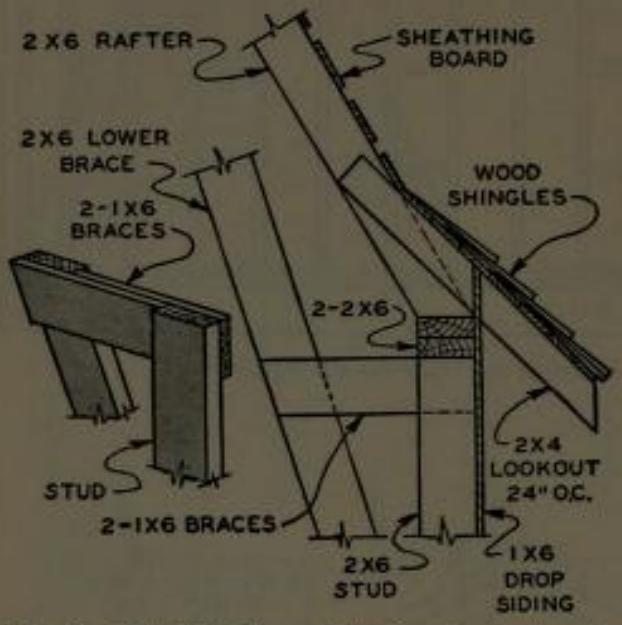


Fig. 20. Detail at Eaves, Showing Lookout and Lower Brace

The kind and amount of materials required for this barn may be estimated approximately by referring to Figs. 18–21.

The Gable-Roof Barn. A *gable-roof barn* is more economical to build than either the gothic or gambrel-roof type. The gable-roof barn shown in Fig. 23 has a high loft with a mow capacity of 15 tons of loose hay. The long rafters of the gable roof, as shown in Fig. 24*(A)*, require a support near the middle to carry the weight of the roof. Note the purlin, consisting of three 2x8's which serve this purpose, shown in Fig. 24*(B)*. The purlin makes it possible to use two pieces of rafter 16 feet and 12 feet in length. These two pieces are cheaper to buy than one stick 28 feet in length. The detail of the ends of the barn framing are shown in Fig. 25. Other details not given here are similar to those for the other two barns previously described.

SMALL BUILDINGS

Other buildings on the farm almost as important as the barn are those that house the machinery, workshop, and small animals, including sheep, hogs, and poultry. Because of the size of these buildings, which are usually small, the farmer is apt to build them himself.

Gable Implement Shed and Workshop. A practical machine shed with a workshop and space for two cars is illustrated in Fig. 26. The

construction is simple. Trusses carry the weight of the roof, permitting large floor space without supporting posts. The absence of such posts allows for free movement of machinery. The simple truss construction and other details are illustrated in Fig. 27.

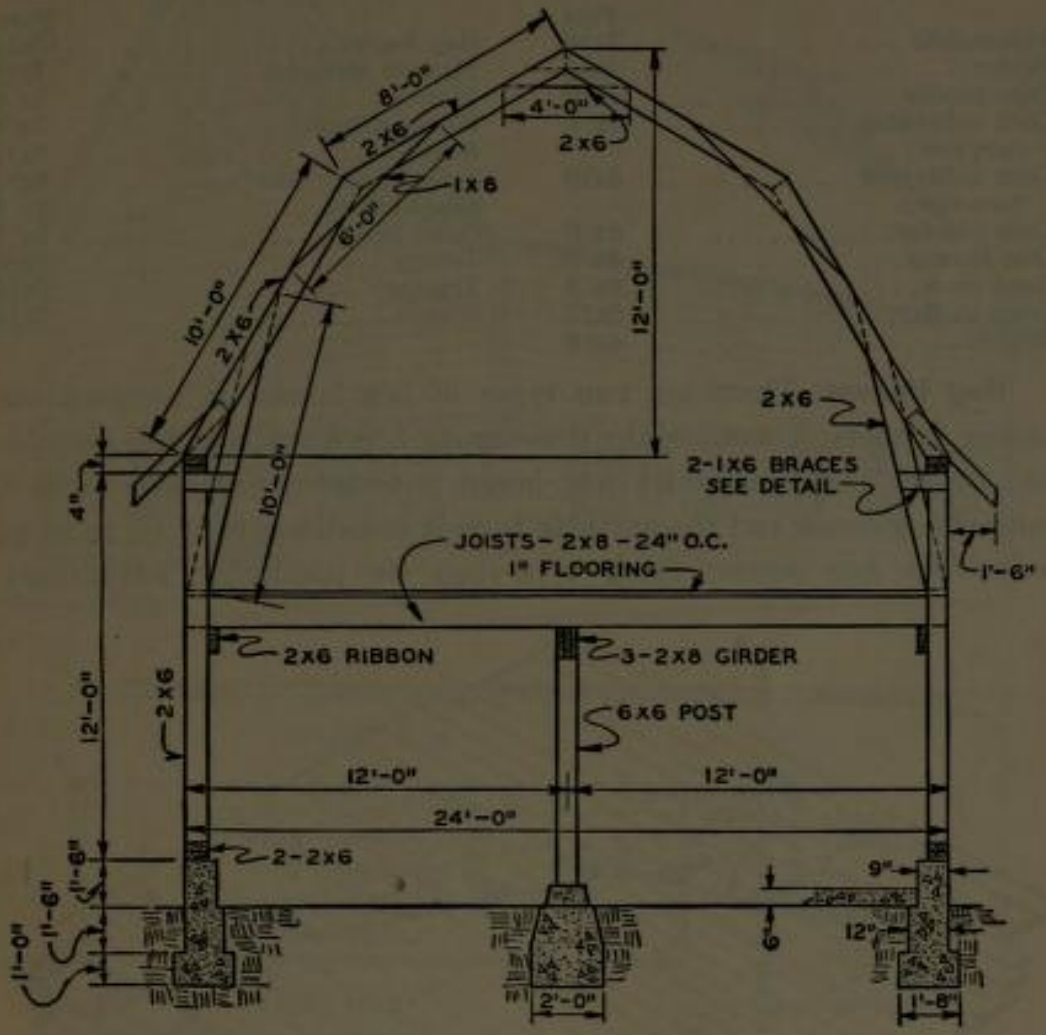


Fig. 21. Cross Section of a Gambrel-Roof Barn

Hangar-Type Implement Shed. Designed to give a large unobstructed floor space with its unbroken curved roof extending almost to the ground, the *hangar-type implement shed* resists strong winds effectively. This type of implement shed is illustrated in Fig. 28. The rafter bents, constructed like those of the gothic-roof barn, are curved ribs made out of six 1x2's glued and nailed or bolted together, as shown in Fig. 29. The rafter bents extend from the foundation to the ridge of the roof with the upper straight portion supported by a truss of

simple design, as shown in Fig. 30. Wood shingles cover the curved walls and roof. For the various pieces of equipment usually housed in an implement shed see Table II.[3]

TABLE II. DIMENSIONS OF VARIOUS FARM EQUIPMENT ITEMS

	Feet		Feet
Automobile	7x16	Hay loader	10x12
Binder	8x15	Manure spreader	7x12
Corn binder	7x10	Mower	5x 8
Corn cultivator (one row)	5x 6	Potato digger	5x 8
		Rake	6x12
Corn cultivator (two row)	6x10	Side-delivery rake	8x12
		Silage cutter	7x 8
Corn planter	6x 6	Sulky plow	5x 7
Disc harrow	5x 9	Tedder	6x10
Gang plow	6x 8	Tractor	7x14
Grain drill	6x12	Wagon	7x14
Harrow	4x 6		

Hog Houses. There are two types of hog houses in common use among farmers. These are the *community hog house* and the *portable hog house*. The community hog house is sometimes spoken of as a *central hog house* and the portable type is sometimes referred to as an *individual hog house*. Each type has its particular advantages,

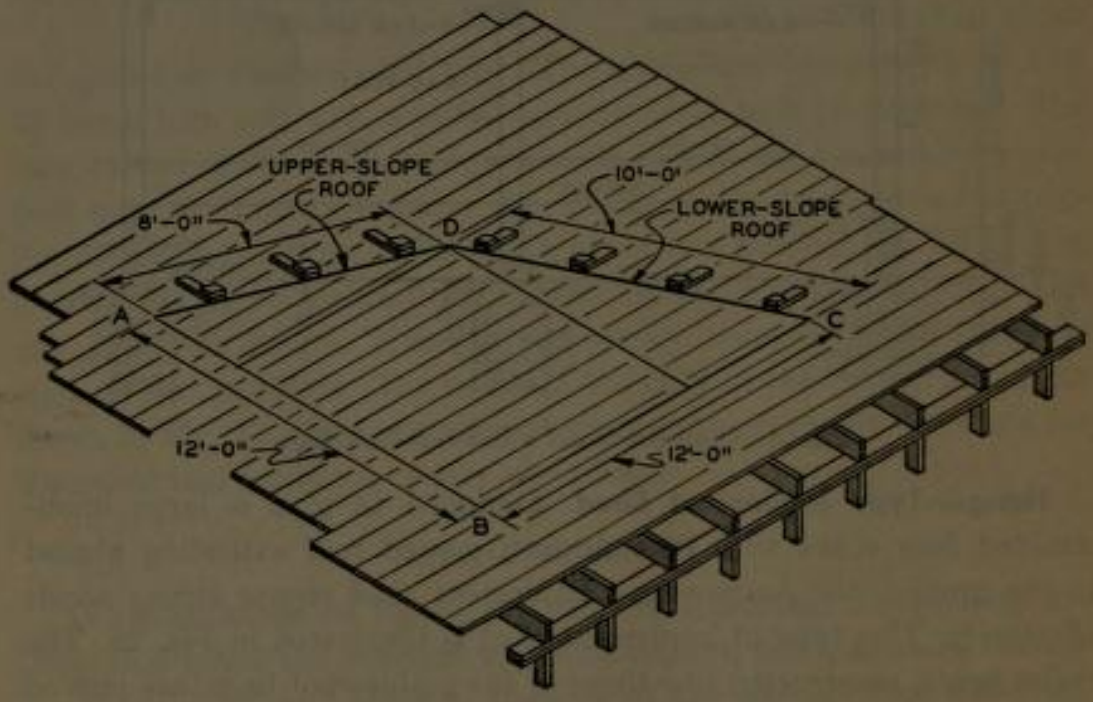
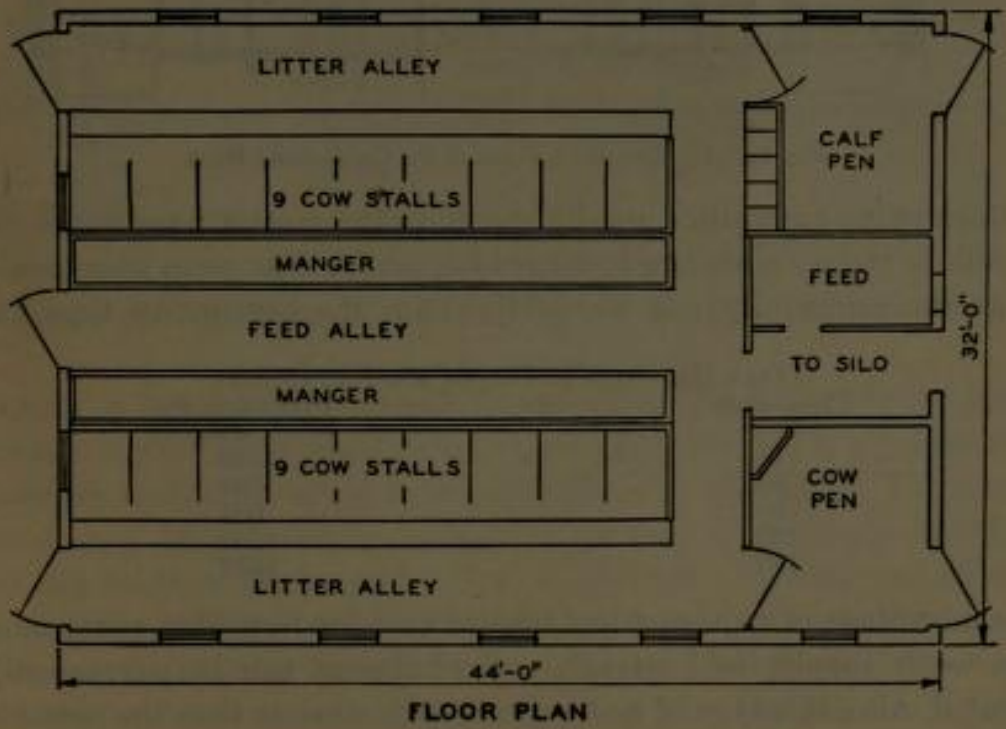


Fig. 22. Detail Drawing of Layout for Rafter Bents for Gambrel-Roof Barn

[3] Figures given in Tables II and III were provided by the Portland Cement Association.



FLOOR PLAN

Fig. 23. High-Loft Gable Barn with Floor Plan

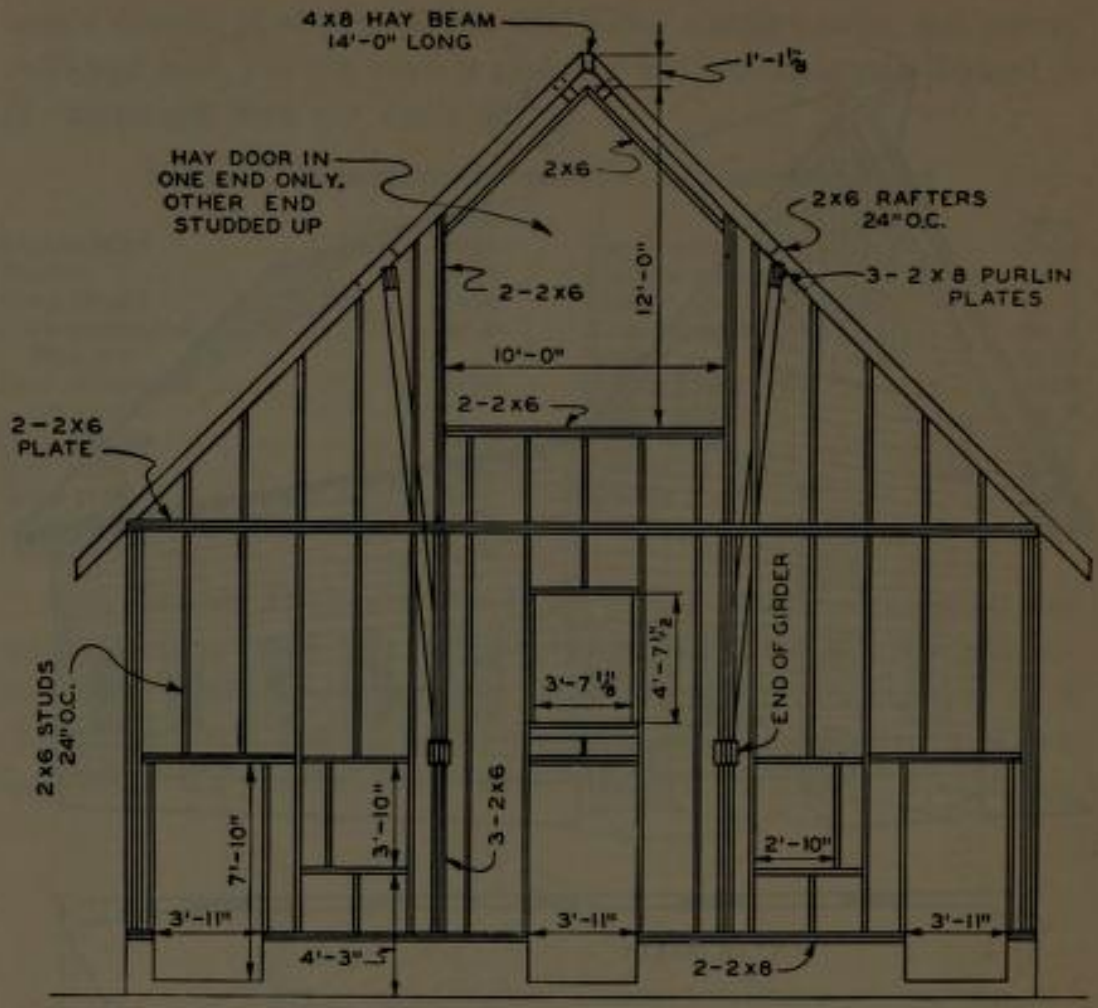


Fig. 24 (*A*). End-Wall Framing for Gable-Roof Barn

though swine authorities usually recognize the greater possibilities for health in the portable hog house, which can be kept clean more easily than the community hog house. However, the community type has

TABLE III. SIZES OF FLOORS FOR HOG HOUSES

NUMBER OF HOGS	MINIMUM SQ. FT. FLOOR REQUIRED
15	150
30	300
60	600
120	1200
150	1500

the advantage of requiring less time to care for farrowing sows, since the water supply, feed storage, and equipment can be conveniently located. Also, this type of house can be kept warmer than the portable type, a highly desirable feature when sows farrow during the cold

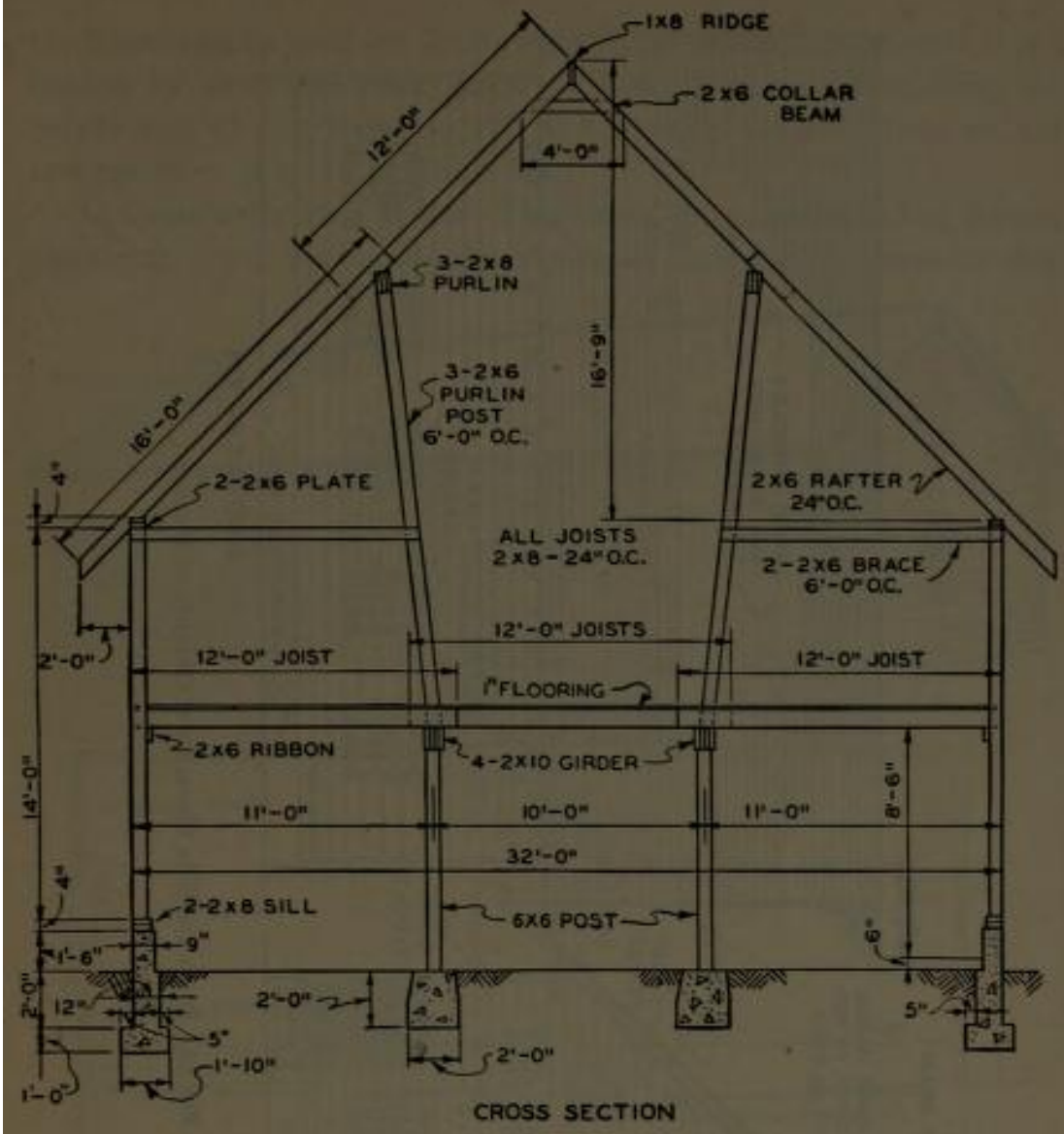


Fig. 24 (*B*). Cross Section of Gable-Roof Barn, Showing Purlin and Purlin Posts

months of late winter and early spring. If the farmer prefers the community hog house, it should be located where it will have proper soil drainage and be protected in cold climates by a windbreak. The windbreak may be provided by natural conditions; for example, building the hog house on the leeward side of a hill. Such a location also affords good drainage. Trees and shrubbery provide a suitable windbreak, or this may be afforded by other and larger farm buildings. If the community hog house is designed with a feeding alley between two rows of pens and with removable or hinged partitions between adjoining pens,

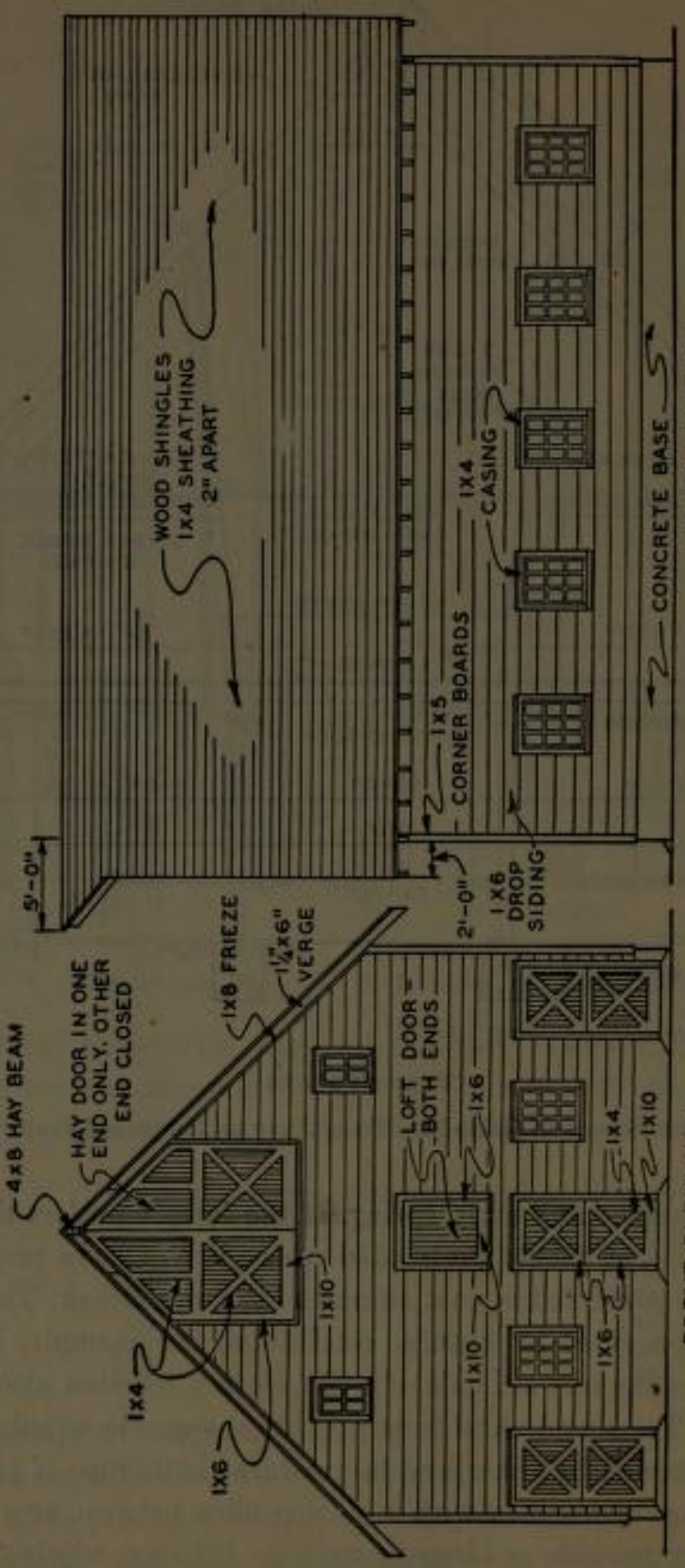


Fig. 25. Front and Side Elevation of Gable-Roof Barn

the house can be used for sheltering and fattening hogs when it is not needed for sows and their litters of pigs. A guide for building the proper size of hog house to suit the housing needs of hogs on the average farm is given in Table III.

1. Community Hog House. Two types of community hog houses are shown here, the *gable-roof hog house* and the *half-monitor hog*

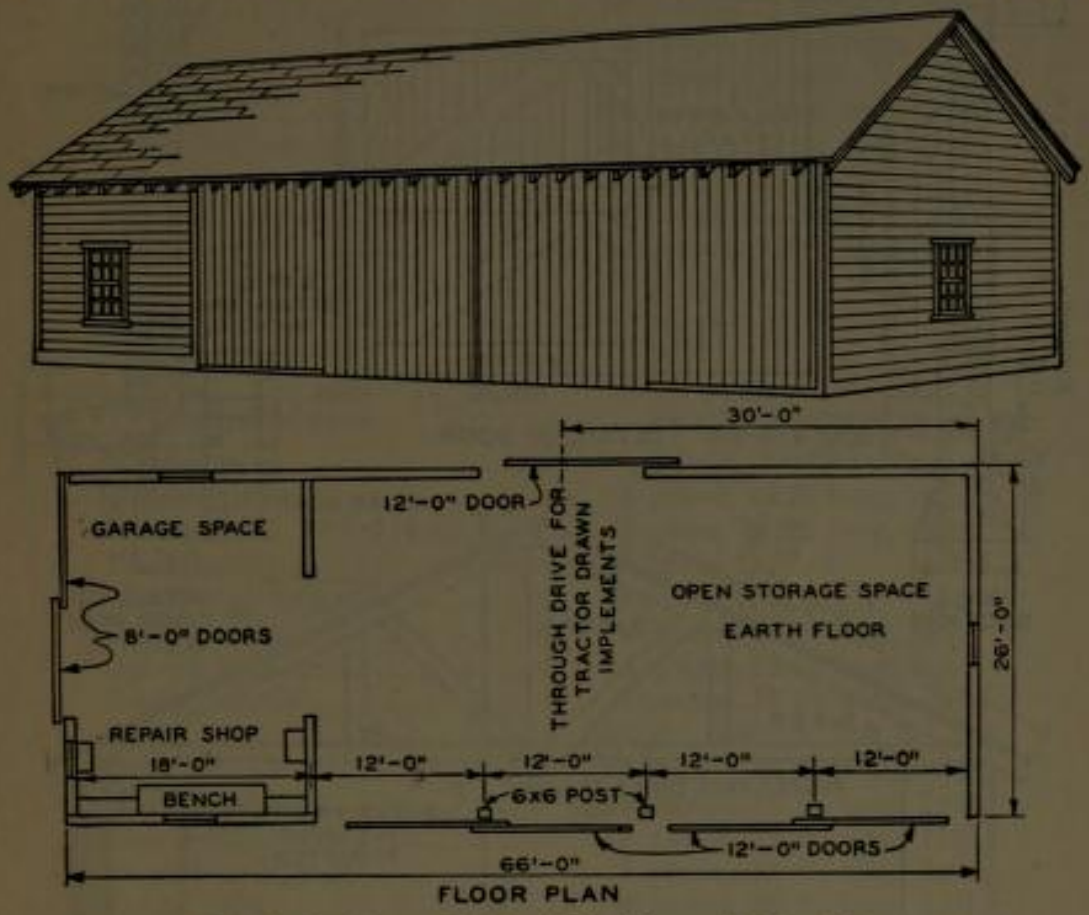


Fig. 26. Implement Shed and Workshop with Floor Plan

house, Figs. 31 and 32. Both types are designed especially for simplifying the handling and proper care of hogs. Concrete footings, foundations, and floors are recommended for community hog houses.

a) Footings, Walls, and Sills. Footings should be from 6 to 8 inches in depth, from 12 to 16 inches in width, and should be placed below frost line. The walls of the community hog house should be low, to insure warmth for the sows and their litters of pigs. Studdings of 2x4's spaced 24 inches on center (O.C.) are suggested. Double construction is especially advisable to give warmth and strength to the building.

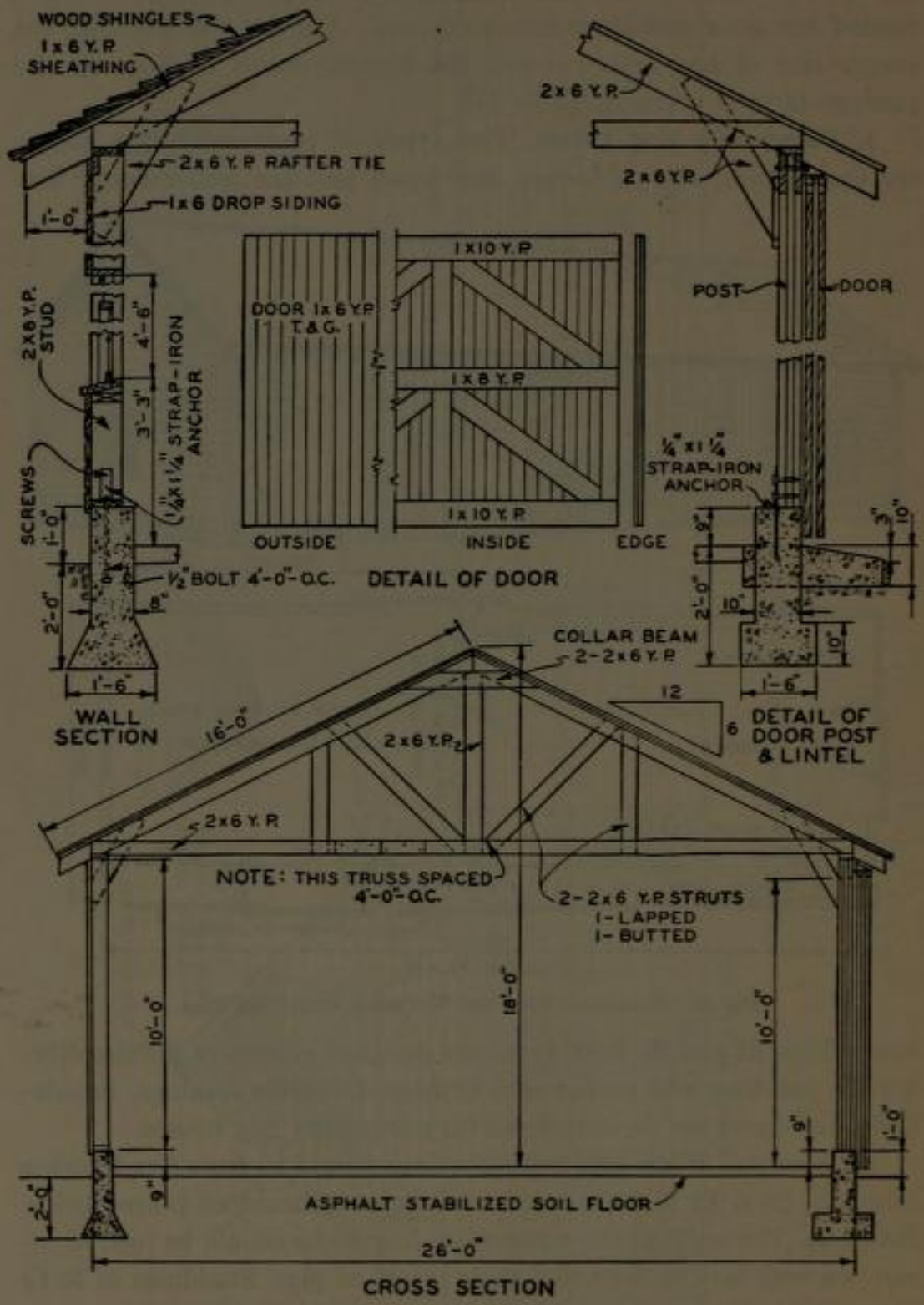


Fig. 27. Cross Section of Workshop, Showing Detail Construction

MATERIALS FOR GABLE IMPLEMENT SHED AND WORKSHOP (Figs. 26 and 27)

FRAMING LUMBER	AMOUNT REQUIRED
Sills	96 lineal ft., 2x6
Studs	75 pieces, 10 ft. long, 2x6
Studs, gable	92 lineal ft., 2x6
Posts	12 pieces, 10 ft. long, 2x6
Plates	254 lineal ft., 2x6
Lintels	10 pieces, 12 ft. long, 2x8
Lintels	2 pieces, 16 ft. long, 2x8
Lintels	76 lineal ft., 2x6
Rafters	68 pieces, 16 ft. long, 2x6
Rafter trusses	15 pieces, 16 ft. long, 2x6
Rafter trusses	15 pieces, 10 ft. long, 2x6
Struts on trusses	760 lineal ft., 2x6
Collar beams	22 pieces, 12 ft. long, 2x6
Rafter ties	12 pieces, 12 ft. long, 2x6
Sheathing	1,640 ft. B.M., 1x6

FINISH LUMBER	AMOUNT REQUIRED
Windows	4 6-light, 10x12 D.S.
Window jambs	4 pieces, 12 ft. long, 1x6
Window sills	1 piece, 12 ft. long, 2x8
Window stop	96 lineal ft., 1x2
Window parting stop	48 lineal ft., ½″x¾″
Inside casing	4 pieces, 14 ft. long, 1x4
Outside trim	4 pieces, 14 ft. long, 1x4
Corner boards	8 pieces, 10 ft. long, 1x4
Doors	886 ft., B.M., T. and G., 1x6
Door battens	10 pieces, 12 ft. long, 1x10
Door battens	2 pieces, 16 ft. long, 1x10
Door battens	18 pieces, 12 ft. long, 1x8
Verge boards, rake	4 pieces, 16 ft. long, 1x4
Frieze, rake	4 pieces, 16 ft. long, 1x4
Molding, rake	54 lineal ft., ½″x1¼″
Drip cap	16 lineal ft.
Shingles	22 squares (4½″ to weather)
Drop siding	1,630 ft., B.M., 1x6

HARDWARE AND MISCELLANEOUS MATERIALS

Rolling-door hangers	7 sets
Rolling-door track	152 ft.
Foundations	30 —½-inch bolts, 16″ long
Strap-iron ties	30 pieces, ¼″x1¼″x10″
Strap iron	4 pieces, ¼″x1¼″x18″
Galvanized-iron ridge roll	68 lineal ft.
Concrete	15 cubic yards

Either Douglas fir or hemlock is the best wood to use for studding, since both of these woods are strong, stiff, light in weight, easy to work, and comparatively inexpensive. For exterior wall covering, 6-inch drop siding is suggested. Western red cedar is desirable for sills, as it is

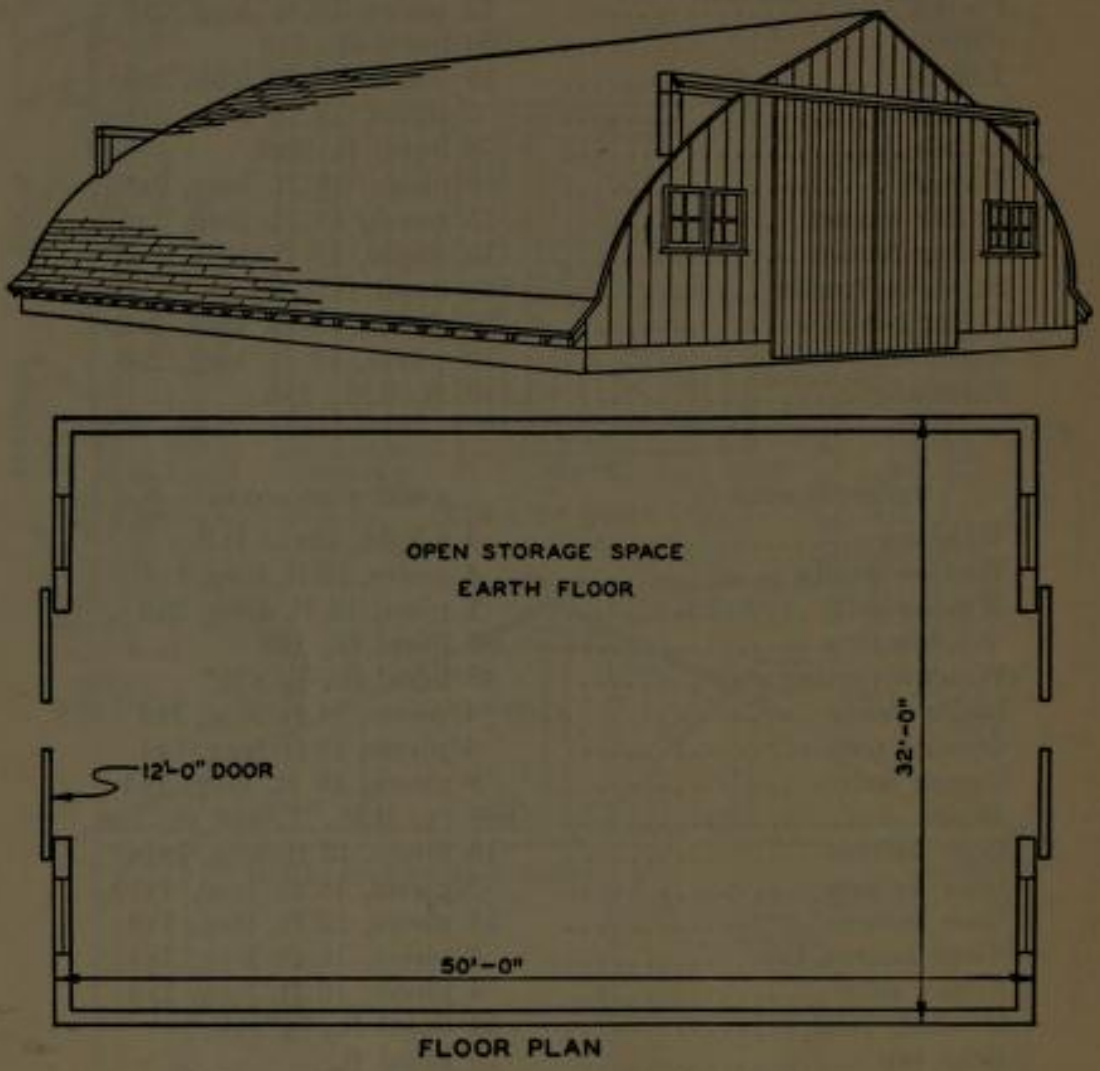
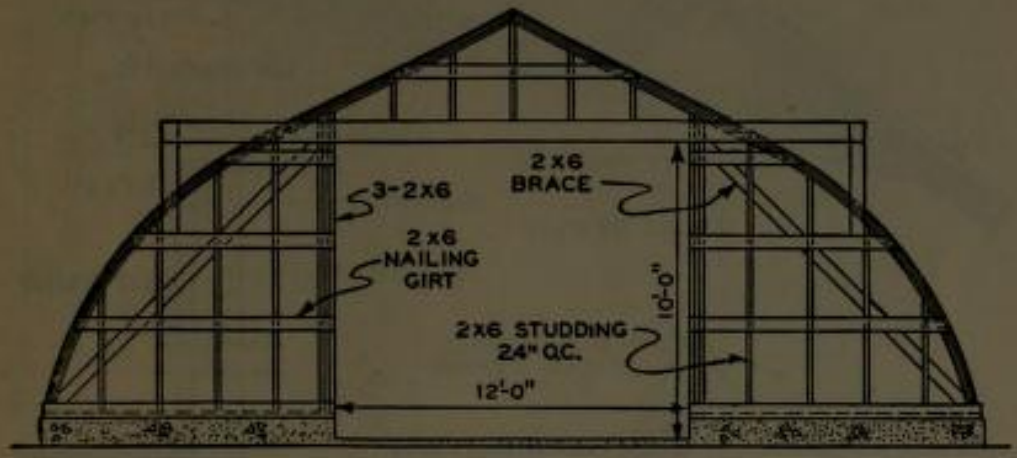


Fig. 28. Hangar-Type Implement Shed with Floor Plan

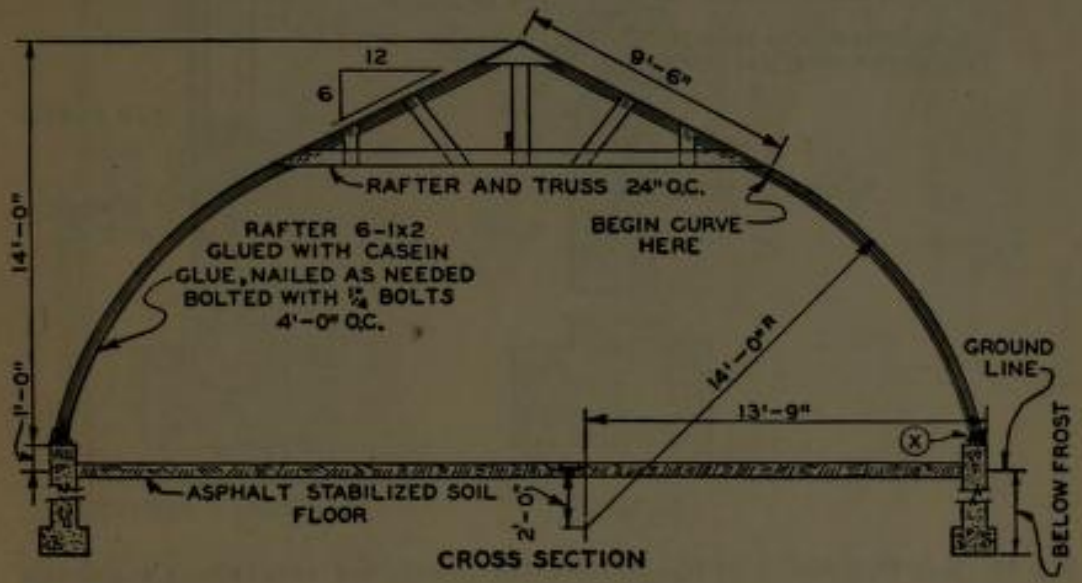
practically immune to decay because its fibers are saturated with a natural preservative which is resistant to decay-producing fungi. This wood is close-grained, highly resinous, and resists water. Cedarwood also has high durability even under unfavorable conditions, such as contact with moist soil or exposure to weather. It does not require painting, since it will stand up under exposure of the severest kind without auxiliary preservatives. Its advantage for use in hog-

house construction is obvious, since red cedar, on account of its natural odor, is repellent to vermin and insects.

b) Roof. For the roof of the hog house it is advisable to use 2x4 rafters spaced 24 inches on center and covered with either 1x4 or 1x6



END-WALL FRAMING



CROSS SECTION

Fig. 29. Cross Section of Hangar-Type Implement Shed, Showing Detail Construction and End-Wall Framing

Douglas-fir sheathing. Red-cedar shingles should be laid 4½ or 5 inches to the weather over the sheathing. This will provide a roof that helps keep the hog house warm in winter, and will also provide protection from heat for the hogs during the summer. Care should be taken in selection of nails. These should be of high quality, such as hot-dipped

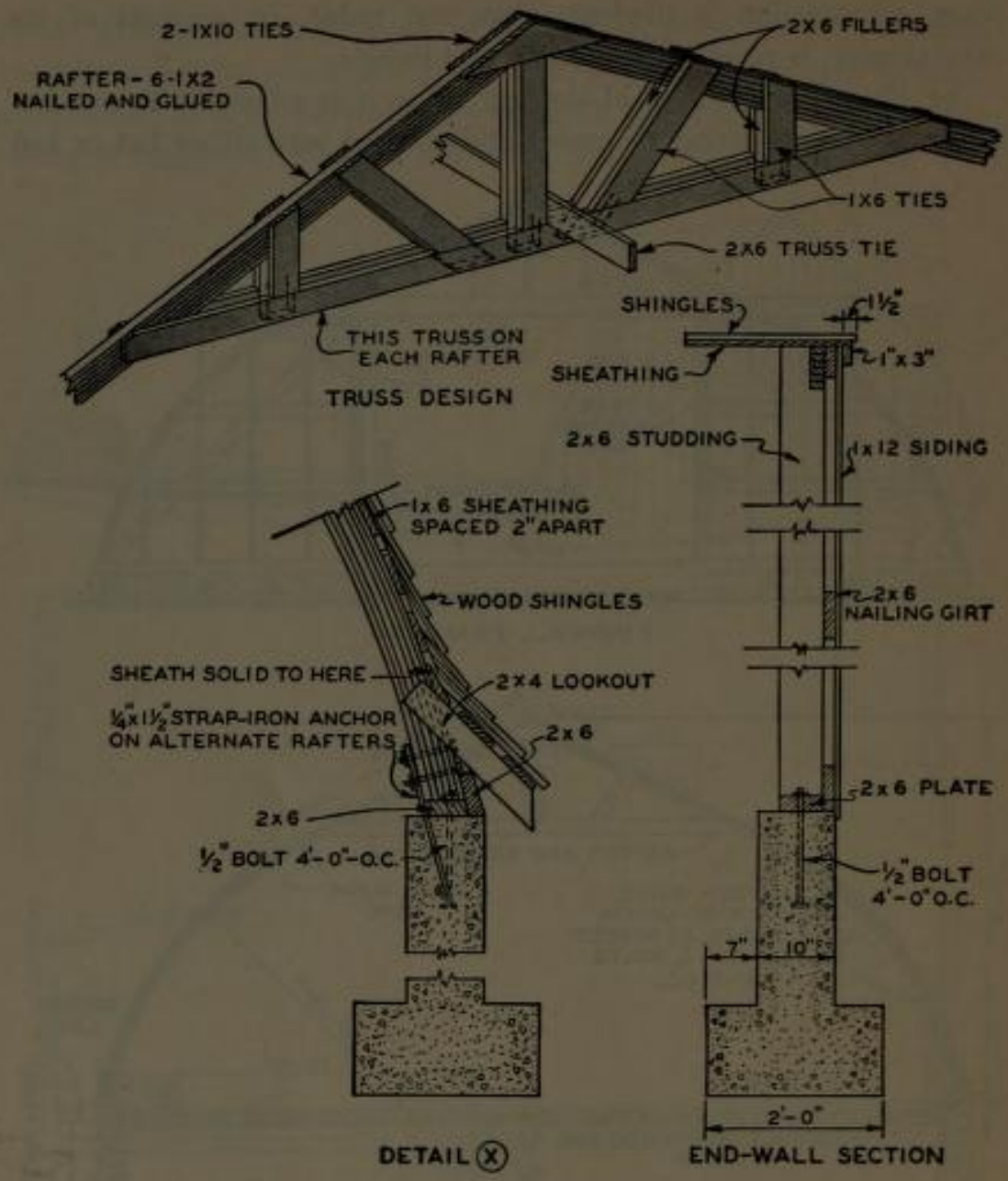


Fig. 30. End-Wall Section of Hangar-Type Implement Shed with Detail Construction Shown at (*X*), and Truss Design

zinc-coated nails or copper nails. Steel nails are not recommended because they rust easily.

c) Windows. The size and location of windows in a community hog house are especially important and should be given careful consideration. The greatest amount of floor space possible should be flooded with the sun's rays at farrowing time. The height of the windows

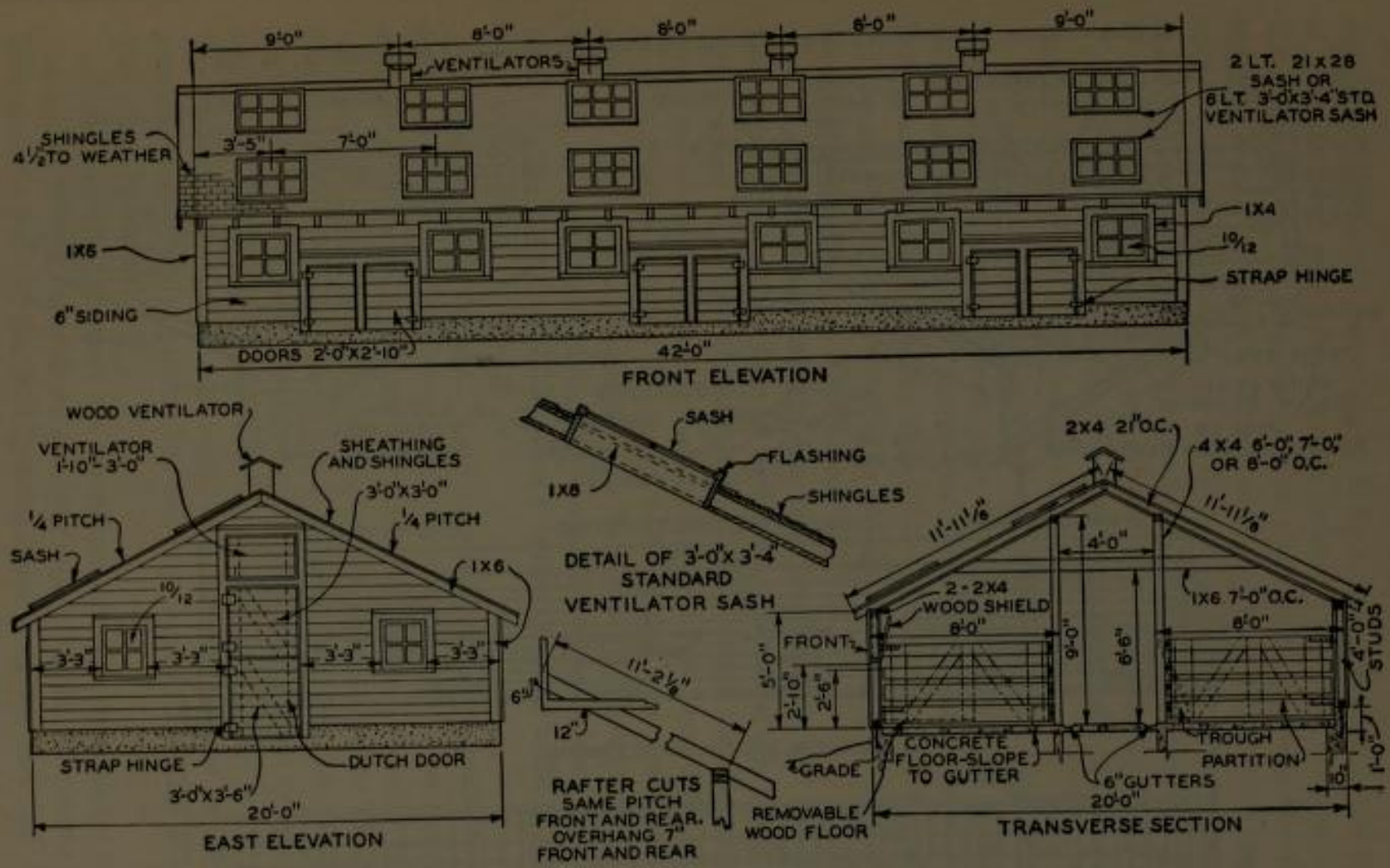


Fig. 31. Gable-Type Hog House, Showing Front and East Elevation, Also Transverse Section

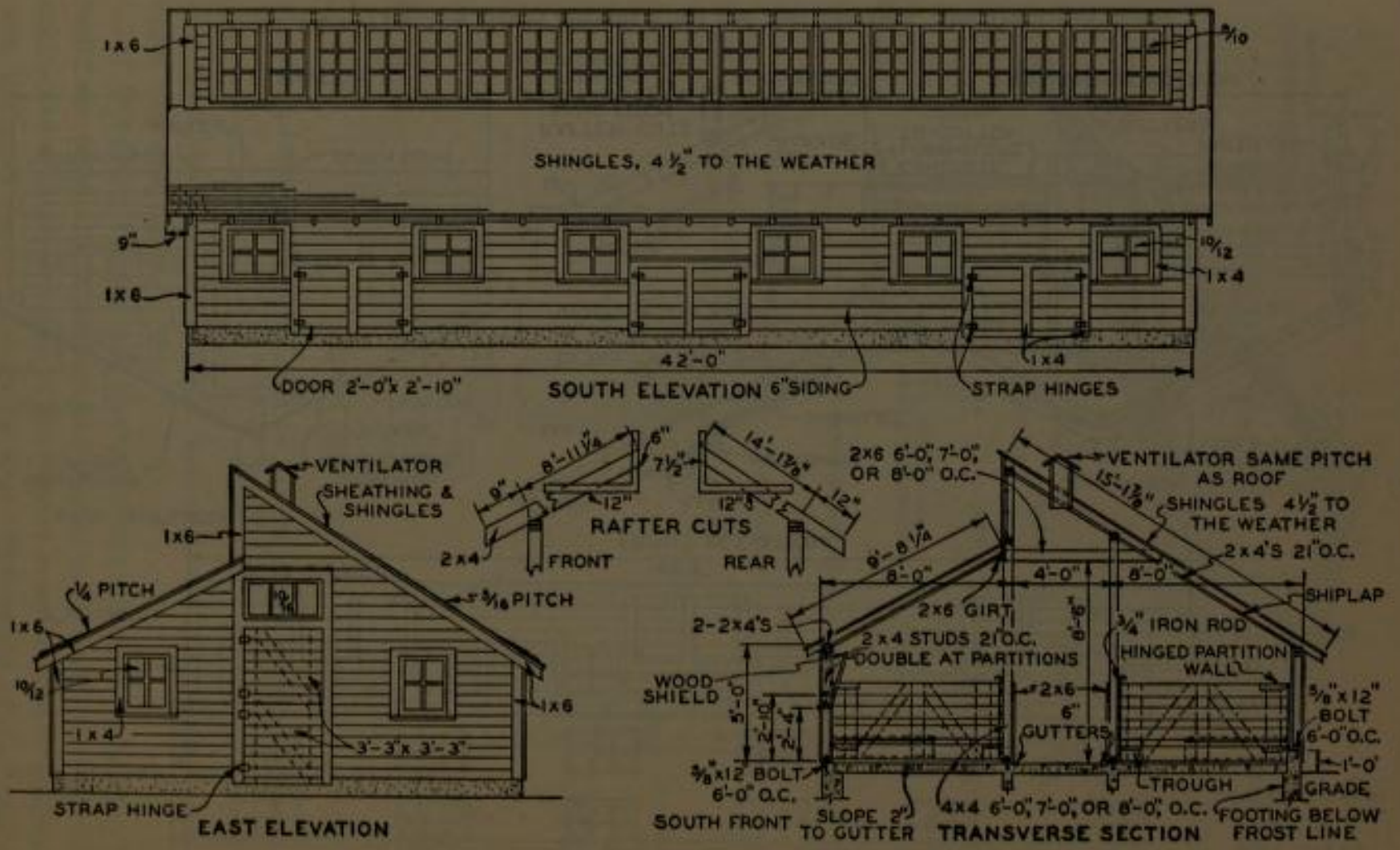


Fig. 32. Half-Monitor Hog House, Showing South and East Elevation, Also Transverse Section

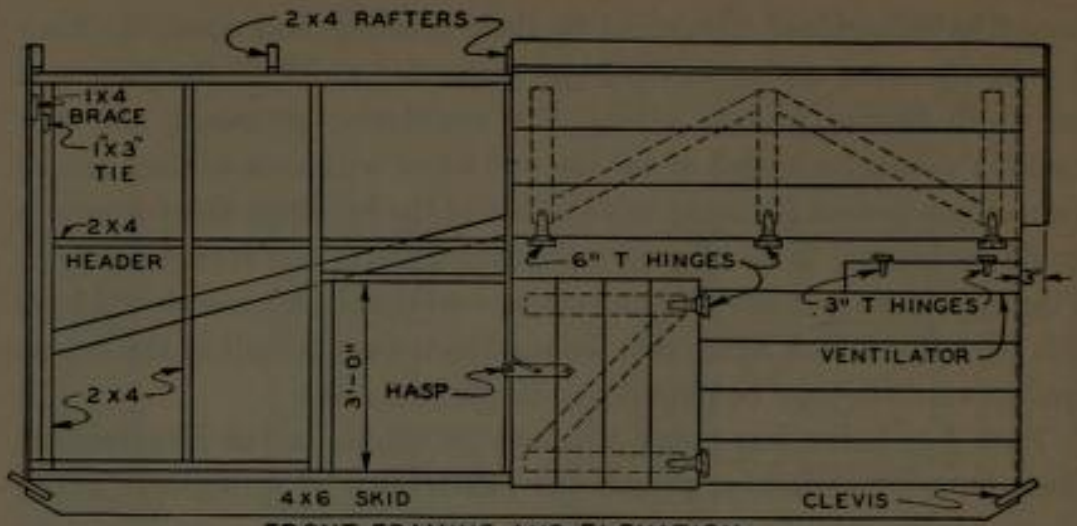
should be determined according to their location and upon the time of year the sows are to farrow, also upon the width of the pens and the width of the feeding alleys. For ventilation purposes, the roof windows should be hinged at the top and fitted with rods so they can be opened by a person standing on the floor of the building. Roof windows should be located so as to give maximum light to the farrowing pens. If the hog house is located on an east-and-west axis, barn-sash windows with four 10x12-inch lights may be used in the south half of the house. Similar windows may be placed also in the end walls.

Each hog house has many windows as shown in the illustrations. These numerous windows permit the penetration of sunlight to every corner of the building. Conventional grouping of the windows, as shown in the drawings, may be changed to suit the needs of the individual owner. Construction details, as well as recommended materials, are given in the drawings, Figs. 31 and 32.

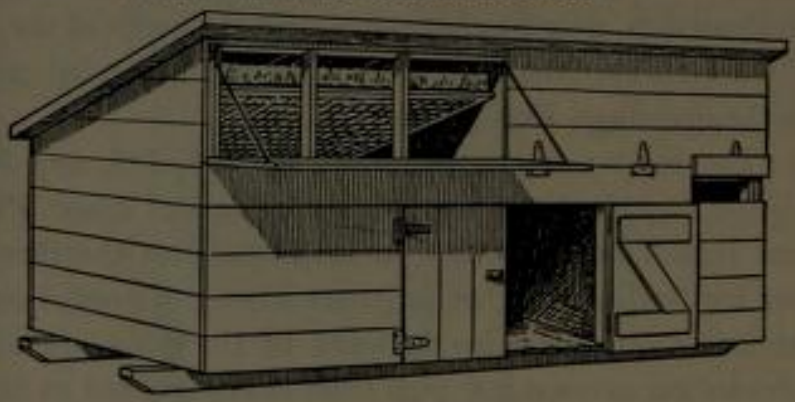
d) *Pens.* The most common pen sizes are 6x8, 7x8, and 8x8 feet. Each pen should contain from 50 to 60 square feet of space. Partitions between pens should be removable to make possible the throwing of pens together for feeding or other purposes when not needed for litters of pigs. Fenders around the inside walls of the pens are advisable since this precaution saves many pigs from being crushed at farrowing time. These guardrails, or fenders, are made of 2x4's placed 8 inches above the floor, with the inner edges 8 inches from the walls to which they are fastened.

2. Portable Hog Houses. There are many types of portable hog houses, but all types are mounted on runners or skids to permit easy transfer from one lot or pasture to another. When necessary to be cleaned, the house can be moved to a new location safely removed from infected rubbish. Thus housed, a brood sow and her litter of pigs are not so liable to be disturbed by other animals nor exposed to contagious diseases. Consequently, the lives of more pigs are saved. The portable type is an advantage to the renter because it affords him the opportunity to provide his own hog house and to take it with him when he moves.

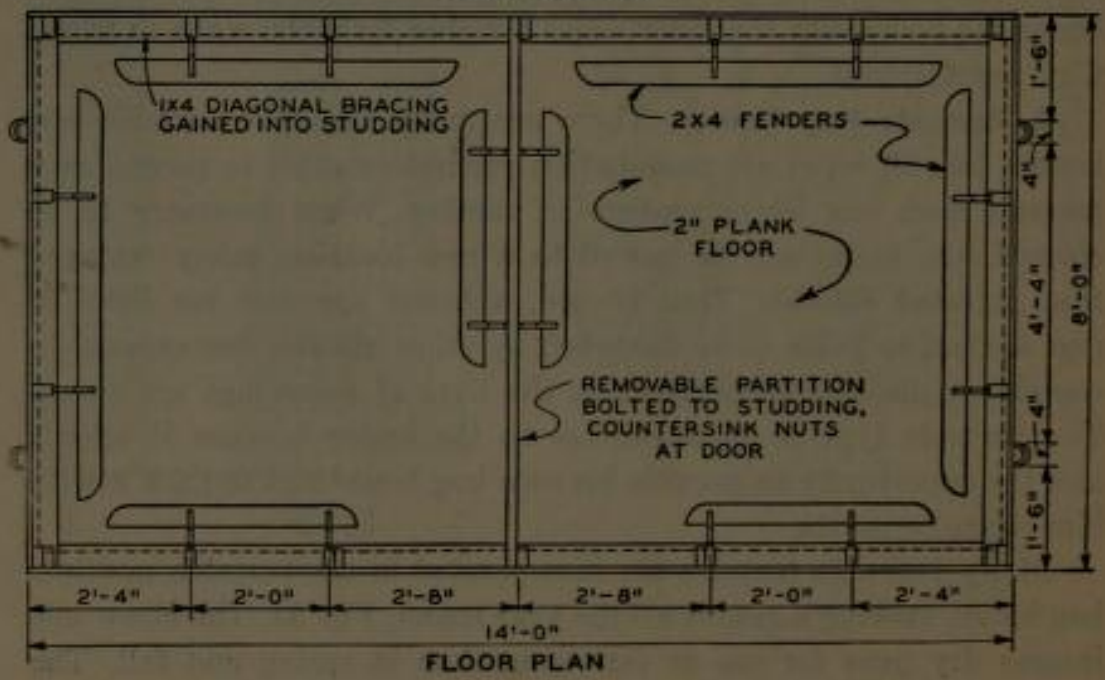
Many desirable features are incorporated in the portable multiple hog house, making it usable all the year round, Fig. 33. The straw loft insures dry pens for use at farrowing time in spring and fall. The



FRONT FRAMING AND ELEVATION



PICTORIAL VIEW



FLOOR PLAN

Fig. 33. Portable Hog House and Floor Plan

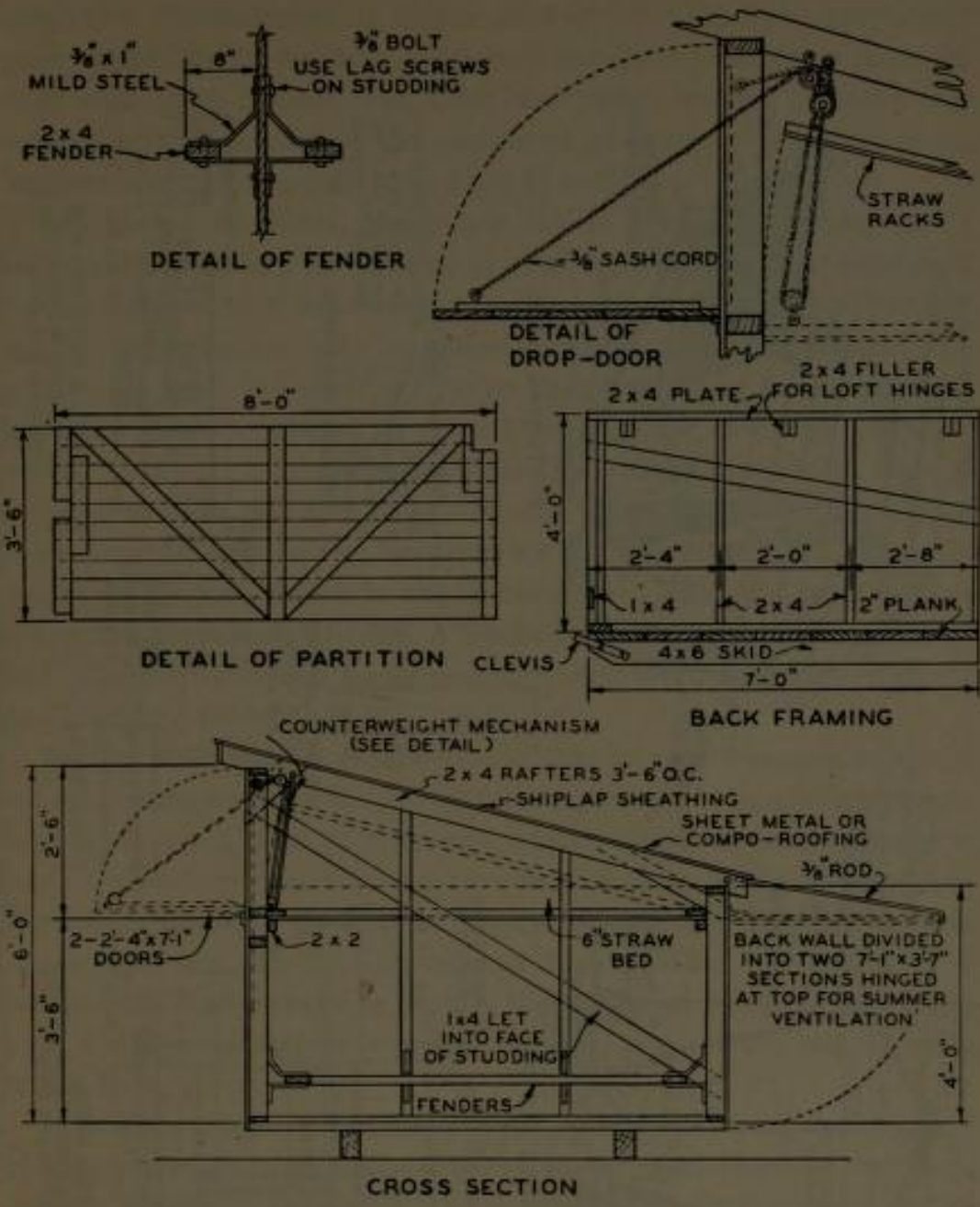


Fig. 34. Cross Section of Portable Hog House, Showing Details of Construction, Including Fender, Drop-Door, Partition, and Back Framing

small doors in front may be opened for ventilation in cold weather. The straw racks are hinged at the rear and counterbalanced by the large doors in front. The racks can be raised out of the way by opening the front doors. For summer use, the partition and fenders may be removed and, when shade is needed, the rear wall sections, which are hinged at the top, can be raised. This feature allows thorough

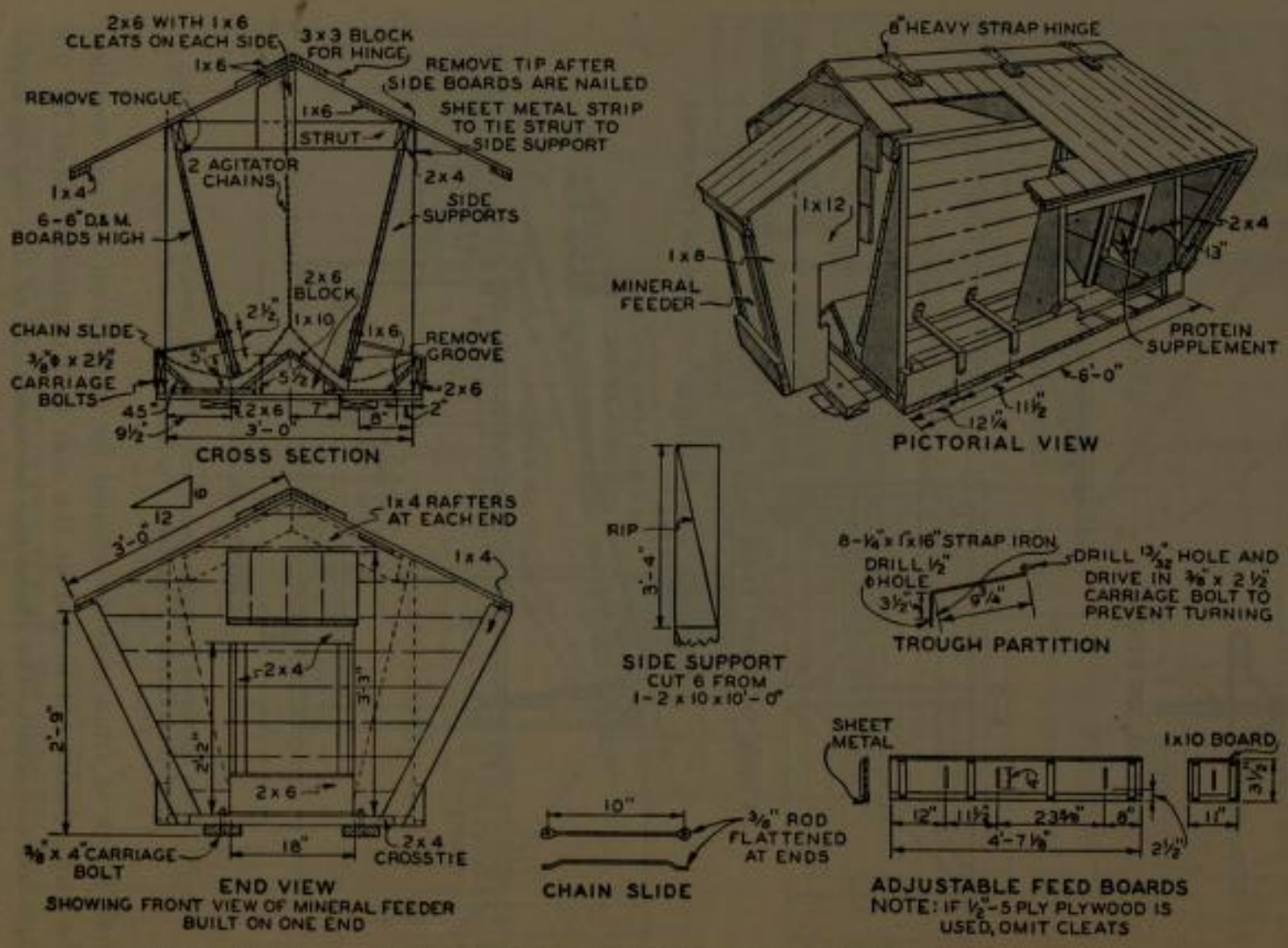


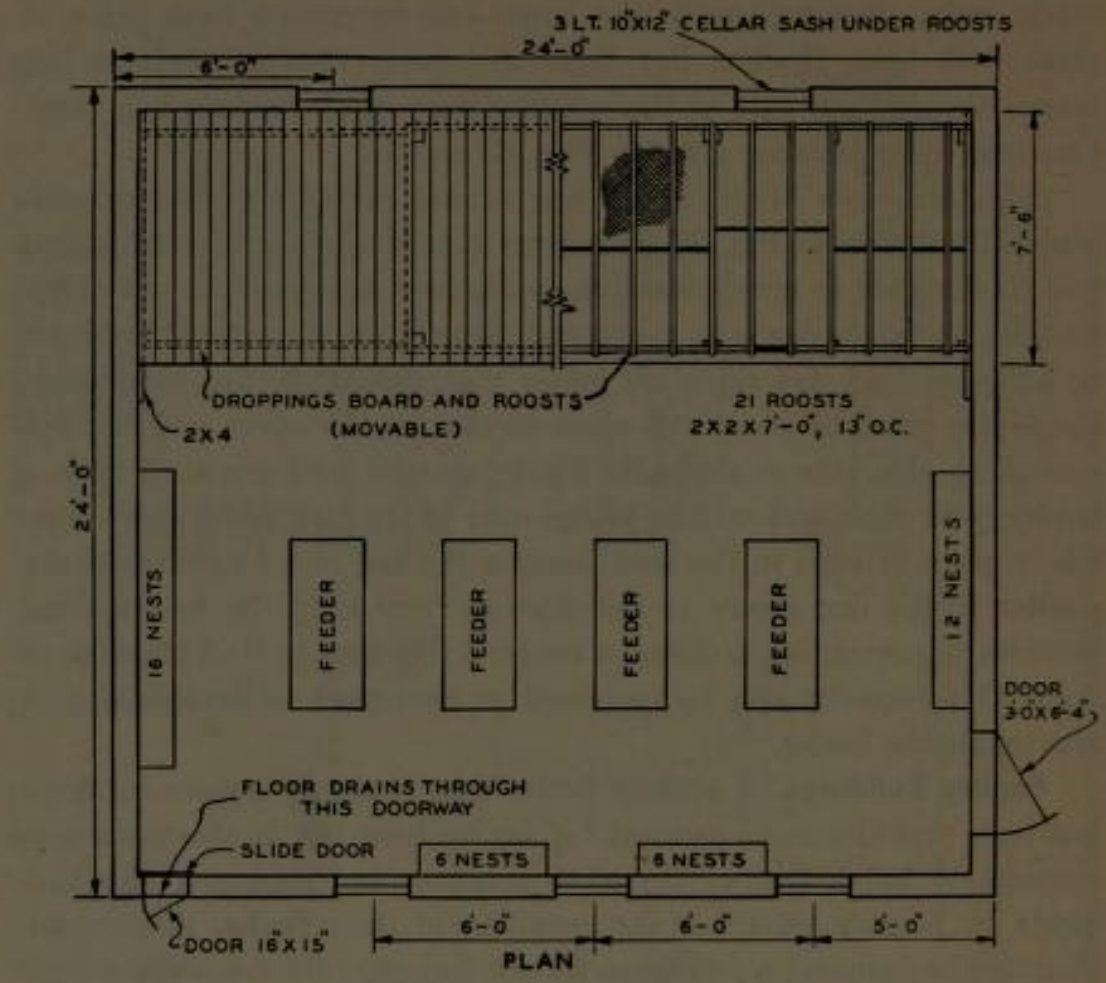
Fig. 35. Outdoor Self-Feeder for Hogs, Showing Cross Section, End View, and Pictorial View

circulation. Furthermore, it makes interior cleaning and disinfecting much easier. Being portable the house can be moved from place to place with little trouble. For these and other reasons portable hog houses should be a part of the equipment of every modern hog farm. Construction details are given in Figs. 33 and 34.

Self-Feeder for Hogs. Many hog raisers prefer the outdoor self-feeder, illustrated in Fig. 35. This type of feeder, with its overhanging roof, is designed to give protection to the feed, keeping rain out of the troughs. If the feeder is to be placed directly on the ground, and not on a feeder floor, 4x4 skids are better than 2x6 skids. For large sows, the feeder must be placed on cross blocks, so the eaves will be high enough to clear the sow's back. Finely ground feed mixtures have a tendency to pack and arch or bridge over in the bin. When there is no whole grain or corn in the feed mixture the use of an agitator chain, similar to the one shown in the drawing, will keep the feed moving downward, preventing arching. A feeder 6 feet long holds 32 bushels of feed. This capacity can be increased or decreased by lengthening or shortening the feeder.

Poultry Buildings. A poultry house that is nearly square in shape not only provides more comfort for laying hens but is also more economical to build. One of the most common and expensive mistakes made by poultry raisers is the crowding of their flocks. Poultry authorities recommend a full three square feet per bird for leghorns and four square feet per bird for heavier breeds. When the ceiling of a henhouse is high enough to permit the caretaker to stand erect and walk about comfortably, it is high enough to meet the requirements of his flock.

A house where hens can live and eat comfortably provides the kind of quarters where they make the best use of good breeding and good feeding, rewarding the owner with a steady and sizable return on his investment. To avoid sudden changes in temperature, the henhouse should be insulated. A poultry house designed for rigorous climates is shown in Figs. 36 and 37. This building has a straw loft providing good ventilation which helps to insure a dry atmosphere, a highly desirable feature for obtaining the best results from laying hens. This type of poultry house, or one similar in construction, will meet the requirements of the average poultry raiser. Both hens and pullets, as



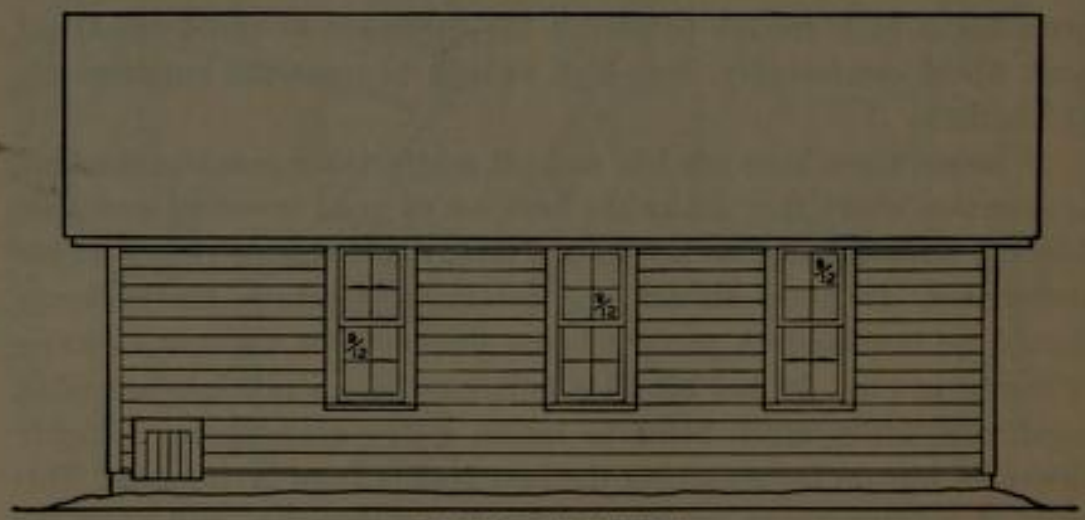


Fig. 36. Poultry House, Showing Front Elevation and Floor Plan

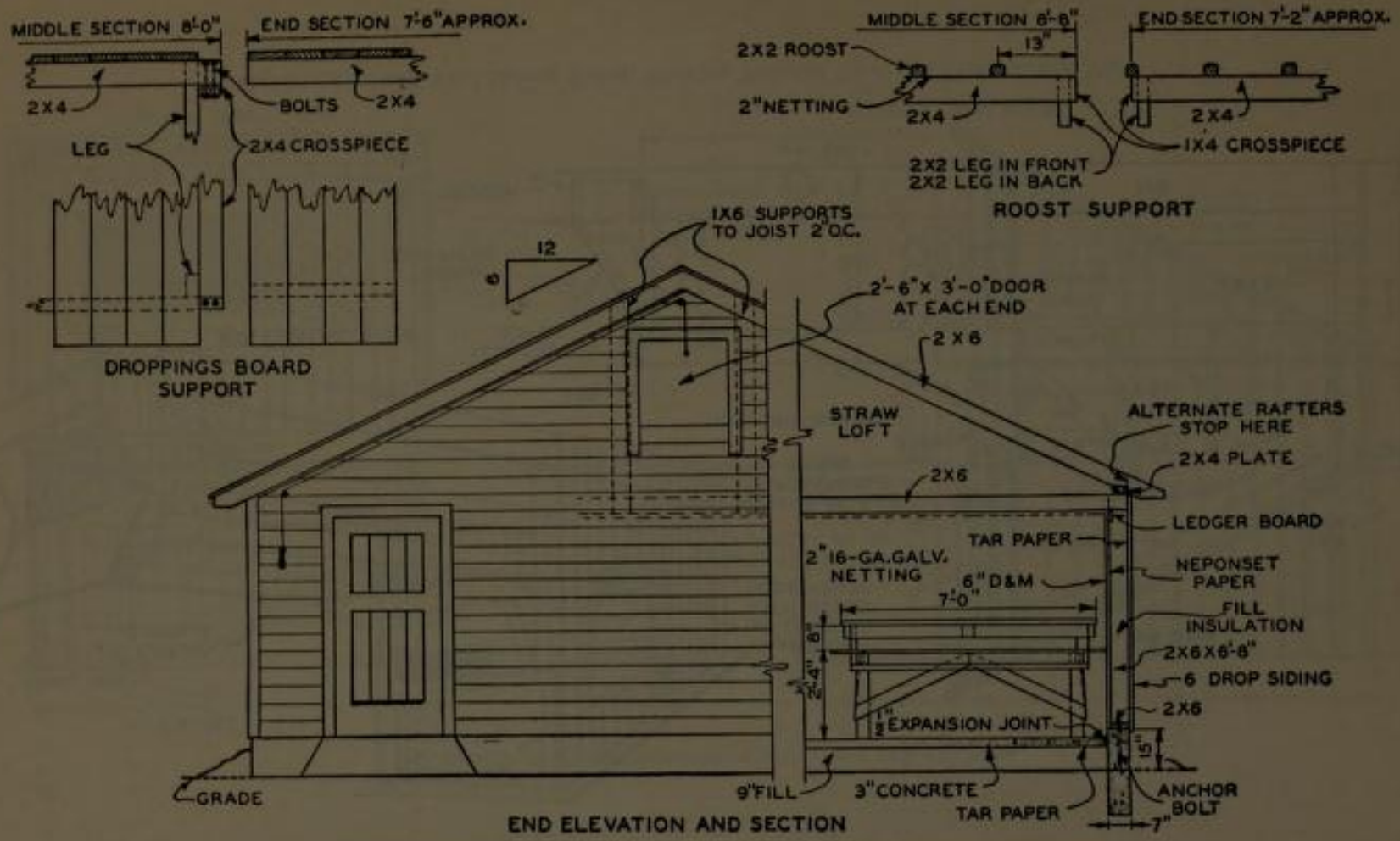


Fig. 37. Poultry House, Showing End Elevation and Detail of Construction

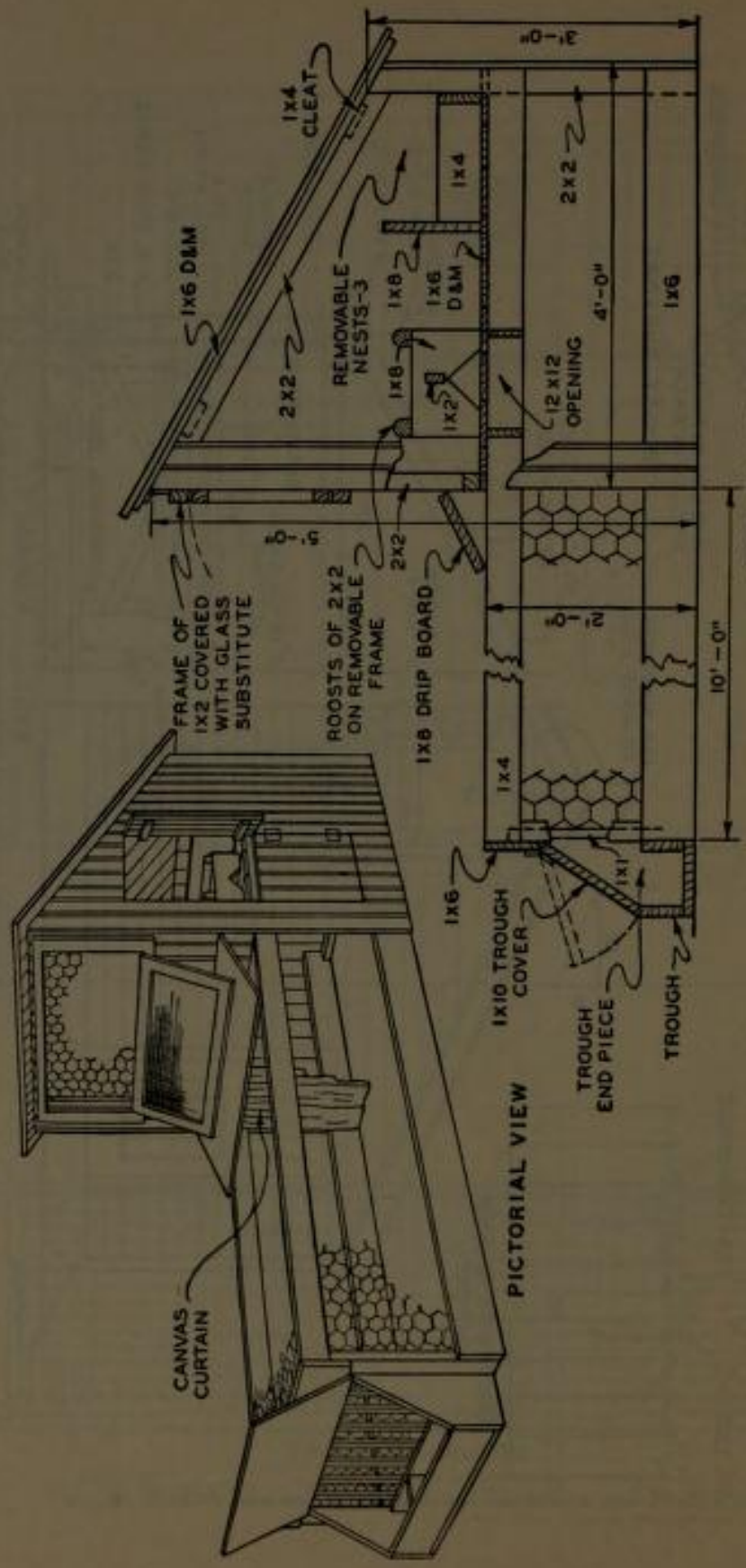


Fig. 38 (A). Back-Yard Laying House, Showing Pictorial View and Cross-Section View

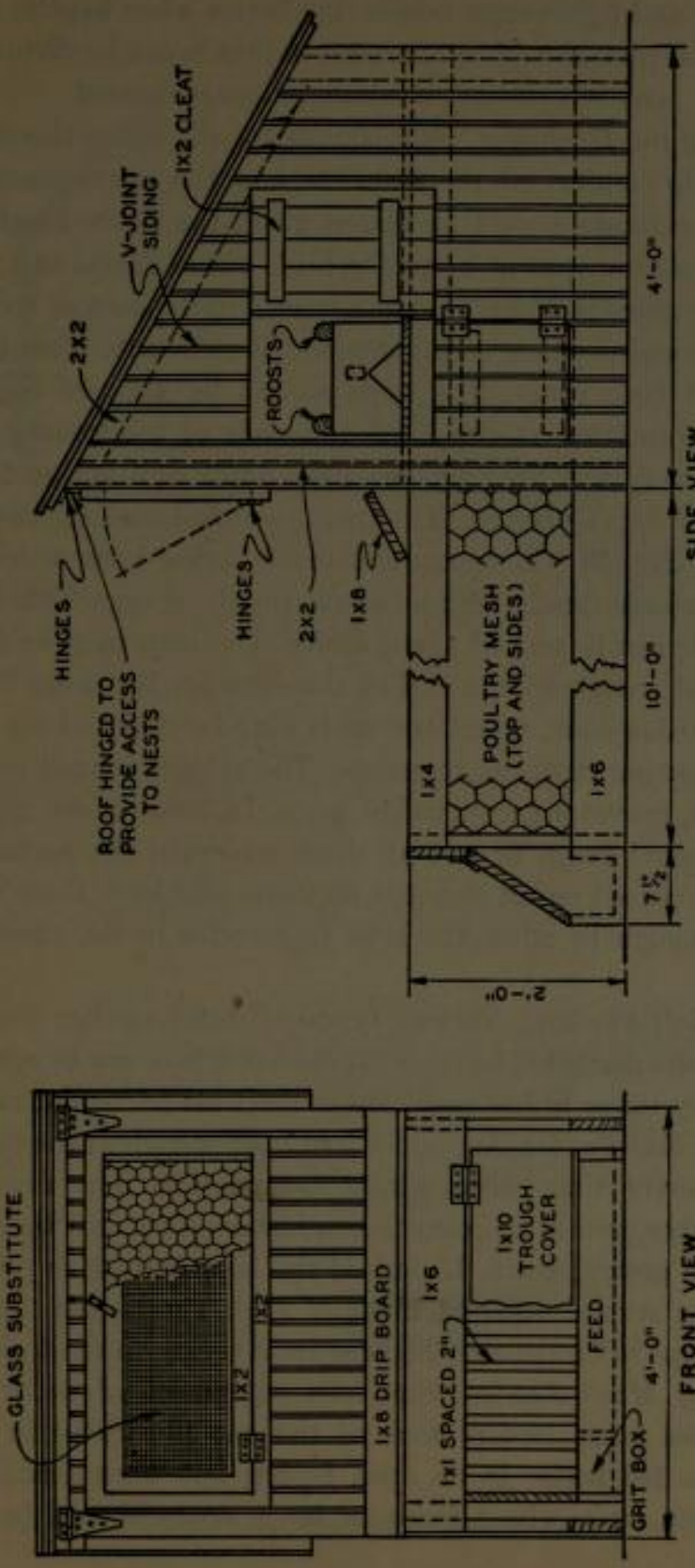


Fig. 38 (*B*). Detail Construction of Back-Yard Laying House

well as heavy and lightweight breeds, lay better when kept in separate pens. The house plan should be arranged so that it can be divided easily into separate pens where such a combination is desired.

Furnishing the Henhouse. Furnishings for the house should be arranged for the comfort of the chickens and the convenience of the caretaker. The roosts should be placed along the entire length of the rear wall. This arrangement keeps the birds out of drafts and provides open working space in front. No more than 7 to 8 inches of roost space should be allowed per hen, as this amount is sufficient; more than this is a waste of floor space. The nests should be grouped together in double-deck formation at the front and ends of the house; allowing one nest for every five hens will meet the needs of a laying flock.

Back-Yard Laying House. The small poultry house such as the one illustrated in Fig. 38 will accommodate 12 laying hens which should furnish the average family with an ample supply of eggs. This structure being portable can be moved about easily. The hens may be fed mash in the covered trough on the end of the runway. By using the upper half of the double door, roosts and nests may be removed for cleaning without permitting the hens to escape. The sloping hinged roof, serving as a door, provides access to the nests. In areas where the ground is apt to become damp or wet at short intervals, the portable henhouse can be placed on an elevated platform and kept there until the soil is dry enough to allow the hens to exercise in the runway with safety.

Poultry Self-Feeders. Various types of metal poultry feeders are available on the market. The three types shown here can be constructed by the poultry raiser in his workshop to meet his particular needs.

1. Indoor Self-Feeder. An indoor feed hopper such as the one shown in Fig. 39 saves time when caring for poultry. The dressed and matched lumber used in its construction insures a feedbox tight enough to hold finely ground grain. If desired the hopper may be partitioned to provide for several different kinds of feed. The hinged top is built on a steep slope to discourage the hens from trying to roost on it.

2. Poultry Mash Feeder. Standard equipment of every poultry raiser includes mash feeders such as the one illustrated in Fig. 40. Mash can be fed better in an open feeder, but when feeding whole grain cafeteria style, about twice as much space should be allowed

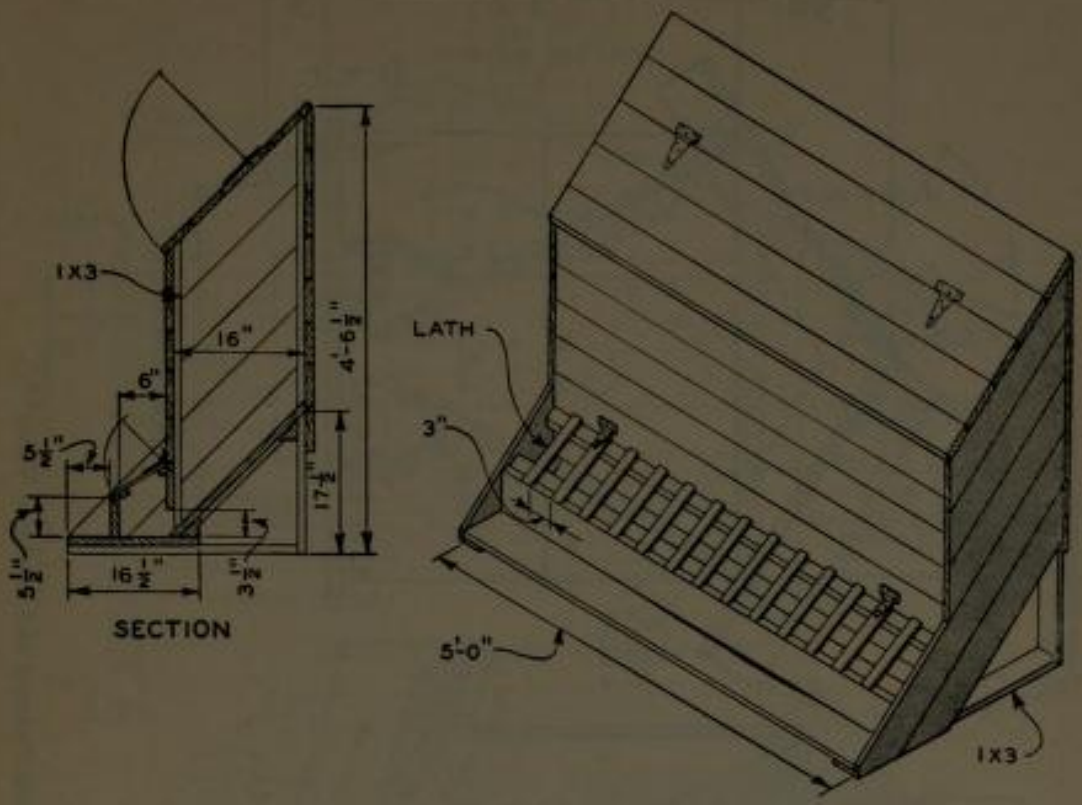


Fig. 39. Indoor Self-Feeder, Showing Perspective and Sectional Views

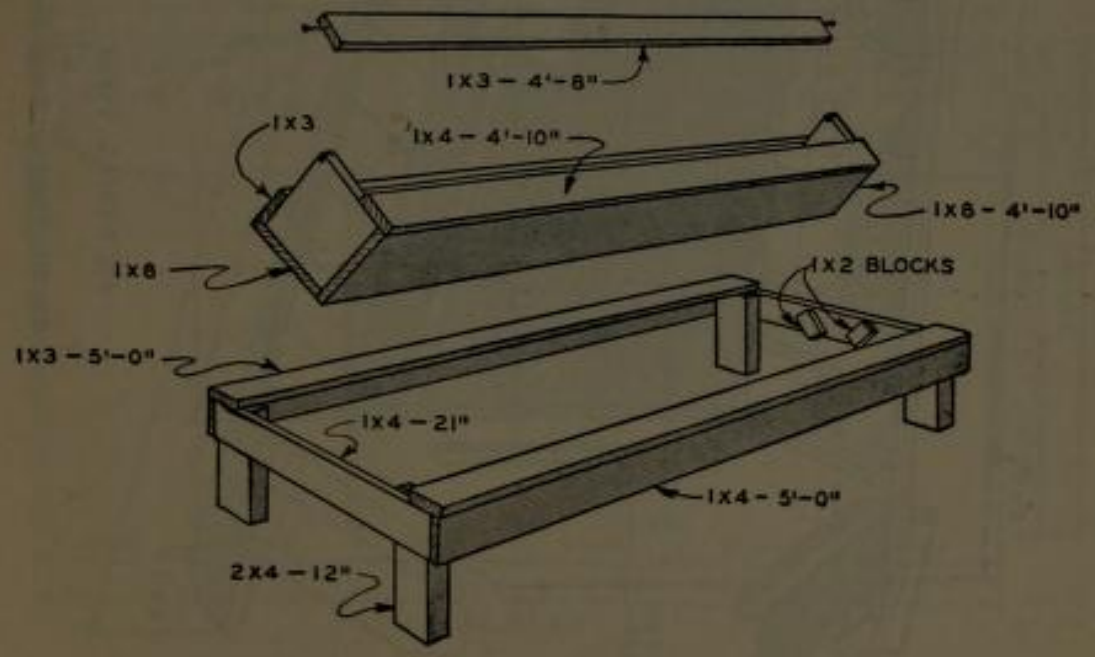


Fig. 40. Poultry Mash Feeder, Showing Trough, Stand, and Revolving Board

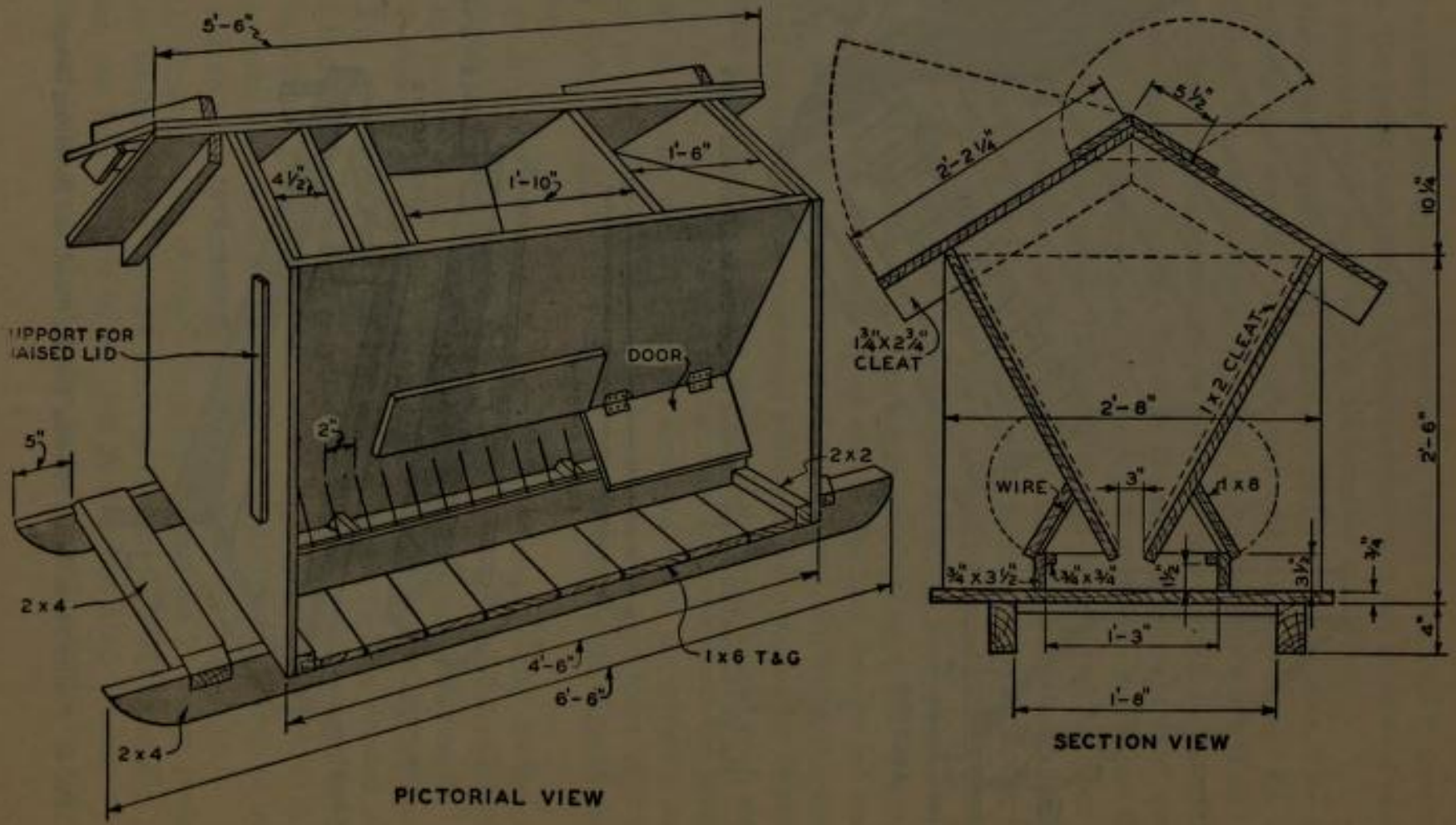


Fig. 41. Outdoor Range Feeder, Showing Pictorial and Sectional Views

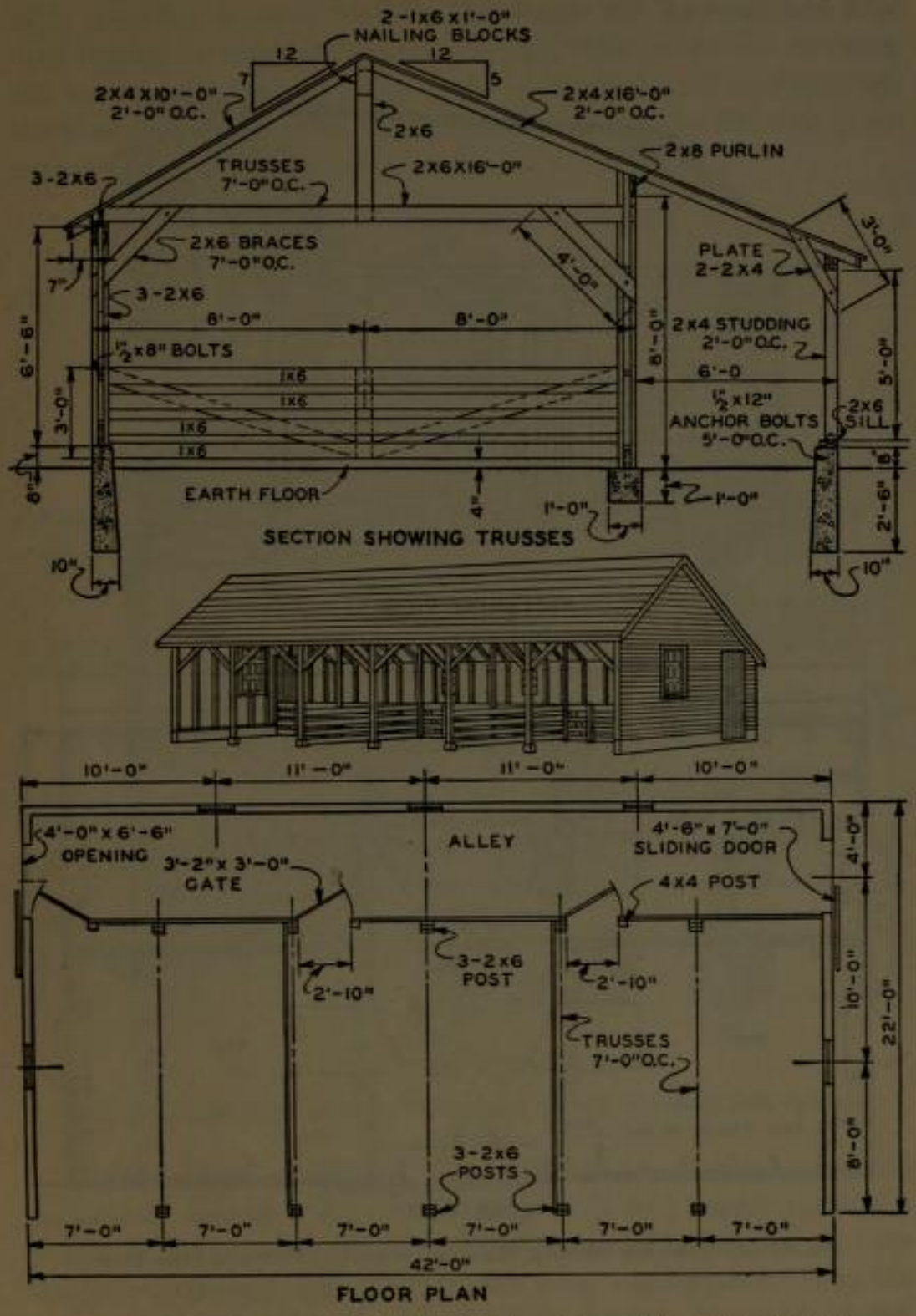
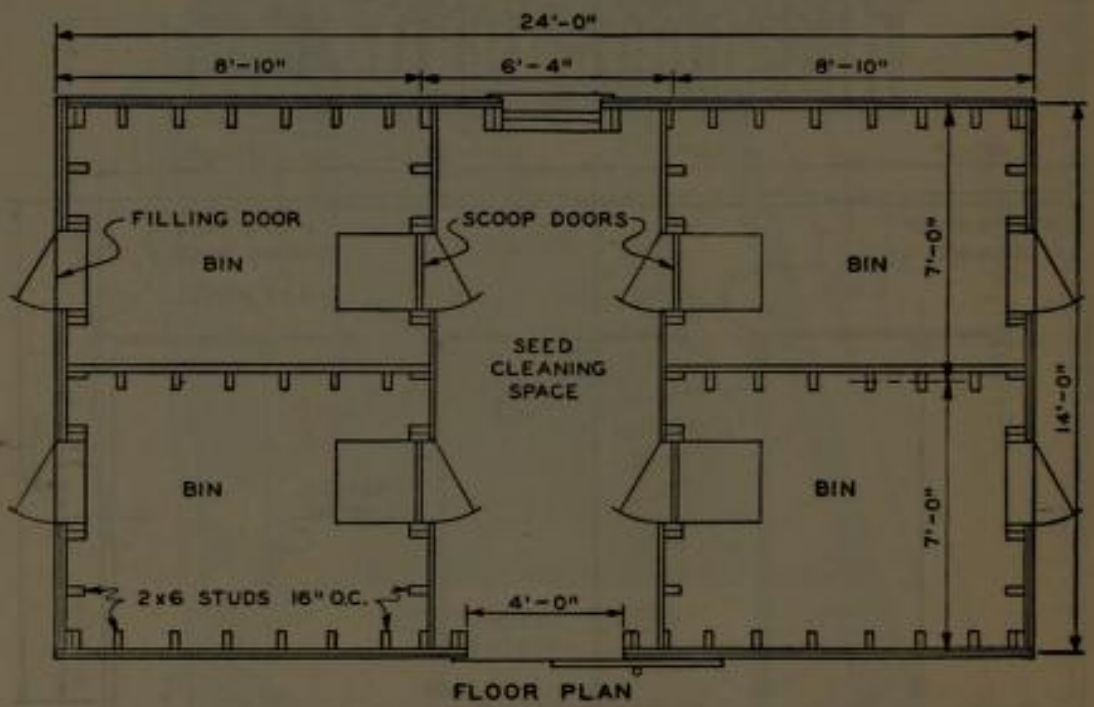


Fig. 42. Open-Front Sheepshed, Showing Floor Plan and Detail Construction

PICTORIAL VIEW



FLOOR PLAN

Fig. 43 (*A*). Four-Bin Granary, Showing Perspective View and Floor Plan

as in the other types of feeders. This feeder will accommodate fifty hens feeding on mash and using both sides. The trough can be taken out and cleaned. The revolving board at the top tends to discourage the hens from roosting on the feeder. Care should be taken to place the nails off center as indicated in the illustration.

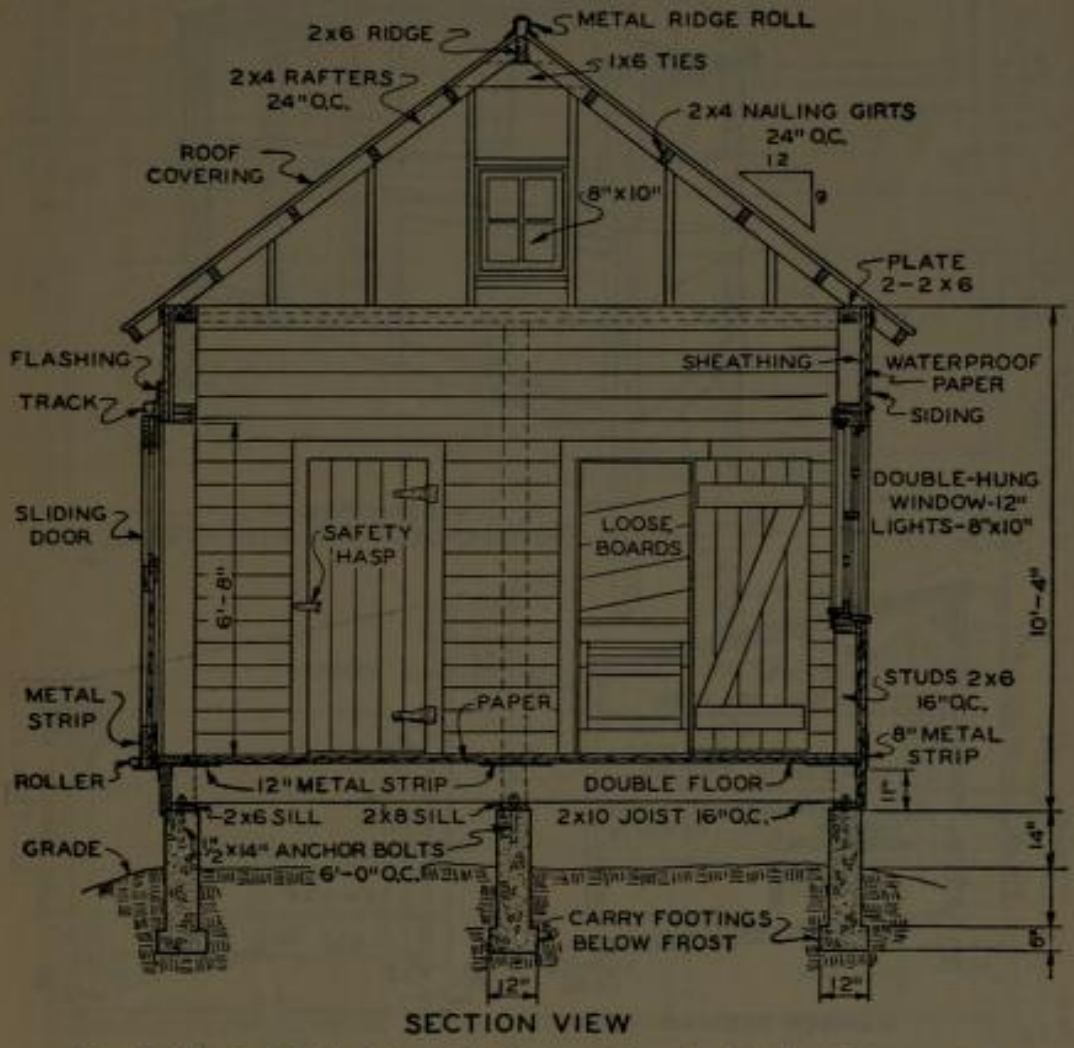


Fig. 43 (*B*). End-Wall of Four-Bin Granary, Showing Details of Construction

3. Outdoor Range Feeder. A portable feed hopper recommended for outdoor feeding is shown in Fig. 41. This feed hopper requires a watertight cover which extends over the trough far enough to keep the feed dry during rainy weather. The sides, sloping inward from the top, force the feed into the trough at the bottom. The skids underneath make it easy to move the feeder to various locations.

Open-Front Sheepshed. The requirements of the average sheep raiser are fulfilled by the open-front sheepshed with its combination roof, as illustrated in Fig. 42. The principal requirements of a sheepshed are dryness, good ventilation, freedom from drafts, and good

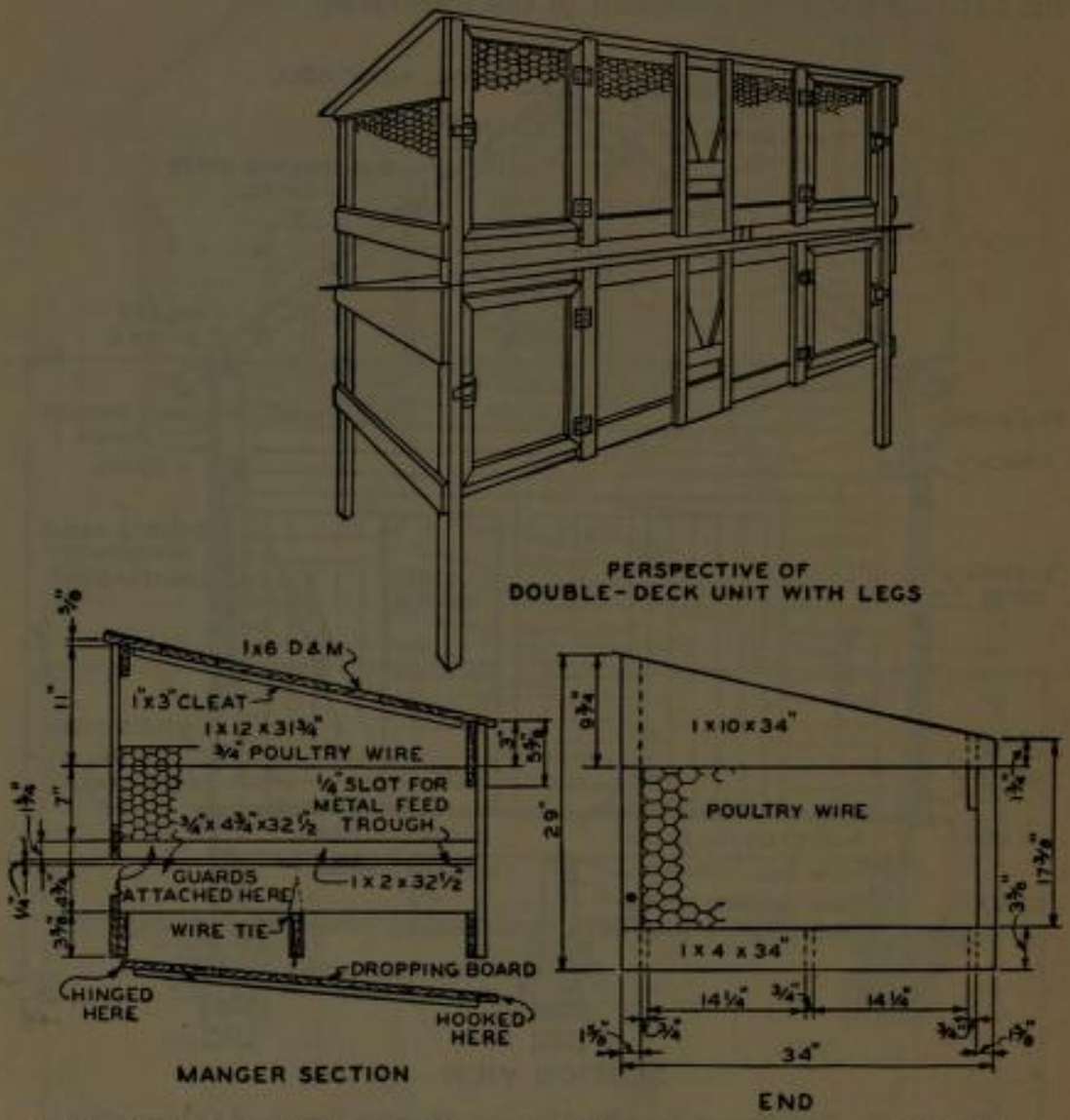


Fig. 44. Rabbit Hutch, Showing Perspective View, Manger Section, and Details of Construction

lighting. A building with an open front to the south makes a satisfactory sheepshed for mild climates. The size of the shed shown here provides shelter and feeding accommodations for a herd of 40 to 45 sheep. Locating a shed next to a larger building or windbreak will give the sheep additional shelter. To prevent surface water from

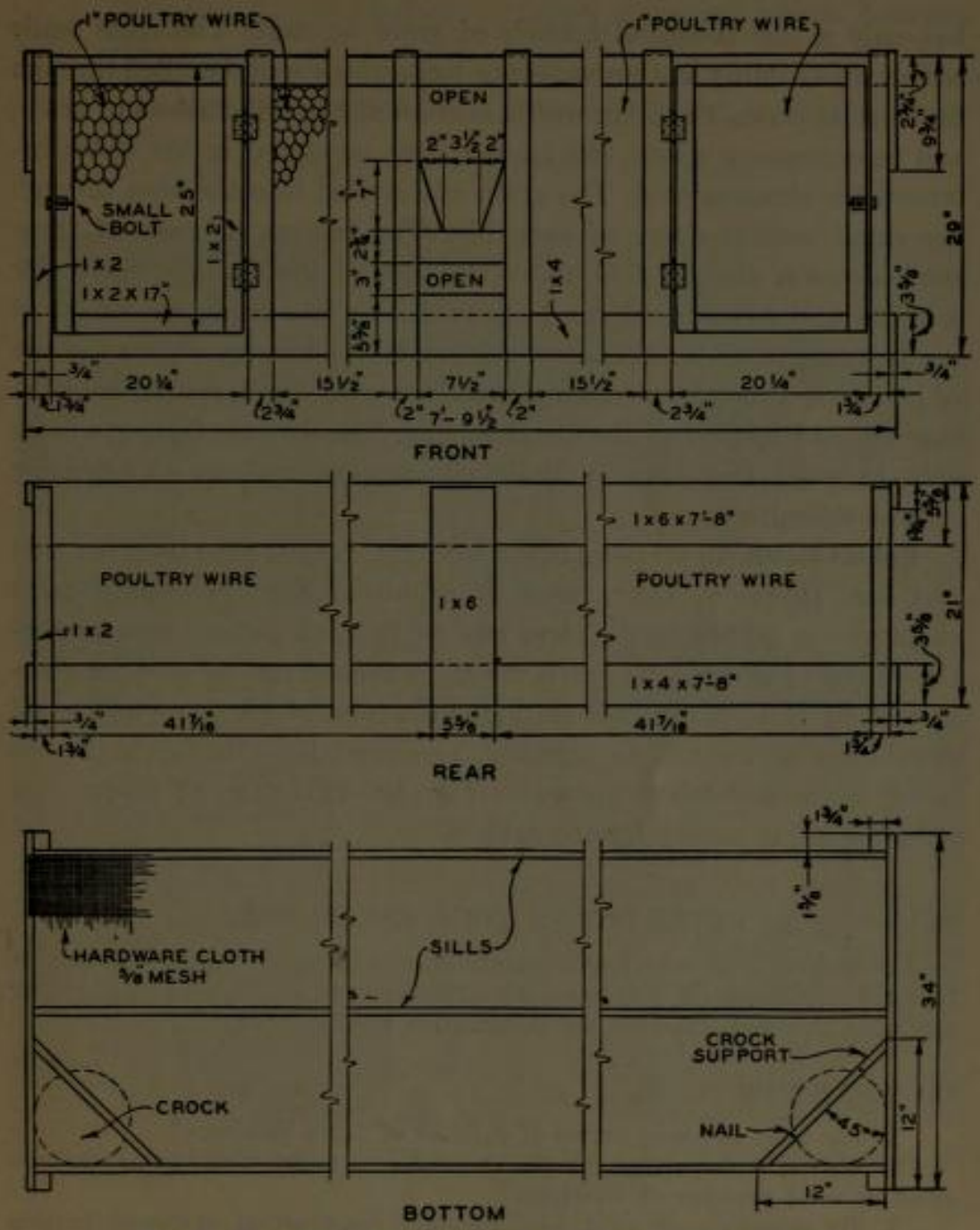


Fig. 45. Floor Plan of Rabbit Hutch, Also Front and Rear Views

draining into the building, the earth floor and foundation should be about 6 inches higher than the surrounding ground.

Granary. A stationary granary of frame construction, adequately braced to withstand the pressure of grain on its outside walls, is illustrated in Fig. 43. This type of granary is suitable for the farmer who

has only a few thousand bushels of grain to store. The cross walls stiffen the building and provide four bins, which may be filled through the outside doors. Each bin will hold from 450 to 480 bushels of grain, and in emergency about 780 bushels may be stored in the space intended for cleaning seed. The grain is shoveled into the bins through the small outside doors of each bin. The bottom of each of three small doors is about 6 feet above the floor of the granary. Space for grinding and mixing feed can be provided by increasing the length of the building to widen the alley. Although the drawing shows the use of corrugated metal for roofing, wood shingles (or prepared roofing) may be used instead of the metal roofing. The average farmer will be able to erect this sturdily designed granary without experiencing serious difficulties.

Rabbit Hutch. In all parts of our country, rabbits are raised for food and fur. However, their value in supplementing the family meat supply, or in adding to the farm income, is much greater in some sections than in others. The hutch shown in Fig. 44 can be used for commercial or home-use rabbit raising. This type of hutch permits good circulation of air and is sanitary. Designed for attachment to the hutch is the self-feeder shown in Fig. 45. This type of feeder is a valuable aid in caring for the rabbits.

CHECKING ON YOUR KNOWLEDGE

If you have read this chapter carefully, you should be able to answer the following questions. If you have any difficulty, you should read the chapter again, so that you will have the information well in mind.

DO YOU KNOW

1. The most common causes of failures of farm buildings?
2. Why it is important for the carpenter to understand the nature and effect of wind pressure on buildings?
3. Six essentials of good wind-resistant construction discussed in this chapter?
4. What type of roof construction is most resistant to wind pressure?
5. The names of three types of barn-roof construction in common use today?
6. The names of five important small farm buildings considered in this chapter?
7. What three types of poultry feeders are in common use by poultry raisers at the present time?

8. The names of two types of hog houses in common use on American farms today?

9. What advantage each type of hog house, discussed in this chapter, has? Which type is usually recognized by swine authorities as having the greater possibilities?

10. The chief requirements of a satisfactory sheepshed?

THE APPRENTICE CARPENTER MUST LEARN THE CORRECT STANCE IN LAYING FINISH FLOORING

Courtesy of American Builder

THE INSTALLATION OF THE FINE LACEWOOD, OAK, AND PRIMAVERA CARSTENITE PANELING OF THIS LIVING ROOM SHOWS OUTSTANDING CRAFTSMANSHIP

Courtesy of American Builder

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