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SHOWING THE EMPLOYMENT OF

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IN THE

PRACTICAL CONSTRUCTION OF BUILDINGS.

BY

R. SCOTT BURN,

Author of "The Hand-Book of the Mechanical Arts," and Editor of "The New Practical Guide to Masonry, Bricklaying, and Plastering," etc.

VOL. I.—TEXT.

LONDON AND GLASGOW:
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1877.

PREFACE.

As the first volume of the Advanced Series embraced a higher range of topics on Brickwork and Masonry than that of the volume of the Elementary Series, of which it formed the natural and necessary sequel, according to the proposed plan of the series; so does this, now presented to the Student, take up and discuss a wider and higher class of subjects in connection with Carpentery, Joinery, and Iron Work. Like the preceding volumes of the series, so this also, in order to be in conformity with the Syllabus of the Department of Science and Art, for the elucidation of part of the scheme of which it is designed, treats of much that is in its nature purely Elementary. But what is given in this way is so given, simply to lead the student up by a regular gradation of examples, from simple studies up to those which embrace more advanced principles, and a higher and wider range of examples of practice. Like the volumes which precede it, and which, as we have said, are its natural and necessary precursors, the feature which distinguishes it from nearly every other work of the same class, is the number of its illustrations, alike in the department of woodcuts interspersed amongst the letterpress, and in the 40 large Plates. Of these it is right to state that they are not all, as so many illustrations are, merely simple outline diagrams; but in a large majority of instances are what may be called working drawings, drawn to scale expressly for the work, or selected with care from examples of the best and the most recent structures of the times. In fact, it is only from their relative smallness—necessitated by that of the surface alone at command—that they differ from the larger drawings of such works having wider scope in this respect. As regards these illustrations, and this refers, of course, more especially to the woodcuts, it will be observed that their number begin at high figures. This requires and admits of easy explanation.

As stated in the Preface to the first volume of the Advanced Series, it was intended to have comprised the subjects of Brick, Stone, Timber, and Iron Work, within the limits of one volume; but from the great number of the illustrations, and the length to which their descriptions consequently extended, this was found to be impossible, without making it much larger in size than the scheme of the series, of which it would have formed a part, admitted of. A division of the subjects of Brick and Mason Work and cognate subjects, and of Timber and Iron Work, was therefore determined upon. But in giving the latter volume, it was deemed better not to break the continuity of the numbering of the letterpress illustrations, so that if at any time a student of the first determined to purchase the second volume, and bind the two together, he would find those numbers consecutive. Profuse, however, as these illustrations are, and to such an extent as is rarely met with in practical literature, and full as are the descriptions, it is perhaps scarcely necessary to state here what was stated in the Preface to the first volume: that neither the scheme nor the extent of the work admits of the Author presenting the student with an exhaustive treatise of the whole subject. That is obviously the work of larger and more ambitious volumes, amongst which he may be permitted to name his own in 4to, entitled *The New Practical Direction to Carpentry and Joinery*, and his still larger work in folio, *Modern Architecture and Building*. Those two works contain notices of useful patented improvements, and of important modern works on the large scale executed both here and on the Continent, in the arts on which they treat; but which, however interesting and valuable, are obviously out of place in a purely educational work like the present. At the same time, this reference to them will serve to the student of this volume a practical purpose, as he has reason to know it did in the case of the elementary volume, and will also, he trusts, be his best excuse for giving the special notice of them now named.

R. S. B.

November, 1877.

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PART I.—CARPENTRY.

CHAPTER I.

Mechanical and Free-Hand Drawing—Drawing Instruments—Drawing Scales—Plans—Elevations and Sections—Working Drawings of a Building—Free-Hand Sketches of Details.

1. Drawing Appliances — Board and T-Square.—The principal appliances required by the pupil in the preparation of drawings used in building construction are (1.) The drawing board; (2.) The "T" square; (3.) "Set" squares and curves; (4.) Rulers. (1.) The *drawing board* is, for common purposes, well enough made of fir or pine; but for superior boards, a mahogany, bay wood, sycamore, or plane tree wood makes a capital board. The wood, of whatever kind, should be thoroughly seasoned, as damp or unseasoned wood is sure to warp when made up into the drawing board; and the preservation of a perfectly flat surface is for this, it need scarcely be said, a *desideratum.* The shape of the board is rectangular, that is, having a greater length than breadth. It may be made of any dimensions deemed advisable; where a wide range of drawing work is to be carried out, including detail drawings, as well as smaller plans and sections, it is useful to have several sizes of boards. For the work for beginners a useful one will be two feet long by sixteen to eighteen inches broad. The body of the board should be provided with cross pieces at each end, grooved at their edges, into which pass the tongues formed at the ends of the body or main surface of the board; the object of these cross pieces is to prevent the body from warping. In large drawing boards, the back is provided with a series of cross pieces having the same object in view. (2.) *The "T-square"*— This is so called from being composed of a thin blade or flat ruler, varying in breadth from one inch and a half up to three or four inches, according to the length of the square, and from three-sixteenths up to five-sixteenths of an inch in thickness. To one end of this the "head" or "butt" is secured at right angles, the two pieces thus assuming the form of a cross or "T," hence the name. In some forms of "T-square," the blade is fastened in the centre of the head or butt, so that on each side of the blade there is a recess formed, so that when the inner edge of the head is drawn along the edge of the drawing board, the blade will slide along the surface of the board at right angles to the head. In other forms of "T-square" the blade is secured to the upper side of the head, the sliding recess or rebate being thus below the blade. Another form of "T-square" is that in which the head is made in two thicknesses, lying flat one upon another, and connected together with a central thumb screw. The blade of the square is secured to the upper of these two pieces, and by means of the screw the lower half of the head can be adjusted to form any desired angle with the upper half of the head. The result of this arrangement is, that by sliding the lower half of the head along the edge of the board, the blade of the square will slide along the surface at the corresponding angle to which the head was adjusted. This form of "T-square" is very useful when a number of lines parallel to one another, but not at right angles to, or parallel with the edge of the board, are required to be drawn. When this form of adjustable "T-square" is used for ordinary drawing, when the head of the square is desired to be at right angles to the blade, it is necessary to see that the thumb screw is screwed tightly up to prevent the lower half of the head from separating and getting out of line with the upper half of the head. The use of the "T-square" in the drawing of lines on the paper secured on the surface of the board, will be now explained. Suppose the head of the square to be sliding along the lower edge of the long side of the board (which in practice is always placed next the draughtsman, or nearest the outside edge of the table upon which the board is placed while the drawing operations are going on), the blade at right angles to it is sliding along the surface of the paper, with its edges parallel to the ends, so that all lines drawn along the edges of the blade of the square will be at right angles to the side of the board; and all these lines, at whatever distances they may be from each other, will be parallel to one another. By shifting the square so that the head will now slide along the right-hand end of the board, the blade will slide along the surface of the paper with its edges parallel to the sides of the board, so that lines drawn along the upper edge, while they will be all parallel to one another, at whatever distances they may be drawn from each other, will be at right angles to the lines drawn when the blade was in the previous position, as before explained. When long lines are required to be drawn upon the surface of the paper or on the board, at right angles to each other, this shifting of the square so that its head shall slide along the lower edge and right hand edge of the board is necessary; but when short lines are required to be drawn at right angles to any line or lines drawn along the edge of the square when in any position, they may be drawn without shifting the position of the "T-square" by using (3.) *the "set square."* This is made of a thin piece of hard wood, the edges of which are made perfectly smooth and square—that is, at right angles to the surface; the form is usually a "right-angled triangle"—that is, at which the hypothenuse is at an angle of 45° to the base. By sliding the base of this along, and keeping it in close contact—which can easily be done with a little practice—with the edge of the "T-square" lying in accurate position on the board, all lines drawn along the "perpendicular" of the "set square" will be at right angles to the lines drawn along the edge of the "T-square," so that these lines can be drawn without shifting the "T-square." When this "right-angled triangle" form of "set square" is used, all lines drawn along its hypothenuse will be at an angle of 45° to those lines drawn along the edge of the "T-square," the base of the "set square" sliding as before along the edge of the "T-square." Other forms of "set squares" are used; a very commonly used one having the hypothenuse line forming an angle of 60° with the base line, this form being useful in putting down isometrical drawings (see *Technical Drawing* p. 7.) "*Curves*" are pieces of thin hard wood, the edges of which are cut to various curved lines, the interior surface having also cut out from it portions, the edges of which also form various curved lines. These are useful for drawing curves not easily or conveniently described by the compasses, or which form part of eccentric curves not describable by compasses. Those are to be had in great variety. (4.) "*Rulers*" are made of two kinds—"ordinary" and "parallel." "Ordinary rulers" made of hard wood are flat, and of various lengths and breadths, and are useful for drawing lines between points to which the "T square" is not conveniently applicable. One of the edges of the ruler is often made with a bevel, but we prefer both edges to be square to the face. The edge of a "set square" affords a good ruling surface, if long enough. "Parallel rulers," as their name indicates, are for drawing lines parallel to one another, to which the ordinary "T square" is not applicable, or not conveniently so. They are of two kinds—the old fashioned, consisting of two blades, connected by brass links; and the single ruler, with wheels or rollers at each end. This is the modern form of the instrument; and when the draughtsman becomes accustomed to its use, it is very much quicker in its operation than the double-bladed parallel ruler. But a beginner is apt to make mistakes in its use, hence by some the old-fashioned ruler is preferred.

2. **Drawing Instruments.**—A complete set of drawing instruments comprises a very considerable number of pieces,—several, however, being duplicates, so far as the principle of their construction and the mode of using them is concerned, but of different sizes and forms;—but a very wide range of work can be done by the aid of the following:—(1.) The "large compasses," with shifting leg, into which can be put (*a*) a leg carrying a pencil, and (*b*) a leg carrying a pen, for the drawing of pencilled and inked circles and parts of circles. (2.) The "spring compasses," one leg of which is adjustible by means of a spring acted upon by a small set

screw. By this instrument, when a measurement is taken in the compasses—as in dividing a line into any number of equal parts—if the measurement is either a trifle too long or too short, the accurate measurement may be taken by adjusting the screw. (3.) "Spring dividers"—these are small compasses for taking small measurements, the legs of which are connected by a spring and a screwed link, the latter being provided with a small set screw, so that an accurate adjustment of the divider is easily attainable; and, when once set, the measurement taken will be retained, as the screw and spring keep the legs always at the same distance. This convenience is very great when the same measurement is to be often repeated in making the drawing. (4.) The "pencil bow compasses," for describing small circles and parts of circles in pencil. (5.) The "ink bow compasses," for describing small circles and parts of circles in ink. (6.) The "drawing pen." The above named instruments will not be here further described. Without them the pupil cannot even begin to the work of drawing, he must, therefore, purchase them; and a few minutes' examination of them will convey to him a more satisfactory notion of their peculiarities and uses than pages of description here. Fuller remarks upon them will, however, be found in the work on *Technical Drawing*, page 6. To the above will be required a common (7.) foot-rule.

3. **Drawing Paper and Pencils.**—For the purposes of the beginner good cartridge paper will do well enough; for superior drawings the regular drawing papers should be used; they are made in sheets of different sizes, as "demy," "royal," "imperial," etc., and of the different makes, that of "Whatman's"—if not the best—enjoys the highest reputation. The pencil most useful is that marked H H, although that marked H will be found, perhaps, most useful for the first lessons for beginners. The pencil should be cut so as to form a long, fine point; some prefer to finish the point round, some chisel-shaped, or flat edged. A piece of very fine sand-paper is useful to finish the point, after being first pointed by means of the knife. India-rubber is used to erase pencil lines, "Indian" or "China" ink to work them in and make them permanent. This is rubbed down with a little water in

colour dishes; these can be had of various sizes. For beginners, the paper may be fastened down upon the board by means of small drawing pins stuck into the corners, or by pieces of gummed paper at the same places. The method of stretching the paper by damping it and gluing it to the board by the edges will be found fully described in the volume on *Technical Drawing*.

4. Scales used in Drawings.—The scale to which drawings are constructed are conventional arrangements by which the proportion is maintained between the measurement which the drawing gives, and the actual length of the same parts when constructed, should be. Thus, a part of any building 15 feet in length could obviously not be drawn full size on paper; but if the length of each actual foot was supposed to be represented by a distance of an inch, a piece of paper a little over 15 inches in length would allow the line to be drawn; with a margin over, the line on the drawing paper would be 15 inches in length; but if the conventional measurement adopted was named in the drawing, it would be known that the line would be representing a line which in actual practice would be 15 feet in length. The formation of scales, of which the above is the general principle, is a matter comparatively simple, and will be found further illustrated in fig. 1, Plate XXXVIII*a*. Thus, suppose it is desired to construct a scale of "2 inches to the foot," take in the compasses from a "foot-rule" the distance or extent of two inches, then draw any line, as *a b*, fig. 1, Plate XXXVIII*a*., and from any point *c*, which will be the "zero" or "0" point of the scale, set off the distance in the compasses any number of times as there are to be feet in the scale, from *c* towards *b*, on the line *a b*, to *d* and *c*. The size of the Plate here limits the number of times the distance *c d* and *b* twice to three. Then each of the distances will represent a "foot." But as there are inches in the foot to be arranged for in the scale, divisions must be made to represent these inches; the large division to the left hand, as from the zero point, *c* to *d*, is that usually allotted to the inch division, this being divided, in large scales, into twelve equal parts, each representing an inch; but if the scale be small, as in fig. 10, then these first divisions, as *a b*, fig. 3, Plate XXXVIII*a*., is only divided into four parts, as *a f*, *f e*, *d e*, *e b*, each of these representing three inches, the extent or length of an inch in these small scales being guessed at. This is exemplified in the scale in fig. 10, which is a scale of "$\frac{1}{4}$ inch to the foot," or of "4 feet to the inch." Fig. 8 is a scale of "2 feet to the inch," or, as more commonly expressed, a scale of "$\frac{1}{2}$ inch to the foot." Fig. 9 is a scale of "3 feet to the inch." Fig. 11 is a scale for a detail drawing, "one-fourth full size" or $\frac{1}{4}$ of a foot, or "3 inches to the foot." Fig. 14 is a scale of $\frac{2}{3}$ of a foot; or two-thirds of full size. Fig. 15, a scale of $\frac{5}{8}$ of a foot or of full size, both with "eighths" marked. Fig. 4 shows the scale of 2 inches to the foot completed, with the division in the first division to the left indicating inches, all the larger divisions being feet. Fig. 2 represents a scale of "1 yard to the 2 inches," the last division, *a b*, being divided into three, as *a d*, *d e*, and *e b*, each division representing a foot, the other divisions, as *b f*, representing a yard. Fig. 7 represents a scale of 10 feet to $\frac{3}{4}$ of an inch, used like the last in laying down drawings of general plans, where the distances and measurements are great. In this scale of tenths, the last division is divided into ten equal parts, each representing a foot, and each of the larger divisions represent ten feet. Fig. 12 is a scale of "5 feet to the inch;" and fig. 13, "10 feet to the inch," with "inches" marked. Fig. 5 is a scale of "$1\frac{1}{2}$ inches to the foot;" fig. 6, a scale of "1 inch to the foot."

5. Practical Use of the Scales in Drawing Plans, &c.—*To take measurements from scales* is a simple matter. Suppose the drawing, of which the dimensions of various parts are required to be taken, is drawn to a scale of "1 inch to the foot;" and suppose that a certain distance from point to point of any given line in the drawing is taken in the compasses, then, by applying it to the scale, as, say, that in fig. 6, which is a scale of 1 inch to the foot, while one leg of the compasses is in the point 4, while the other reaches to the point 6 in the last division of inches, then the measurement of the distance in the compasses, and by consequence that of the part represented in the drawing, is shown to be 4 feet 6 inches. Again, suppose that to a general plan a scale of "10 feet to three quarters of an inch" is attached, and the actual length of a line taken in the compasses from the drawing be required to be known; if by applying the compasses to the scale, as in fig. 7, Plate XXXVIII*a.*, the one leg of which being at the division marked 50, and the other reaches to the point 5 on the division to the left; then the distance is known to be 55 feet.

To lay down measurements from a scale is the exact converse of the above, and is simply done. Thus, suppose that on the line *a e*, fig. 1, Plate XXXVIII*b.*, it is desired to lay down a line, as *a b*, representing the side of a box, as *a b c d*, and that the drawing is to be made to a "scale of $\frac{1}{4}$ of an inch to the foot." First, draw the line *a e* along the edge of the square, in a light pencil line; if the length of the side of the box, as *a b*, is to be 8 feet 9 inches, then on the scale, as in fig. 10, Plate XXXVIII*a.*, put the point of one leg of the compasses in the division to the right, marked 8, and draw out the compasses till the point of the other leg reaches exactly to the point indicating the ninth division on the division of inches to the extreme left of the scale; then take this distance, and with one point of the compasses, on the line *a e*, at *a*, measure from *a* to *b*, this will give a line in length equal to 8 feet 9 inches, as desired. The depth of the box, as *a c*, which we shall suppose to be 1 foot 2 inches, is measured from the scale in fig. 10, Plate XXXVIII*a.*, in the same way, and the mode of drawing it is as follows:—Suppose that the edge of the square is coincident with the line *a b*, previously drawn, move the square so that the edge be a little below the line, as *f g* in fig. 1, Plate XXXVIII*b.*; then take the "set square," as represented by the dotted lines at *h*, and, putting the base on the edge of the square, as *g f*, slide the set square till the perpendicular of the base be coincident with the point *b*, on the line *a e*, and draw a line along the edge *b d;* then slide the "set square" along the edge of the "T-square," till its perpendicular be coincident with the point *a*, in the line *a e;* next, from the scale in fig. 10, Plate XXXVIII*a.*, take the distance in the compasses of 1 foot 2 inches, by measuring from the first large division marked 1 to the second small division in the part *o*, 12; and, with this distance in the compasses, set one leg in the point *c*, and with the other mark a point in the line *a c*, at *c;* next, move the "T-square" up the board till its upper edge be coincident with the point *c*, and draw a line along the edge cutting the line *b d* in the point *d;* the outline of *a b c d* will then be drawn, and the lines *a b*, *c d* will be parallel to each other, as will also *a c*, *b d*. Dimensions, when marked on drawings, are usually put in, as shown in fig. 1, Plate XXXVIII*b*., between the marks, as <------>, with a dotted line; the acute angles of the marks being the limits of the line of which the dimensions are figured.* In some drawings, owing to the complications of the parts, or to preserve the drawing itself from being marked with figures, the dimensions are indicated in the manner shown in fig. 1, Plate XXXVIII*b*.; the lines, as *c a*, *d b*, being extended in dotted lines to a short distance beyond the drawing, and the dotted line put between the marks <------> as shown. The other measurement in this diagram is indicated in like manner at *k e*. In finished drawings these dimension marks <------> should be put in neatly and carefully. This will best be done by the aid of the "set square," as shown in fig. 2, Plate XXXVIII*b*. Thus, let *a b* be the dotted line terminated by the dimension marks at *a* and *b;* let *c d* represent the upper edge line of the "T-square," and the dotted triangle, *d e f*, the "set square," the base, *e d*, of which is placed on the edge, *c d*, of the "T-square;" adjust the "set square" so that its hypothenuse, *e f*, is coincident with the point *b;* then along the edge draw a short line, marked in the diagram by a strong black line; the corresponding angular line is drawn in at *a*, by sliding the "set square" along the edge of the "T-square," till the point in the hypothenuse is coincident with the point *a*. The reverse angular line is put in by reversing the position of the "set square," as shown by the dotted lines, *g c h;* the angular lines should all both be of the same length. In place of putting to drawings the scale in the manner as indicated in fig. 10, Plate XXXVIII*a*., it is the practice of some architects and builders to write merely on the drawing the scale to which it is made, as "scale, 1 inch to the foot," "scale, $\frac{1}{2}$ inch to the foot," and so on. Some make the matter more simple still, by merely writing "$\frac{1}{8}$th scale,"

* The figures, as "$\frac{1}{4}$," put to the foot of the diagrams to follow in this volume, are meant to denote the scale to which the drawings are made. Thus, in fig. 1, "$\frac{1}{4}$" means that the scale of the drawing is "$\frac{1}{4}$, or one-fourth of an inch te the foot."

or "one-eighth scale;" or "$\frac{1}{12}$th scale," or "one-twelfth scale." This does not mean that the $\frac{1}{8}$th scale, for example, is "$\frac{1}{8}$th of an inch to the foot," but that it is $\frac{1}{8}$th of a foot, or "equal to a scale of $1\frac{1}{2}$ to the foot." A $\frac{1}{12}$th scale is thus equal to 1 inch, as there are 12 inches to the foot, and is equal, therefore, to a scale of "1 inch to the foot;" a $\frac{1}{24}$th scale is equal to "half an inch to the foot;" a $\frac{1}{6}$th scale equal to "2 inches to the foot." But in all cases it is by far the most satisfactory method to draw a properly divided scale to each drawing. The easier methods above named go on the assumption that in the office, scales (on ivory or box-wood) of various sizes are at hand, from which the specific dimensions of certain parts can be taken; but drawings are often referred to in the actual carrying out of the work, in circumstances where these scales are not available, so that it is better to put a properly divided scale to each drawing as recommended. At all events, this should be done in the drawings of pupils beginning practice. Scales of tenths, as in figs. 7 and 13, Plate XXXVIII*a.*, are, as already stated, used for laying down drawings of general plans, as block plans, where the measurements are long. As a useful lesson in drawing, and as further exemplifying the use of scales, we shall suppose fig. 3, Plate XXXVIII*b.*, to represent the plan of the ground upon which a house is to be erected. The scale to which this is drawn being that in fig. 7, Plate XXXVIII*a.*, which gives 10 feet to $\frac{3}{4}$ of an inch, the first thing to be done is to draw a line representing *a b* in fig. 3, Plate XXXVIII*b.*, along the upper edge of the "T-square," the blade of which is parallel to the lower edge of the drawing board—the butt or head of the "T-square" being thus placed on the edge of the right-hand end of the drawing board. The length of the line *a b* is marked in the drawing as shown to be equal to 35 feet. This is taken from the scale in fig. 7, Plate XXXVIII*a.*, by putting one point of the compasses in the division marked "30," and extending the other to the point "5," in the division to the extreme left of the scale. Then, from any point on the line *a b*, fig. 3, Plate XXXVIII*b.*, as *a*—this point being selected so as to put the drawing when finished as nearly in the centre of the paper as possible—mark off the distance taken from the scale to the point, as *b*, fig. 3, Plate XXXVIII*b.*; the length of the line *a b* will then be equal to 35 feet, measured from the scale, fig. 7, Plate XXXVIII*a*. The next point is to obtain the position of the point *c* in the drawing, fig. 3, Plate XXXVIII*b*. On the drawing which is being thus copied extend by a very fine and light pencil line—so that it can be easily erased—the line *d c* to some distance beyond the point *c*, as, say, to the point *e*. Next, at right angles to the base line *a b*, draw another line, lightly put in by a pencil line, so as to cut the line *d c* extended in *e*. On the paper on the drawing board draw now a line from *a* (or, rather, from the points on the drawing board corresponding to the point *a* in the copy, which is supposed to be fig. 3, Plate XXXVIII*b*.), perpendicular to *a b;* this can be done by shifting the "T-square" so that the blade will be run parallel to the end of the board, the head or butt running along the lower edge of the drawing board; or, if the line is not too long, the "set square" can be used, as described in connection with fig. 1. Take *from the copy* the distance *a e*, and measure it on the scale, fig. 7, Plate XXXVIII*a*., and set off, from *a* on the drawing board, this distance, cutting the line *a e* in the part *e*. Through *e* draw along the edge of the square—which is again shifted, so that its blade shall be in its original position, that is, parallel to the lower edge of the drawing board—a line *e f;* this line will correspond to the same line in the copy, fig. 3, Plate XXXVIII*b*., and will be the same distance from the line *a b*. Take in the compasses the distance *e c* from the copy, and measure it from the scale, fig. 7, Plate XXXVIII*a*., and from the corresponding point *e* on the drawing board, set off this distance from *a e* to *c;* the position of the point *c* will thus be obtained, and, if the operations have been correctly performed, the length of the line *a c*, when measured from the scale, fig. 7, Plate XXXVIII*a*., will be found to be as marked—33 feet 6 inches. In practice, where the copy is to be the same size as the original, the length of the lines *a e* and *e c* need not be measured from the scale, but simply transferred from the copy to the drawing board, as above described. The next operation is to measure from the scale the distance *c d* 22 feet, and transfer it to the drawing board, or, rather, the paper on its surface. On examination of the copy the line *d g* will be found to be exactly at right angles to the line *c d*. The "set square" should then be brought into use, and by it the line *d g* should be drawn of same length, and on it the distance taken from the scale—namely, 13 feet, set off from *d* to *g*. The line *g h* will be found, on examining the copy, to be parallel to *a b;* draw, then, on the paper the line *g h* at right angles to *d g*, or parallel to *a b*, and make it equal to 7 feet; join *h b*, and the plan is complete. The line *b h* is not at right angles to the line *a b;* and the accuracy of the drawing will be tested by measuring this; and if the drawing be correct, it will be found to be 20 feet. But in place of the copy being accurately drawn—as it is supposed to be, in fig. 3, Plate XXXVIII*b*.—the case may be supposed that the copy might be a rough outline sketch, something like the form of fig. 3, with the dimensions or measurement marked on it; in this case, if the pupil was desired to make an accurate drawing to scale of this rough sketch, no such facilities for ascertaining the position of the point *c* in relation to the point *b a* would be afforded such as we have described. The pupil would therefore have a very different process to go through before he could make his drawing. We have also stated that by examination of the copy he could ascertain whether the line *d g* was or was not at right angles to *c d*. This could only be done if the copy was accurately drawn, and very simply by placing the copy on the drawing board, and marking the base line parallel to the edge of it, by means of the "T-square," and then shifting the square to test the line *d g*. Examination like this can, after a little practice, be very quickly made. But, if a rough sketch was provided, the line *d g* might be put in obliquely, as also the line *g h*. The pupil will find in the volume noted on page 14 full instructions how to draw from rough sketches, or from the ideas of his own mind, which, in the case of original work, take the place of rough sketches. For the method of constructing and of using "diagonal scales," see the volume noted on page 14.

6. Scales for Detail or Enlarged Drawings.—These are constructed on the principle already explained for scales for general plans, but are designed to give facilities for measuring fractions of the inch, just as the division to the extreme left of scales, such as in fig. 6, Plate XXXVIII*a*., give fractions of the foot. And as there are eight equal parts in an inch, which are technically called "eighths of an inch," the last division of the scale to the left is divided into eight equal parts, each of which is equal to $\frac{1}{8}$th of an inch as read off from the scale. A scale constructed on this principle is shown in fig. 14, Plate XXXVIII*a.*, which is a scale of 3 inches to the foot. The measurements are taken from this in the same way as already described, so far as feet and inches are concerned; but if, in the measurement, parts of an inch be given, the compasses are extended to the point indicating the measurement in the last division of the scale to the extreme left. Fig. 15 is a scale of $\frac{5}{8}$ths of a foot, or $\frac{5}{8}$ths of full size. Detail drawings in practice, as a rule, are drawn to scales, some regular proportion of a foot, as $\frac{1}{4}$th of a foot, or "3 inches to the foot," $\frac{1}{6}$th or "2 inches to the foot," and sometimes half size, which is equal to "6 inches to the foot." The scales being named in the order above given, as "one-fourth full size," "one-sixth full size," "one-half size." When details are made, say half size, no regular scale is required to be constructed; as all the measurements can be taken from the ordinary foot rule, for all that is necessary is to take half of the full size measurements which the object would present: thus, if a distance was 6 inches, 3 inches would be taken; if 4 inches, 2 inches, and so on. Again, if the detail would be drawn to "one-fourth full size," one-fourth of the full size measurements would be taken: thus if the measurement was 8 inches, 2 inches would be laid down on the drawing; if 6 inches, $1\frac{1}{2}$ inches would be taken from the ordinary foot rule, and so on. In these, the eighths of an inch, if any, in the measurement, would be approximately taken or allowed for: thus, $\frac{3}{4}$ths of an inch, or "six-eighths" in a detail drawing "half full size" would be represented by a measurement of three-eighths; an eighth by half this or "$\frac{1}{16}$th" of an inch, and so on.

7. Plans, Elevations, and Sections.—The various structures, and parts of structures, met with in building construction, are solids, having length, breadth, and thickness, and sides more or less numerous, according to their form. The paper on which the drawings connected with building construction are made, having only surface, that is, length and breadth, some method of representing upon a flat surface the form of solids, so as to show each side and the peculiarities in construction dependent on, or connected with, that side is obviously required. The delineation upon paper of an object which is a solid is, technically speaking, a "projection;" and the peculiar method of projection employed in building construction is called "orthographic projection." For the principles of this, and other kinds of projection, as "isometrical," the pupil is referred to the volume in this series on *Plane and Solid Geometry.* The projection of any body taken on a line parallel to its base, or as viewed when looking down upon it in the direction of a line at right angles to its surface, is called a "plan," as fig. 4, Plate II., which may be supposed to represent the plan of a house, or of a box with the lid or top taken off. Plans of houses, in reality, "horizontal sections," taken on a line, at a distance a little above the ground level, which line is parallel to the base. A "section" is the view of an object, representing it as it is supposed to appear, when it is cut either horizontally or vertically by a line parallel to any given line in the plan. Thus, fig. 4, Plate XXXVIII*b*., may be taken as a "horizontal section," on the line *a b*, in fig. 5, Plate XXXVIII*b*., showing the thickness of the walls of the house, or the thickness of the sides of the box, as the case may be. The section in fig. 6, Plate XXXVIII*b*., is called a "longitudinal section," or a "longitudinal vertical section," on the line *a b* in the plan, fig. 4, Plate XXXVIII*b*., this line being parallel to the front and back lines. If the section was taken on the line *c d*, fig. 4, Plate XXXVIII*b*., the section would be called a "transverse or cross section," or a "transverse vertical section." "Elevations" are views of the vertical or standing part of objects, and are called "front elevations," "back elevations," "end elevations," or "side elevations," according to the side from which the object is viewed; the point of view being taken from a point at right angles to the surface of the front, back, end, or side of the object. Thus, fig. 5, Plate XXXVIII*b*., is a front elevation, and gives the height of the openings *e*, *f*, and *g*, in plan, fig. 4, Plate XXXVIII*b*., the breadth of which only is there given; fig. 7, Plate XXXVIII*b*., is the "end elevation," A, fig. 4; fig. 8, Plate XXXVIII*b*., the "end elevation," B, fig. 4, Plate XXXVIII*b*. If the object were a house, these two end elevations would be distinguished by the points of the compass to which they looked, as "west-end elevation," "east-end elevation." The "back elevations" of fig. 4, Plate XXXVIII*a*., will be the same as fig. 5, omitting the openings *e* and *f*, with the opening *g*, the same as in fig. 5, Plate XXXVIII*b*. Where there are peculiarities in the back part different from the front part of any object, a back elevation would be necessary. The pupil desirous further to pursue the subject of drawings is referred to the volume noted in p. 14. But we give a few examples of a simple kind to show methods of copying and laying down drawings. In fig. 9, Plate XXXVIII*b*., we give a drawing showing a "front elevation" of a building, of which, in fig. 10, we give part "ground plan." The two drawings are placed in relation to each other to show the method of taking the lines of an elevation from the distance given in the ground plan, and *vice versâ*. A glance at the two figures 9 and 10, in Plate XXXVIII*b*., will show this; the dotted lines being carried up from the plan to give the lines of front elevation, or carried down from the elevation to give the lines of the plan. The letters of the two diagrams, figs. 9 and 10, show corresponding parts; and the pupil, by a study of these should be able to understand, to see the principle of the method adopted, and be able to apply it to other subjects of a like nature. In Plate XXXVIII*c*., fig. 1, we give a diagram showing the method of "laying down" or "setting out," the principal lines of the elevation of building in fig. 9, Plate XXXVIII*b*. The line *a b*, fig. 1, Plate XXXVIII*c*., is first drawn as the "ground line" or "base line." Near the centre of this line, as at the point *c*, a line *c d* is drawn at right angles to *a b*. This is the main "centre line" of the building, and corresponds to the line *k l*, in fig. 9, Plate XXXVIII*b*. From *c* the distances *ce*, *eg* (equal to the distance of centre lines *mn*, *op*, fig. 9, Plate XXXVIII*b*.) are set off; and lines *ef*, *gh*, are drawn parallel to *cd*; these give the centres of the side wings, *ab*, *cd*, fig. 9, Plate XXXVIII*b*. The heights of the points *r*, *s*, *t* (taken from the copy of the drawing in fig. 1, Plate XXXVIII*c*., being to a larger scale than that in fig. 9, Plate XXXVIII*b*.), are then to be set off from the base line *a b*, fig. 1, Plate XXXVIII*c*., to the points *f*, *h*, *d*, and *b*, and lightly pencilled lines drawn through these, parallel to the base line *a b*. The distance of the terminating lines of these lines on each side of the centre line, *po*, *kl*, *mn*, fig. 9, Plate XXXVIII*b*., should then be taken and set off from points *f h* and *d*, on both sides of the centre lines *e f*, *c d* and *g h*, this will give the width of the respective parts. The heights of the top and bottom lines of windows, as *i* and *e*, fig. 9, Plate XXXVIII*c*., should then be taken and set off in the lines, *e f*, *g h*, fig. 1, Plate XXXVIII*c*., to the points *m n*, *o p*, and through these points lines drawn parallel to *a b*, the full lines show the parts when inked in, the dotted lines represent the lightly pencilled in lines at the first operation. Fig. 2, Plate XXXVIII*a*., is an enlarged sketch of the window *e*, in fig. 9, Plate XXXVIII*b*., showing the method of drawing it. First, draw a "centre line," *a b*, and a "base line," *c d*, at right angles to this; then set off the various heights, as *b*, *e*, and *f*, those taken from the copy, or the scale according to dimensions given. Then take half the width of opening and set this distance off, on each side of the centre line, *a b*, to the points *g* and *h*; then draw parallel to *a b* lines *g k*, *h i*, making the line drawn through *f* parallel to *c d*. Measure next to the end *s c d*, and draw *l c*, *m n* parallel to *a b*. Fig. 3 shows the lines required to draw the door in fig. 6, Plate XXXVIII*b*., fig. 4 being an enlarged sketch, showing the method of putting in the panels; in this, *a b* is the "centre line" of the door, corresponding to *a b* in fig. 3, and the line *c d*, fig. 4, Plate XXXVIII*c*., gives the top line of panels, the widths of the panels being set off from the point *a*, to *e* and *f*. Fig. 5 shows the method of drawing a pediment terminating a roof. The line *a b* gives the upper line of last number of the cornice, and *c e* the centre line of roof; from *b*, set off the height *b c*, measure from *a* to *d*, and join *c d*. Fig. 6, Plate XXXVIII*b*., is a front elevation of a house, the leading lines of which are given in fig. 7, showing the method of commencing the drawing; fig. 8, Plate XXXVIII*b*., is pediment of door; fig. 9, drawing, enlarged, of chimney stalk, and fig. 10 shows the method of drawing in the "quoins;" the distance, *a b*, being divided into nine equal parts, and lines drawn through them parallel to *c d;* the line *a b* is the outside boundary line, and the projections of the quoin stones inward from this are given by measuring from the point *e* to *f* and *g*; and drawing from these, lightly pencilled in lines, the intersection of which, with the lines drawn through the points 1, 2, 3, etc., parallel to *c d*, give the widths or breadths of the quoins.

8. As forming a practical exemplification of the connection of plans, elevations, and sections, with one another, we give, in Plates XXXVIII*d*., XXXVIII*e*., and XXXVIII*f*., a set of "plans" of a cottage villa. The student should carefully note the connection of one drawing with another, so as to be able to lay down in elevation from a plan, etc., taking the measurements in order. The plans, elevations, and sections, form what is called a "set" of drawings, but in addition to these a number of other drawings are also prepared; these, as already stated in a previous paragraph, are known as "details" or "detailed drawings," which, in number and elaboration of finish, vary according as the architect may consider necessary, or as the builder or contractor may require.

9. These detail drawings, when commencing anything of an elaborate character, in which the lines and parts are numerous and complicated, are of course drawn in the manner and by the aid of all the appliances already described. But in a great many instances, the architect is often, while "upon the ground," called upon to furnish the workmen quickly with "free-hand sketches" of various parts, which, while yielding no pretensions to accuracy of measurement of these parts, or even of drawing, serve nevertheless to afford to the workmen the necessary information as to the form of the part required, and as no "scale" can, of course, be given, the dimensions are simply marked upon the sketches, as in figs. 1, 2, and 3, Plate XXXVIII*g*. Free-hand sketches of various parts, for the guidance of workmen, do not require to be finely executed, they must of course indicate accurately the form or outline and the connection of the various parts. There are some draughtsmen, however, who have a wonderful facility in executing sketches which, although called "rough," possess all the accuracy and finish of work done carefully in the study. Not many, however, possess this ready faculty; and although its possession is greatly to be desired, a less perfect capacity will be found useful enough for every-day work. While a facility to execute rough free-hand sketches of various parts is useful to the practical man in preparing drawings of

parts which require the instant attention of the workman, the converse is of course of equal utility to the practical man, in enabling him to take sketches on the spot, from which afterwards, in the quietness of his study, he can prepare finished drawings; care being taken to mark all the dimensions in their proper places. Enough—in connection with which the student will find in other works of this series—has been said on the subject of drawing to enable the student to gather up its chief principles; and to induce him to devote that time to their fuller study, or the special works devoted to their elucidation, which will impart to him the knowledge necessary in following out the pursuits to which he may have devoted his career. We now, therefore, proceed to the more immediate purposes of our work; taking up first that division of construction which treats of Carpentry, or the use of timber in large pieces for work more or less heavy, exterior or interior, as distinguished from the operation of Joinery, which deals with smaller pieces used generally for interior fittings, and which demand finer work and more accurate adjustment of parts. The first department of carpentry work we shall take up for consideration and illustration being that of floors, of which there are several forms or varieties. Recently what may be called "combined floors," in which certain other materials are used along with timber, have been introduced, chiefly with a view to secure the great desideratum of a fire-proof floor. The most important of these will be noticed in their place.

CHAPTER II.

FLOORS.

10. *Single Floors.*—This species of floor consists of a series of timbers termed "joists," or "flooring joists" *aa*, as fig. 194,

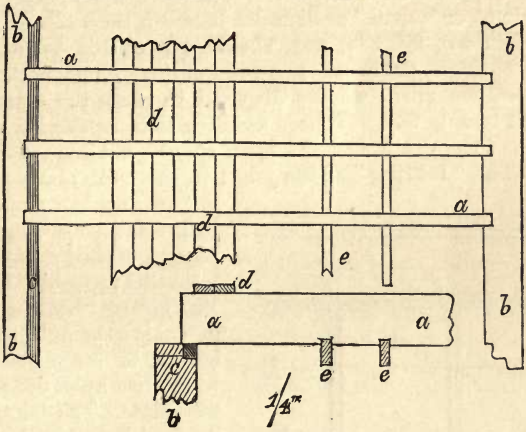


Fig. 194.

the ends of which rest on the walls *b b*, and run in a direction at right angles to these. In better class work the ends of the joists rest upon, and are framed into, or secured to, "wall plates," as *c c*, fig. 194, these being set into and rest upon the walls of brick or stone. In ground floors, in the best work, the joists rest upon wall plates supported by piers of brick or stone, these being carried up from the ground to the level of the under side of flooring joists. The object of these piers is to preserve the soundness of the timber, by leaving it exposed on all sides; timber being found to decay much more rapidly when built into walls and surrounded by brick, or stone and mortar, than when left freely exposed to the air. In the upper floors of buildings the joists are built into the walls, as in fig. 194. At right angles to the "flooring joists" *a a*, the "flooring boards" *d d* are placed, resting on the upper side of the joists. Such is a "single floor" as employed on the ground floor of a building; but in the upper floors, where a ceiling is to be carried by the floor timber, "ceiling joists," as *e e*, fig. 194, are secured to the lower edges of the joists, running in a direct line at right angles to these. To these "ceiling joists" the laths which support and carry the plaster are secured. The "bearing," or "span," or distance between the walls in which the joists *a a*, fig. 194, rest, should not exceed twenty-four feet for single floors on the ground level, but as this is, however, too great, we are disposed to place the maximum span at twenty feet. Where a ceiling is to be carried by the floor, as in upper floors, the span should not exceed fifteen feet. The "bearing" of the joists on the wall plates should not be any less than four inches, but, according to the bearing of the joists, may go from this up to nine inches. By the term "bearing," here given, is meant the part, or length, of one of the joists which rest upon the wall or wall plate. The distance or interval between the joists is usually fourteen inches. Where any opening is required in a floor, as *a a*, fig. 195, the flooring joists *b b* are jointed into and rest upon what is called a "trimmer" *c c*, this being jointed into, and being borne by, the "trimming joists" *d d*, which are stronger than the ordinary joists by one-eighth of an inch for each joist as carried. Where the bearing of the joists is

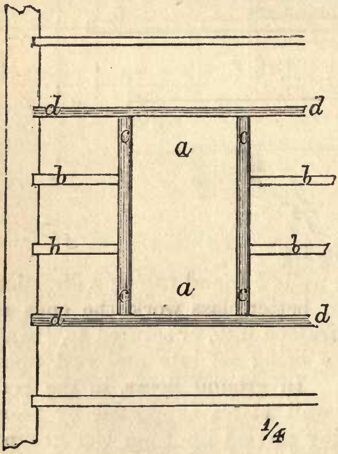


Fig. 195.

considerable, and the depth therefore increased, they should be strengthened, and lateral movement prevented by what is called "strutting." The simplest form of strut is a flat and thin piece of board, as *a a*, fig. 196, placed between the joists, the strut bearing at its ends in the faces of the two contiguous joists *b b*. A more complicated and complete form of strutting is known as "herring-bone strutting," and is also illustrated in fig. 196, and is formed by two pieces, *c d*, crossing each other, butting at each end on the faces, or inner sides, of the joists *e e*, and secured thereto by nails. In superior work the struts are slightly notched at the bearings into the joists, as at *f*. As simple longitudinal struts, as *i i*, in fig. 196, are sometimes apt to give way laterally, the best plan is to make the edges butt up on one side to triangular fillets nailed to the joists, as shown in fig. 196, at *g g*. For joists with a "bearing" of from eight to ten feet, one row of strutting will be sufficient, allowing another row for each four feet of increase in length of bearing of the joists.

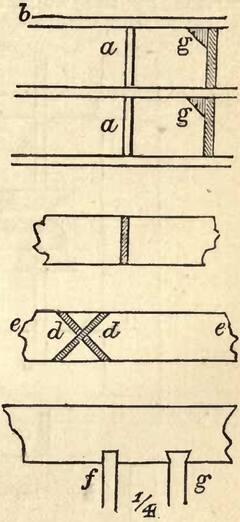


Fig. 196.

11. *Framed and Double Floors.*—In this kind of floor there is an additional member called a "binder," or "binding joist," as *b b* in fig. 197, *a a* being the "flooring joists," *c* the "ceiling joists," and *d d* the "flooring boards." The thickness of the binding joist varies with the bearing; as a rule, they are made half as thick again as the flooring joists of the corresponding floor; the bearing on the wall will be ample if at six inches. The distance between the binders, measured from centre to centre, is generally from five to six feet.

12. "*Double Framed Floors.*"—Floors have an additional member, this being called a "girder," or sometimes simply a

"bearer." Floors of this kind are used with large bearings, or where heavy weights have to be supported; *a a*, fig. 198, the "girder," *e e* the "binding joists," *f f* the "flooring joists," *h h* the "ceiling joists." The ends of the "girder" are carried by the walls, and are, or should be, placed in the

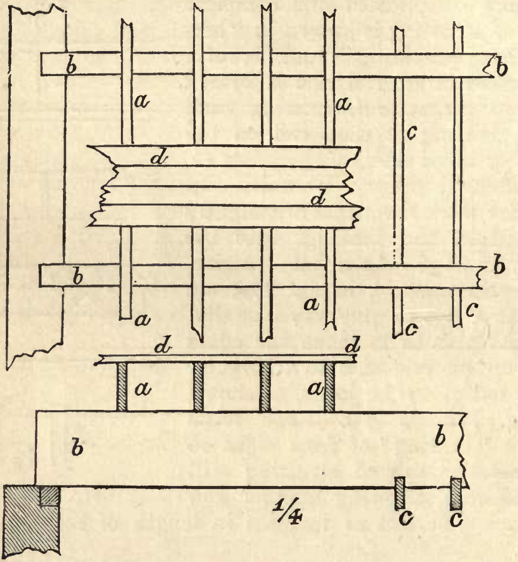


Fig. 197.

parts where there is no opening, as that of a window or door, below; that is, on the part of the wall which is solid from bearing of girder to the ground or footing. And in order to allow of the pressure on the wall being distributed as much as possible, the girder *a a a*, fig. 199, rests upon a "plate," or "template" *b b*, which will be better if of stone than of wood. This plate should have a considerable projection on each side of the bearer; a stone cap *c c*, and backpiece *d*, are usually added, thus enclosing the end of the girder *a a* in an open box, so to call it, thus freely exposing the timber to the air. Girders are sometimes placed in cast-

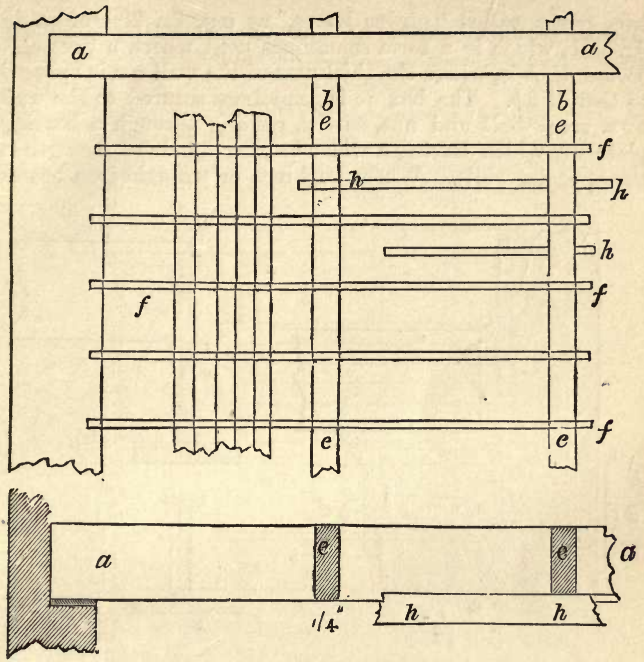


Fig. 198.

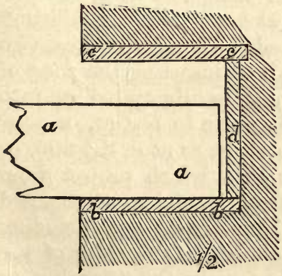


Fig. 199.

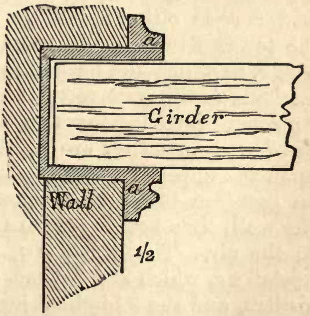


Fig. 200

iron boxes, called "girder boxes," as *a a*, fig. 200, or as in fig. 201, which is a form sometimes used where a "set off" occurs, that is, where the thickness of the wall *a a* is reduced to that at *b b*. The box *c c* is sometimes secured to the wall by a screw-bolt and nut, as *d d*, passing through a bearing plate *e e*, which having a wider bearing, tends to strengthen the opposite walls. Where cast-iron or wrought-iron beams

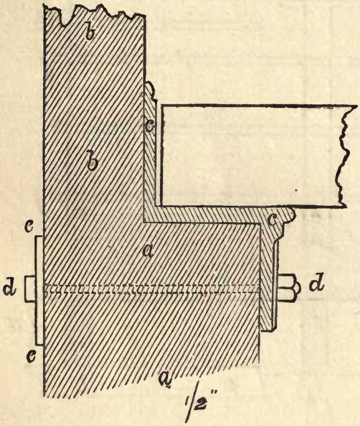


Fig. 201.

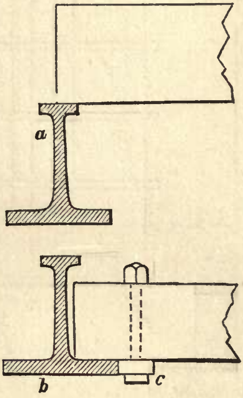


Fig. 202.

are used as girders, as in fig. 202, the wood-binding joist bearer rests either upon the upper flange, as at *a*, or upon the lower flange of the beam, as at *b*, or upon a projecting part *c*, to which the beam *d* is bolted. The first of these two methods is the strongest. In place of inserting the ends of "girders" into apertures in the walls, as illustrated, or into cast-iron boxes, they are sometimes made to rest at, or bear upon the upper surfaces of stone corbels, as at *a*, fig. 203, or on cast-iron boxes or brackets as at *b*, which project from the wall, thus keeping them free from it, and quite exposed to the air. The girder *a a*, fig. 198, carries the "binding joists" *e e*, which are framed, or jointed, to the sides of the girders, and the "binding joists" *e e*, carry the "flooring, or bridging joists" *ff*, upon which the "flooring boards" *gg*, are placed. The "ceiling joists" *h h*, are carried by the binders, and to these are secured the laths and plaster ceiling. The

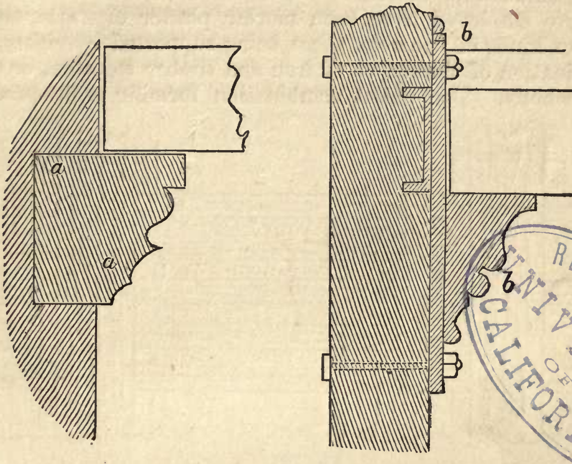


Fig. 203.

distance apart of the "girders," *a a*, fig. 198, is usually ten feet from centre to centre, the bearing on the wall nine to twelve inches. Floors are, in the better class of floors, provided with what is called "deadening" or "deafening." This is made as follows:—To the sides of the flooring joists *f f*, fig. 204, small "fillets," or "firring pieces," *k k*, are inserted, which carry the "sounding boards" *l l*, on which is laid the "pugging," made of coarse plaster or mortar.

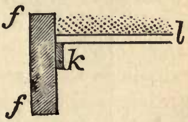


Fig. 204.

13. *Varieties of Floors.*—The most striking, and indeed the only variety of floor which comes under our notice here, is what is known as the "fire-proof floor," of which there are several kinds now to be briefly noticed. The principle of a fire-proof floor may be briefly stated. Wood, of which ordinary floors are constructed, being highly inflammable, it must either be combined with other material not easily, or

altogether, incapable of being consumed by fire; or the timber may be altogether dispensed with, and the floor made wholly of incombustible material. The incombustible materials hitherto employed have been mortar, plaster of Paris, and various kinds of concrete, these being supported by either a combination of timber, or of iron and timber together, or of iron wholly. The oldest combination forming a fire-proof

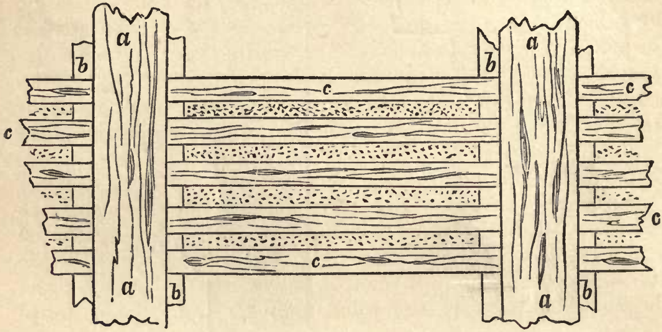


Fig. 205.

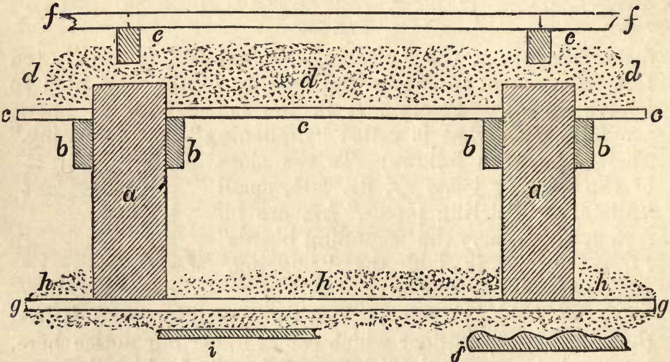


Fig. 205*a*.

floor, and which is yet in some places still used, is that illustrated in figs. 205 and 205*a*, which is taken from our article in "The Field," alluded to in the vol. on *Brickwork and Masonry*, when treating of Concrete Construction generally. In this, *a a* are the joists, to the under and upper edge of which fillets or battens of wood are nailed, the upper edges being placed at a distance of two or three inches from the upper surface of joist. On these fillets are placed laths *c c*, on which is laid the mortar *d d*. In this, while soft, the battens *e e* are imbedded, these carrying the flooring-board *f f*, or if concrete be used, then the battening and boards may be dispensed with, and the floor surface formed with concrete alone. The ceiling may be formed in the ordinary way, but to make it fire-proof, fillets, as *g g*, may be nailed across the lower sides of the joists *a a*, and mortar or concrete *h h* forced between the interstices which may be left an inch wide. The surface below the fillets, as *g g*, being either left plain as at *i*, or corrugated as at *j*, this last being done by means of a boarded platform placed beneath the fillets *g g*, while the concrete or mortar is being forced between the fillets *g g*. The drawing, fig. 205*a*, shows a cross section at upper, and, fig. 205, plan at lower, parts. A fire-proof floor and ceiling may be formed, as in fig. 206, by a series of

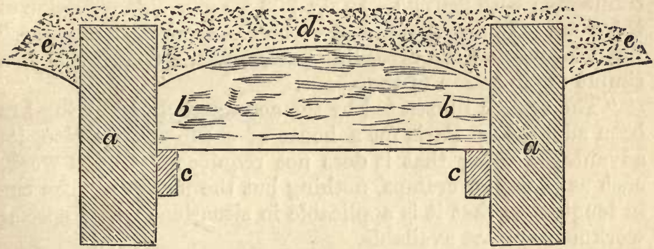


Fig. 206.

small arches, these being formed by the timber moulds *b b* placed between the joists *a a*, and resting upon fillets *c c*, nailed to the inside of the joists, which may be removed when the concrete filling up, as at *e e*, is set. The ceiling being finished in the usual way, or as illustrated and described in connection with last figure given. Fig. 207 illustrates, on side elevation, a floor formed by a combination of iron with timber and concrete, which is much used abroad. Wrought-iron rolled beams *a a* are placed so as to rest at their ends upon the walls, being placed about thirty to thirty-two inches apart, these beams carry saddles *b b* of wrought or cast iron, which again carry wrought-iron laths *c c*, and on the upper surface of which rests square iron bars *d d*, and above the whole the concrete *e e*. The floor is formed by wood-battens *f f* resting upon, and notched into, the upper flange of the beam *a a*, the flooring joists *g g* resting upon the battens.

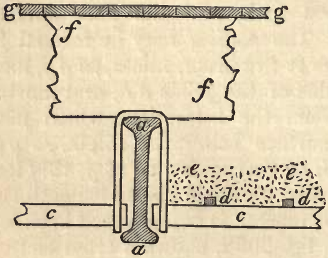


Fig. 207.

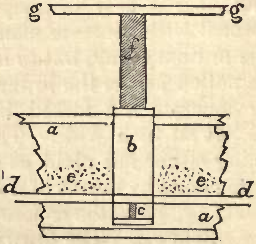


Fig. 208.

The floor may be made fire-proof if concrete, as described in connection with fig. 205. In fig. 208 we give side elevation of this floor. In figs. 209 to 213 we borrow from the "Engineer" illustrations and the preceding paragraphs, a description of a simple modification of the above.

"The system illustrated by the accompanying drawing has been adopted in Paris for a house of cheap construction, its advantages being that it does not require any forged work, such as braces or cramps, nothing but the joists and iron cut in lengths, so that it is applicable in situations where special workmen are not available.

"In the case illustrated the joists of double T iron are 32 inches apart, from area to area, every other one being anchored in the walls; the iron laths, or lattice work, being composed of $\frac{2}{5}$ inch square iron, and resting on the lower shore of the joists. The laths are nearly 32 inches in length, and rather less than 7 inches distant from each other, and are slightly curved, as shown in fig. 210, thus leaving a space beneath of about half an inch in the centre for the parget work.

"The end laths are nearly 44 inches long, curved like the others, the end being bent down to the extent of 2 inches to form a cramp, as shown in fig. 211.

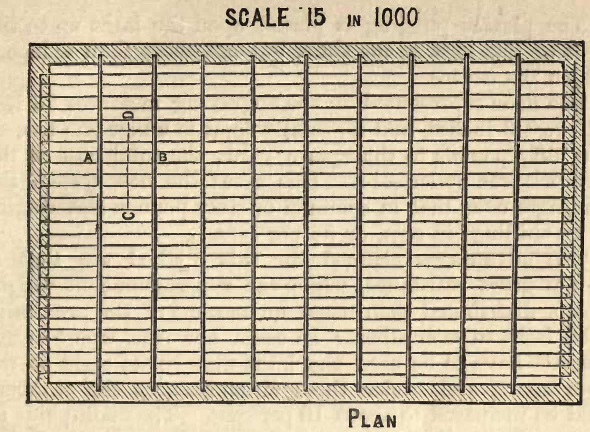


Fig. 209.

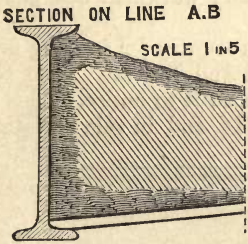


Fig. 210.

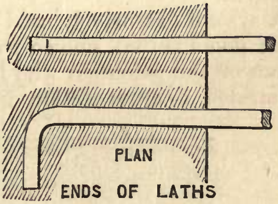


Fig. 211.

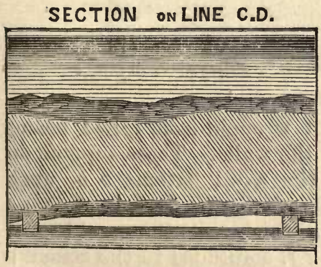


Fig. 212.

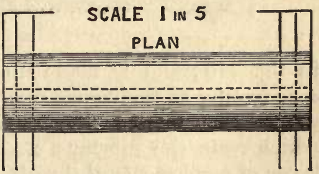


Fig. 213.

"The plaster pugging is placed upon the laths up to the height of the joist at the sides, but not more than 4 inches thick in the centre.

"The floor represented in the engraving measures 26 feet by 16 feet 3 inches, and its total weight is under one ton, or about fifty pounds to the square yard; the total cost of the iron work was under £14. This gives the new system the advantages over that in common of sixty pounds less weight, and 16 shillings in cost, or 5¾ per cent.

"The advantages claimed for this method are that it presents great resistance, while the superincumbent weight is better distributed than usual on account of the proximity of the laths to each other. In cases, however, where larger materials have to be used the laths may be set eight or ten inches apart, and under these circumstances the economy would be increased to about 10 per cent. The main point is, however, that all the iron work may be ordered of the required lengths, so that any ordinary workman can put it together."

A system extensively used in this country for forming fire-proof floors is that known as "Fox and Barret's" from the names of the patentees who introduced it to notice. This is illustrated in cross section in fig. 214, and in side elevation

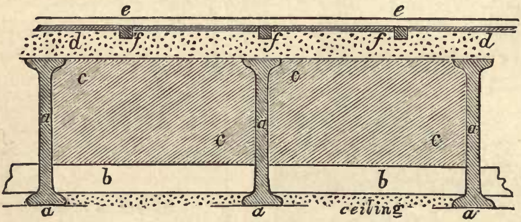


Fig. 214.

in fig. 215; and is made up of wrought-iron rolled beams *a a*, resting at their ends upon the walls. These support on their lower flanges or shores the wood battens *b b*, upon which rests the mortar *c c*. On the upper surface of this a layer of concrete, as *d d* rests, in which rests the wood boards *e e*, these being nailed in fillets *f f*, embedded in the concrete *d d*. In fig. 216 we give the cross section of the form of fire-proof floor introduced by the Messrs. Burnett of Deptford, in which the concrete floor surface—a floor formed as in the illustration already given—is supported upon hollow brick,

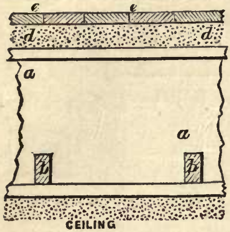


Fig. 215.

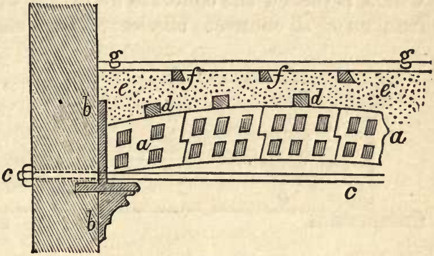


Fig. 216.

or upon bricks made light by being punched with apertures as shown, these are placed together so as to form an arch with a gentle rise; the outside ones resting upon or butting against cast-iron boxes *b b*, and the whole being further secured by the wrought-iron tie rod *c c*. The arches of hollow bricks *a a*, may carry wrought-iron bars *d d*, upon which rests the concrete *e e*, *f* being the battens.

In figs. 217 and 218 Cooper's system is illustrated, in which the concrete is carried upon plates of corrugated iron *a a*,

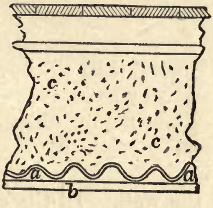


Fig. 217.

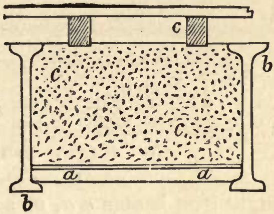


Fig 218.

these being supported by the wrought-iron beams *b b*, *c c* being the concrete, and the floor being finished in the way already illustrated. Although not coming under this division of our work with the strictest attention to arrangement, still, while treating of the subject of fire-proof floors, we consider it best to give an illustration of one in which no timber at all is used, but the whole structure made up of iron, brick, and concrete. This form, illustrated in fig. 219, is that which has been used for many years in factory work, and consists of cast-iron girders *a a*, supporting a brick arch *b b*, upon which is placed the concrete flooring *c c;* tie rods of wrought-iron as *d d* connect the cast-iron beams *a a* at intervals.

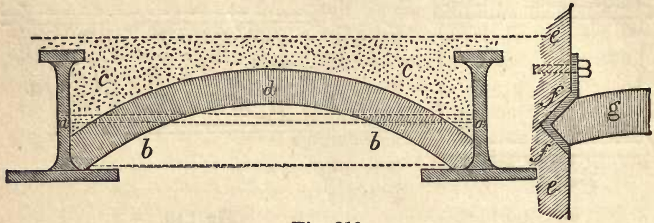


Fig. 219.

Where the arches join the walls *e e*, they butt up against the inside of cast-iron "skewbacks" *f f* bolted in the wall. For proportions of iron beams, see chapter on Strains on Beams. The next form of fire-proof floors we shall describe is that known as Dennett's, and although only but recently introduced has been largely used; the principle of arrangement is much the same as in other systems, but the kind of concrete is different, and it is used in the form of arches of gentle rise as illustrated in fig. 220, these arches butting against either

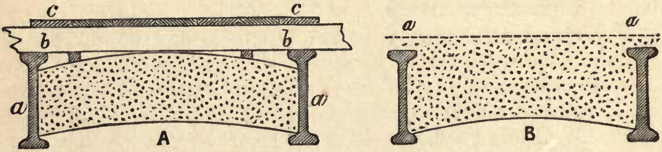


Fig. 220.

wrought-iron beams *a a*, or against the wall. In the case of buildings of comparatively narrow space the floor may either be finished as at A with timber bottoms and boarding *c*, or filled up to the level *a a* with the concrete, thus forming a solid mass. When the floors are formed as in B, the concrete is formed of pieces gradually decreasing in size, till at the floor surface they can be worked and finished off with a trowel. Floors thus formed are said to be peculiarly well adapted for bed-rooms, as they are "cleanly, non-absorbent, free from vibration, and are therefore comparatively noiseless." The ceilings may be finished off flat by using a series of light joists; the curved soffits or under sides of the arches may be left exposed and may be coloured or decorated as required. We have said that the concrete used by Mr. Dennett is different from the kind ordinarily employed, in which lime is used. These, when subjected to the action of heat and having water poured upon them, are exceedingly apt to crack and give way, swelling out also to twice their original bulk, and thus exercising a destructive influence upon the walls; so that floors formed of them are by no means so strong and secure as has been supposed.

Mr. Dennett uses gypsum calcined, the coarser qualities being used; and these are generally found to be mixed with clay, a fortunate mixture, as the clay is the very material which, when burnt, is afterwards used artificially in mixing up the concrete. The gypsum is employed along with masses of material possessing great porosity, such as broken brick, oolitic stones, furnace dross, and the like. The materials are placed upon temporary arches or platforms, the upper sides of which assume the curve of the required arch; and they are pressed down with considerable force, and the whole is allowed to set or harden, which process is completed in from two to six days, leaving the mass a cement very much harder than that of plaster of Paris, and capable of sustaining heavy weights and great pressure. The last form of fire-proof floors we shall illustrate is that known as Homan's system, in which the iron beams employed are of the kind shown at *a a* in fig. 221, and more generally known as "Phillip's double flanged girder." Floors constructed with these do not require any cross bars to support the concrete, and are much lighter and stronger than other forms.

14. **Flooring Boards** are of three kinds, "folding floors," "straight joint floors," and "dowelled floors." In the first of these systems, the boards are laid four or five close together; thus, suppose the board *a a*, in fig. 222,* to be the

*Where figures, as "1½" in fig. 222, are placed at the under part of a diagram, they denote the scale to which the drawing in the figure is drawn, thus fig. 4 is drawn to a scale of "1½ inches to the foot," or "1½."

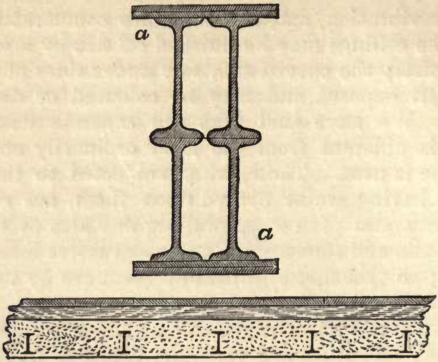


Fig. 221.

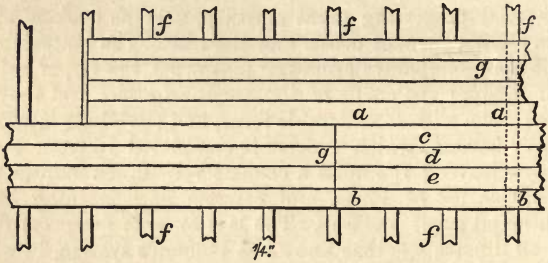


Fig. 222.

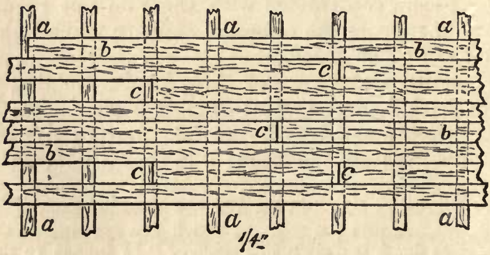


Fig. 223.

last laid down, the fourth board, *b b*, is then nailed to the rafters, so as to make the space between it and *a a* a little less than the space required by the three intervening boards, *c d* and *e*, these being forced into the space between *a a* and *b b*, and when flat, secured by nails to the joists *f f f f g g*, the "heading joints" *g g*, which should be arranged so as to meet in the centre, or, at least, above the edges or solid face of rafters. In "straight-joint floors," the boards are laid across the joists *a a a a*, fig. 223, with the vertical, or side joints, in one continuous line, one board being laid down and secured to the joists at a time, and the next forced up close in contact with it, so as to make the joint good, this being done with an instrument known as a flooring clamp. In "dowelled" floors, the boards are laid straight, joints edge to edge, but are kept together by dowels, or pieces of oak or beech set into the edges of the boards, as shown in fig. 224, in which the dowels are inserted, as shown at *a a a a*, two

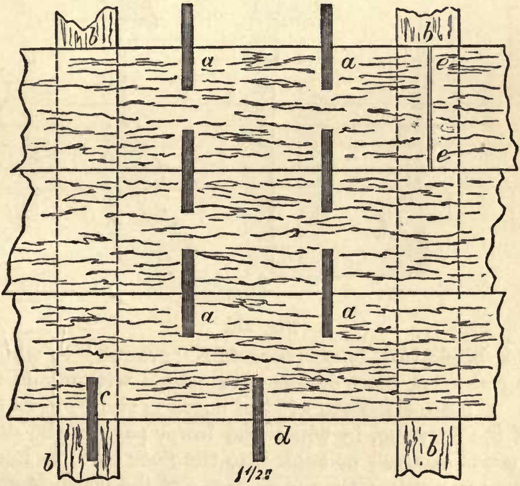


Fig. 224.

dowels being given to the space between the two joints, *b b*, *b b;* or the dowel may be placed so that it will be above the joists as at *c*, the other as *d* in the centre of the space between the two joists *b b*.

15. Skirting Boards.—In order to conceal the joints where the flooring boards butt up against, or approach to the wall, and otherwise to add to the finish of the room, boards more or less ornamented with mouldings, and of greater or less depth, are fixed round the walls of the room at their lower parts where they join the floor. If this finish is made up with a board comparatively narrow, and finished with a moulding of a simple character, the arrangement is known as a "skirting board." If the depth is considerable, and finished with a base and a projecting cornice, it is called a "dado," or "plinth." The simplest form of skirting board is shown at *d*, fig. 225, in which *a a* is the line of floor, *b* the wall,

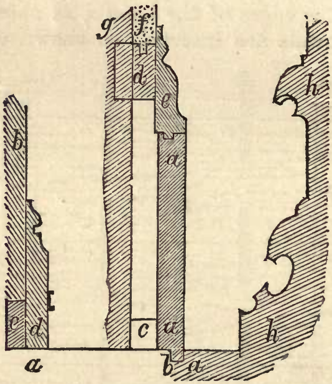


Fig. 225.

c a wood-brick, in this case termed a "ground" to which the skirting board *d*, more or less ornamented with mouldings, is fixed. A more elaborate kind of board is shown in the other part of the drawing, in which the lower part of the skirting board *a a* is grooved or sunk into the floor at *b*, to keep out the dust; *c*, a fillet; the upper part *e* of the board is grooved into *a a*, and fixed to the "ground" and fillet *d;* the thickness of *d* averaging one inch, regulating the thickness of the plaster *f*, which is grooved into *d*, *g* is the wall; *h h* shows a Gothic design for a skirting board; and fig. 226 a design in elevation and section of a "dado" or "plinth" (see above).

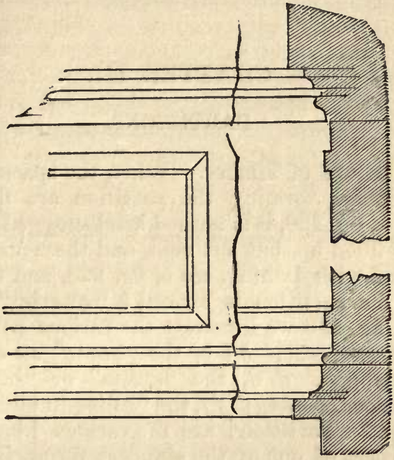
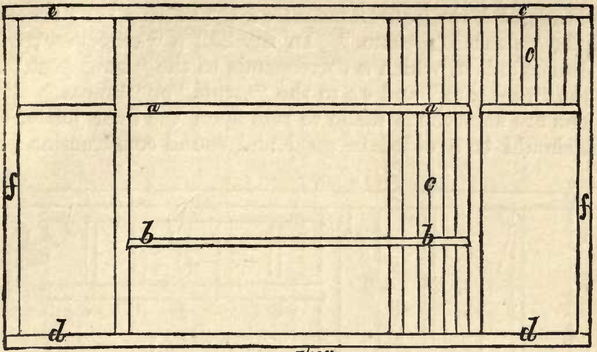


Fig. 226.

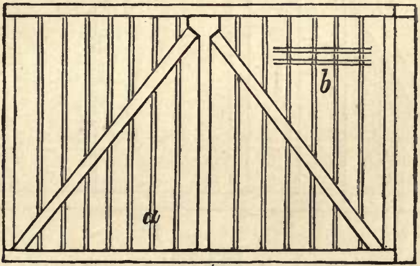
CHAPTER III.

PARTITIONS.

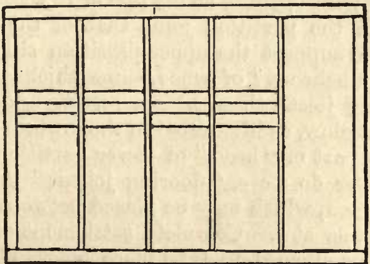
16. Partitions of Timber.—When the spaces between the various timbers forming the partition are filled up with bricks, see *a*, fig. 228, it is termed **brick-nogged**; if the spaces are not so filled up, but left void, and these and the timbers first covered with lathing, see *b*, fig. 228, and the laths then plastered, the partition is termed **a "quarter"** or **"quartering."** In fig. 230 we illustrate the various parts of a partition, *a a a*, the "sill;" *b b b*, the "head;" *c c c*, the "posts" or "quarterings;" *d d*, the "struts" or "braces;" *e*, the "head at a door opening;" *f f*, the "filling-in pieces" or "single quarterings." Partitions are of various kinds. Fig. 229 illustrates part of one of the simplest forms, in which there are only "sill," *a a*; "head," *b b*; "post," *c*; and "filling-in pieces," *d d*; this is called a "framed partition." Another simple form of partition is shown in fig. 227, where longitudinal ties *a b*, are used; to which the boarding *c c* is secured; this being papered or painted; *d d* the side, *e e* the head, *f f* the posts. In figs. 228 and 230 we give what are called "framed and braced" partitions. Fig. 230 is a "framed and braced partition," as is also the upper part of fig. 231. When folding doors or a large opening in the centre of a partition are required, as at *a* in fig. 231, or where the partition is to support a second partition above it, as in the same figure, the lower partition is to be "trussed" in the same manner as a roof is trussed (see "Roofs" in next chapter); and the partition is then termed "framed, braced, and trussed," or simply a "trussed partition." In fig. 231, the trussed part is at *g g*, *h h*, *i i*. The other parts are the same as shown in fig. 230 of this chapter. The "truss" in fig. 231 is what is called a "queen-post" truss (see "Roofs"); *g g* corresponding to the



3/16″ Fig. 227.



1/8″ Fig. 228.



1/8″ Fig. 229.

tie beam; *h h* the "queen posts; *i i*, the "struts" or "braces;" *j j*, the "straining beam." In fig. 232 a "king-post truss" is illustrated, in which *a* corresponds to the "king post," *b b* to the "tie-beam," and *c c* to the "struts" or "braces." Partitions are sometimes made to rest upon the floor joists, but this should be avoided in good and sound construction; as,

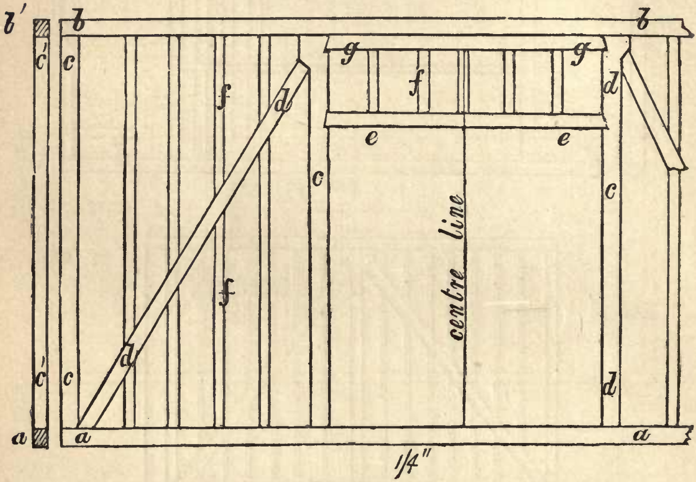


Fig. 230.

if done, the joists in settling, which they do in all cases more or less, will allow the partition to drop, and the result will be a crack or joint opening at the line of the cornice, or where the plaster of the partition joins that of the ceiling. The best plan is to support the upper partition sill upon upright blocks or "puncheons" of wood, same thickness and depth as the flooring joists, these blocks resting upon the head of the partition below, as illustrated in the lower part of fig. 232; where *a a* is part of "head" of lower partition; *b b*, part of "sill" of upper do.; *c c*, "flooring joists;" *d*, "puncheon" or block of wood, which may be placed between the joists, or close to them, as at *e*. Complete settlement of all the timbers should be allowed to take place before plastering of a partition is begun to.

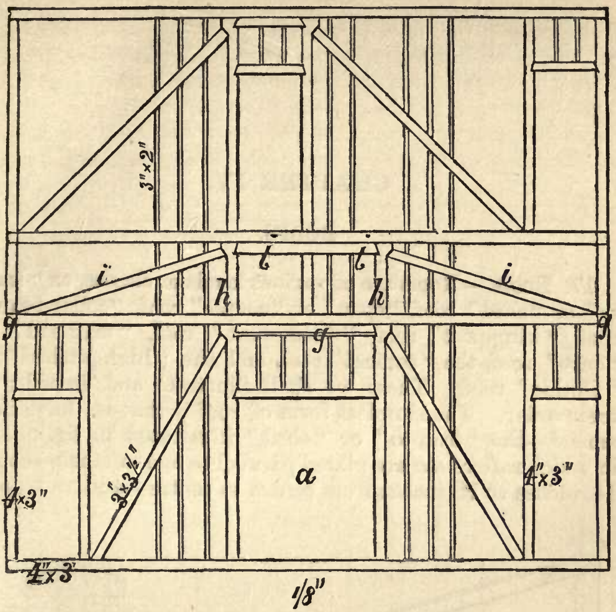


Fig. 231.

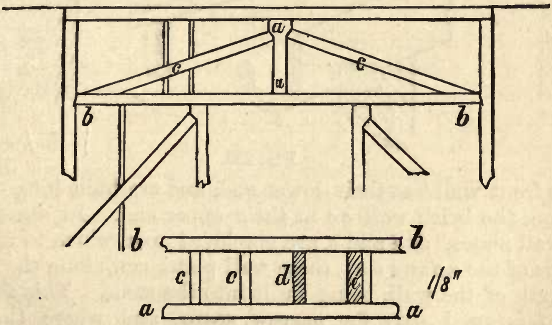


Fig. 232.

CHAPTER IV.

ROOFS.

17. Roofs.—Roofs are of various kinds or classes, as "lean-to" or "shed" roof, "span" or "couple" roof, "collar-beam" roof, "king-post" roof, "queen-post" roof, "mansard" or "curb" roof, the "conical" roof, and the "high-pitched" or "Gothic" roof. These we shall illustrate and describe in their order. The simplest form of roof is that we have first named—the "lean-to" or "shed," illustrated in fig. 233—in which rafters *a a* are placed parallel to one another—about 14 inches to 18 inches from centre to centre—and rest upon

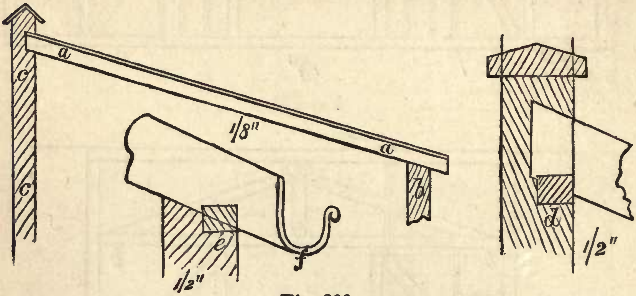


Fig. 233.

the front wall *b* at their lower end, and are built into, or rest upon, the brick wall *c c* at their upper end. In some cases "wall plates," as *d* and *e*, are employed upon which to rest the ends of the rafters *a a*; these wall plates run along the whole length of the wall, being built into the same. This form of roof is used only for narrow spans, and where the roof covering is to be light, as asphalte or tar coating. Fig. 234 illustrates a form of "lean-to" roof a little more complicated, and calculated for wider spans than that in fig. 233; in this a new member is introduced, namely, the "tie beam" *a a*, resting at its extremities upon the wall plates *b b*, and to

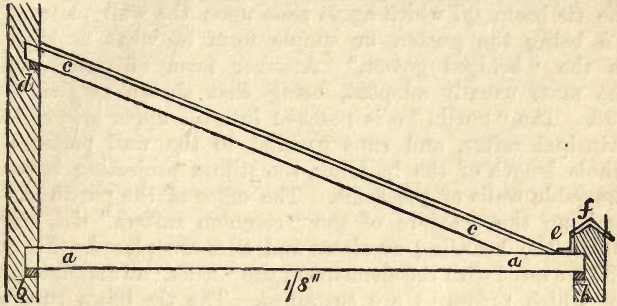


Fig. 234.

which the lower end of the rafters *c c* is notched (see Joints of Timber), the upper end resting upon the wall plate *d*, the gutter being formed at *e*, behind the parapet *f* of the front wall. In fig. 235 a still stronger form is shown; in this four

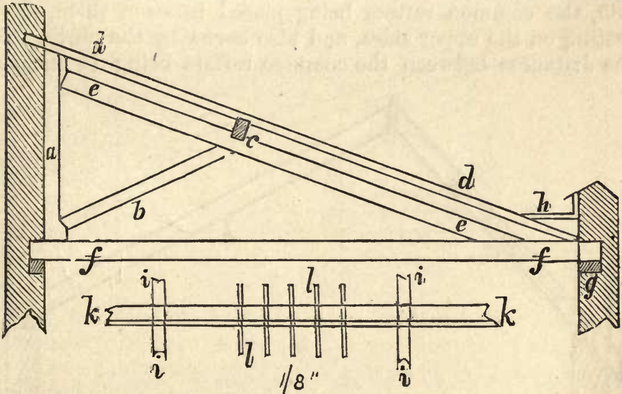


Fig. 235.

new members are added, namely, the "king post" *a*, the "brace" or "strut" *b*, the "purlin" *c*, and the "common rafter" *d*. The brace *b* butts at its lower end against the foot of the rafter *a*, and at its upper against the under side of the "principal rafter" *e e*, the upper end of which butts against the upper end of the king post *a a*, the lower on the tie beam *f f*, which again rests upon the wall plates *g g*, *h h* being the gutter, or simple form of what is known as the "bridged gutter." Another form of gutter, and the most usually adopted, being that shown at *f* in fig. 233. The "purlin" *c* is notched into the upper side of the principal rafter, and runs parallel to the wall plates the whole length of the building, sometimes projecting beyond the gable walls of the same. The office of the purlin is to bear up the pressure of the "common rafters" *d d*, upon which the boarding or slates and tiles are placed. In fig. 235 we meet with the elements of the "truss," an arrangement by which pressures are sustained. The tie beam runs at right angles to the walls, the principal rafters the same, the purlin and wall plates parallel. These members make up what is called the truss, and which support the common rafters and the roof covering. The "trusses" are placed upon the walls at distances usually of ten feet, as at *i i*, fig. 235, the common rafters being placed between them, as *j*, resting on the upper sides, and also borne by the purlin *k k*, the distances between the common rafters being 14 inches.

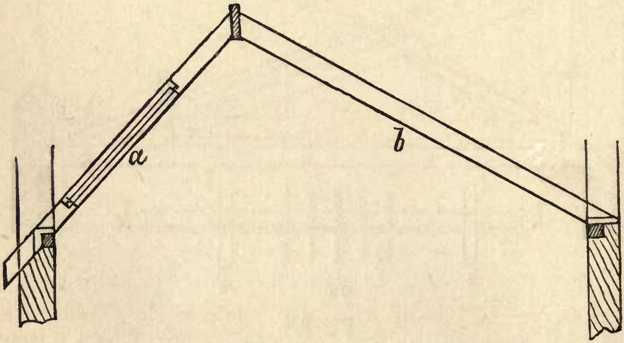


Fig. 236.

In fig. 236 we illustrate a form of "double lean-to roof," which may be called the "weaving-shed roof," as it is almost universally used for that class of building, the whole length of the side *a a* being glazed or fitted up with windows to throw the light upon the ranges of looms below, no light being on the side *b*.

"*Span Roof, or Couple Roof.*"—The simplest form of roof of this kind is shown in fig. 237, in which the rafters *a a*, *b b*

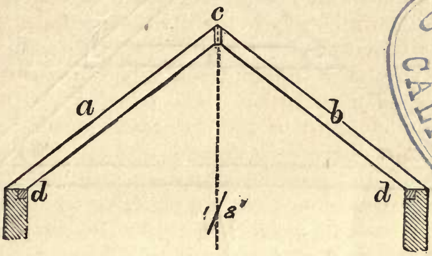


Fig. 237.

simply butt against each other at the apex *c*, and rest upon the wall or wall plates *d d*. This form of span roof is strengthened by the addition of the member *a a*, fig. 238,

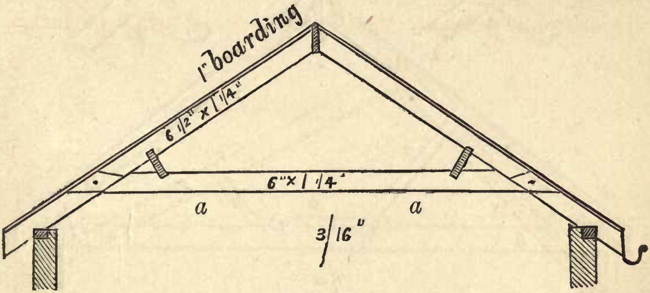


Fig. 238.

called a "collar beam," hence the roof is named a "*collar-beam roof;*" of this kind another modification is shown at fig. 239, in which "purlins" *a a* are used, and a second short collar beam *b* nearer the apex than the beam *c*. In fig. 240 another form of span roof is illustrated, in which the "rafters" *a a*, *b b* are supported by the "braces" or "struts" *c c*, which butt at their lower end against the "straining cill" or "straining piece" *d d*. In place of the rafters at their apex simply butting against each other, as at *f*, or being crossed, as at *g*,

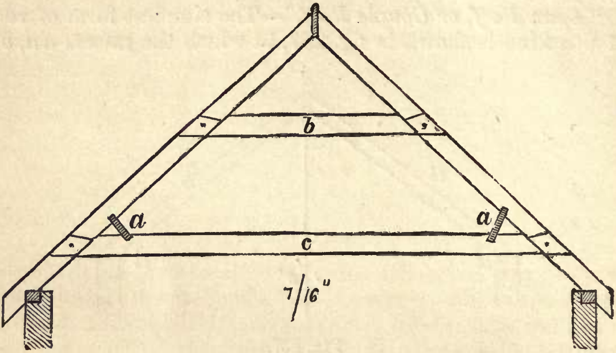


Fig. 239.

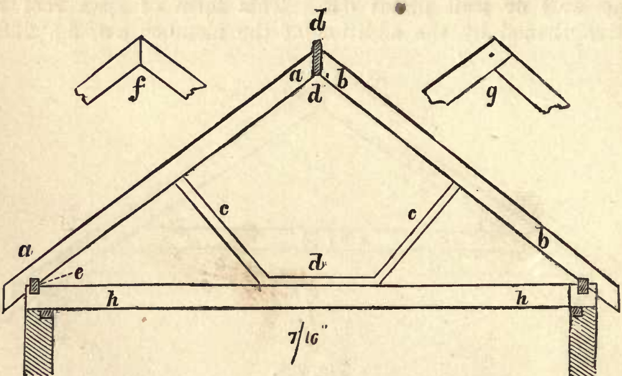


Fig. 240.

and nailed together, they usually butt against a flat piece of timber *d d*, which is called the "ridge pole" or "ridging piece." The rafters, also, in place of simply resting upon the end of "tie beam" *h h*—another new member in this form of roof—rest upon what are called "pole plates" *e e*, which are notched into the "tie beam," and run parallel to the wall plates the whole length of the building. In fig. 241 another

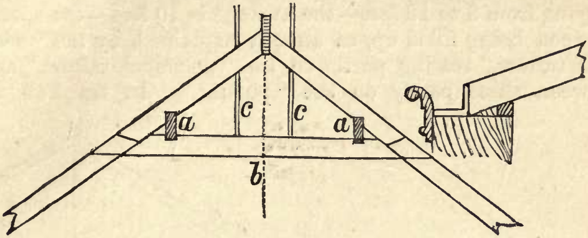


Fig. 241.

form of span or "collar-beam" roof is shown, in which the purlins *a a*, and the "collar beam" *b* support vertical uprights *c c* to form a ventilator in the roof. The sketch *d* shows a method of forming the gutter (see Gutters). We now come to the "*king-post*" roof, in which the "truss" for the first time is fully exemplified: this is illustrated in fig. 242, in

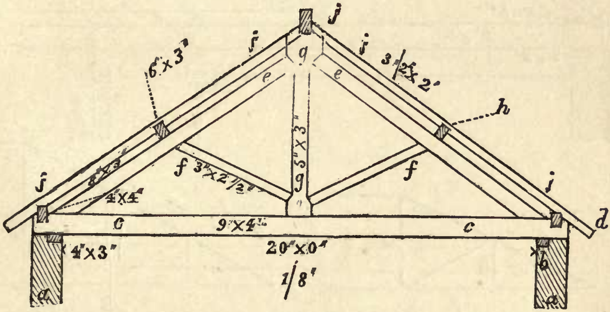


Fig. 242.

which *a a* are the 9″ side "walls;" *b b* the "wall plates," 4″ × 3″; *c c* the "tie-beams," 9″ × 4″; *d* the "pole plates," 4″ × 4″; *e e* the "principal rafters," 6″ × 3″; *f f* the "struts" or "braces," 3½″ × 2½″; *g* the "king post," 5″ × 3″; *h* the "purlin," 8″ × 3″; *i* the "common rafters," 3½″ × 2″; *j* the "ridge pole," 8″ × 1½″. The tie beam, principal rafters, king post, and struts, form what is called the "truss," and support the common rafters with their roof covering, as of slates, tiles, etc. The trusses are placed in the wall at distances varying from 8 to 12 feet—the average is 10 feet—the spaces between being filled up, as already explained, by the "common rafters," resting partly on the "principal rafters," and between these partly on the "purlins." In fig. 243 we

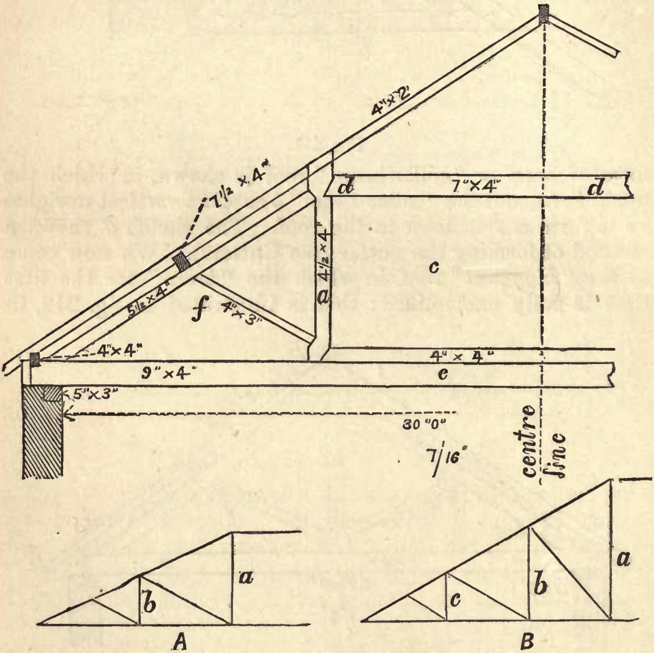


Fig 243.

illustrate the "*queen-post roof.*" In this what may be called two king posts, as *a b* (one only in diagram), are placed some distance apart, so as to afford a space, as *c*, between them, which space might be used as an apartment; these posts, as *a b*, are in this form of roof, however, called "queen posts," they are separated or kept out at the top by the "straining beam" *d*, and at the foot by the "straining sill" *e*, *f* the "struts" or "braces," *g* the "principal" or "common rafter." In the lower part of the same figure, in A, we give a diagram of a queen-post roof with two queen posts *a b*, and in diagram B one with three queen posts; the diagram in B will be adapted for a 60 feet span, of which the scantling of the timbers will be as follows:—Principal rafters, 8″ × 6″; common rafters, 6″ × 3″; purlins, $9\frac{3}{4}$″ × 6″; wall plates, 8″ × 6″; tie-beams, 15″ × 10″; queen posts, 10″ × 8″; small do. (*b* and *c*), 10″ × 4″; straining beam, 11″ × 6″; braces, 6″ × 3″, this being adapted for wider spans than the upper figure. In fig. 244 we illustrate another form of queen-post roof. In

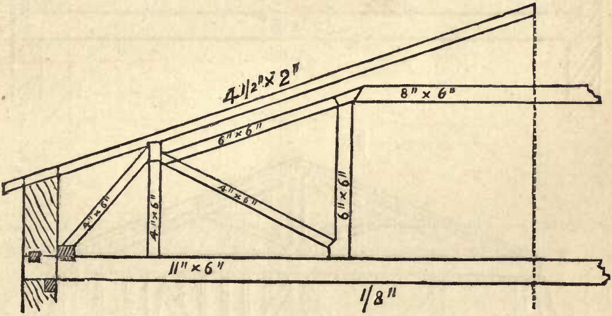


Fig. 244.

fig. 245 we illustrate what is known as the "*curb roof*," or, from the name of its designer, the "*mansard*" roof, by which name it is better known on the Continent, where it is very widely adopted, as by its use a good apartment may be placed in the roof, being lighted by windows, as *a*, fig. 245, or lighted by a "dormar window," which see. Another arrangement of "curb" roof is shown in fig. 246, in which doors *a b* are placed in the partition, the tie beam *b* of the upper truss being supported by a central post *c*. In Plate XXXIX., fig. 3, another arrangement is given, the vertical posts or studding, as *a a*, forming the sides of the apartment or room in the roof, are called "ashlets," and sometimes puncheons, although this term is properly applied to the short posts of a partition above the door.

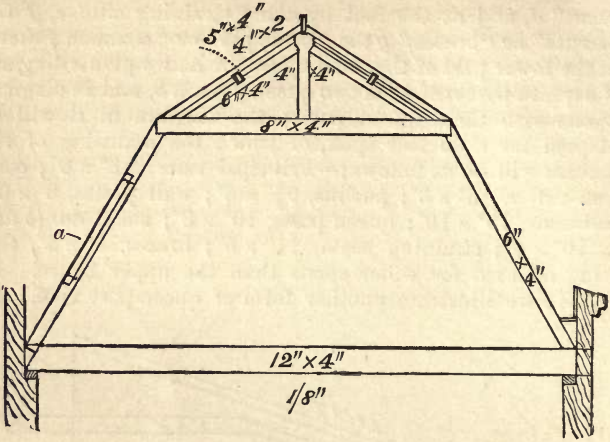


Fig 245

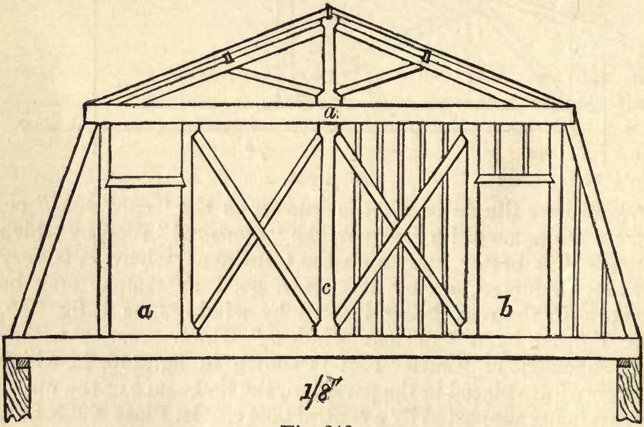


Fig. 246.

"*Conical roofs*" are but seldom used, being chiefly for kilns, horse-thrashing machine houses, circuses, gas works, etc. One form is shown in fig. 247, in which the upper diagram gives a sectional elevation—*a a* the walls, *b b* a tie beam stretching across the diameter of the circular building *c c*, the rafters, ring, or timber strutting *d d* are placed all round, and on these the rafters rest, all terminating at the apex of the cone. The outer circular wall is shown at *e e* in the diagram, *f* and *g* representing the lines of purlins *d d*,

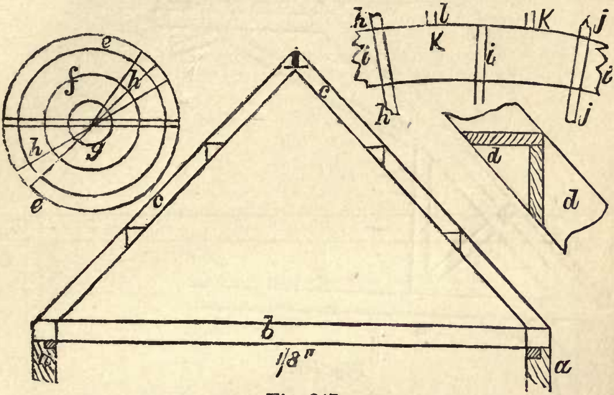


Fig. 247.

h h the principal rafters, *i i* is part of a purlin, *j j* a principal rafter going from wall *e* to apex *g*, *h h* a common rafter going from wall *e* to second purlin *g*, *i* one stretching from *h* to *g*, and *k l* from *e* to *h*. An example of a conical roof for a circus is given in figs. 1, 2, 3, and 4, in Plate XLI., being that designed by M. Hittoff for the Napoleon Circus in Paris, and which we have reduced from drawings given in the *Encyclopædia of Architecture*, published at 13 Rue Bonaparte, by M. Bance. Fig. 1 is the upper part with ventilator *a a* and flag-staff *b b*, *c c* the upper part of one of the trussed girders, fig. 2, *d* the lower part, *e* the wall, figs. 3 and 4 two parts of the plan of one of the girders with intervening rafters.

High Pitched Roofs.—These are met with very frequently on the Continent, and in districts where the snowfalls are heavy, so that the snow may be quickly dislodged. In Plate XXXIX., in figs. 1 and 2, and fig. 1, Plate XL., examples of Continental high-pitched roofs are given. In figs. 248 and 249 we give diagram of Gothic or high-pitched roofs—the

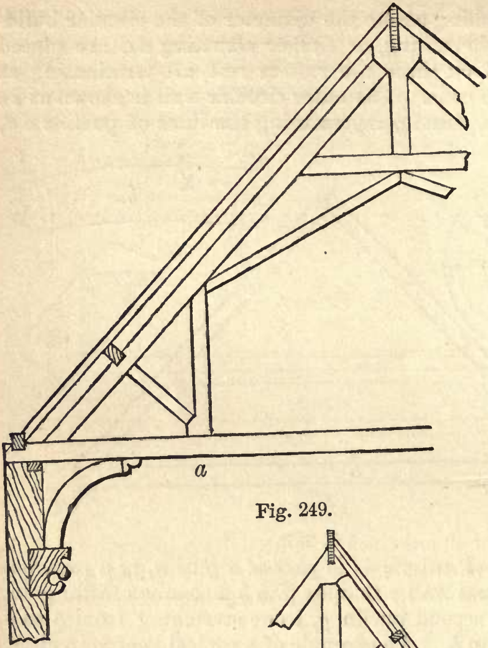


Fig. 249.

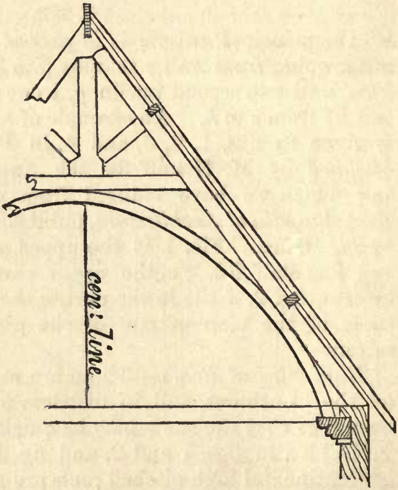


Fig. 248.

beam *a a*, in fig. 249, being usually, in this class of roofs, called a "hammer beam" in place of a tie beam. In fig. 250 we illustrate a *low-pitched*, and in fig. 251 a *flat*, roof. When

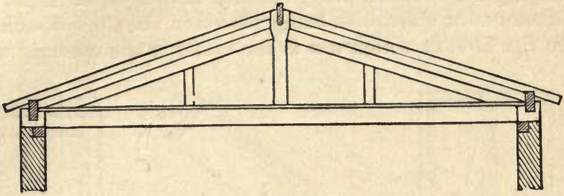


Fig. 250.

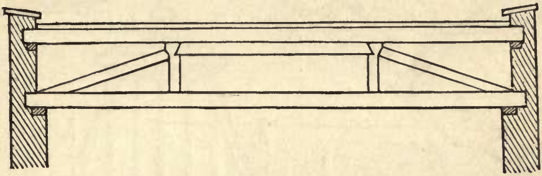


Fig. 251.

the attic or roof chambers are lighted by windows, the faces of which are vertical, the arrangement is called a dormer window, as in fig. 252, where *a* is a side and *b* a front view.

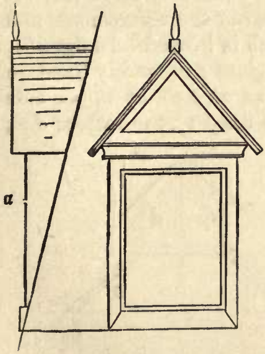


Fig. 252.

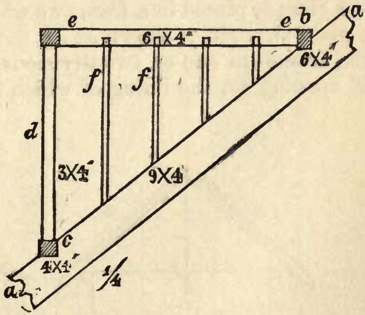


Fig. 253.

Fig. 253 illustrates a section showing at *a a* part of the common rafter, from which the window rises, *b b* cross-piece let into the rafter, *d* vertical post, *e* ridge-piece, *f f* small rafters.

Skylights.—These are generally employed to light attic apartments or staircases, being placed in the slope of the roof, as in fig. 254, in which *a a* is the rafter, *b* the opening which

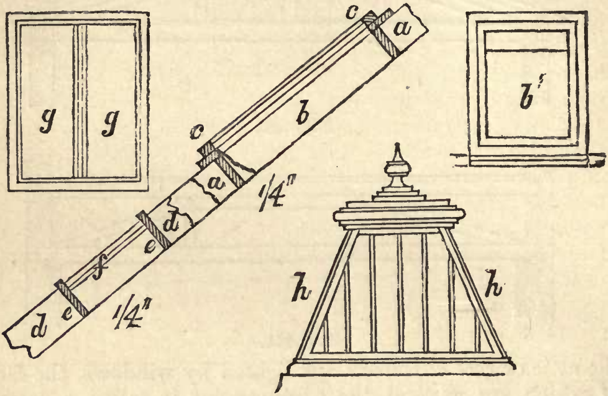


Fig. 254.

may be the width of the space between two or more rafters; the opening is lined with wood towards the apartment, and the glass is placed in a frame *c c* which is hinged. In fig. 254, a plain skylight is shown at *e e*, the glass *f* is merely fixed in the frame (in one or two divisions, as at *g g*), at upper side of opening *e e*, the lining of which is fixed to the rafters *d d*;

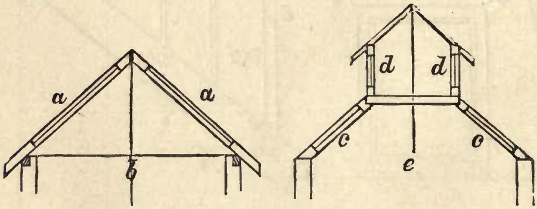


Fig. 255.

at *h h* a staircase skylight outside elevation is shown. Fig.

255 gives diagrams illustrating a conical-shaped roof or skylight at *a*, lighting a staircase *b*; *c c d*, another form lighting the staircase at *e*.

Gutters. — We have already, in preceding figures of Roofs, illustrated the simpler forms of gutters, in which hollow or concave troughs — as they may be called—of metal are fastened to the ends of the common rafters, which are made to project beyond the wall for that purpose. In fig. 256 we illustrate what is called a "bridged gutter" *a*, which is formed behind the wall *b b*; the rafters *d d* butt against a wall plate *c*, and the gutter *a a* is carried by the bridging piece *f*, in which is laid the boarding *e e*, which is covered either with lead or zinc. In fig. 257, *a a* is the tie beam, which is supported

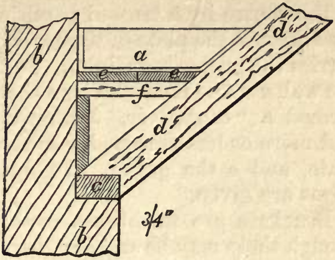


Fig. 256.

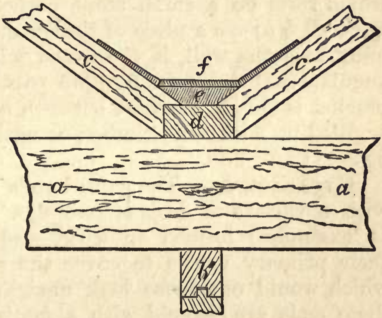


Fig. 257.

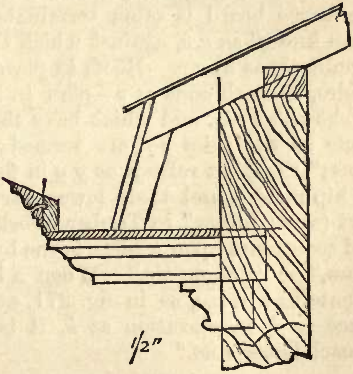


Fig. 258.

in the centre by a trussed partition *b*; *c c*, the rafters, which butt against the plate of timber *d*; *e*, the bridging piece, which carries the gutter boarding *f*. In fig. 258 the gutter is outside the wall *a a*, and is carried by a short projecting piece of timber, termed a "cantaliver," *b b*, built into the wall at one end, and more or less enriched, *c* is the common rafter, *d* the wall plate, and *e* the gutter. In figs. 259, 260, and 261, other forms are given.

Brackets are sometimes used in place of cantalivers, although these may be and are often called enriched cantalivers; a form of bracket is shown in fig. 262, the lower end of which rests on a small stone corbel *a*, tailed or built into the wall *b b*; *c c* a piece of timber moulded in front and also built into the wall, is connected with the corbel *a a* by an angular part *d d*. In fig. 263 part of another design for a bracket is shown, the part between *a a* being either left open or filled up with solid timber, or with ornamental work as in figs. 264 and 265.

Barge Boards.—The gabled ends of roofs are ornamented with a variety of designs (see figs. 266, 267, 268, and 269 as examples) formed in wood and termed barge boards; their primary use is to cover the ends of the roof timber which would otherwise look unsightly. In some instances these ends are covered with a fascia board, that is a plain board as in *c c*, fig. 269, moulded in the edges. In fig. 269 the barge board is often terminated by a finial, termed a "hip knob," as *a b*, against which the barge or fascia boards terminate, as at *c c*. Roofs in place of being terminated by gables, at both ends as *c*—plan in *b*, fig. 270—are arranged as shown at *c d*, and which have their ends *c d* at the same angle as the sides *e f*, are termed "hip roofs" or "hipped roofs;" the short rafters, as *g g* in fig. 271, are termed "jack" or hip rafters, and their lower part rests upon an angular part (see "Joints" in Timber Work), called an "angle tie," and sometimes upon a piece borne by this, called the "dragon beam," or "dragon tie." When a hipped roof does not terminate in a ridge, as in fig. 271, at *h* as at *i*, but in a flat space as *j*, in elevation at *k*, it is called a "pavilion" or "coach-house roof."

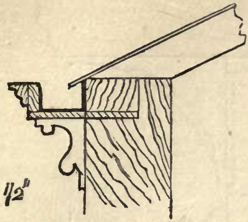


Fig. 259.

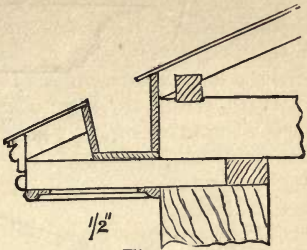


Fig. 260.

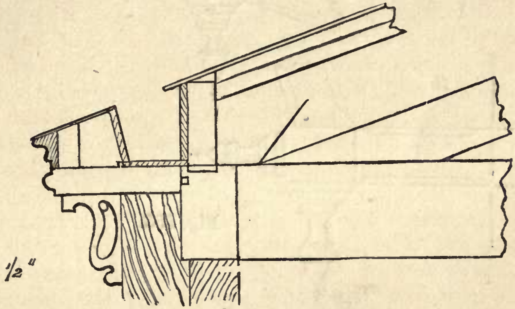


Fig. 261.

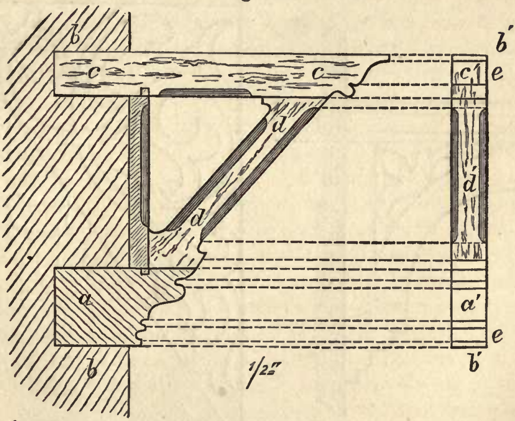


Fig. 262.

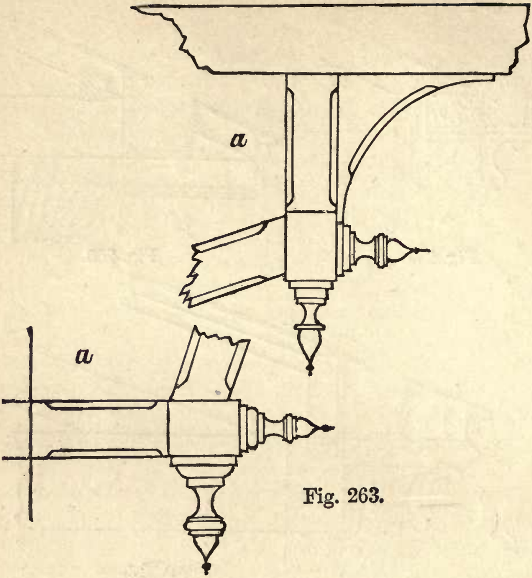


Fig. 263.

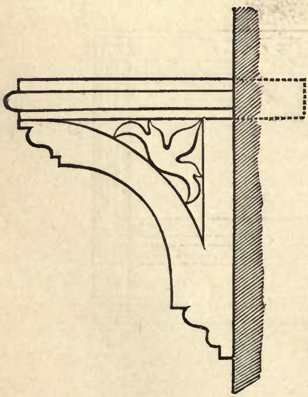


Fig. 264.

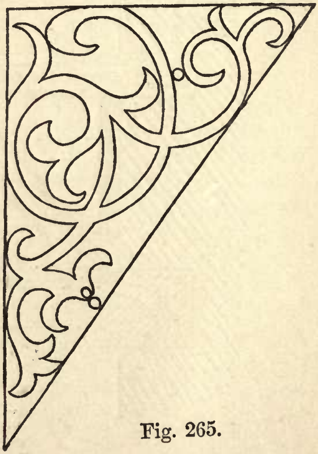


Fig. 265.

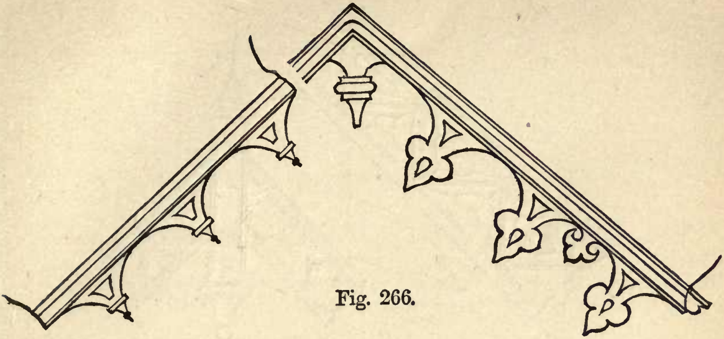


Fig. 266.

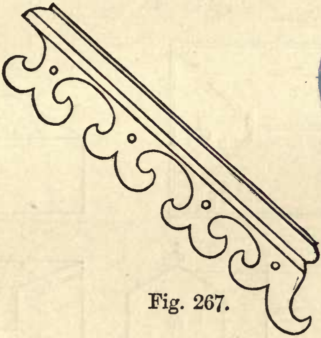


Fig. 267.

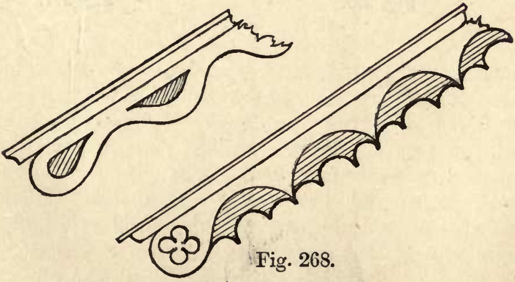


Fig. 268.

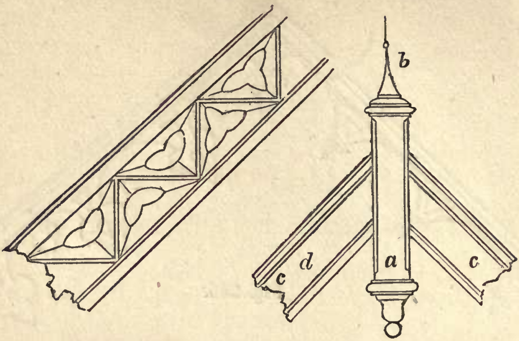


Fig. 269.

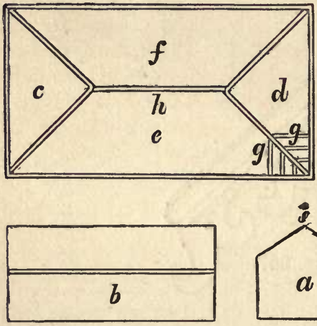


Fig. 370.

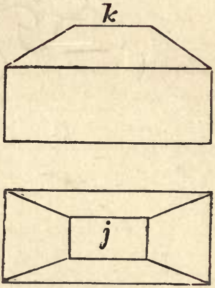


Fig. 271.

CHAPTER V.

MISCELLANEOUS TIMBER STRUCTURE.

Centres—Bridges—Gates—Storing up Timber Work—Scaffolding—Timber sheds—Houses—Hoists and Havellers.

18. Centres, which are certain arrangements of timber framing, used to support the brick or stone work of arches when these are in course of construction, and are therefore purely temporary structures, and are taken down after the brick or stone arch has firmly settled. The taking down of the centres from beneath the brick or stone work is called **striking the arch,** and to aid this a certain arrangement is made use of, which will be presently explained. In fig. 272

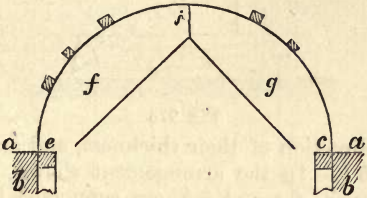


Fig. 272.

a simple form of centre for a semicircular arch is shown; in this the lines *a b*, *c d* show the side walls terminating the width of opening, *e c*, which is to be finished with a semicircular arch at top. When the walls are at the height of the line *a c*, which is the springing line of the arch, the "centreing" or "centre" is erected. The upper part of the arrangement of timbers which is to support the arch is framed in a way more or less complicated, according to the width of the opening, *e c*, in the span of the arch. In fig. 272 this part is simple, being formed of two planks, *f g*, the outer edges of which are cut to the circle of the arch, this being described from the point *h* in the line *a c*. These two pieces butt at their upper termination at *i*, and are nailed at their lower end *j*, as in fig. 273, and *k*, to a cross-piece *l l*. In some cases this cross-piece is omitted, the ends *j* and *k* simply resting on the pieces *m* and *n*, which run across the

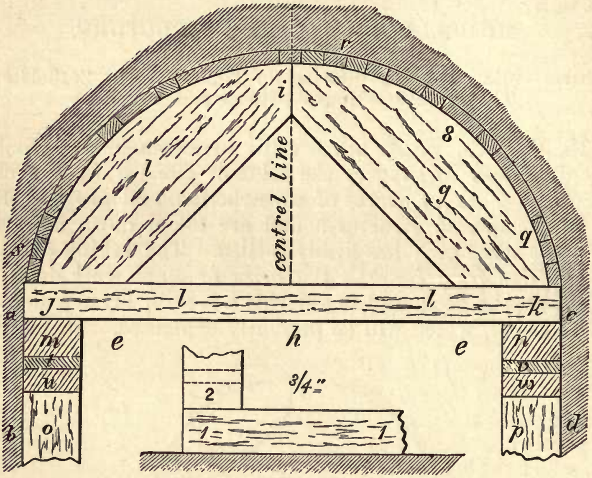


Fig. 273

walls in the direction of their thickness, and at right angles to the piece *b b*. In the arrangement shown, the pieces or "centre" proper, *f g* and *b b*, are supported by the cross-pieces or cushion timbers *m* and *n*. These are again supported by the upright posts *o* and *p*, the lower ends of which rest upon the ground, in the case of arches being built on the ground floor of a building, and upon a sill in the wall in the case of an arch being built on an upper storey. To prevent the feet of the posts penetrating the ground or *soil*, they rest upon a piece of timber or sill, as *a a*, in fig. 275. The cross-pieces, *m* and *n*, pass through, as above stated, the opening across the thickness of the wall, *a b*, *b c*, and are terminated at the opposite or inside face of the wall, supposing the side, as seen in drawing, to be the outside of the wall. The inner end of the cross-pieces, *m* and *n*, support an arrangement of timber precisely similar to that shown in *j f i*, *i g k*, and *l l*. This is illustrated in fig. 274, which is a side or edge elevation of the centreing and wall—the wall, *a b*, *a b*, being that lettered also as *a b* in fig. 274. In fig. 274, *c c*, *d d* indicate the parts corresponding to *j f i*, *i g k* in fig. 273—*c c* being that at the outer, *d d* that at the inner face of wall; *m m*, in fig. 274, is the cross-piece, *m*, in fig. 273; *o o*, the post corresponding to *m* and *o* in fig. 273. The two pieces, *c c*, *d d*, fig. 274, support or carry cross-pieces, *q r s*, these uniting the two sides, *c c*, *d d*, of the centre proper. These pieces are either placed close to each other, as at *r s*, fig. 273, forming a platform or floor, so to say, in which the bricks or stones forming the arch are laid in course of building; or the pieces may be laid, each being separated from its neighbour by a short space, as shown at *q q*, in fig. 273. The interspaces may be less than the breadth of a brick in small arches; or in the case of arches of wider span, and where stone is used, may be much wider. These cross-pieces are termed **bolster pieces.** The arrangement for "striking the centres" is shown at *t w*, *v w*, in figs. 273 and 274. In this double wedges are employed, the large end of one of the wedges, as *t* in fig. 274, being placed at the small end of the other wedge, as *w*. When the building of the arch is completed, the centre is not removed at once, but the whole allowed to remain for a length

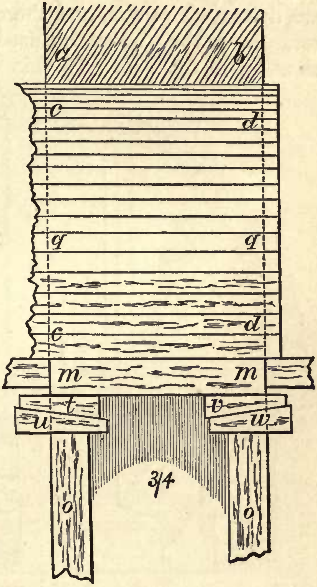


Fig. 274.

of time, longer or shorter according to circumstances. As the brickwork or stonework of the arch gradually settles, the wedges are gradually driven out or loosed, thus allowing the cross-pieces *m* and *n*, and the upper part of the centre, to drop gradually. When the settlement is completed, the wedges are driven clean out, and the centreing wholly removed. In some cases the wedges are used at the lower part of the posts, as at *m*, in fig. 275. In this fig. two other forms of centres

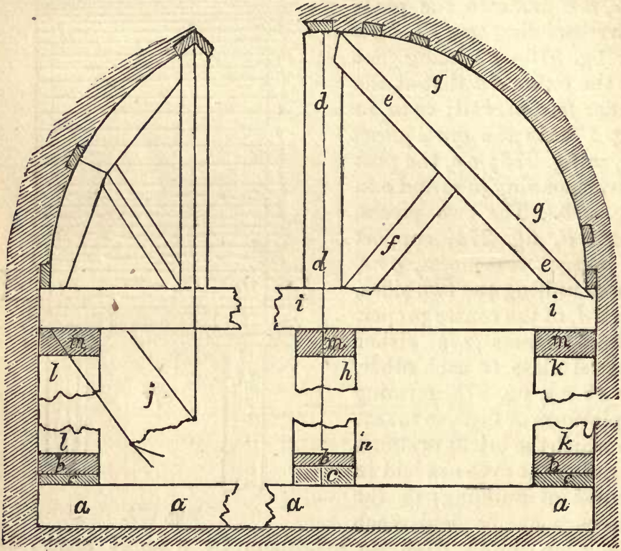


Fig. 275

are illustrated; in the one to the right a central post *d* is used; an angular piece, *e*; and a strut or brace, *f*; the space above *e* is filled in with a piece of plank, *g g*, the outer edge of which is cut to the arch. The centre to the left is for a pointed arch. In both of these, in place of two vertical posts, as *o* and *p* in fig. 273, three are used, the third, as *h h*, being placed in the centre of the cross beam, *i i*. In some cases where this central post is used, a diagonal strut, shown by the dotted lines *j*, fig. 275, is used on both sides of *h h*; and, in some cases, the side posts, as *k k*, *l l*, are dispensed with, and the diagonal struts, as *j*, used in place of them. In fig. 275, *m m m* are the cross-pieces corresponding to *m* and *n* in fig. 273. In fig. 276 is illustrated a form of centre used for a "segmental" arch; in fig. 277 one for a "scheme" arch. (For a description of the various forms of arches see Volume on *Brickwork* and *Masonry*, Advanced Series). In fig. 276,

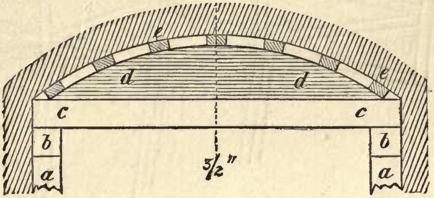


Fig. 276.

a a, the upright posts; *b b*, cross-pieces, corresponding to *m* and *n*, fig. 273; *c c*, sill, corresponding to *l l*, fig. 273; *d*, the filling-in piece, carrying the "bolster piece," *c c*. In fig. 277,

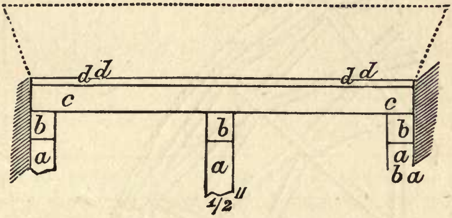


Fig. 277.

the same letters indicate the same parts as above, but there is no filling-in piece, as *d d*, the brick being laid upon planks, *d d*, carried by the piece *c c*. In both of these the striking wedges are placed against the wall at the foot of posts *a a*, or as in fig. 275. In fig. 278 we give the upper part *a b* the centre line, of an open built centre for a bridge; and in fig. 279 the lower part.

Bridge.—In fig. 279*a* we give a diagram showing an arrangement for a centre keeping the water-way quite free—

all points of supports from the ground being done away with. The simplest form of timber bridge may be described as a

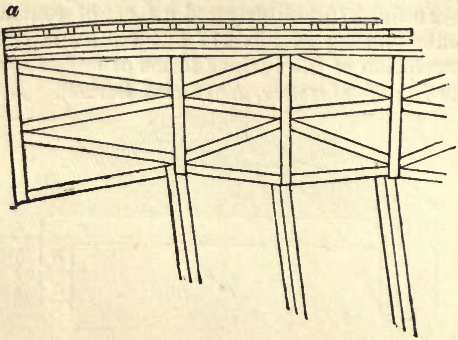


Fig. 278.

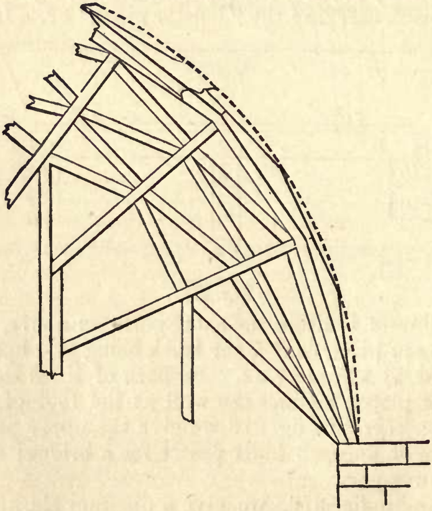


Fig. 279.

bearer *a a*, fig. 280, thrown across the opening to be crossed; protection being afforded by the railing, constructed of uprights *b b*, cross or diagonal struts *c c*, and hand-rail *d d*; the flooring being made of simple planking *ee,ff*, these constitute the elements of a simple bridge in crossing narrow spans.

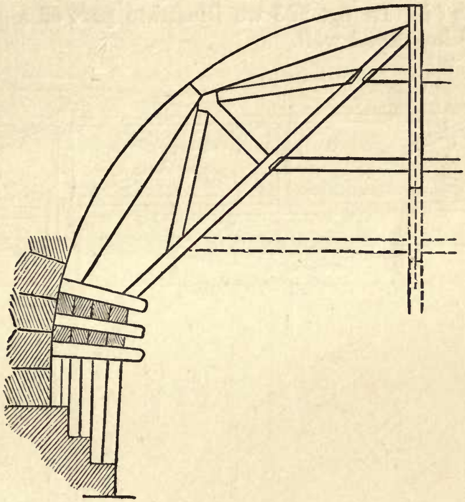


Fig. 279*a*.

If the span is increased the beams may be trussed with iron rods, as *g g g* (see illustrations of trussed beams further on), or the beam may be trussed, king-post fashion as on the right-hand side of *a b* in fig. 283, or queen post as on the left-hand side; and for still larger spans the beam may be built and curved (see further on for illustrations of built beams). Figs. 280 and 281 are part elevations of a bridge or gangway, and fig. 282 the cross elevation showing roadway and hand-rails.

19. Gate.—A gate consists of framework, as in *a b c d*, hinged or hung to a gate-post *e*, firmly secured to the ground, and catching on a latch attached to another gate-post at the opposite side of the opening. This framework is generally filled in with five horizontal bars, as *f f*, sometimes with vertical ones. To prevent the weight of the gate acting in the direction of the arrow, as at *g*, an essential part of an arrangement of the gate is the diagonal strut or brace *h h*, forming the frame into two triangles, which is the strongest form of all. To produce uniformity another strut may be added, as *i i*. In fig. 285 we illustrate part of a gate with rails and low-coped wall.

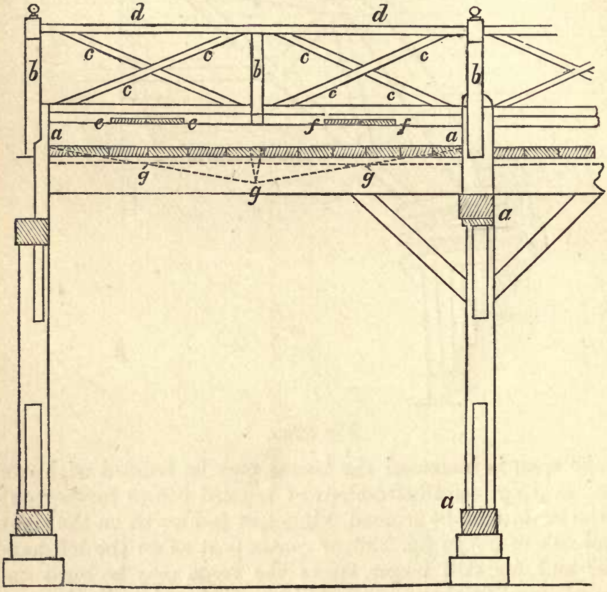


Fig. 280.

Shoring-up Timbers.—In the various works of the builder, in making excavations, as those for drains, tunnels, and the repairing of decayed or dangerous houses, timber is used in a variety of ways, the operation being known as "shoring-up." In shoring-up a drain the simplest arrangement is shown in fig. 285, in which *a a* are the sides of the excavation, the interior is either lined with planks, as *b b*, or planks, as *b b*, are placed at intervals vertically, and kept apart by the horizontal stays *c c c*, or by diagonal ones, as *d d*. The shoring-up

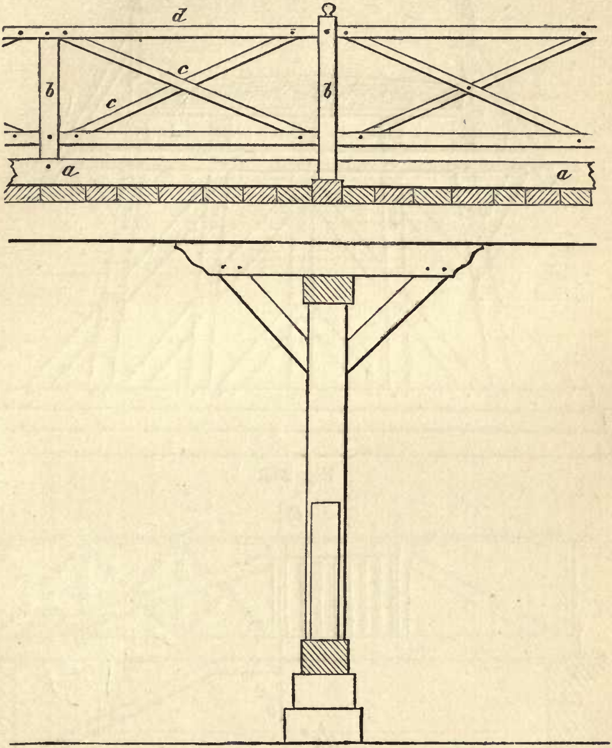


Fig. 281.

of the sides of an open excavation, or a wall which shows signs of decay and failure, may be effected by the arrangement shown at A in fig. 286. Fig. 286*a* illustrates a method for "underpinning" a wall *a a*, the side elevation of which is shown at C in same figure. By "underpinning" is meant the operation of supporting the upper part of a building or wall, as *a* (C), fig. 286*a*, while the lower part *b* is being repaired or removed to be replaced by a different arrangement

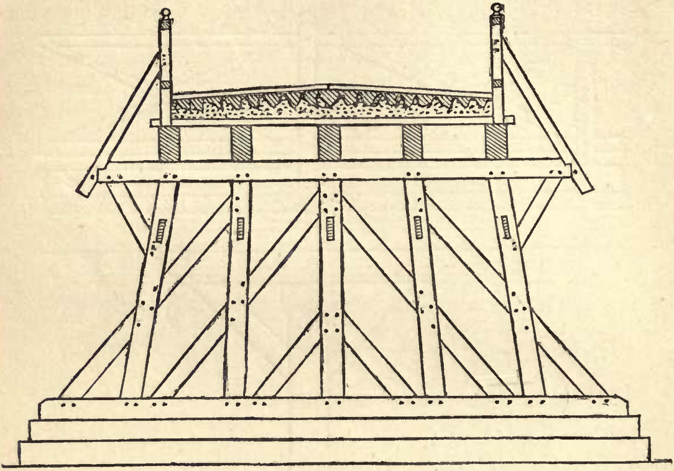


Fig. 282.

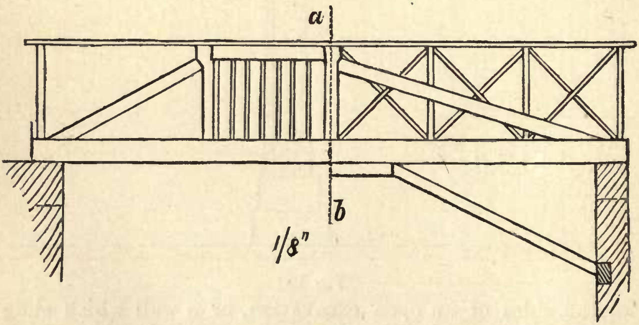


Fig. 283

or new materials. The upper part is by the cross beam *d* and shoring *e* (B), while the outer end of *d* may be supported by a vertical piece *f*. We take, fig. 287, from the *Building*

News, a method suggested by a correspondent for shoring-up the houses of a street, on both sides of which are houses, as shown by the walls. In figs. 288 to 293 we illustrate the method of shoring-up used in the construction of the tunnel at Viezzy, on the Soissons Railway, near Paris, for which

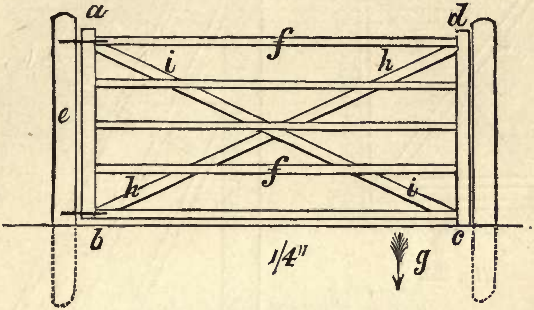


Fig 284.

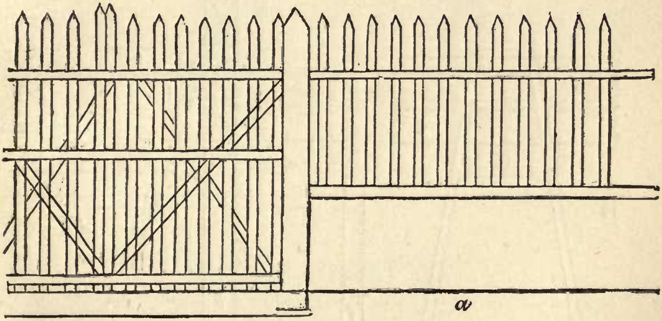


Fig. 284*a*

we are indebted to the volume for 1861 of the *Nouvelles Annales de Constructione*, published by Dunod, Paris, a most valuable work, and one abounding in fine examples of construction in various branches. Fig. 288 shows the first

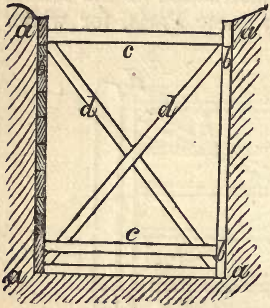


Fig. 285.

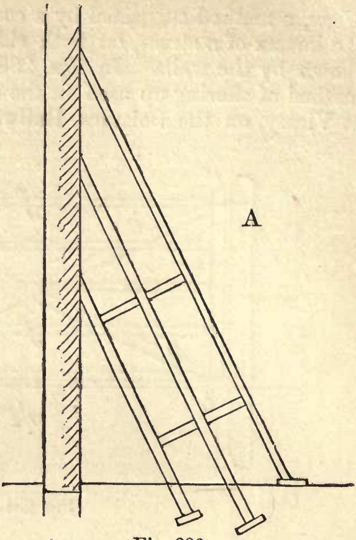


Fig. 286.

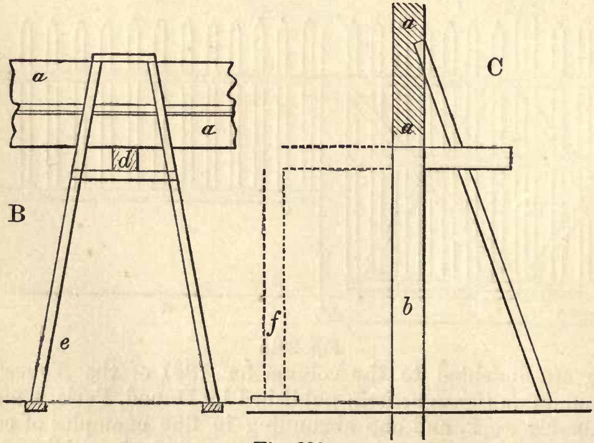


Fig. 286*a*.

operation, fig. 289 being a side elevation; fig. 290 illustrates the method of shoring-up the "gallery of execution," fig. 291, do., where the opening of the tunnel is enlarged; fig. 292 the

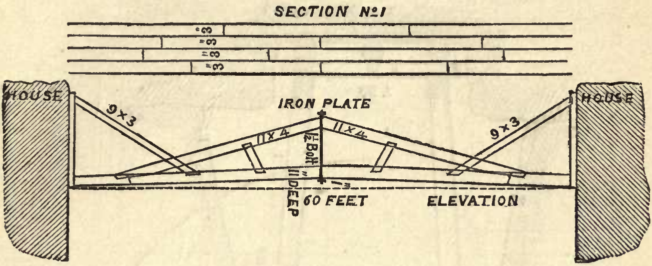


Fig. 287.

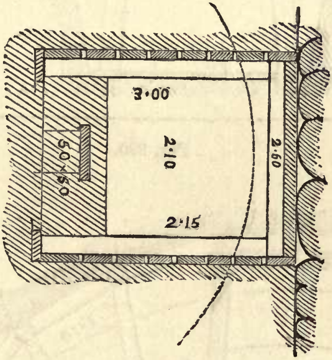


Fig. 288.

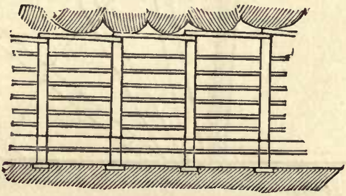


Fig. 289.

centre and the shoring-up of the masonry of the vault of the tunnel, and fig. 293 the method of underpinning the side wall of the vault.

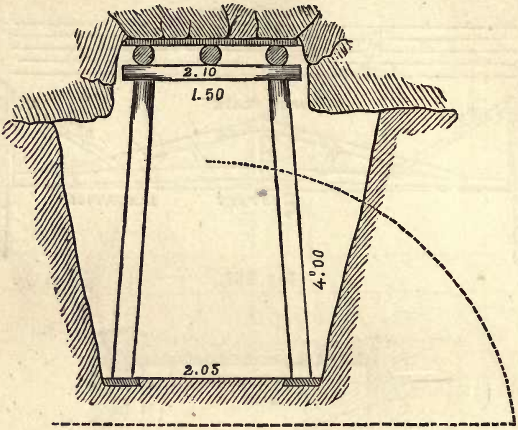


Fig. 290.

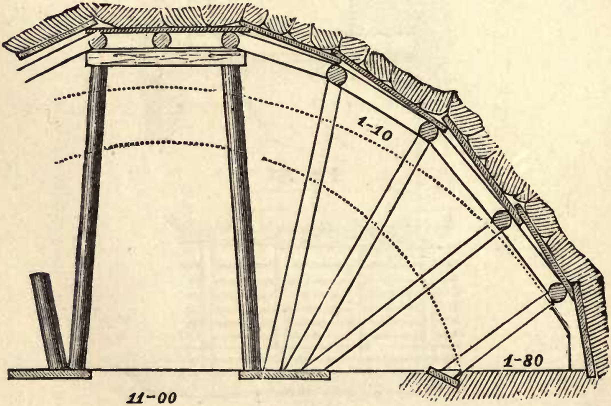


Fig. 291.

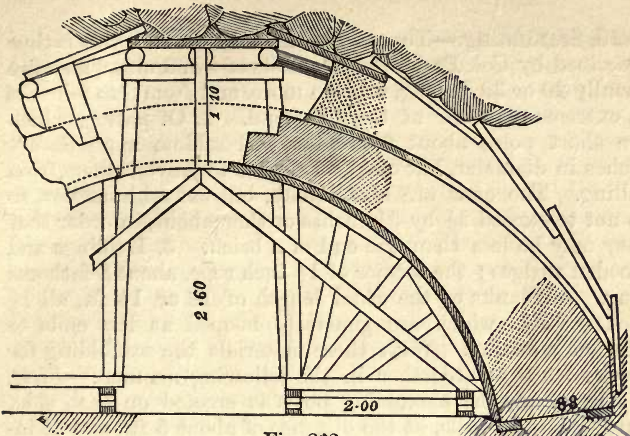


Fig. 292.

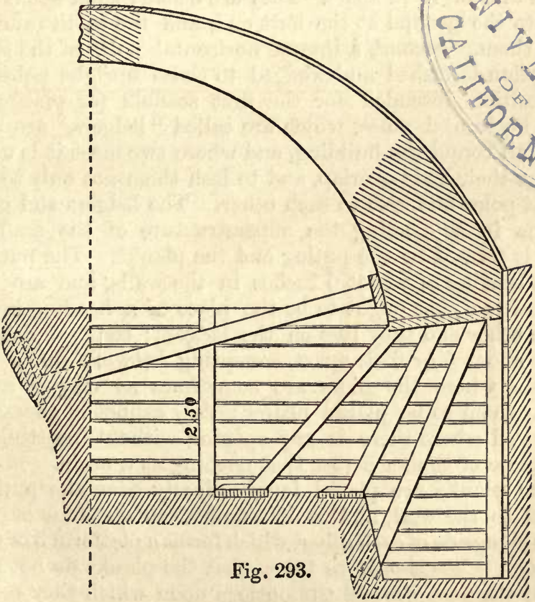


Fig. 293.

20. Scaffolding.—The scaffolding used by bricklayers is thus described by Col. Pasley:—"Consists of—1. Poles which are usually 20 or 30 ft. long, or even more, and from 6 to 9 inches in extreme diameter at the butt end. 2. Of putlog, which are short poles about 6 ft. long, and seldom more than 4 inches in diameter, but chopped square to prevent them from rolling. The ends are also square, but cut still smaller, so as not to exceed $2\frac{1}{2}$ by $3\frac{1}{2}$ inches or thereabout, in order that they may be less than the end of a brick. 3. Lashings and wooden wedges; the former of $1\frac{1}{2}$ inch rope, about 3 fathoms long. 4. Planks of the usual length of 12 or 14 ft., all $1\frac{3}{4}$ inches thick, which are generally hooped at the ends to prevent splitting. With these materials the scaffolding for brickwork is put together in the following manner:—*First*, a line of upright scaffolding poles is erected on each side, parallel to the walls, at the distance of about 5 ft., and at intervals of 8 or 10 ft. apart. They are usually sunk about two feet into the ground at the butt end, and the earth rammed round them. *Second*, a line of horizontal poles of the same description is lashed and wedged to those upright poles, in the position intended for the first scaffold (or platform). These horizontal poles, which are called "ledgers," are continued all round the building, and where two meet it is usual to make their ends overlap, and to lash them not only to the upright poles but also to each other. The ledgers and poles combine in supporting the superstructure of the scaffold, which is formed by the putlog and the planks. The putlogs have a bearing of about 6 inches in the walls, and are laid in a position that ought to be the place of a heading brick. At the other end they rest on the ledgers; they are usually placed about 5 or 6 ft. apart, excepting between doors and windows, where the piers are sometimes so narrow as to require them to be placed nearer; they cannot of course be introduced where there is any opening without inserting an extra piece of timber across that opening as a beam.

"The planks are placed longitudinally over the putlogs parallel to the wall, and it is common to use four or five planks alongside of each other, which forms a platform 3 or 4 ft. in width. Care should be taken that the planks do not project any distance beyond the putlogs upon which they rest.

"In high buildings, one tier of upright scaffolding poles is seldom sufficient; a second tier is therefore lashed to the first, having an overlap of not less than 10 or 12 ft., where the tops of those of the lower tier agree with the bottoms or butt ends of the upper tier; and in this case it is usual to introduce also diagonal scaffolding poles to connect the whole together, which extend longitudinally at an angle of 45° or thereabouts along the line of upright poles and ledgers, and being lashed to both they stiffen the whole. In addition to these longitudinal braces, transverse struts are sometimes added to prevent the line of scaffolding from separating at top from the wall. These also consist of scaffolding poles, which are made to stand out at bottom at same distance from line of uprights, and to these the principal struts, smaller struts or braces consisting of shorter poles, are occasionally added, which are also fixed in a transverse direction and nearly at right angles to the former, to which they are connected about the middle height of the principal struts." In fig. 294, *a a* is the wall, *b b* the upright poles in front of the building, *c* the "ledgers," *d* the "putlog," *e* the

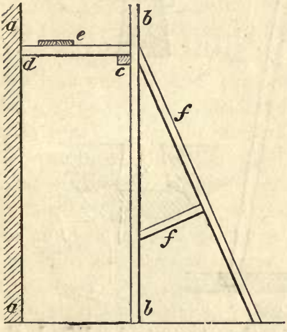


Fig. 294.

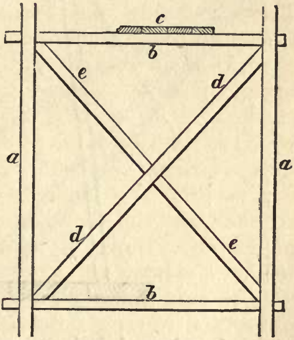


Fig. 295.

planking, *f f′* the braces or struts. The scaffolding used by masons is of a varied character, more or less complicated, according to the nature of the building. Fig. 295 illustrates the elements of scaffolding, consisting of uprights *a a*, either sunk into the ground or resting upon cross beams or planks—horizontal pieces *b b*, the upper one of which carries the planking *c*, forming the platform upon which the workmen stand. In building stone houses the most recent improvement has been the doing away with all external scaffolding, working wholly from the inside; the different heights being reached by gangways or broad planking upon the surface of which cross-pieces are nailed, forming a series of steps or foot-holds; these gangways being supported by the walls and partly by light scaffold timbers. The construction of buildings is now greatly aided by the use of

21. Hoists and Travellers.—A simple form of hoist is shown to the left in fig. 296. The stone to be lifted is secured to the chain by a contrivance called a "lewis," and the stone is hauled up by a crab or winch placed on the ground near the hoist. The "lewis" is shown in section in fig. 296 at *a d d*.

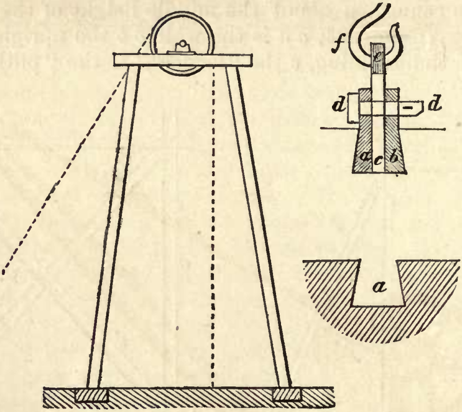


Fig. 296.

A wedge-shaped hole *a* is cut in the stone to be lifted, three irons, *a′ b c*, are inserted in this, *a′* and *b* first, *c* last, and the three are kept together by a pin *d d*; the hook of the lifting chain is passed through the ring *e*. A "traveller" of a simple kind, worked by manual labour, is shown in fig. 297. A cross beam *a a* carries the rails upon which runs the hoisting

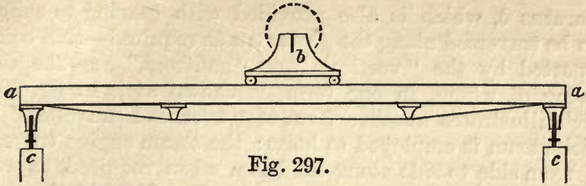


Fig. 297.

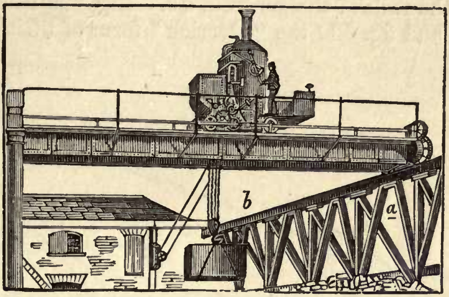


Fig. 298.

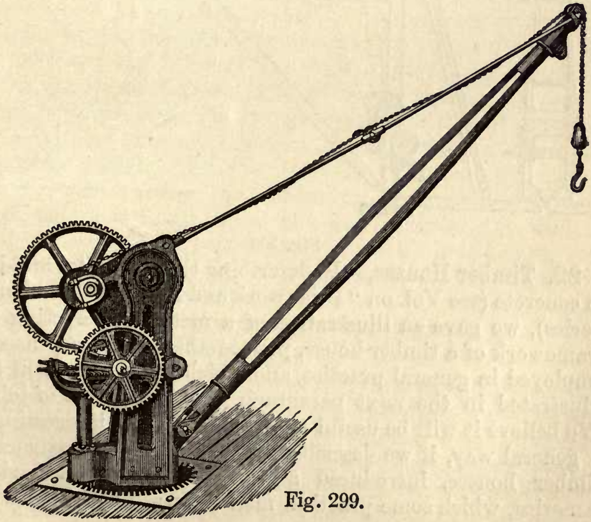


Fig. 299.

apparatus *b*, which is also provided with gearing to enable it to be traversed along the girder *a a* as required—this being supported by the "verticals," or "gantrees," *c c*—the side shoring of which, in one form, is shown at *a* in fig. 298, which illustrates another form of "overhead traveller," in which steam is employed to hoist; the steam engine traversing from side to side along the beam when required, as well as along the rails of the gantrees *a b*. Fig. 299 illustrates an ordinary, and fig. 300 the "Derrick" form of lifting cranes.

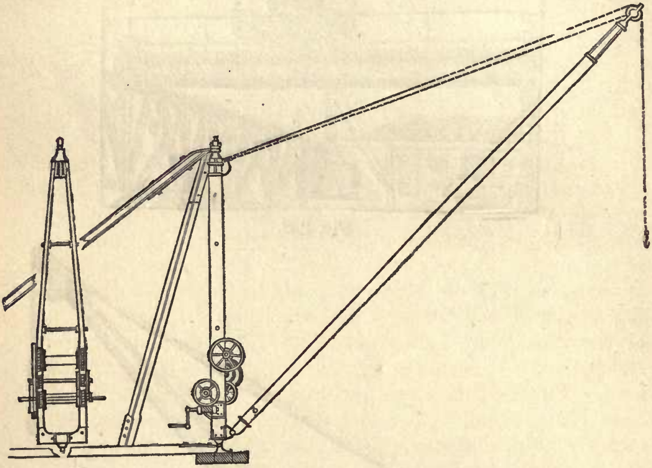


Fig. 300.

22. Timber Houses.—In describing the method of building in concrete (see Vol. on "Brickwork and Masonry," Advanced Series), we gave an illustration of a method of erecting the framework of a timber house, put together in the way usually employed in general practice, and which the student will find illustrated in the next paragraph, where we treat of joints. We believe it will be useful to the student, and interesting in a general way, if we describe here a method of constructing timber houses, introduced and now largely practised in America, which some practical men there say has none of the defects which the older fashioned method, in their belief, possesses. The new style of putting timber together claims to be not only more quickly put in hand than the old method, but enables much lighter materials to be used; hence saving expense in first cost, dispenses with many, if not nearly all, of the usual operations of "carpentry;" thus saves money in labour; and, lastly, gives with lighter materials stronger structures. So far as a strict examination of the principles of this system of timber framing, and a review of the large number of structures which have been built upon it, show, it is difficult to believe otherwise than that these important claims have been and are fairly met.

The system is named the "Balloon Frame System," although why that name has been given to it we fail to see, unless indeed upon the principle of "lucus a non lucendo;" inasmuch as the buildings once fixed on solid earth will be so firmly attached thereto, that the heaviest hurricane will not make them, balloon fashion, fly. Be this as it may, we now proceed to note the chief details of the system thus oddly named. The principle followed out in the system is the employment of the timber in such a way that all the strains, or as many of them as possible, shall be made to act in the direction of the length of the fibres of the wood, thus taking advantage of the strongest characteristic of wood, namely, its tensile strength, which is on the average one-fifth of that of wrought-iron. Timber thus employed can be used of much less thickness than usual. Another feature is dispensing almost entirely with cutting the timber so as to obtain notches, scarfs, tenons, etc., all these, with one exception (fig. 305, at *a b c*) being dispensed with; and the securing of the various parts together being made dependent entirely upon the nails. These are driven, as will be seen from the diagrams, diagonally, rarely, if ever, at right angles to any part. The value of the "diagonal" principle, applicable as it is to a great variety of mechanical purposes, is not so well known and acted upon as it ought to be. The adoption of it in this case, acting in conjunction with the plan of dispensing with the usual methods of notching and cutting the timbers, tends materially to give the maximum of strength with the minimum of material in the structure.

The first part of the work to be done, say in building a cottage on this system, is the laying of the sill, *a a*, fig. 301. This may or may not be laid down upon a base of brick or stone, which some would deem necessary to keep off the damp from floor of house; but if the student will observe the arrangement shown in fig. 301, he will come to the conclusion that the floor will be drier than nine-tenths of the floors of cottages as usually built, and this from the distance kept between the surface of the soil—ever more or less damp, rarely dry—and the flooring boards *b b*. Still further,

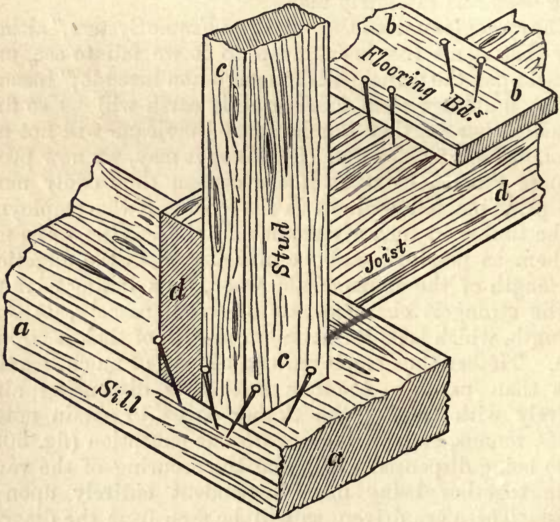


Fig 301

to secure dryness the space thus left may be filled with clinkers or non-absorbing materials. If, before the flooring boards *b b* be laid down, a layer of smithy clinkers or coke be put between and under the joists, the floor will be a very dry one. Of course it will be necessary to level the foundation or site upon which the sill *a*, fig. 301, is laid, and if the site or surface of soil within the boundaries of the sill be excavated or hollowed out a few inches deeper than the surrounding level, the house will be so much the drier, especially if the layer of clinkers be added as already specified. The sills for ordinary sized buildings—indeed for the general run—is eight inches by three, but six inches by three will suffice for small buildings. The sills may simply meet at the corners, the end of the side sill butting square up against the side of the sill at the end of the building, or if preferred the two sills may be spliced or scarfed with a half lap joint, as shown at *a b* in fig. 302. But this is opposed to the

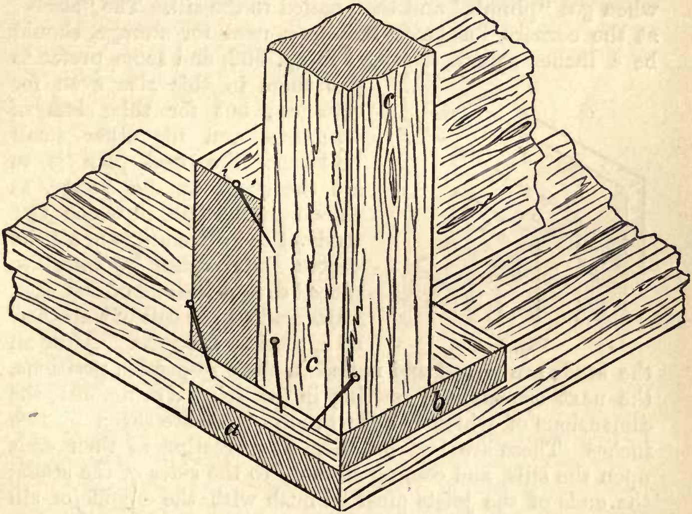


Fig. 302.

principle of the system. The sills being laid all round the outline of the building, and perfectly level—the level being tested by a spirit level or by a mason's square level—the next operation is putting up the vertical upright posts called "studs," as *c c* in fig. 301. The ends of these which rest upon the sills *a a* must be sawn off perfectly square. The scantling or dimensions of the studs is four inches by two, the length is immaterial, that is, the studs need not at first be cut to the exact length before being set up, as they can all be easily cut when necessary. The back stud must be held in place till nailed, the nails being driven in diagonally; four nails are used to each stud, two to each side. The stud must be kept temporarily in position by nailing two laths or pieces of wood to act as stays or struts to the stud and the side of sill. The distance between each stud, from centre to centre, is sixteen inches, excepting at those parts where windows and doors are inserted; at such points the distance between the studs corresponds to the desired width of window or door opening. Each stud is set up, stayed with the lath when got "plumb," and then nailed to the sill. The "studs" at the corners, for large buildings used for storage, should be 4 inches square, as at *c c* in fig. 302, and some prefer to put them in this size even for cottages; but for this class of structure, and for other small buildings, the best plan is to set the studs at the corner, as shown in fig. 303, in which two studs of the dimensions of all the others, four inches by two, are placed so that the end of one, as *a*, butts against the side of the other, as *b*, *c* being the joist. After all the studs are placed and nailed in their respective positions, the next operation is putting in the joists *d d*, fig. 301, the dimensions of which for the ground floor are seven by two inches. These are laid on their edges resting at their ends upon the sills, and coming close up to the sides of the studs; the ends of the joists must be flush with the outside of sill and stud, as shown in figs. 301 and 302. Each joist has two nails at the end, one driven into the side of the stud, the other into the face of the sill, and both driven diagonally. The flooring boards *b b*, fig. 301, run at right angles to the joists, and are also nailed diagonally to the latter as shown.

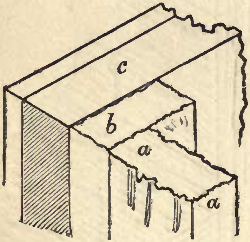


Fig. 303.

The next operation is the putting in of the joists of the second floor, supposing the cottage to be of two storeys, this is shown at fig. 304. Take the intended height or distance from the upper surface of flooring boards *b b*, fig. 301, to the lower edge of joists of second floor, as *a a*, fig. 304, and mark it off with a saw draught upon the edge of a straight-edge,

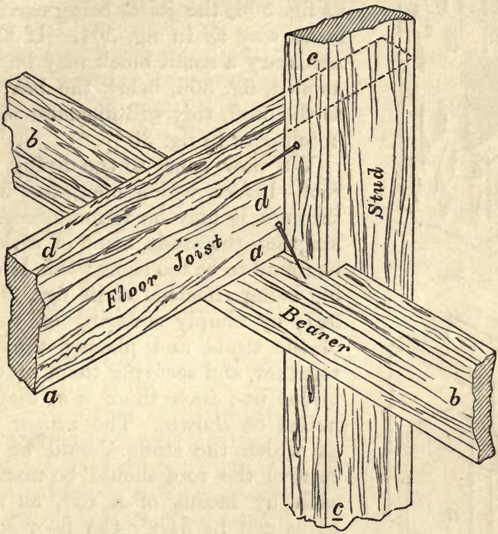


Fig. 304.

or wooden rod. With this mark off upon all the vertical studs the height of line of ceiling *a a*, fig. 304, *a b*, fig. 305, and at this line *a b*, fig. 305, cut on each inner side a notch four inches wide from *b* to *c*, and one inch deep from *c* to *d*; into these notches a bearer *b b*, fig. 304, is placed, and nailed diagonally to the stud *c c*. The floor joists *a d*, *a d* rest at their ends upon the bearer, and have their outer ends flush with the outside face of the stud *c c*, the two being secured by diagonally driven nails; one nail being driven into the stud, the other into the edge of the bearer. Simple as this arrangement is, it is so strong that the "joists will break in the centre before the bearing gives way—no tenoned joist in the old style of frame will hold half the weight." This bearing gives a perfectly flush surface to the whole inside ready for lathing and plastering; but if the inside is to

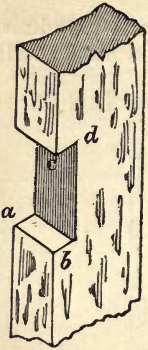


Fig. 305.

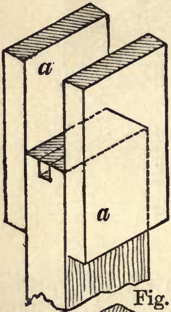


Fig. 307.

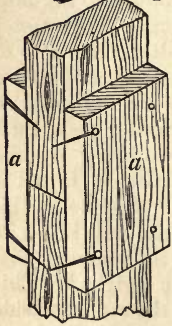


Fig. 306.

receive a boarded lining, the bearer, as *b b*, fig. 304, may simply be nailed to the inside edge of the stud as shown at fig. 306, the joists being carried the same way as in fig. 304. If thought necessary a small block may be nailed, as at *a*, fig. 306, below the bearer and to the stud, this will dispense with the notch *a b c* in fig. 304.

We now come to the fixing of the roof—before which operation is gone through it may be found necessary to lengthen the studs, some of which may be found to be too short; this lengthening being effected, as in figs. 306 and 307, by simply squaring off the ends of the studs and placing these ends together, and securing them by outside pieces one inch thick *a a*, diagonally nailed as shown. The proper height at which the studs should be cut to receive the roof should be marked on each by means of a rod, as already explained in fixing the floor joists of the second floor; and then all the studs are sawn square off. A wall plate, as *a a*, fig. 308, the dimensions of which are four inches by one inch, is nailed to the upper face of the studs *b b* in the manner shown in the drawing. This wall plate receives the lower ends of the rafters, as *a a*, fig. 309, which are notched in their lower edge so as to embrace the wall plate *c*; it will be noted that each rafter is placed exactly above the stud *b*, and as the studs are spaced to be 16 inches from centre to centre, this will be the spacing between the rafters *a a*, fig. 309. The notch in fig. 309 may be dispensed with by placing a wedgespiked piece below the rafter resting in the wall plate, the angle of the wedge being that of the slope of the roof. The dimensions of the rafters are 6 inches by 3 inches. The roof for the majority of cottage spans will be strong enough if made

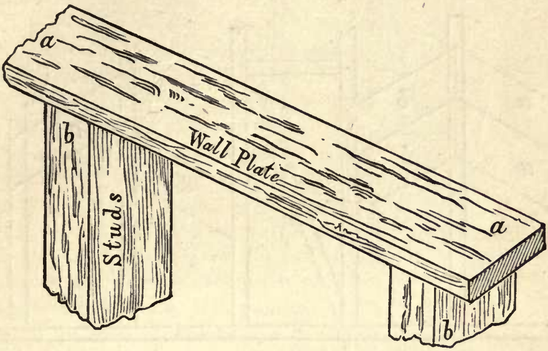


Fig. 308.

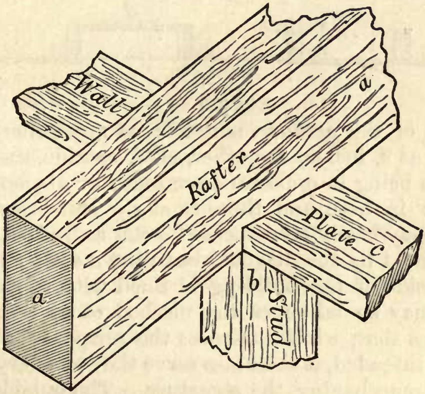


Fig. 309.

"collar beam" style, the dimensions of this being 4 inches, by 1 inch. If the cottage is lined inside, the strength of the structure will be greatly added to if the boarding constituting the lining be put in diagonally, and at *a* and *b*, fig. 310, one set of boards inclining, as at *a*, the other as at *b*. If these diagonal boards are only used at intervals by way of braces,

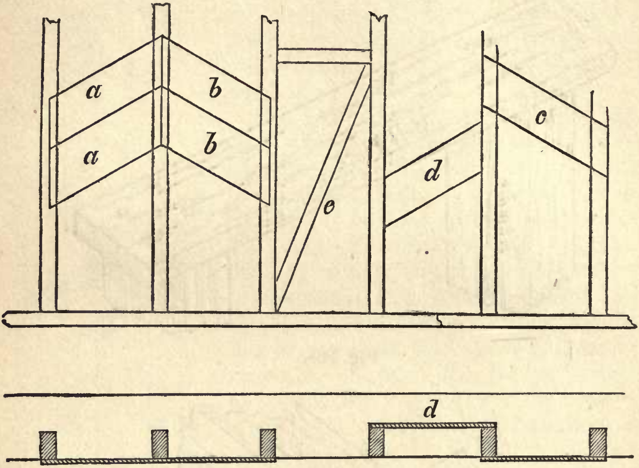


Fig. 310.

the strength of the arrangement will be much increased by placing one, as *c*, inside, the other, as *d*, outside, the inclination of these being in opposite directions; or diagonal braces may be put in here and there as at *e*. But braces of this latter kind may easily be dispensed with, as indeed may the bracing afforded by the diagonal boarding *a a*, *b b;* it is only when the inside of the building is lined with boarding that advantage may be taken of the method of so placing this diagonally, as that, while it serves the purpose for which it is primarily intended, it shall also serve the secondary purpose of greatly strengthening the structure. The outside will be "clap-boarded," either with horizontal or with vertical clap-boards, the latter being the best of the two; or in place of clap-boards, boarding with "rolls" or "feathers" may be used, this style of outside covering looking better than the clap-board system. In figs. 311, 312, we illustrate what is called the half-timbered style, and in figs. 2 and 4, Plate

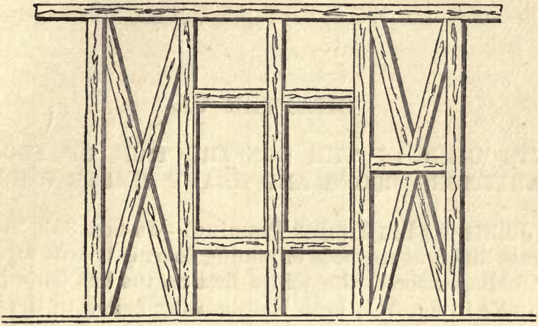


Fig. 311.

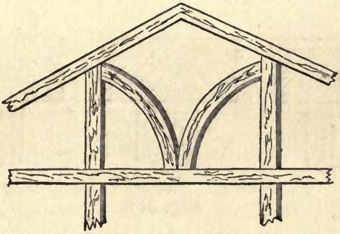


Fig. 312.

XLII., and fig. 1, Plate XLIII., we illustrate constructions in connection with timber sheds; fig. 2, Plate XLII., being a double folding gate; fig. 3, part section of roof; fig. 4, the finial of gable end; fig. 1, Plate XLIII., being a window with part underneath sill.

CHAPTER VI.

JOINTS USED IN THE CONSTRUCTION OF FLOORS, PARTITIONS, ROOFS, AND HEAVY TIMBER WORK.

23. Joints used in Timber Framing.—In figs. 313, 314, we illustrate different methods of joining flooring boards together. For "folding floors," the joints first on the left hand in fig. 313, and *c* in fig. 314, both boards being nailed to the joints at their edges, but when the boards are rebated, as at *b* in fig. 314, or centre drawing on fig. 313, or tongued and grooved as in third drawing in fig. 313 and *a* in fig. 314,

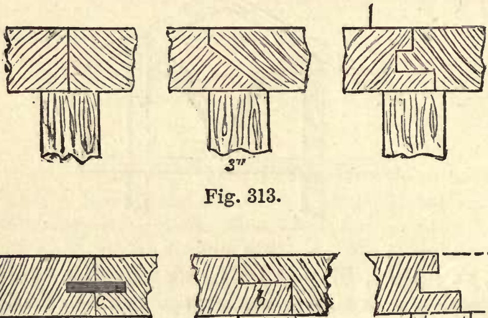


Fig. 313.

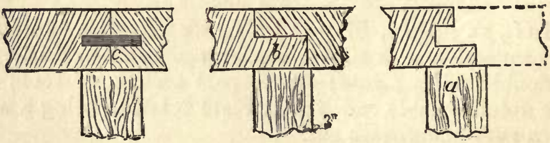


Fig. 314.

only one edge or board is nailed down. Flooring boards vary in breadth from 5 to 9 inches, with a varying thickness of from $\frac{3}{4}$ to 2 inches; a general average being 1 to $1\frac{1}{4}$ inches. The methods of joining the joists of a floor to the wall are various, a common method is illustrated in fig. 315, *a* the flooring joist, *b* the wall plate on which a groove is cut, *c* the wall plate, to allow the lower edge of the joist to pass into it, the depth of the groove, as at *d*, being equal to the depth to which the joist is to enter. In fig. 316 another method is illustrated, a part being cut out on the face of the wall plate, as in fig. 315, of same width as the thickness of the joist, but a rib, *a a*, is left in the centre, across its breadth; this goes into a groove *b*, cut in the lower edge of the joist,

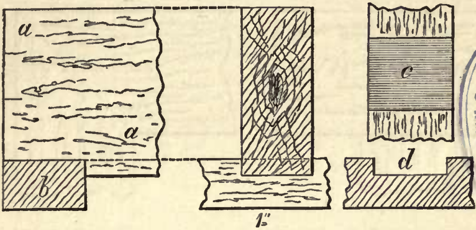


Fig. 315.

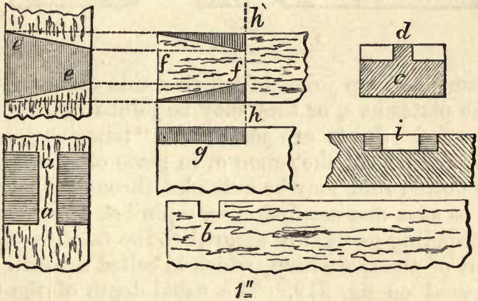


Fig. 316.

and of the same depth as the rib *a a*; a cross section of the wall plate is shown at *c d*, showing the rib *a a*. Dovetail joints are sometimes used in connecting joists with wall plates, the best form being that illustrated in fig. 316, well known as the "swallow-tail" joint. In this a part is cut out in the upper face of the wall plate as at *e e*, the end of the joist on its lower edge being formed of the corresponding shape, as at *f f*; the side elevation of this is shown at *g*, and a cross section on the line *h h* at *i*. Wall plates are joined together in the direction of their lengths by the "half-lap" joint at *a b*, fig. 317, and at the corner of the wall, as at *c*,

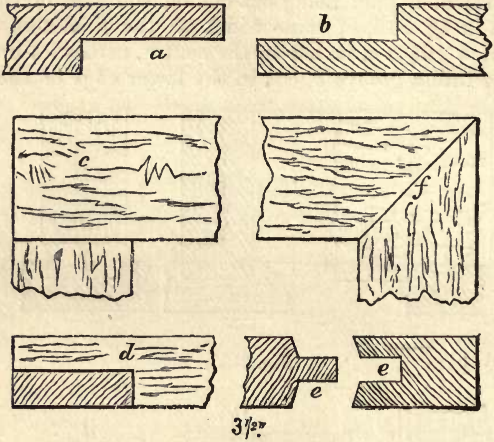


Fig 317.

by the same half-lap joint, of which a side elevation is at *d*, one of the plates at *e*, or they may be joined by the "mitre" joint, as at *f*. Joists are jointed to "trimmer joists," by the joint in fig. 318; the tenon *a*, in place of stopping short, as at the dotted line, may be extended through the trimming joist *b b*, as at *c*, and secured by a "pin" *d*, as shown. The ends of "binding joists" are secured to the faces of "girders" by a joint of the same kind, which is called a "tusk tenon," as illustrated on fig. 319. The usual depth of the tenon *a* is one-sixth of the whole depth of the binding joist *b*; and the plate of the tenon *c* is one-third of the depth of the joist measured from its lower side. The "ceiling joists" *a*, fig. 320, are joined to the "binding joists" *b b*; a notch *c* is cut out of the lower edge of the binding joist, into which the ceiling joist *a* is passed; *c* shows the under side of binding joist with notch *e* cut out of it. Another method is adopted in which a chase or sunk part *a*, fig. 321, is cut out, in a horizontal direction, on one face of the binding joist *b*, near its lower edge, the end of the ceiling joist *c* being provided with a projecting part or tenon *d* passing into the chase or mortice *a*.

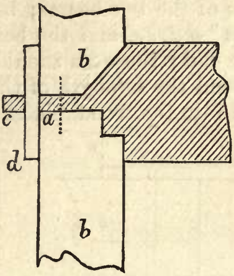


Fig 318.

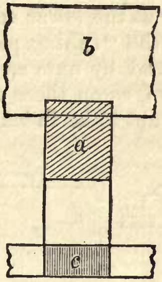


Fig. 320.

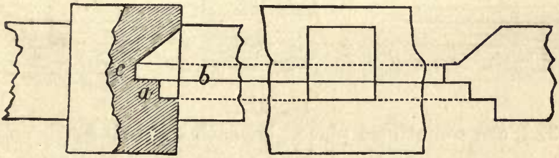


Fig. 319.

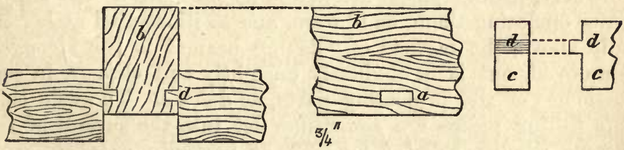


Fig. 321.

24. Lengthening of Beams.—Where "beams" are required of such lengths as prevent them being in one piece, two beams are lengthened by joining them in various ways. The simplest and the strongest mode of joining two timbers together in the direction of their length is what is known as "fishing." In this the two beams *a* and *b*, fig. 322, to be joined, have their ends carefully squared off, and made to butt against each other at *c*; they are kept together and secured by the flat pieces of timber *d d*, *e e*, one placed at the upper, the other at the lower edges of the two beams; bolts, *f g*, pass through the "fishing pieces" *d d*, *e e*, and the beams *a b*, and are secured by nuts at the end; the nuts should be screwed tightly up, as on these depend the strength of the joints. As they are apt to be indented into the wood, plates of iron, as *i*,

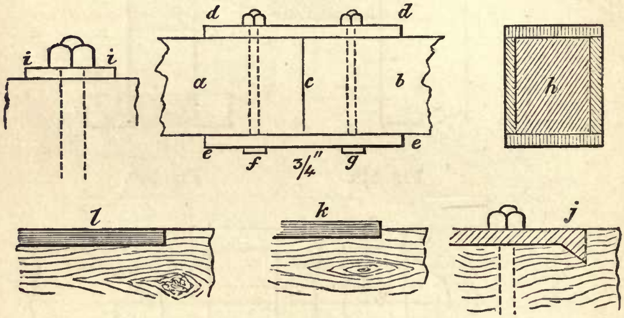


Fig. 322.

fig. 322, are sometimes placed beneath the bolt-heads and the nuts, or in place of the fishing pieces being of timber, as at *d d*, they are of iron, as shown at *j*. Usually two fishing pieces are employed, as in fig. 322 at *d e*; in some cases, however, fishing pieces are placed at the sides of the beams, thus enclosing them, as it were, and as illustrated at *h*. As said above, the method of "fishing beams" is the strongest employed, but it is obviously unsightly and clumsy, in consequence of the projecting parts, as *d d*, *e e*. To avoid this, the fishing pieces are sometimes let into the surface of the beams wholly, as at *l*, fig. 322, or partially, as at *k*, same figure; but this method, although adding to the sightliness of the joint, greatly takes from its strength. Other methods are therefore adopted, where appearance can be gained without sacrificing the strength of the joint too much. The principle upon which those other joints are made is that known as **scarfing**, which enables the joint to present a smooth, or rather flush appearance on all sides. The simplest form of scarfed joint, known as the **half lap**, with flat or rectangular "tables," by which term the projecting parts or scarf joints are designated, is illustrated in fig. 323. In this a part *a b c* is cut out at the end of each beam, equal in depth to half of the full depth of beam, and of length equal to the required length of scarf. The two ends, when brought together, form the joint, as in fig. 323, the projecting part of one, as *d*, falling into the recessed part *e* of the other. The two are secured together by the timber or iron plates *f*, *g*, and by screw bolts and nuts; *h i j k l* show different sections.

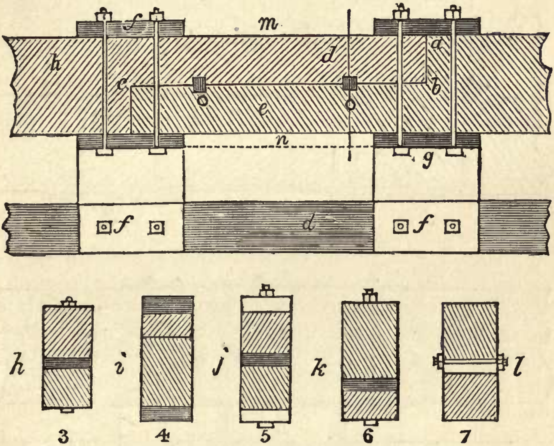


Fig. 323.

The plates are better when extending beyond the ends of the joints, as shown in the drawing. In place of being short they may be as long as shown by the dotted line *n*. In addition to the bolts and nuts, "keys," as *o o*, are sometimes added. Fig. 324 illustrates another form of the "half-lap" joint, A being vertical section, B horizontal section on the line *a′ b′*. A very common form of scarfed joint, with angular or oblique "table," is illustrated in fig. 325, where the meeting faces of the two beams, *a* and *b*, is oblique, as at *c c*; the ends being indented angularly, as at *d e*; the two being secured together by the plates *f f*, *g g*. Another form of scarfed joint,

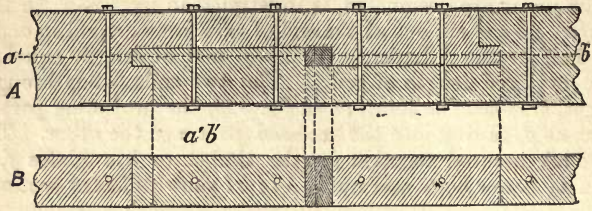


Fig. 324.

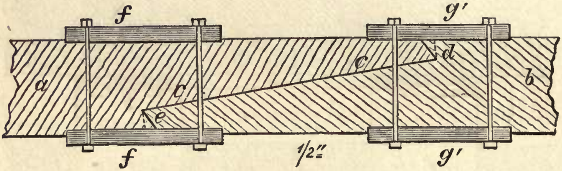


Fig. 325.

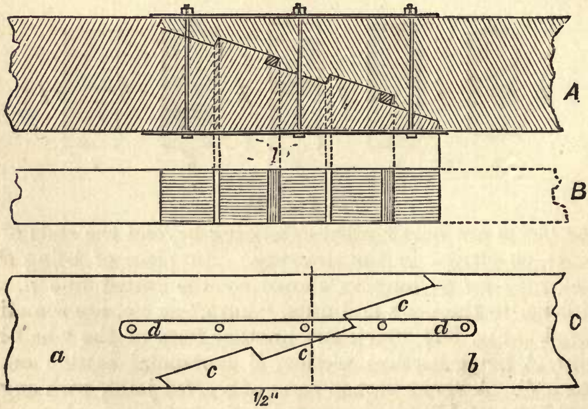


Fig. 326.

with three tables, is illustrated in fig. 326—*a b*, the two beams; *c c*, the oblique tables, an iron plate *d d* securing the two. At A a scarf joint with five tables is shown, B the plan.

25. Increasing the Depth of Beam.—Where beams are required to be of greater depth than can be conveniently obtained by a single beam, two beams are laid edge to edge, and secured in various ways. Fig. 327 illustrates one method

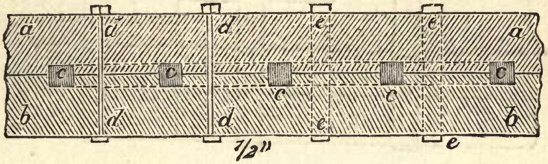


Fig. 327.

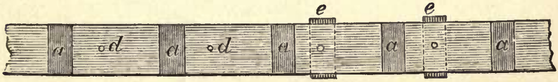


Fig. 328.

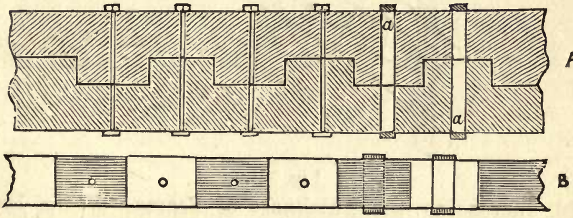


Fig. 329.

known as **cogging, caulking** or **keying.** A series of grooves, as *a a*, fig. 328—which is a plan of the upper edge of the lower beam *b b* in fig. 327—are cut in the edges of the beam, at equal distances, as shown, and keys or cogs *c c* driven into the grooves. These prevent all lateral or side movements of the two beams *a a*, *b b* upon one another; and the beams are secured and kept together vertically by the screw bolts *d d*. In place of these, straps, as *e e*, are sometimes employed. These are also sometimes used in place of bolts in scarfing of beams, already illustrated, and also at *a a*, fig. 329 (A). Other methods of increasing the depth of beams are illustrated in figs. 329, 330, 331. In figs. 329, 330, A is elevation and vertical sections, B plan. Fig. 331 is used in bridge work.

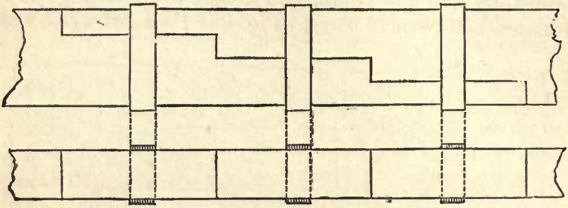


Fig. 330.

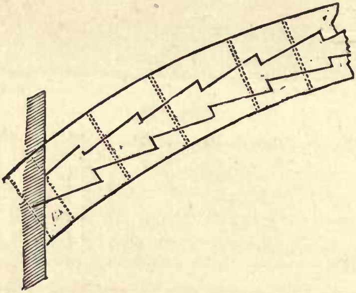


Fig. 331.

26. Increasing the Thickness of Beams.—When beams are required to be of great thickness, in place of employing one very thick beam, two beams, *a* and *b*, fig. 332, are used, laid face to face, and strengthened either by inserting a **flitch** or plate of wrought-iron *c* between the two beams, and securing them together by screw bolts and nuts. The arrangement thus shown is sometimes called a "sandwich" beam, although generally a "flitch" beam. In fig. 332, A is a cross section, B elevation of the iron flitch, C plan of top. The two beams are secured together by screw bolts, which pass through the beams *a*, *b*, and the flitch *c*, as at *d d*. In figs. 3, 4, 5, 6, Plate XLIII., we give different forms of "trussed beams," figs. 3 and 4 are trussed with flat cast-iron bars *a a b*, figs. 5 and 6 with wrought-iron rods *a a b*; in all these drawings A is an inside elevation of one beam, with the truss fixed in place, B is the plan of bottom edge looking upwards. The beam to be trussed is usually made out of two beams formed by cutting up a beam in the direction of its length, and reversing the sides, so that what formed the inside of the beam is turned to the outside. This plan of sawing up a single beam to form either a flitch beam or a trussed one is very good, as it exposes the central part of the wood to the action of the air, and shows defective parts. In fig. 4, Plate XLIII., *b* and *c* are the two beams, and A shows the

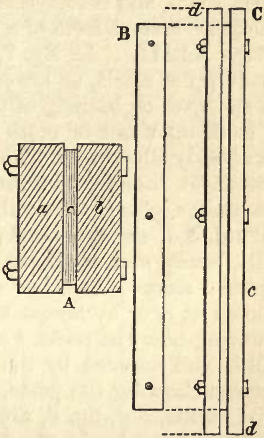


Fig. 332.

arrangement of the truss between the two. This consists of a central stud of wrought-iron, *d*, the head of which is formed with a plate which lies on the upper edges of the beam, as shown in plan at B; the lower part is provided with a screwed part and a nut, *c*, for tightening up the stud; the nut presses upon a small washer plate as shown. The upper part of the stud, *d*, fig. 4, Plate XLIII., is made with two angular butting faces, against which the upper ends of the struts or braces, *a a*, of hard wood or of iron butt, the low end butting against the stud *f*. This stud is provided with a bolt, *g*, to resist the pressure and keep it in place; or the stud is made wider, and let in at both sides into grooves cut in the faces of the two beams. The whole parts are further secured by bolts, *h*. Fig. 3, Plate XLIII., is part elevation and part plan of a beam trussed on the queen post principle, a straining piece, *b*, being placed between the two studs, *c*;

a the struts. In Plate XLIII., figs. 7 and 8, the elevation of a method of forming girder beams of greater depth than could be made out of a single beam or of two beams, is illustrated. This form, as the student will perceive, is an open beam, and is sometimes called a "trellis beam," although the more correct form of a trellis beam is illustrated in fig. 2, Plate XLIII. In fig. 7, Plate XLIII, the open beam is made up of a **sill**, or lower beam, *a a*, this may be according to the span or bearing of the beam—either in one length, or if made up of one or more lengths, these may be **scarf** jointed as already illustrated. The "head," or upper beam, *b b*, supported at intervals by **studs, posts,** or **puncheons,** or short beams, *c c*, placed vertically. Between the beams, **braces** or **struts,** *d d*, are stretched; butting at the ends against the sills, heads, and studs, as shown. The heads and sills are further secured together either by screw bolts and nuts as shown at *e*, or by straps at *f*. Fig. 9 is a vertical section showing how the posts, *c c*, are mortised into the head *b*, and sill *a*, and secured by the bolt *e*, or strap *f*. Fig. 11 is a section showing the parts, *a a*, in which the ends of the cast-iron struts, *d d*, fig. 8, are placed; the struts *d d*, fig. 7, are wholly of wood. In the "trellis beam," fig. 2, Plate XLIII., the space between the heads and sills is filled up by double strutting, forming a series of diagonal squares or openings. Fig. 10 shows a method of making the central stud of a king post trussed beam other than that shown in fig. 5.

27. Brestsummers, or Bressumers, are beams of considerable thickness and depth thrown across wide openings, as that of a shop front, to support breast of front wall, built above the opening. They may be strengthened by one or other of the methods just described, and should have a bearing of at least nine inches in the wall at each end. "Templates" of stone, or timber, should be used, on which the ends of the brestsummer rests; a very usual size for the brestsummer is 14 in. by 12, or 14 in. by 9. A **lintel** is a beam or small brestsummer thrown across a narrow opening made in a wall, as that for a window or door opening of the usual width. It is the ordinary practice to allow one inch in depth for each foot of width of opening; a good proportion for a lintel is 7 in. by 5. The bearing on the wall should be nine inches. If the wall be thick, two or more lintels are used; and it is good practice to give the lintels a bearing upon oak templates, which should stretch across the full breadth of wall.

28. Joints used in the Construction of Partitions.—In fig. 333 we illustrate the various forms of joints used for this purpose; *a*, *b*, and *c* illustrate one method of joining the foot of "post" *a*, with the cill *b*; *c* a plan of same showing the "mortice" *d*, into which the "tenon" *e*, is passed;

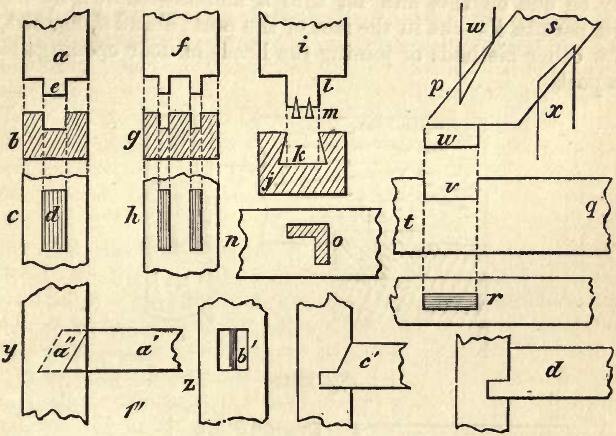


Fig. 333.

f, *g*, and *h* illustrate another method in which a "double tenon" is used, *f* being elevation of post, *g* "cill," *h* part plan. In *i* and *j* the elevation and section of a third method is shown, this being what is called a "foxtail" tenon and mortice; *k* the mortice made with "dovetail" sides; *l* the tenon, in the under side of which the two smaller wedges *m* are driven. When the post is driven home, these wedges *m* force out the sides of the tenon *l*, and make it fill up the space of the mortice *k*. In *n*, *o* shows a mortice of another form, the tenon at foot of post being made to fit into this. Tenons are sometimes made in the form of a cross, the arms of which are at right angles to each other; at *p*, *q*, and *r*, we illustrate a method of joining the foot of a brace or strut *s* to the cill *t*, by a tenon *w* partly cut at the foot of *s*, which goes into the mortice *v*, plan in *r*; *w* and *x* show methods of joining the fitting-in pieces or studs in the brace or strut *s*, the feet and heads of the fitting-in pieces being jointed to the "cill" and the "head" of the partition by the method shown in *a*, *b*, and *c*, fig. 333, at *e* and *d*; *y* and *z*, same figure, illustrate a method of joining the head *a′* of a door opening to the posts, by the sloping shoulder; a tenon *a″* may be cut on this and let into a mortice—shown by the dark part in *b′*—cut in the face of the post; *c′* and *d*, fig. 333, show other methods of joining the heads of door openings to the posts.

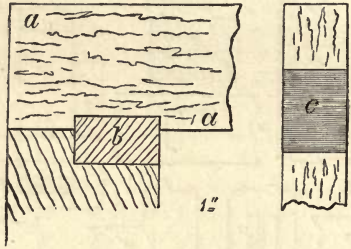


Fig. 334.

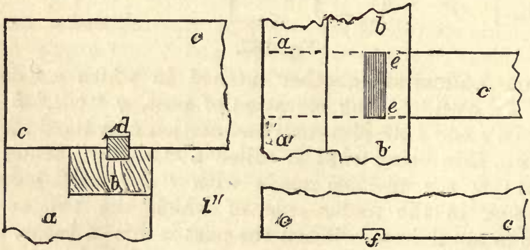


Fig. 335.

29. Joints used in the Construction of Floors.—In fig. 334 is illustrated a simple method of *joining tie beam a a to the wall plate b;* a notch, as *c*, being cut in the lower edge of tie beam to admit of the wall plate passing into it. This joint is improved by adding a "key," as *d*, in fig. 335, shown in plan at *e e*; *f* shows the notch cut in lower edge of tie beam *c c*, into which the upper part of "key," or "cog," *d* fits; *a a* is the wall, *b b* the wall-plate. In fig. 336 we illustrate a method of *joining a "pole plate" b to the tie beam a a*, by a notch *c* cut in the upper edge of tie beam *d*. In

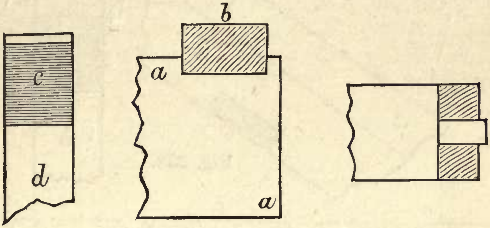


Fig. 336.

fig. 337 another method is illustrated in which a "key" or "cog" *a* is used. Fig. 338 illustrates a method of *joining the joists a a of floor to the wall plate b b*; a chase *c c* is cut out in face of wall plate, but with a rib or key *d* left in its centre; this rib passes into the part *e″*, cut out of the edge of the joist

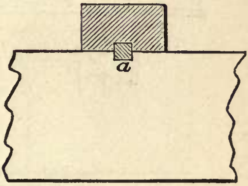


Fig. 337.

aa, being plan of same; another method is illustrated at *e″*, this part being cut out of lower edge of joist, which is made to embrace the wall plate *b b*, this remaining uncut. In fig. 339 are illustrated, at *a b c*, three other different ways of joining joists to wall plates, or when one timber crosses another at right angles; the dotted lines show the joists; in *c*, a wedge *d* is used to tighten up the joist. Fig. 340 illustrates an arrangement in which the tie beam *a a* is secured to a cross beam *b*, *c* being the plan of under edge of *a a*. The *joining the foot of a rafter with the tie beam* is done in a variety of ways; two ways, at *a* and *b*, fig. 341, are shown. The simplest method of effecting the junction is shown at *c*,

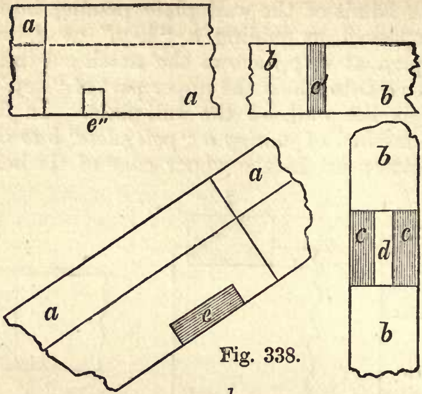


Fig. 338.

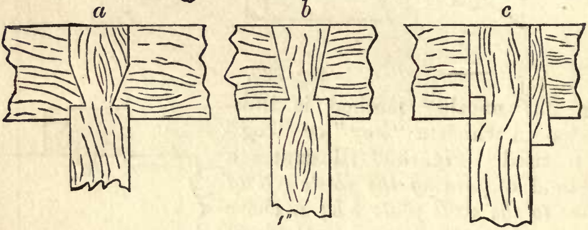


Fig. 339.

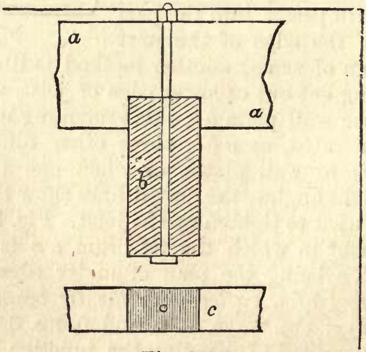


Fig. 340.

same figure; but this is very weak, the whole strength of the joist depending upon the nail which secures it to the beam.

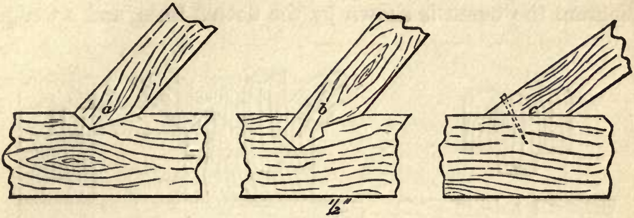


Fig. 341.

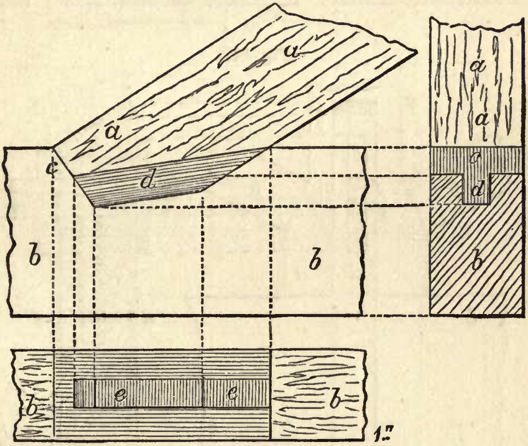


Fig. 342.

By cutting slots on the face of the beam of the same shape as the feet *a b* of the rafters, the joint is rendered much stronger. In fig. 342 another method is illustrated, in this a tenon *d* is cut on the sloping face of the foot of rafter *a a*, which goes into the mortice *e e* in face of tie beam *b b*. In all these joints with sloping faces the butting end, as *c*, should be at right angles to the upper line of face of rafter *a a*. Fig. 343

illustrates two methods of *joining the foot of a king post with the tie beam;* at *a* a tenon is cut on foot of rafter which goes into the mortice *b* cut in upper side of tie beam; in the lower diagram the tenon is shown by the dotted lines, and a wedge

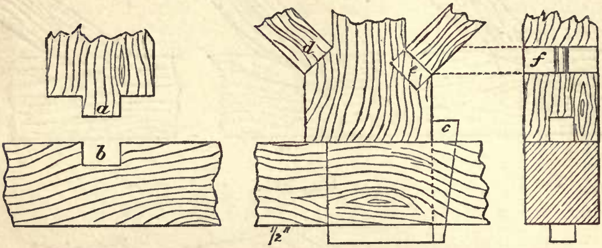


Fig. 343.

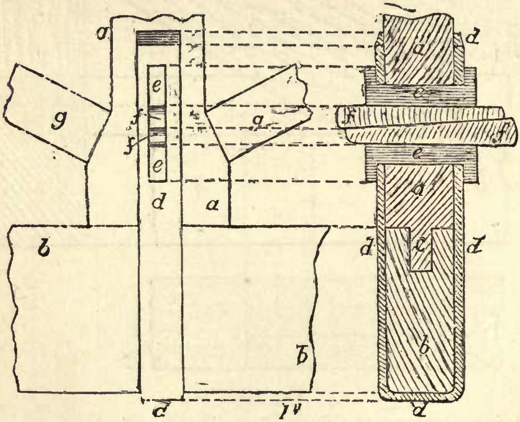


Fig. 344.

c is used. In fig. 344 a more complicated method is shown, in which an iron strap is used to unite the foot of the king post *a a* with the tie beam *b b*, the foot of the king post is tenoned at *c* into the tie beam; *d d* the strap, *e e* the iron "gibs," *f f* the "keys," for driving all up tight. The feet of the *common rafters are joined to the pole plate,* as in fig. 345, at *a b*, where no pole plate is used, the wall plate is placed near the outside line of wall, and the common rafters joined to it, as at *c*, fig. 345. The *junction of feet of struts or braces with the foot of king post* is illustrated in fig. 343, the simplest method being shown at *d*, the end butting against the sloping shoulders of king post. A better and stronger method is shown at *e*, a tenon being cut at end of strut, passing into a mortice *f* cut in shoulder of king post. The *junction of upper end of strut with head of king post* is illustrated in fig. 346, in two methods—one on each side of the centre line *a′ b′*, at *b c* a simple tenon *d* is made, the face *b c* being of the same width as that of the strut *i*, to shorten this face the joint *e f g′* is some-

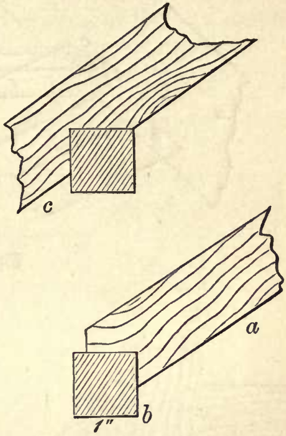


Fig. 345.

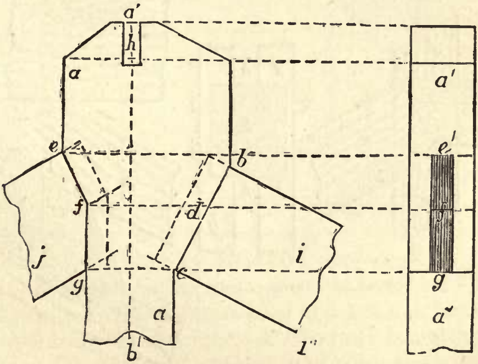


Fig. 346.

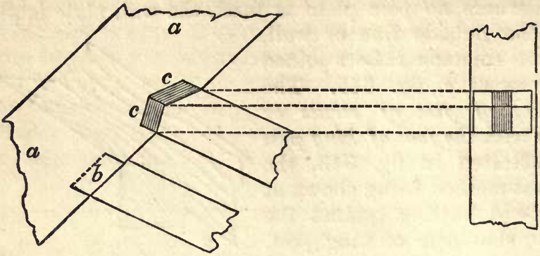


Fig. 347.

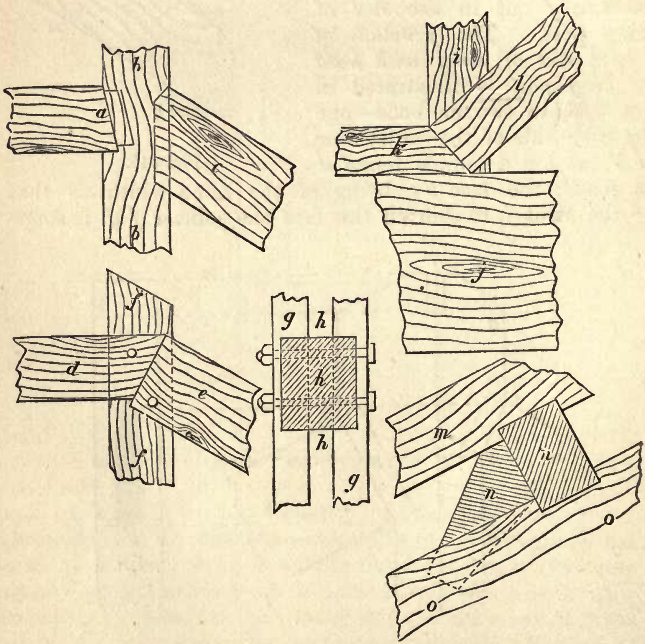


Fig. 348.

times used, an angular tenon *f* being given to the strut *j*. The ridge pole is inserted in the grove *h*. The *strut or brace* corresponding to *g g*, in fig. 344, may be *joined to the under side of rafter a a*, fig. 347, by one or other of the two methods shown; as by a simple tenon at *b*, or by an angular tenon at *c c*. In fig. 348 we show the method of *joining head of "straining beam" a of a queen-post roof with "head" of "queen post" b*, *c* being the end of the principal rafter.

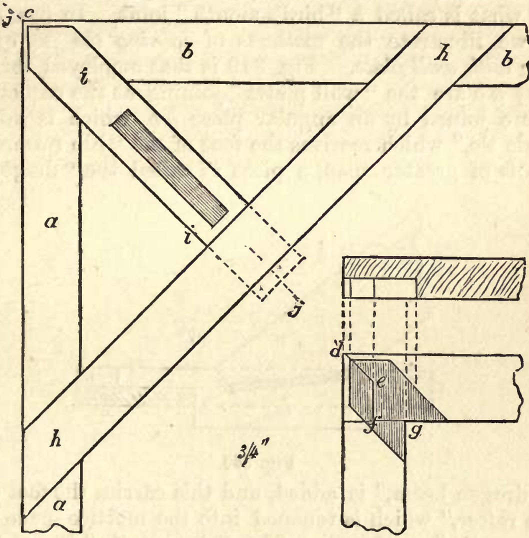


Fig. 349.

Another method is shown at *d e*, the queen post *f f* being made in two pieces, as at *g g*, the "straining-cill" and strut *e* being placed between these pieces, as at *h*, and the whole being secured together by bolts and nuts as shown. In same figure, *i* shows the *foot of queen post connected with tie beam j*, and the end of "straining-cill" *k* and strut joined in same way to the queen post *i*, made of two pieces as at *g g*. In the same figure *n* shows a "*purlin*" *and a method of joining it to the "principal rafter" o*; the purlin *h* butting up against the piece *n* fitting into a groove made in the upper face of the principal rafter *o*, *m* common rafter. In fig. 3, Plate XXXIX., is illustrated the usual method of *joining the collar beam a with the rafter b*, a part being cut out at *c*; if the faces of the collar beam and rafters are required to be made flush, the junction is made with a "half-lap" joint, half of the part of collar beam being cut away and half of the rafter being sunk with a groove or mortice of the shape of *c*; *d* shows the *junction of foot of rafter with wall plate*, with what is called a "bird's-mouth" joint. In figs. 349 to 351 we illustrate the methods of *joining the feet of cross rafter with wall plate.* Fig. 349 is that employed for small roofs; *a b* are the "wall plates" joining at the corner *j*, the two are joined by an angular piece *h h*, which is called an "angle tie," which receives the foot of the "hip rafter;" but in roofs of greater span, a piece *i i* called the "dragon tie,"

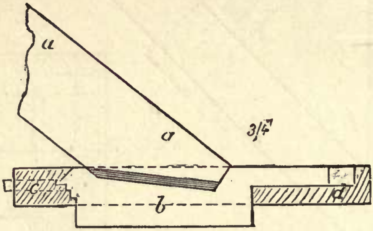


Fig. 350.

or "dragon beam," is added, and this carries the foot of the "hip rafter," which is tenoned into the mortice made in the "dragon tie," as shown. The "dragon tie" *b*, fig. 350, is tenoned into the "angle tie" *h h*, fig. 349, by a "tusk tenon" *c*, the other end of the dragon tie at the corner *e*, fig. 349, is half lapped to the wall plates, as shown at *d*, fig. 350.

PART II.—JOINERY.

PART II.—JOINERY.

CHAPTER I.

DOORS—PANELS—MOULDINGS.

30. Varieties of Doors.—In fig. 351 we give an illustration of that class of doors in which there are no "panels" employed, this class having four members, as follows:—"Ledged door," this is constructed with a series of vertical boards *a a*, from one inch to two inches thick, "tongued and grooved" into each other, or in bad work only laid edge to edge, these boards being held together by horizontal bars *b b*, a vertical section is at *a′ b″ b′*. A "ledged and braced door" is made up of vertical boards *c c*, horizontal bars *d d*, and diagonal braces *e e*. A "ledged and framed door" is made up of an outside frame *f g h i*, the spaces filled in with vertical boards *j j*. A "framed, braced, and ledged door" is made up of a frame *k l m* and *n*, with a horizontal bar *o*, braces *p p*, and ledged boards *q q*. The second class of doors is made up of a variety of forms, the two elements of which are a "framework," as *r s t u v w*, in fig. 351; and panels, as A, in fig. 1, Plate XLIV., which fill up the spaces, as *x*, in fig. 351, a six-panelled door is at 1, 2, 3, 4, 5, 6. The names of the doors vary according to the style—as a "four-panelled door," in fig. 1, Plate XLIV.; a "six-panelled door," in fig. 352; a "two-panelled door," as in fig. 353; a "folding door," as fig. 354, is made in two parts, hinged at each side, and opening in the centre; a "casement door," as in fig. 355, has the upper part framed with a window, the lower part only being panelled. The *frame* of a panelled door is made up of two vertical posts or pieces *s t*, fig. 351, B B fig. 1, Plate XLIV., these being called the "styles;" that style on which the hinges are fixed, as *r* in fig. 351, and B, fig. 1, Plate XLIV., is called the "hanging style;" those to which the lock is fixed, as *t* in fig. 351, and C in fig. 1, Plate XLIV., is called the "lock style;" the top cross-piece, as *u* fig. 351, and D D fig. 1, Plate XLIV., is called the "top rail;" the bottom cross-piece, as *s* fig. 351, E fig. 1, Plate XLIV., the "bottom rail;" the centre cross-piece *v*, fig. 351, and F F fig. 1, Plate XLIV., the "lock rail;" the vertical pieces in the centre, as *u u* fig. 351,

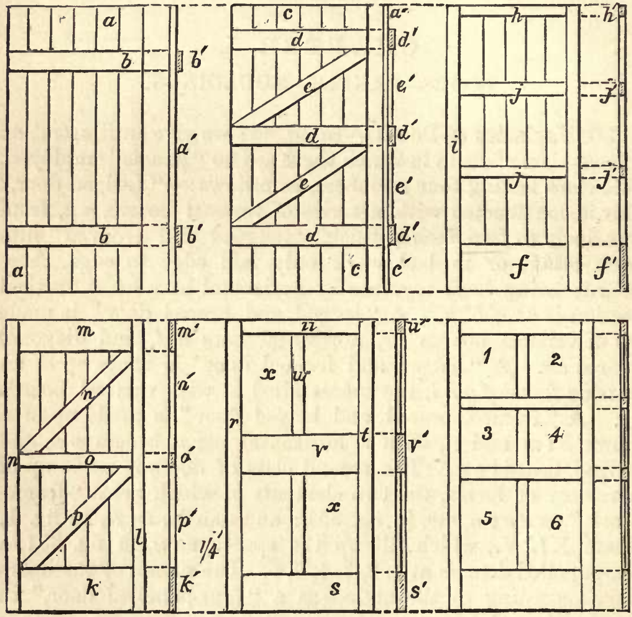


Fig. 351.

and G G fig. 1, Plate XLIV., are called "muntins." The spaces, as *x x*, fig. 351, are filled in with panels, as A, fig. 1., Plate XLIV., the panels being grooved or tongued into the frame, as shown in fig. 4, Plate L., which is a section on the line *a b* in fig. 1, Plate XLIV.; fig. 5, Plate L., being an elevation of fig. 4 same plate. *a a*, fig. 4, is the "muntin" (G G, fig. 1, Plate LXIV.); *gg* the ' panel;" *cc* the "mouldings," stuck or fixed on to the "panel" or to the "muntin." The panelled work, as *r s t u*, in fig. 351, is hinged, or "hung," as the technical term

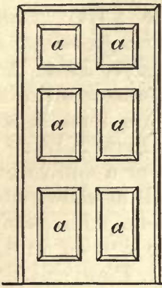


Fig 352.

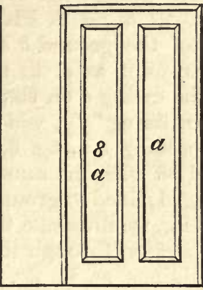


Fig. 353.

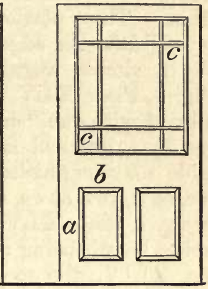


Fig. 354.

is, to what is called the "door casing," this being a framing of three parts, one horizontal, as *u* in fig. 351, which is called the "head," and two side vertical pieces, as *s* and *t*, which are called the "jambs;" these pieces are secured to "wood

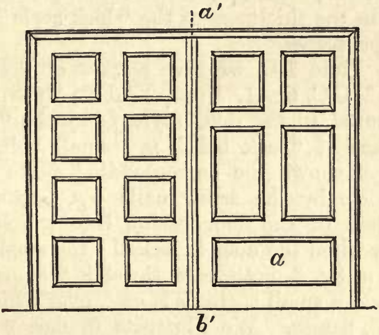


Fig. 355.

bricks," or "grounds," built into the wall or partition. The framework of a door, as *r s t u*, fig. 351, is surrounded, in good work, by mouldings more or less elaborate, as H H H in fig. 1, Plate XLIV., these mouldings are known as the "architrave" of a door, and the arrangement is shown in fig. 1, Plate XLV., in which *a a* is the "partition," *b b* the "jamb" of "door casing," *c* part of the "hanging style," B B, fig. 1, Plate XLIV., *d d* part of the "ground," *e e* the "architrave," with its mouldings, fig. 2 being the elevation of this. The "plaster," as *a*, fig. 8, Plate XLV., is either "keyed" into the edge of the ground *b* by a groove, as at *c*, or by a simple angular joint as *c* in fig. 7, Plate XLV. In fig. 1, Plate XLV, the casing *b* on the outside of the door *c* is lined with the "door lining" *f f*, which is finished at the edges by a quirked moulding *a a*, fig. 6, Plate XLV. The outside may be finished off with the same or a double architrave, as shown at *e e*, fig. 1, fixed to grounds as shown at *d d*.

In fig. 1, Plate XLVIII., we illustrate the mouldings of the skirting board, being a section through the line *e f* in fig. 1, Plate XLIV., the mouldings, as in fig. 1, Plate XLVIII., surmounting the flat fascia board H H, fig. 1, Plate XLIV. In fig. 1, Plate XLVIII., A is the section, B the elevation of the mouldings. In fig. 1, Plate XLIV., *g* is the "door handle," *h* the "handle of bolt," *i* the "scutcheon," or "escutcheon," covering the key-hole of the lock, which is a "mortice lock;" that is, the lock is concealed within a mortice cut in the thickness of the "lock style" C C of door; *j j* the "finger plates."

In fig. 3, Plate LI., we give a view of the edge of the "lock style" C C, fig. 1, Plate XLIV., showing the brass plate *i i* secured to the door style *j j* by the "screw nails" *k k*, *l* the face of "lock bolt," *m* "small bolt," *n* "handle bolt." Fig 2 shows the corresponding plate fixed to the door casing *o o* by the screw nails *p p*, *q* the opening to the hole made in the door casing into which the bolt *l*, fig. 3, passes when the door is locked; the small bolt *m* and handle bolt *n*, fig. 2, both pass through the opening *r r*; to the brass plate a small spring *s* is cast, over which the handle bolt *n*, fig. 3, passes. We illustrate in figs. 2 and 3, Plate XLIV., and in figs. 3 and 4, Plate XLV., the lock rail and panel of a door fitted with a "rim lock," that is, a lock secured to the outside of the door. In fig. 3, Plate XLIV., we give part of the front or inside (towards the room) elevation of the door—for a bedroom—which is four-panelled, the panels being surrounded on the side next the room with mouldings *c d*, fig. 3, Plate XLIV., and shown in section in fig. 2, Plate XLIV.; but which are flat, as at *a a* in this figure, towards the passage or landing. In fig. 2, Plate XLIV., *b b* is the panel, *c* the moulding outside this, *d d* part of the lock style. In fig. 3, Plate XLIV., *c d* are the mouldings, *e e* part of "lock style," *f f* part of "lock rail," *g* the handle of door, *h* the brass "escutcheon" covering the keyhole of the lock. The manner of fitting on the lock is shown in edge view of lock style in fig. 3, Plate XLV., and in front view in fig. 4. In fig. 3, *a a* is part edge of "lock style," *b b* the ends of the "tenons" by which the "lock rail" *a a*, fig. 4, is secured to the style, *c c* parts of the panel mouldings corresponding to *c*, fig. 1, Plate XLIV., *d d'* the handles inside and outside the door, *e* "handle bolt," *f* "lock bolt," *g* small "bolt," "latch lock," or "snib," moved in and out by the plate *h*. In fig. 4, Plate XLV., *a a* is part of lock rail, *b b* part of "lock style," *c* handle of "rim lock," *d* escutcheon of keyhole of lock, *e* handle bolt, *f f* screw nails securing rim lock to door.

31. **Panels** are grooved into the rails and styles of a door. In general, the grooves to receive the edges of the panels are one-third of the thickness of the framing. This, however, does not regulate the thickness of the panel, but this thickness depends upon the kind of panel. The varieties of panels are as follows, as in fig. 26, Plate LIII., where the panel *c c* is "square" back, *b*, and front, *a*; that is, where its surfaces do not come beyond the lines of groove in the framing *d d*; as in fig. 17, Plate LIII., where the panel *a* is called a "flush" panel, being two-thirds of the thickness of the framing *b b*, the face *c* being flush with the surfaces of the framing *b b*, the back *d* being "square." Fig. 19, Plate LIII., is a "raised" panel, the central part *a* being raised, its surface flush with the surfaces of the framing *b b*, the sides or margin *c c* sloping off as shown. Fig. 21, Plate LIII., shows another form of raised panel. When the centre of a raised panel is separated from the margin by a moulding, the panel is termed a "moulded raised panel," as at figs. 3 and 4, Plate LIII., at *a* and *b*. When the panel is "flush," and is provided with a moulding on its two edges running with the grain of the

wood, as at *a a*, fig. 22, Plate LIII., in section at *b b* in fig. 23, and in fig. 20, larger scale, it is said to be "bead and butt" or "bead butt." When the moulding is carried round the panel, but struck on the edges of the styles *a a*, fig. 24, Plate LIII., and rails *b b*, the moulding mitreing at the corners, it is said to be "bead and flush" or "bead flush," this is shown in section at fig. 25, and in larger scale in fig. 16. When the panel is "flush," the moulding is stuck on the framing, as at fig. 18, Plate LIII., at *a*, on all sides of the panel. When the moulding is struck or run on the framing, it is said to be "stuck on," see fig. 2, Plate LIII.; when it is secured on the panel, it is said to be "laid on," fig. 1, Plate LIII.

32. **Mouldings.**—Figs. 5 to 12, Plate L., show different kinds of mouldings for "panels," or for "architraves;" the principal elements of which are the "ovolo," as in fig. 12; the "cavetto," as in fig. 8; the "ogee," as in fig. 10; figs. 5, 6, 9, 11, are quirked mouldings; fig. 7 is what is termed "ovolo and bead;" fig. 6 "quirked ovolo, bead, and fillet;" fig. 5 "quirked ogee, fillet, and bead." All mouldings which which project from the surface, as *a* in fig. 18, whatever be their outline, are known by the generic term of "bolection" mouldings. The following are what are called the regular mouldings.

In Plate LIV., fig. 1, we give the fillet at *a a*, the office of which is to divide different mouldings, in an assemblage of mouldings, from each other. In same fig., *b* is what is called the "torus," "half round," or "bead;" when it projects from the surfaces, as from *c d*, it is termed a "cock bead." When a number of small beads run parallel to each other, as in fig. 356, the assemblage is called a "reeding." When the top *a* of a bead *b*, fig. 2, Plate LIV., is flush with the face *c*, and separated by a hollow part or return *d*, it is called a "quirked bead;" if the returns are double, as at *a* and *b*, fig. 3, it is called a "double quirk." In fig. 4 we show the

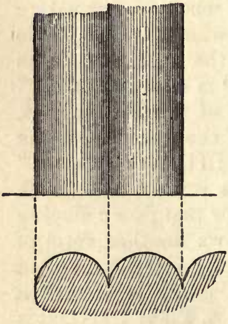


Fig. 356.

"ovolo" or "quarter round," fig. 5 being another form of the same; fig. 6 is the "cavetto" or "hollow;" fig. 7 the "scolia;" fig. 8 the "cyma recta;" fig. 9 the "cyma reverse," sometimes called the "ogee;" fig. 10 is a moulding often used in the bases of parts in which mouldings are required to connect a lower fillet *a* with an upper one *b*. Fig. 14 is the "congee;" if this is reversed so as to have the fillet under, it is called the "apophygee," and is used to connect the lower fillet, say of *a*, the base of a column, with the face *b* of the column itself. Fig. 15 illustrates at *a a* the termination of what is called a "raking moulding," the lines of which incline, as at *b*, to the line *c*, terminated by *d*, which are the ordinary mouldings of which *a a* is the raking termination. The method of finding the outline *a a* from that at *d* will be found in *Technical Drawing and Projection as applied to Architecture and Building.*

Fig. 18 illustrates what are called "dentils," which are small pieces with flat faces, as *a a*, which project from a surface, as *e e*, below mouldings, as *d d*, fig. 22. Fig. 22 illustrates the assemblage of mouldings known as an "impost," being the part from which the ribs or mouldings of an arch, as *a a*, spring. The drawing to the right is an elevation of the inside of the impost. Figs. 357 and 358 illustrate different methods of "fluting surfaces," and figs. 356, 359, and 360, of reedings. In figs. 11, 12, 13, 16, 17, 19, 20, 21, Plate LIV., different "Gothic" mouldings are illustrated; fig. 17 belonging to the "Norman" style; figs. 11 and 13 to the "early English;" figs. 20 and 16 to the "Decorated;" figs. 12, 19, and 21, to the "Perpendicular."

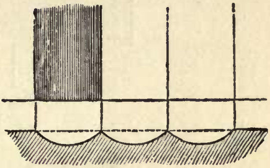


Fig. 357.

The student will find a description of the styles of Gothic architecture, and methods of describing the curves of the different mouldings, described in Parts I. and II. of the *Technical Drawing for Architects and Builders.*

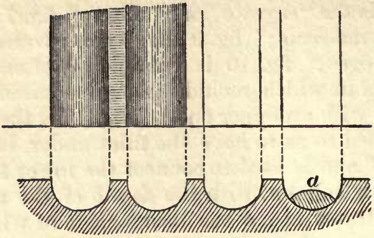


Fig. 358.

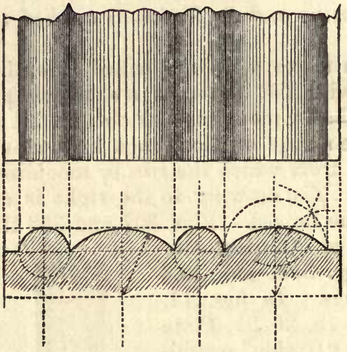


Fig. 359.

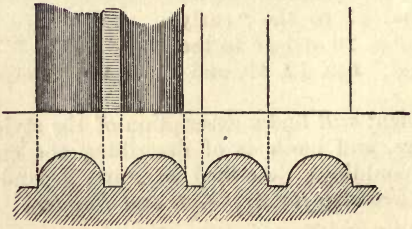


Fig. 360.

CHAPTER II.

WINDOWS.

33. **Varieties of Windows.**—Windows have their surfaces, as a general rule, flat, and more or less recessed from the surface of wall, in such cases they are known as "sash windows," as in fig. 1, Plate XLVII. A sash window may be either "fixed" in its casings or frame, or it may be "hung," as it is technically termed; that is, either the upper, as A, fig. 1, Plate XLVII., or lower sash B, may be capable of sliding up or down, the arrangement being known as "single hung;" or both halves A and B, as is usually the case, may be made to slide up or down, in which case the arrangement is known as "double hung." A "casement," or "French window," illustrated in fig. 1, Plate LI., has its upper part, as *a*, generally fixed, while the lower part is divided vertically into two parts B and C, which are made to open either inwards or outwards. A sliding or rolling window is shown in fig. 7, Plate XLVI. If the face of a window projects from surface of wall it is usually made as what is called a "bay window," illustrated in elevation, in fig. 361; the plan or outline of a bay window may be as fig. 362. A section of a bay window is given in fig. 15, Plate LIII., with part of the sash window of upper storey. When

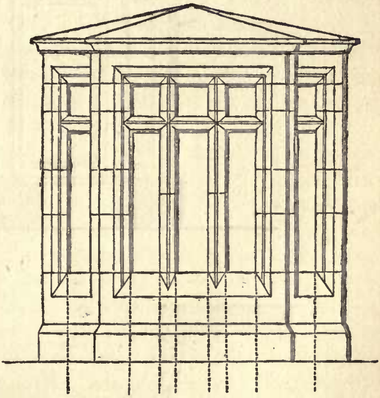


Fig. 361

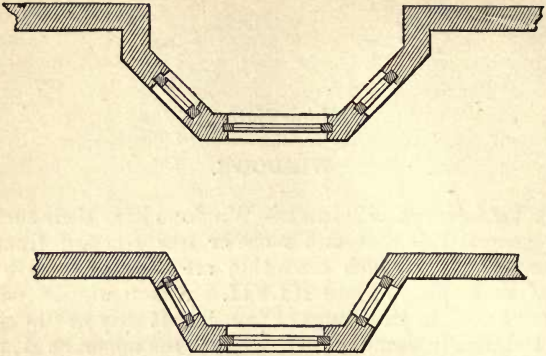


Fig. 362.

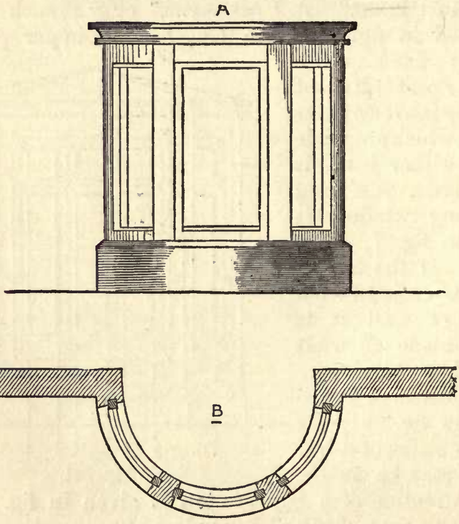


Fig. 363.

the plan of a window is circular, as in fig. 363, it is called a "bow window," A being elevation, B plan.

An "oriel window" is a window which projects from an upper floor, and is generally circular on plan. When the sash window is fixed, it is secured to a framing which leaves the opening in the wall, this framing being secured to wood bricks or grounds fixed in the wall. But when the window is "hung," it is placed in what is called a "cased framing," the sides of which are hollow, as at *a a*, fig. 5, Plate LII., and the top piece or head is like the head of a door, this is shown at *l*, fig. 2, Plate XLVI. The lower part of the frame, as *b*, fig. 3, Plate LII., rests on the "sill," or "cill" *a* of the window; this sloping at its outer side to allow of the rain to pass off, and throated or grooved on the under side. The "cased framing," or "casing," is made up of pieces as follows. In fig. 5, Plate LII., *h* is called the "pulley style," or pulley piece, which supports at the head of the window the pulleys over which pass the cords which carry at their lower end the weights shown by the circles in fig. 5, Plate LII., at *a a*, and secured at the other to the sash frames of the window. The pulley piece *h* is secured to the "outside lining" *b* and "inside lining" *g*, these two being joined by a piece parallel to *h*, and called the "back lining." To form the recess or groove in which the frame of the window sustaining or carrying the glass panes will slide up and down, two pieces are secured to the pulley style *h h*, fig. 5, Plate LII.; the piece *j* is grooved to the pulley piece and called the "parting bead," the piece *i* being secured to the "inside lining" *g*, and is called the "inside bead." To prevent the two weights in *a* and their respective cords—one being used to balance the lower and one to balance the upper sash—from becoming entangled, they are separated as shown in *a a*, fig. 5, Plate LII., by a piece called the "parting slip." All these pieces now described run from bottom "cill" of window to "head," to which they are secured; the inside bead *i* being generally fastened to the inside lining, so that it can be easily taken out, and release the sash frames when the windows require to be cleaned.

Fig. 2, Plate LII., illustrates the plan of a sash window, in which the shutters (see Shutters) *e e* are placed in shutter boxes *a a*, which are at right angles to the face of window, instead of being splayed or made angular, as is usually the case, as in fig. 5. In fig. 2 (fig. 1 being elevation at bottom), *e e* shows the shutters folded up, *b c d* the three parts opened up and covering the window. Fig. 3 is a section of lower part of window, *a* the "stone cill," *b* the "oak cil'" of window frame, *c* the lower bar of sash frame, *d* "dado" lining the part below window, *e e* the mouldings of shutter box casing. In fig. 364 we illustrate the finish to the lower part of the central compartment of a bay window, *a* part of sash bar, *b* oak

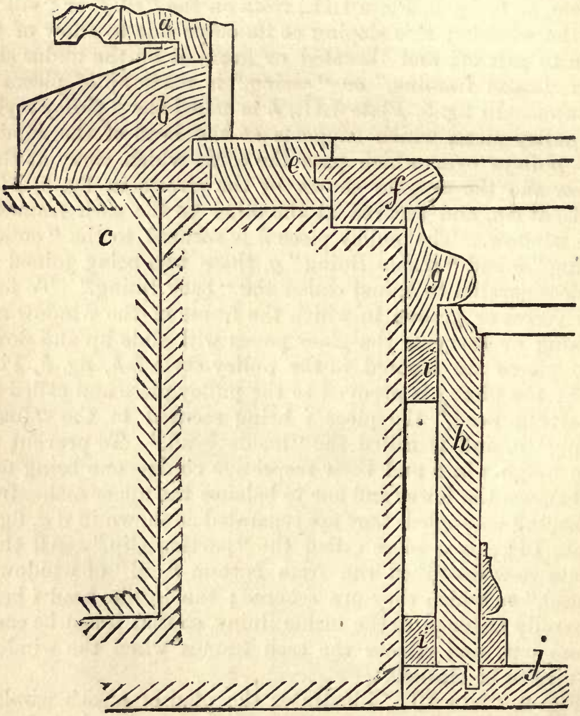


Fig. 364.

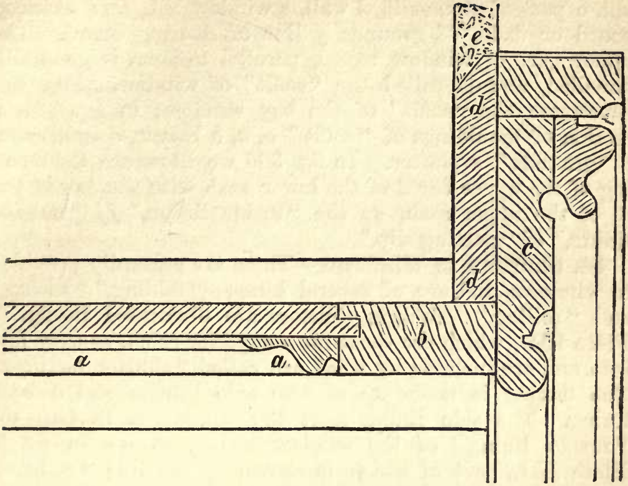


Fig. 365.

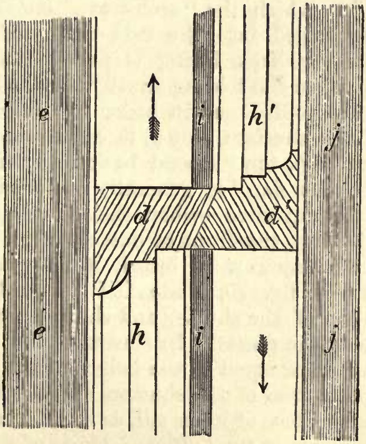


Fig. 366.

cill, *c* part of stone cill, *d* wall, *e* window cill, *f g h* skirting board or dado, *i i* grounds, *j* line of flooring board. The upper part of window recess, parallel to floor, is generally panelled, and is called the "soffit" of window. Fig. 365 illustrates the "soffit" of the bay window; in fig. 364, a section of mouldings of "soffit" *a*, *a*, *b* bearer, *c* architrave, *d* "grounds," *e* plaster. In fig. 366 we illustrate the meeting of the upper bar *d* of the lower sash with the lower bar *d′* of the upper sash, *e e* the "inside lining," *j j* "outside lining," *i i* "parting slip."

34. Shutters to Windows.—These are generally provided to windows, and are of several kinds—"folding," "lifting," and "rolling." Folding shutters are illustrated in fig. 4, Plate LII., which are those for a superior room, as they fold into and are inclosed by what are called "shutter boxings." The boxing is made up of two side linings and a back lining. The side lining next the window is in fact the "inside lining" of the window casing, as *a a* in fig. 5, Plate LII., part of which is shown by the line *a a*, fig. 4, Plate LII. The other side of the shutter boxing is at *b b*, and the "back lining" is at *c c*. The side *b b* forms the "ground" to which the "architrave" *d d* is secured; *e e*, the plastering keyed into the side lining of boxing. In superior work the back lining is panelled at *f*, to show finished work when the folding shutters—called "flaps"—as *g g*, *h h*, *i i*, are pulled out in order to cover the window. The front of the shutters, as *g g*, is called the "front flap" or "first flap;" *h h*, the "second back flap;" *i i*, the "back flap." The "front flap" is generally panelled in front, so that—as in the day time—when the shutters are in their place in the boxing, the front or outside of *g g* may be ornamental. If the flap is very broad, it may be panelled in two, as shown at fig. 10, Plate LII. Fig. 4, Plate LII., is a cross section of the shutter and shutter boxing, showing the thickness of the pieces. In elevation the length of the shutters would show equal to the height of the window to be covered. The bottom of the shutters slide above, and rest a little above upper face of inner sill, as fig. 5, Plate LII. The arrangement shown in fig. 4, Plate LII., is of course repeated at the other side of the window, the shutter flaps being of such a width that they cover only half of the breadth of the window, the other half being covered by the flaps in the boxings at the other side. Fig. 5, Plate LII., shows the shutter boxings to bevil away from the window, of which the left-hand casing is shown at *a a; b b* the wall; *c* the plastering; *d d* the architrave; *e e* the front flap of shutter; *f f* the second back flap; *g g* the back flap.

In *lifting shutters* are those which descend into recesses formed in the wall, in front of the window, and may be made in two or more "lifts" or rises, generally for windows of ordinary height in two. The arrangement is shown in fig. 6, Plate LII., which is part plan, and in fig. 7, which is part section of a sash window with "lifting shutters. In fig. 6, *a* is the "pulley style" of the window casing; *b* "outside lining;" *c* "inside lining." This forms also the outside lining of the shutter box, or rather the shutter-weight box, of which *d* is the pulley style; *e e* the weights to counterbalance the weight of the shutters *f* and *g*. These are shown in section, fig. 7, Plate LII., at *a* and *b*, in the grooves or recesses formed for them in front of the wall *e e; c* and *d* show the grooves in which the shutters *a* and *b* slide at their outer edges. When not in use the recesses and the shutters are covered up with the flap *e*, which may be hinged or fitted, as shown in drawing, the flap being removed by being drawn forward out of the groove at back. When the shutters are pulled up the lowest shutter rests upon the top of flap which is closed. The shutters are panelled in front, as in fig. 10, Plate LII., Lifting shutters are sometimes reversed in position, being placed in recesses above the window, and then being pulled down when in use, in place of being lifted up.

Sliding, Rolling, or Running Shutters, are those which being placed horizontally, are made to slide in grooves into recesses made in the wall, right and left of the window, if the shutter is in two portions; or if in one, one recess only is made at the side of the window. This is illustrated in fig. 5, Plate XLVI., and described in a succeeding paragraph.

Bay Window Shutters.—In fig. 8, Plate LII., *a* is the part of the window showing casing *b; d d* part of window, with casing *e e*, *f* being the stonework of window. In fig. 9, Plate LII., the plan of this window at the return is given with the shutter *a a*, and shutter boxing at *b b*, *c* being the casing corresponding to *e e* in fig. 8, Plate LII.

35. Casement or French Window.—In Plate XLVI., fig. 1, scale half-inch to the foot, is the inside elevation of this; fig. 2, the vertical section; fig. 3, the plan. In the elevation the two upper panes, *a a*, are, with their frames, fixed, being divided by the horizontal rail or transom, *b b*, from the two lower sashes, *c c*, *d d*, which open right and left to the outside. In the plan one of these, as *c c*, is shown as opened, the other, *d d*, being closed; *e e*, the shutter boxes; the shutter, *f f*, is shown in one of these only; *g g*, the architrave; *h h h h*, the wall; *i*, the window sill. Fig. 4, Plate XLVI., is a section of the architrave, *g*, in fig. 3, one-sixth of the full size. In fig. 2, *a* is stone cill, *b* the wall, *c* the lining, *d* the skirting board, *g g* the architrave, *h h* top and bottom rails of upper and fixed sash, *g′ g′* top and bottom rails of half of casement, *b* middle rail or transom, *e* oak cill of window frame.

36. Sliding Horizontal Window.—In fig. 5, Plate XLVI., we give an inside elevation of a window, placed horizontally, one half of which slides to the right, the other half to the left, recesses being formed to right and left of opening, on which the halves, *a a*, *b b*, of window slide. In fig. 7 a plan of one of the recesses is shown, *a a* that in which the left-hand sash *a a*, fig. 5, slides, *b b* being part of the plan of sash. The shutters, as *a a*, fig. 6, also slide into recesses placed on either side of the window opening, one of the recesses, that to the left, being shown in plan *d d*, fig. 7, *e e* being part plan of the shutter. In fig. 6, *b b* is the sash, *b b*, fig. 5, *c* the oak cill, *d* the stone cill, *e* the wall, *f* ground, *g* the skirting board, *h* the wood lintel, *e* the wall.

37. In Plates XLVII., XLVIII., XLIX., and L. we give "working drawings" with "dimensions" shown of a sash window, in which fig. 1, Plate XLVII., is part elevation, A being the upper frame, or "sheet," as it is technically termed, B the lower, C the part where the upper and lower sheets meet. Fig. 2 gives the outline of plan of window. Fig. 2, Plate XLVIII., gives the elevation of one half or side of the shutters when open, A A being the outside flap, B inside plain flap, the outside flap showing the panels, C C, when the shutters are closed in their boxes; D the handle by which the shutters are opened or pulled out of their boxings. Fig. 3 shows the shutters when closed together, previous to being put into their boxings, A A the inside flap, B B the outside shutters, with edges of panels, C C; D, the hinge for uniting back-flap, A, with outside shutter, B. Fig. 4 is section of fig. 2 through the line *a b*, A is the back flap, B B the styles of the front shutter, C C the panels, D D the mouldings.

In Plate XLIX., fig. 4, we give vertical section of window, *a a* being part of the "wall," *b* part of "stone cill," throated at *c*, *d d* oak or "timber cill," *e* beaded lining, *f* window cill or beaded lining to top of plain dado or lining to wall as shown, *g g* "inside lining," *h h* "outside lining," *i* "bottom rail" or "bar" of sash frame, *j* the groove in which this slides. Fig. 3, Plate XLIX., shows the plan of the two sash frames at their point of junction when the two "sheets" are closed, *b* being upper bar of lower sash, *a* being lower bar of upper sash, *c* the sash weight-rope, *d* the "parting slip or bead," *e* "outside bead." In fig. 1, Plate L., we give plan, and in fig. 2 elevation, of the part marked *b c* in fig. 2, Plate XLVII., showing in fig. 1 section of "architrave" which surrounds the window at *a a*, part of "shutter box" at *b b*, with half-inch lining at back *c*, *c c* wall, with lining *d*, and skirting board, as shown in the section on the line *a b*, fig. 3, Plate L., fig. 5 being this section.

In fig. 2, Plate L., *a a* is the base, corresponding to D D in fig. 1, Plate XLVII., *b b* the mouldings of architrave *a a* in fig. 1. In fig. 6 we give an elevation of the panel with which the part *a* in fig. 2, Plate XLVII., is ornamented; fig. 4, Plate L., being the section of same on the line *a b*, fig. 6, Plate L.

In Plate LI. we give in fig. 1 the elevation of a continental form of "casement window," fig. 4 being section on the line *a b*, fig. 1, showing the junction of the two styles, one, *a*, being the style of "sheet" C, the other, *b*, of "sheet" B, the joint being weather-proof by the covering-slips *c d*, one, as *c*, being secured to *a*, the other, *d*, to *b*; *d* shows the vertical iron rod *e e*, fig. 1, Plate LI., which secures the window, this passing into the hold-fast place *f*, being moved out and in of this by the handle *g*. In fig. 5, Plate XLV., we give a section on the line *c d*, fig. 1, Plate LI.; *a a*, the wall; *b b*, the stone cill, throated at *c*; *d*, lower bar or rail of window; *e*, the inside window cill; *f*, the panelled wall lining, panelled as in fig. 1, Plate LI., at *h h*, *i i* being the skirting board. In fig. 4, Plate XLIV., we give side view of the part *a*, in fig. 4, Plate LI., and part section on the line *c d* in fig. 1, Plate LI.

38. Fittings to Windows.—The sash bars which carry the glass are more or less numerous, according to the number of panes of glass in each sheet. Since the introduction of plate glass at a comparatively cheap rate, many windows have each sheet formed of one pane only, dispensing altogether with crossed sash bars, filling up the frame as in fig. 1, Plate XLVII. In fig. 1, Plate XLIX., we give a section of the "sash bar" of the window in fig. 1, Plate XLVII. The glass pane, *c*, rests in the rebatted part at *b*, and is secured in its place by the putty, *d*; *e e* is elevation of the bar. The intersection or meeting of horizontal bars, *g g*, and vertical, *h h*, is shown at *f*. The window (lower sheet) is lifted by means of "finger rings," as shown in fig. 2, Plate XLIX., in which *a* is the lower bar of sash frame, *b* the plate of the ring *c*, secured by screw nails to *a a*. The section or side view is shown at *a′*, *b′*, *c′*. In fig. 367 we illustrate the pulley frame *a a*, which carries the pulley *h* over which the rope or chain *f* sustaining the sash frame is passed; *b b*, the "pulley piece;" *c c*, the outside bead; *d d*, the "inside bead;" *e*, the brass bearing for the axis of the roller for window blind to revolve in. Fig. 367*a* illustrates the "catch" by which windows are secured, by preventing the upper and lower "sheets" from being separated;

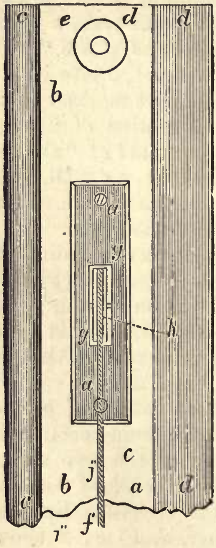


Fig. 367.

e e, the top of upper bar of lower "sheet;" *g g*, the top of the lower bar of upper sheet; to *e e* a plate *a* is screwed, to which is cast a horn *b*, projecting a little above the plate *a a*, leaving a space into which the part *d* of the catch can slip, this being moved by the handle *c*; *f*, a small spring to bring back the catch *d* when released from the horn *b*.

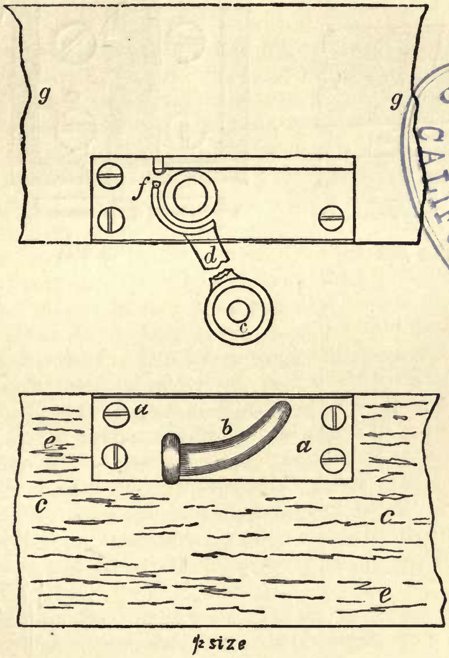


Fig. 367*a*.

39. Hinges.—Hinges to shutters and to doors are of various kinds and makes. In fig. 368 the usual method of hanging shutters is illustrated; in some cases the leaves of the hinge *a b* are sunk into the flaps, as in fig. 369, which shows a simple form of hinge for a door; *a a* being the "hanging style" of door; *b b* the door casing, *c c* the hinge, let into the style and casing, as at *d d*; *e e* is the end view of hinge,

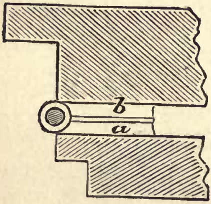


Fig 368.

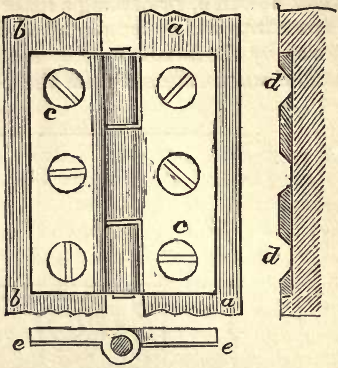


Fig. 369.

CHAPTER III.

JOINTS USED IN JOINERY.

40. Pieces Laid and Joined Parallel to one another.—As the width of a "board" is limited from 7 to 9 inches ("planks" are timbers, the thickness of which does not exceed four inches, and the width above nine inches; a "balk" is the large square timber in the form in which it is imported into this country), it is necessary in forming comparatively large and wide surfaces—such as a door—to join the boards together in the direction of their length. This is done in a variety of ways, the most commonly adopted of which are illustrated in figs. 370, 371, and 372. In fig. 370, at *a a*, the boards are simply planed square on their edges and secured together by nails; boards so prepared are said to be "shot," *b b* shows elevation. In same figure, *c c* section, *d d* elevation, illustrates the method of joining boards by "rebated" edges, and *e e f g* by "tonguing and grooving." Boards are also joined, as *g*, by inserting a feather or slip *h* in a groove made by bringing the rebated edges of two boards together. One edge of a board may be "grooved," as at *j*, and the other "tongued," and furnished with a "quirk bead" on the edge, this moulding prevents any opening of the joint, arising from the shrinking of the wood, from being seen; sometimes both edges are beaded.

Another method is shown at *l m*, the two boards are "grooved," or "ploughed," on their edges, and a separate "tongue" *m* is driven up the groove thus formed, the tongue *m* is also called a "slip feather." When the boards are thick two "slip feathers," *a*, fig. 371, may be used; *b b* is front elevation, *c* section. "Dowels" or "pins," as *d d*, projecting from the edge of one board, and going into holes *e e* made in the edge of the other board, is another method of joining boards together. The boards *f f* may also be kept

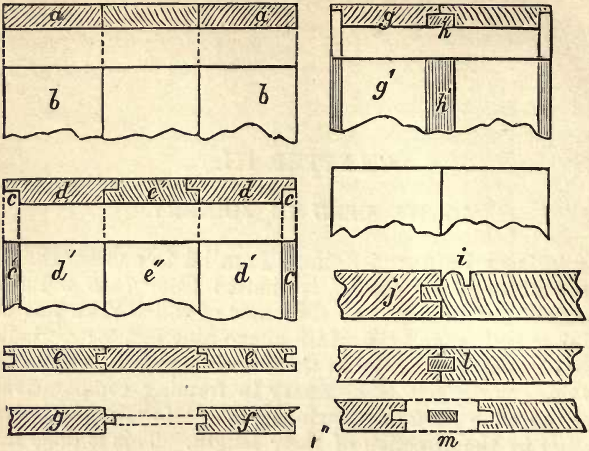


Fig. 370.

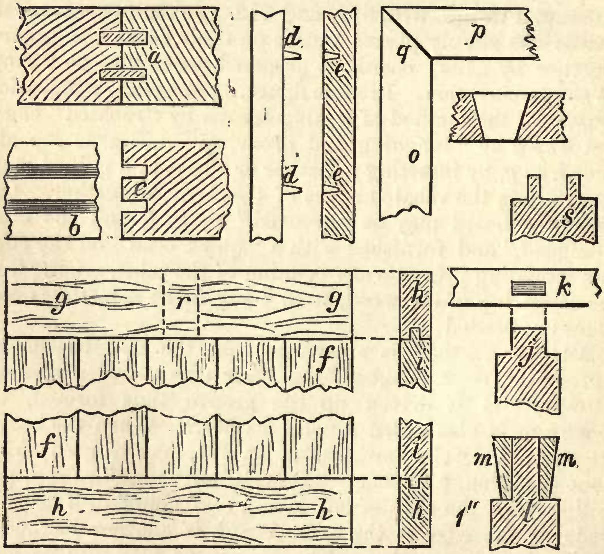


Fig. 371.

together by cross-pieces at top and bottom, as *g g*, these being grooved, and the boards at their ends tongued and put together, as at *h h i*; or the boards may be tenoned, as at *j*, into the edges *k* of the boards. To prevent the tenons from shrinking they may be wedged up, as at *l*; the mortice being shaped dovetail, as at *n*, and the wedges *m m* filling the space up. The boards, as *f f*, may be enclosed at the sides as well as at the ends, as shown at *o p*; the usual method of joining at the corners being a "mitre" joint, as at *q*. In this case the cross-pieces are said to be "clamped." The method of fixing boards together, known as "ledging," has been already illustrated in connection with ledged doors, which see. Boards are said to be "mitre clamped" when the cross-piece, as *a a*, fig. 372, is finished at one side by a mitre-shaped tenon, which goes into a dovetail shaped mortice *c c* made in the boards

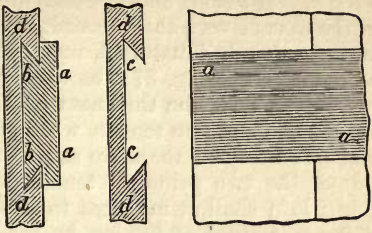


Fig. 372.

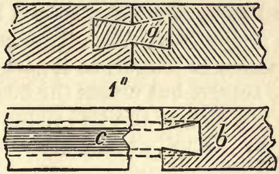


Fig. 373.

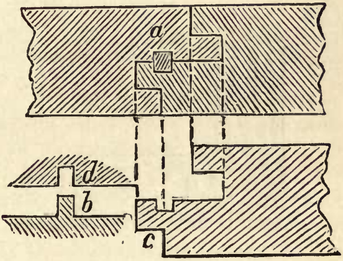


Fig. 374.

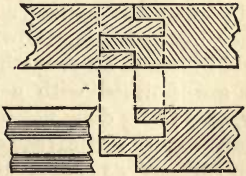


Fig. 375.

d d a a. If tenons and mortices are used, as in fig. 371 at *j*, in the case of very thick boards, a double mortice and tenon joint, as already illustrated, may be employed; if the piece to be tenoned, as *j*, fig. 371, be wide, two tenons may be given to it, as at *s*, if the thickness of the wood permit of it, in addition to the two tenons, what are called "stump tenons" may be employed, these are short tenons or pins, one on each side of the two principal tenons, these short tenons or pins going into shallow mortices in the other pieces. Fig. 373 shows a method of joining boards together by a dovetailed tenon *a*, *b* is section, *c* front view. Fig. 374 is a more complicated form of joining boards by grooving and tonguing, to which a slip feather *a* may be added, or the tenon *c* may have a projection or tongue, as *b*, going into the groove *d*; this joint is very secure, but unless the boards are well seasoned, shrinkage is apt to tear the two asunder, and cause an ugly rupture or crack. Another and less complicated method is shown in fig. 375.

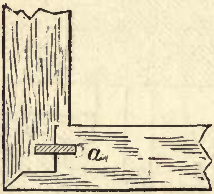


Fig. 376.

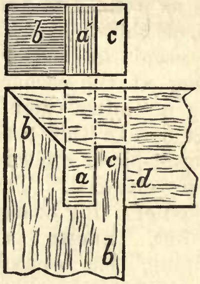


Fig. 377.

41. Pieces joined at Right Angles to each other.—Fig. 376 illustrates one method, a "slip feather" or "tongue," as *a*. Another method being shown in fig. 377. In fig. 378, *a*, *b*, *c*, and *d* illustrate other methods in which one or other of the pieces are finished with a "double-quirked" bead at the corner, this being done not only for ornament but to prevent the sharp corner or "arris," as *e*, being injured. In *d* either a "slip feather," as *f*, or a "tongue, as *g*, may be used; *h*, *i*, and *j* illustrate other methods; *h* a simple tenon, *i* a "dovetail tenon, the perpendicular piece may be let into the horizontal one, as at *j* and *k*. The horizontal piece *l* may be joined to the vertical piece *m* by a mitre joint, but with the addition of a tenon *n* cut in the face of the mitre of *l*, and going into the mortice *o* in the face of the mitre of *m*.

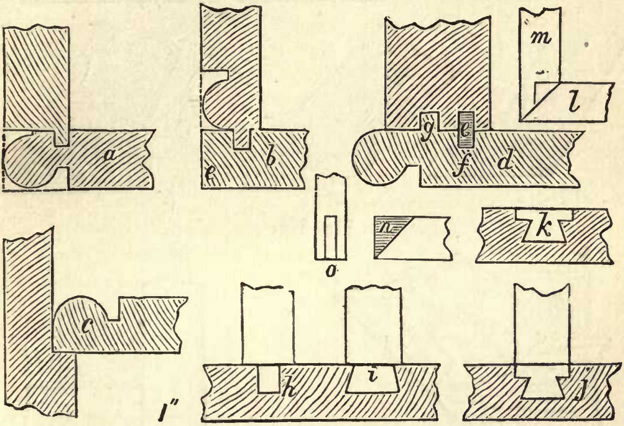


Fig. 378.

42. Pieces joined at Angles other than Right Angles.— In figs. 379 and 380 various methods are illustrated. The joints here illustrated may be strengthened by adding what are called "blockings," as *a a*, in figs. 380 and 381; these in place of having the sharp "arris" or corner, as at *b* in fig. 380, may be formed as shown by the dotted lines in fig. 381. For joining pieces at right angles "dovetail" joining is used for fine work in joinery. Fig 382 illustrates what is known as the "common dovetail," in which one piece has "tenons," "dovetails," or "pins," formed dovetail fashion, as at *a*, these going into dovetail shaped mortices *b*; the projecting parts *c*, formed by these, going into the corresponding hollow parts *d*. In this form of joint the ends of the tenons or pins are seen at both sides of the pieces to be joined, as *a′ a′* show the ends of tenons *a a a* at the return side of the edge *b c*. In what is called "lap-joint dovetail," the ends of the tenons show

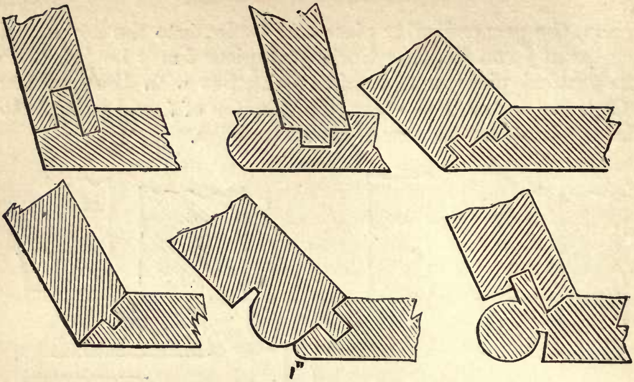


Fig. 379.

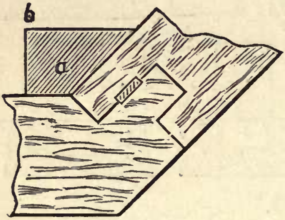


Fig. 380.

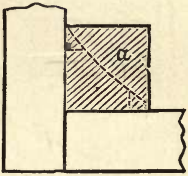


Fig. 381.

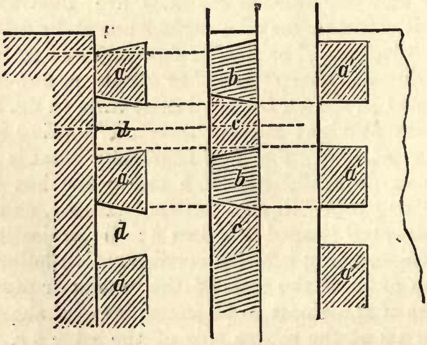


Fig. 382.

only at one side, this is effected by cutting the tenon or pin of one piece short off, and in corresponding proportion making the mortice in the other piece shallower, so that it does not go completely through; this is illustrated in fig. 383, the

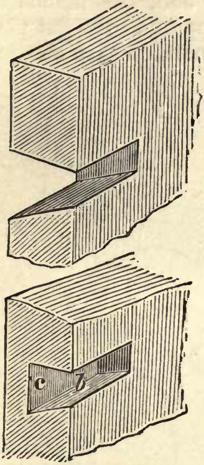


Fig. 383.

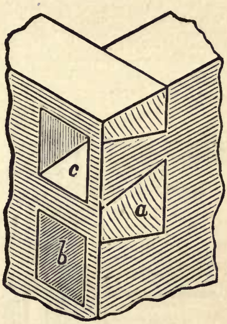


Fig. 384.

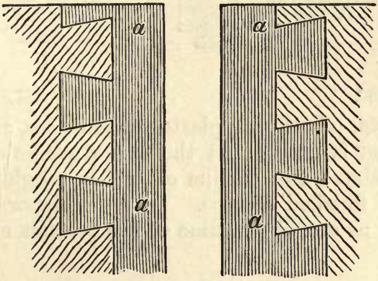


Fig. 385.

upper drawing showing the mortice used in "common dovetailing," the lower, the mortice *b* stopping short at *c*; this is further illustrated in fig. 384, *a b* being the common mode, showing the ends *a b* of tenons at both sides; *d* the "lap joint," showing the tenon at one side only; *c* shows the inside of a mortice. In "mitre" dovetailing, the tenons show on neither side of the pieces to be joined, the whole being concealed; this is illustrated in fig. 385, the tenons and mortices both being shortened and stopping at the flat pieces *a a*, which are mitre-jointed at the corners, so that the joint shows but a fine line at each corner.

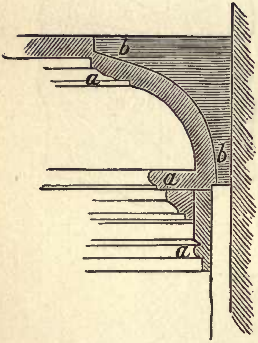


Fig. 386.

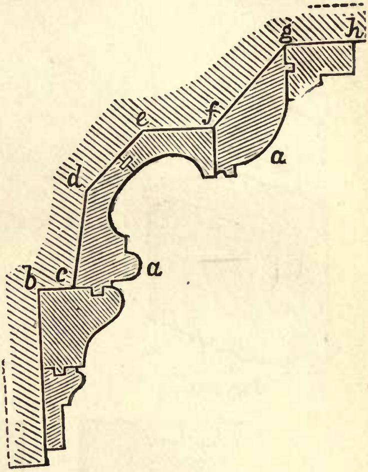


Fig. 387.

43. Brackets.—In fixing plaster on cornices, as at *a a*, fig. 386, the plaster is worked on the face of pieces of wood *b b*, so called as above, the outline of which roughly resembles the outline of finished cornice. In more elaborate cornices, as in fig. 387, as *a a*, the outline of the bracket may be as at *b c d e f g h*.

PART III.

WORK IN IRON, LEAD, AND ZINC.

PART III.

WORK IN IRON, LEAD, AND ZINC.

CHAPTER I.

WORK IN IRON.

44. Iron Straps.—In the framing together of large timbers, in addition to the "joints" we have already illustrated, the parts are secured and kept together by means of iron straps, and by screw-bolts and nuts. In fig. 8, Plate LVI., we illustrate *a a* form of strap for joining the foot *a* of a king post with the lower part of struts *b b*; and in fig. 9 a form of strap used for joining the upper parts of these members. In fig. 12 a more complicated form of strap is illustrated, which, if reversed in position, would answer for the lower part, as in fig. 8. Fig. 10 illustrates a form of strap used to join the head *a a* of a queen post with the straining cill *b*, and head of strut *c*. Fig. 13 illustrates a form of strap used to connect the head of a strut or brace *a* with the principal rafter *b*. Fig. 14 is a form of strap used to connect a collar beam *a* with rafter *b*; fig. 11 shows a more complicated form. Fig. 15 illustrates the use of a screw-bolt and nut in connecting the foot of a principal rafter *a* with the tie beam *b*; butting pieces or cushions, as *c c*, of iron should be used to prevent the head of the bolt and nut from entering the wood, the faces of these should be at right angles to the centre line of bolts. In place of a bolt, a strap, as shown by the dotted lines *d e*, might be used to connect the two pieces *a b*. Iron straps are provided with screw-nail, or bolt holes, by which they are secured to the timber; in fig. 17 we illustrate a method of enlarging the strap, so as to form an "eye" and butting place, as *a*, for the screw-bolt head or nut to butt against; *c* being the edge view of same. In the chapter on Roofs the student will find another method of securing straps by means of "keys" and "gibs."

45. **Iron and Timber Combined Work** is further illustrated in Roofs and General Framing, some drawings of the great variety of combinations of which we give in Plates LV., LVIII., and LIX. In Plate LV. there are several combinations suitable for "king-post" and "queen-post" roofs, as already illustrated. Thus, fig. 2 shows an arrangement for connecting a wrought-iron "king bolt," or "suspending-rod" *a*, with a cast-iron "box," or "king-post head" *b*, in which hollow places are made at the sides, in which the ends of the rafters *c d* are housed; *e*, the "ridge-piece" or "ridge pole." The upper end of bolt *a* is finished off with an eye-piece, as at *a*, fig. 14; this passes between the hollow part of the eye *f* of box *b b*, and a pin (as *a*, fig. 9) is passed through all, and secured by a split key (as *b*, fig. 9). Fig. 4 shows another method of securing the upper end of bolt *a*, fig. 2, to the box *b b*, the bolt being passed up an aperture made in the box, and secured by keys *a b* passing through slots made in the box and rod. Fig. 3 shows a method of joining foot of king bolt to timber tie beam *b*, by screw nuts *c d*, the lower part of the bolt being screwed. In fig. 13 another method is shown; an iron stud *a a*, with eye *b*, being bolted to the tie beam; *b* is the end of king bolt, being secured as shown at *a b*, fig. 9. Fig. 1 shows part of a roof truss of iron and timber combined, to which the details above explained in figs. 2, 3, 4, and 9 are applicable. In some cases the timber tie beam is dispensed with and a wrought-iron rod substituted, as at *a a*, fig. 5 (as a rule, in combinations of wood with iron, those parts in tension (see remarks on strains in a succeeding chapter) may be of wrought-iron, those in compresssion, of timber or of cast-iron. Fig. 6 shows the detail of junction of tie rod *a a*, feet of braces or struts *b b*, foot of king bolt *b*, with the cast-iron shoe or box *d d*, in which the feet of the braces *c c* are housed; the lower part *e e* is made double or hollow, to admit of the tie rod lying in it, this being provided with an eye, through which the king bolt end passes; or if the king bolt is secured by a key, as

at *f*, the tie rod may be left plain. The other end of the tie rod may be jointed to an eye—as shown by the dotted lines *c*, fig. 7—made at *a*, in the rafter, shoe, or box *b b*, which receives the feet of the rafters *b b*, fig. 5, or secured to the rafters by a jointed link *c*.

Figs. 8 and 9, Plate LV., show three methods of joining the wrought-iron "queen bolts" *a a*—substituted for timber—with the straining piece *b b*, *c c* being the end of a "principal rafter." In fig. 8, *c* is tenoned into *b*, and the "queen bolt" is simply passed through a hole in the piece *b*, and secured by nut at the upper and screwed end. A stronger method is shown in fig. 8 at *e e*, which is a strap embracing the piece *b*, and secured by a pin and split key passing through the eye *f*; this is shown in section in fig. 9. In fig. 10 a cast-iron box or shoe *a a* is made, in which the ends of the pieces *b* and *c* are housed, the king bolt *d* being secured by a nut *e* at top, and by a "jamb-nut" at *f*. Fig. 11 shows a method of securing the foot of the "queen bolt" *a*—corresponding to *a*, fig. 8, *d*, fig. 10—with the tie beam *b b*, *c d* being the foot of brace or strut, housed in the cast-iron shoe *d d*, bolted to the tie beam, *b b*; the queen bolt *a* may be used as one of the bolts. Fig. 12 illustrates a method in which a second queen bolt *a*—as *a*, fig. 1, Plate LVIII.—may be joined to the cast-iron box *b b*, in which is housed the ends of the principal rafter *c c*, the strut or brace *d*, and the purlin *e*.

An illustration of a railway shed is given in Plate LVII., in which wood is combined with iron. The sides of this shed are open from the ground line *e e*, fig. 1, to the under side of the longitudinal timber bearer *f f*, and fitted in above this with the cross-pieces *g g*, and the boarding *h h*. On the upper beam or bearer *i i* rests the cast-iron beam *j j*, cast with open circles, as shown; above this is the timber bearer *k k*, to which the rafter boxes *l* of the wrought-iron roof are secured. Fig. 2 is section on the line *a b*, fig. 1; and fig. 3 a sectional elevation, showing relation of the timbers and pillar, or column, in fig. 1; fig. 4 is side elevation of fig. 3; fig. 5, horizontal section on the line *a b*, fig. 4; fig. 6, inside view of the column or pillar at lower cap or shoe *d*, fig. 1; fig. 388 is side elevation of do.

The scale for fig. 1, Plate LVII., is $\frac{1}{4}$ inch = 1 foot; for details, one-twelfth full size or one inch to the foot. In Plate LX., fig. 11, we show an arrangement for carrying a girder of wood *a a*, on the cap *b*, of a cast-iron column *c*, the girder being secured to cap by a screw bolt and nut, as shown. The drawing also illustrates a method of crossing an opening, as that of a shop front, by the built wrought-iron beams *d d*, supported at each end by cast-iron columns *c*, and the upper plate, as *e e*, carrying the wall *f* of upper storey. The built beams, as *d d*, are secured at intervals by bolts, as *g*. Should these beams *d d* be required to carry timber or other beams on their flanges, these will rest on and be secured to the lower plate of *d d*.

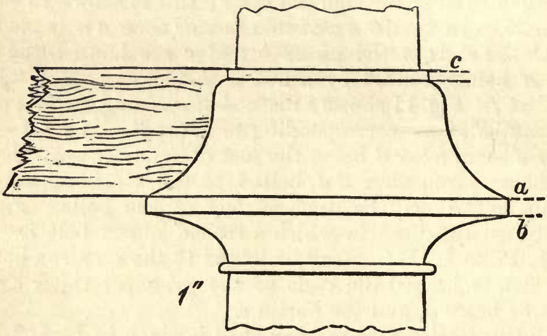


Fig. 388.

46. Iron Columns or Pillars.—Iron columns are always made of cast-iron, never or rarely of wrought-iron, this latter not being calculated to resist the strains of compression in which columns are chiefly subjected, like cast-iron. In section columns are generally circular, as *a* in fig. 389; but they may be varied in outline, as at *b*, or fluted, as at *c*, *c′*, or *c″*, or flat, as at *d*, or as across at *e*. They are usually made hollow, not solid, as at *a′*. The hollow column gives the greatest strength with the least metal, but it has to be of greater diameter to support a given weight than a solid one.

The strength of a cast-iron column depends upon the proportion of the length to the diameter—for buildings where heavy weights have to be sustained, the length should not exceed ten times the diameter; eight times will be safer; for buildings where lighter weights have to be sustained, or slight shocks from machinery given, the length may be increased to thirteen times the diameter; up to fifteen for public buildings, and for ordinary structures twenty times, which proportion should never be exceeded. Columns are generally tapered from base to cap, a good taper is one in ten. If the diameter of the column at base is one foot, and the length ten times the diameter, the thickness of metal should be one and a half inches, for a length of thirteen times the diameter, the thickness to be from three quarters to one inch; for fifteen times six-tenths to three-quarters of an inch; and for twenty times from half an inch to five-eighths of an inch. The section of cast-iron struts, or braces, may be as at *e*, fig. 390, or as in fig. 390 at *a*, this being a square and hollow set diagonally; *b* is another section.

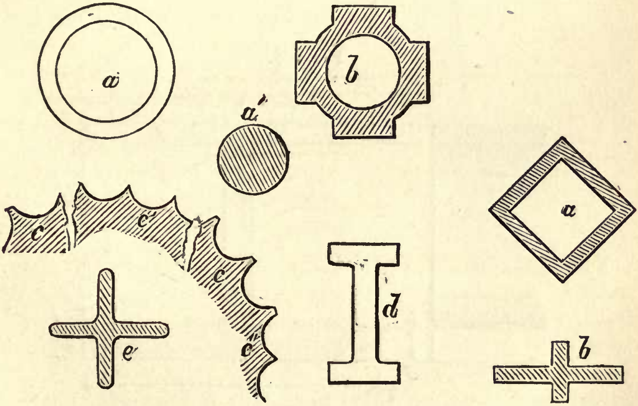


Fig. 389. Fig. 390.

The forms or outlines of columns are various, according to the taste or desire of the designer; examples of caps and bases are given in fig. 1, Plate LVII.; figs. 2 and 4, Plate LVIII.; in figs. 1, 2, and 9, Plate LIX.; and in figs. 9, 10, and 11, Plate LX. In place of columns round in section, cast-iron pillars or "stancheons," as they are sometimes called, are used of the section, as in fig. 391 at *a;* the form here illustrated is used to carry a series of horizontal timber beams or bearers *b b*, the ends of which rest upon the cross part *c*, cast at intervals in the recess.

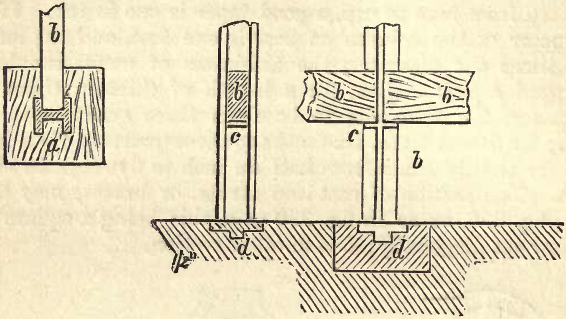


Fig. 391.

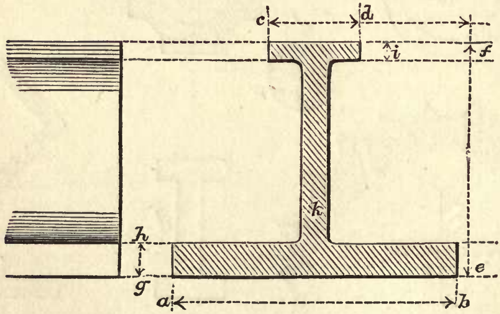


Fig. 392.

The methods adopted for securing the bases of iron columns to the ground, etc., are various; one method we show in fig. 391 at *d*, a projecting part being cast at base, which goes into a socket cut in the stone block *d*. In Plate LX., in figs. 9 and 10, two other methods are shown, the block or projecting part *a a* going into the hollow part *b* of the base of column.

47. Iron Beams, as substitutes for timber, are formed either of cast or wrought iron. The usual and most approved form of *cast-iron beams* is shown in fig. 392, in which the area of section of the upper flange *c d* is one-sixth of that of the lower flange *a b*. Beams of cast-iron are also made of the section as shown at *a*, fig. 393, although this is a section not to be recommended. Fig. 393 also illustrates the method of supporting brick arches for roofs or ceilings to fire-proof apartments; *a* the cast-iron beam; *b* the stancheon or pillar supporting it at intervals in its length, the ends of the beam *a* being let into the end walls, as shown at *e; d d* one of the side walls, against which one of the ends of the arch *c c* butts, the other butting against the beam. *Wrought-iron beams* are of various forms. In fig. 394 *a* shows a solid rolled beam, of which the sections in use are various. In the left-hand half of fig. 11, Plate LX., the form of beam known as a "plate" or a "built beam" is shown. This is made up of a central plate of wrought-iron *i;* a top plate *e e*, and bottom plate to correspond. *i i* is called the "web" of the beam, the top and bottom plates are connected to the central plate or web by the angle-irons *h h*, one on each side, and two at top and at bottom; fig. 12 shows the appearance of a "built beam" at the side, *i i* "web," *h h* angle-irons, *e e* top plate.

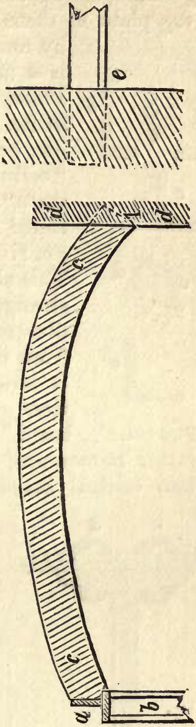


Fig. 393.

A "box beam" is illustrated in fig. 2, Plate LX., this being made up of two side plates, as G, a bottom plate I, a top plate E, these being connected and secured together by means of the angle-irons F and H. This is a section on the line *a b*, in fig. 4, same Plate, which is a side elevation of the beam in fig. 2. The upper part of fig. 4 shows two box beams, forming a double box beam, or a "cellular beam" B B. In fig. 395 we illustrate "Phillip's flanged beam," in which the rolled beam *a b b* is provided with a plate *c c*, riveted to the upper flange of the beam. This simple arrangement adds greatly to the strength of the beam *a b b*. In fig. 396 we illustrate the form known as Zore's beam, from the name of the (French) inventor; it is now being largely introduced into practice. In fig. 397 we illustrate an "open beam," "lattice" or "trellis beam." These two latter names are, however, only applicable where there are two central stays or braces, as shown by the dotted

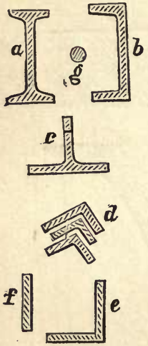


Fig. 394.

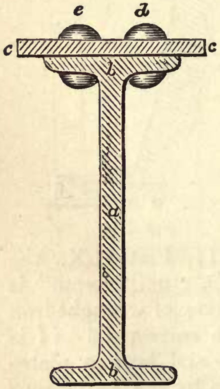


Fig. 395.

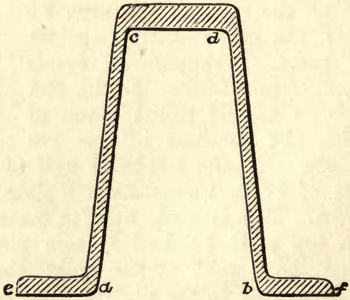


Fig. 396.

lines *a a*, and the lines *b b*. The full lines represent a form of "open beams," in which only one brace or cross-piece, as *b b*, is used. The top member *c c* is of iron, the lower *e e* of flat bar-iron, the vertical *d* of T-iron, the other vertical or end-piece of "L"-iron, and the brace or cross-piece *b b*, flat bar-iron.

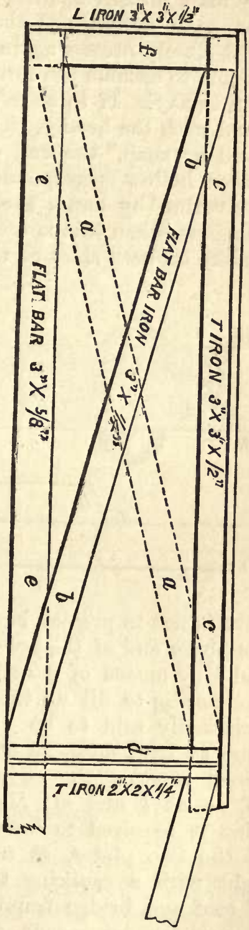


Fig. 397.

48. Junctions of Iron Work.—Several forms of *joints* used in putting iron frame work together will be found illustrated in a succeeding paragraph, when describing Iron Roofs and Bridges. The present paragraph will concern itself with the elements of the subject. In iron framing, the following, as illustrated in figs. 394, 398, and 399, are used. In fig. 394, *a* is a section of a rolled beam, sometimes called an "I"-beam, *b* is "channel"-iron, *c* "T"-iron, *d* "angle"-irons, *f* "flat bar"-iron, *e* "L"-iron, *g* "round bar" or "rod"-iron. These are joined together either by "rivets," as in fig. 398, by "pins and split keys," as in fig. 399, or by "bolts and nuts," as in fig. 8, Plate LIX. We shall now notice these more in detail.

49. Rivets are made of wrought-iron, and have two parts; the "head," as *a*, fig. 398, and the "tail" or "shank" *b*; this is made of so much greater a length, as at *c*, than the thickness of the two parts *d e* to be joined together, that when the extra length, as shown by the dotted lines *c*, are hammered down, a second head is formed, thus clasping, as it were, the two parts *d* and *e* together. The rivet is put red hot into the holes of the two pieces *d* and *e*, and while one man presses against the "head" *a* with his tool, the other man hammers at the end *c* of the "shank" or "tail," till it closely presses against the surface of the piece *d*, and is made to assume the form of a cone as at *c*, or the rounded form as at *f*. If to be left rounded, as at *f*, so as to correspond with the head *g*, the end *f* is finished off with a tool called a "snap," the end of which is provided with a cup-shaped hollow corresponding with the form of *f*. In place of riveting by hand, the operation is now often done by machine; when this is used the rivets are finished, as *f* and *g*, alike on both sides of the pieces to be joined. When the

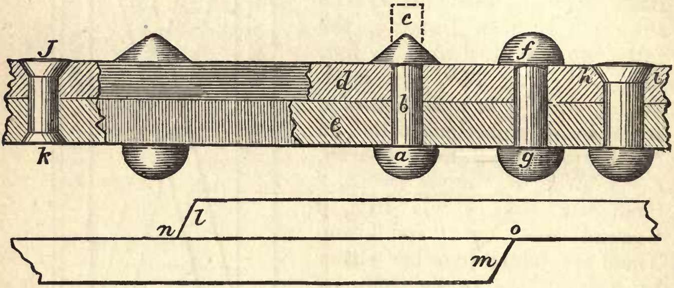


Fig. 398.

rivet is not to project beyond the surface of the piece, as *d*, the upper end of the hole in the piece *d* is sloped off as at *h* and *i* by means of a drill; and the end, as *c*, is made by hammering to fill up this conical cavity; the rivet is then technically said to be "countersunk." This is sometimes done at both ends, as at *j* and *k*. When two plates are joined together the ends are generally sloped or bevelled off, as at *l* and *m*; and if in the case of a boiler the joint is required to be water-tight, the points of junction of the two plates, as *n* and *o*, are "caulked" or driven tight with a caulking tool. Plates of iron, as the parts of roof and bridge framing, are put together and retained in position by means other than rivets, as by screwed "bolts and nuts," by "keys, gibs, and cottars," already illustrated, and by pins and split keys, as in fig. 399; in this *a* is the "pin," *b* the side view of "split key," so called from its edge being split or divided into two by a cut, as shown at edge view at *c*. The pin is passed through the holes in the two pieces as *d e*, the "split key" is next passed through the slot *g* in the pin, and the two halves of *c* forced open as at *f*;

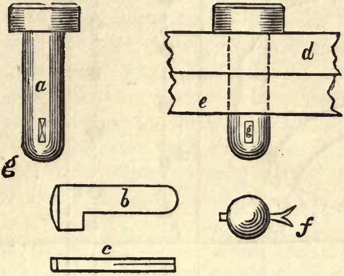


Fig. 399.

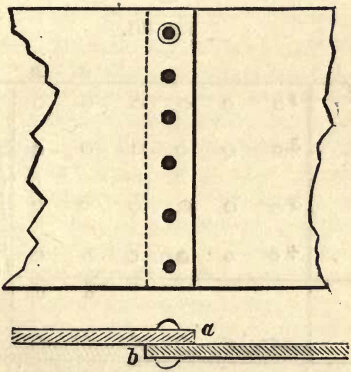


Fig. 400.

the key is thus kept in place. The strength of a joint, as that shown in fig. 398, does not depend altogether upon the strength of the rivets, or the way in which the rivets are put in, that is, upon good and bad workmanship; but, as shown by the great authority on iron work, Fairbairn, also upon the way in which the rivets are placed in relation to one another. Thus there is a great difference in the strength of a riveted joint when the rivets are placed as in fig. 400 and in fig. 401. In the method illustrated in fig. 400, which is called "single rivet-

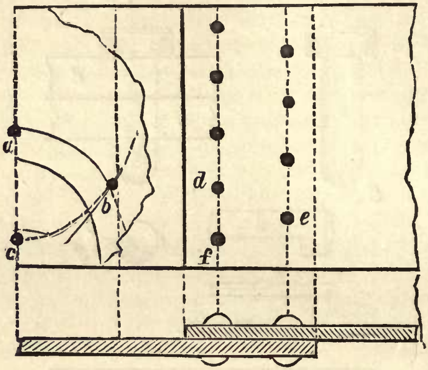


Fig. 401.

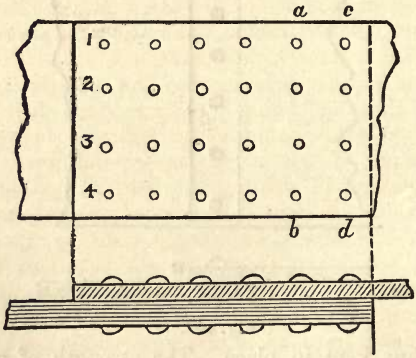


Fig. 402.

ing," if the strength was represented by 56, that of the method known as "double riveting," fig. 401, would be 70. The advantages of "double riveting" would not be obtained by simply making two rows, or another row parallel to that in fig. 400, or as at *a b c d* in fig. 402; but the rivets must be placed so as to form a series of triangles, as in fig. 401. These triangles are not equilateral, as at *a b c*, but rather isosceles, as at *d e f*. Fig. 402 illustrates the method of joining plates together by what is called "chain riveting," in which rows, as 1, 2, 3, 4, are placed parallel to one another; this kind of work is used chiefly in bridge and large frame work of iron, as illustrated in Plate LX. But not merely upon the good workmanship given to the "hammering," etc., of the rivets, and the placing of them in proper position in relation to each other does the strength of riveted plates depend. Another important point is the accuracy with which the holes are bored which receive the rivets, so that the two holes shall exactly coincide with each other.

This accuracy, as we have elsewhere remarked, is a point of still greater importance to be aimed at when there are several plates placed together, as in the top or bottom flanges of box or plate girders; for it is obvious that if the holes do not coincide in all the plates, undue strain will be thrown upon the plates. The difficulty found in practice of getting the rivet holes so accurately adjusted, that the rivets will go fair in, is such, that "drifting," as it is called, is resorted to in a great many instances, the operation having for its aim the bringing in of the rivet holes into the straight as near as possible. "Drifting" being what may be called a "brute force" method of overcoming the difficulty brought about in nine cases out of ten by careless or indifferent marking out, and punching or drilling the holes at first, should not be allowed; but such rivet holes as do not exactly correspond, or are out of line, should be brought right by the use of the "rymer," by which the irregularities of metal in the line of the rivet holes will be pared off. To lessen the difficulty of obtaining accurate adjustment of rivet holes, the thickness of flanges, or top and bottom plates of "built beams," should not exceed 4 inches if the required sectional area to obtain the necessary strength in the beam is not given by this thickness, the breadth of the flanges should be increased in the desired proportion. The rivet holes should be spaced out by "templates" so as to insure accuracy in the meeting or coincidence of the holes in the various plates when put together *in situ*, and the edges of the plates butting against each other should be placed so as to insure fair joints. In no case, where good work is required, should the edges and ends be left rough and uneven where they are to butt against each other. It is scarcely necessary to say that, in order to reduce the number of riveted joints, the plates which make up built beams should be as long as possible.

A great deal has been said as to the relative merits of punching and drilling; and of this we may only remark, that drilling, beyond doubt, gives the best results; and, in addition to greater accuracy in the adjustment of the corresponding holes in different plates, it avoids the injury done to the fibre of the plates by punching. Any one has only to thoroughly examine drilled and punched plates, to be convinced of the mechanical accuracy of the drilled plates. It is, however, a question of paying and not paying, drilling being more expensive than punching. For small work, where thin plates are used, punching will be found to be, and is found practically to be, the best. If, however, where punching is decided upon, the rivet holes are accurately spaced out, and the adjustment of the plates be carefully looked to, the punching and the riveting honestly done, good work may be fairly expected. The standard of good work is accurately formed rivet holes, all the holes in the different plates coinciding with each other; the rivets filling up closely the interior of the holes, and the sectional area of the rivets equal to the sectional area of the plate, measured in a direction at right angles to the tensile strain exercised upon the plate, in other words, at right angles to the line of rivet holes; and finally, well made rivets of the best iron, put in red hot, and hammered tight in.

In figs. 398, 399, 400, and 402 the jcint is called a "lap-joint," from one plate, as *a*, fig. 400, lapping or overlapping the other plate as *b*. In fig. 403 we illustrate the "butt joint," in which no lap is used; but the two plates, as *a b*, "butt" up against each other, as at *c*, the joint being made good by a plate termed a "fishing" plate *d*, this being riveted as shown, or two fishing plates may be used, a second as *e* being placed above. When several plates are joined together, the "butt joint" must not be common to all, as shown by the dotted line *a b*, fig. 404; but the several joints must be disposed so that they shall lie against

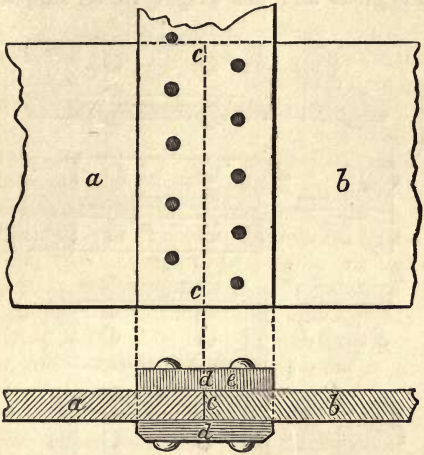


Fig. 403.

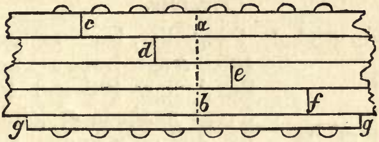


Fig. 404.

the solid part of the plate below, as at *c*, or of the solid parts of two plates, as at *d*; *e* and *f* show the other two joints; one fishing plate as *g g* is here used. In fig. 404*a*, we illustrate the junction of two pieces of angle-iron *a b*, by a fishing plate of angle-iron *c*, as in section. "T"-iron, as at *d′ d′*, may be jointed, when in two pieces, by a flat plate *e*, or by angle-irons, as *f*, at each side, as at *g g*, and for additional security a flat plate *h h* may be riveted at top. The junction of two pieces of channel-iron is shown at *i i*, smaller fishing plates as *j j* of channel-iron being used. The arawings to the left are sections, those to the right elevations. When rafters of iron roofs are required to be strong, in cases where the length is great and the weight to be supported heavy,

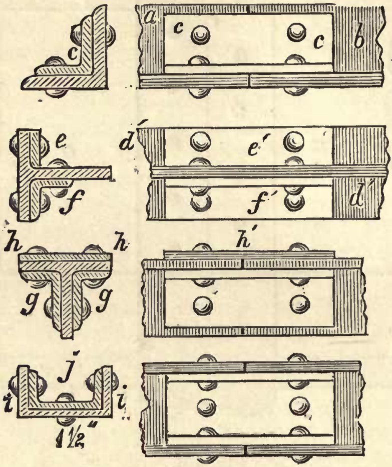


Fig. 404*a*.

two "T"-irons are bolted together, back to back, as in fig. 405. Angle-irons are used for "purlins;" figs. 406 and 407 show different methods of joining them; in fig. 406, *a a* is the rafter, *b b* the purlin, secured to the rafter by the angle-iron *c*; in fig. 407 the purlin *b b* is secured to the under side of the rafter *a a* by bolts and nuts. In fig. 408, the angle-iron *b* forming the purlin, is riveted to the upper flange of rafter *a a*. This figure also illustrates the method of securing a timber purlin, part of which is shown at *c c*, by a short piece of angle-iron, as *c* in fig. 406; a bolt

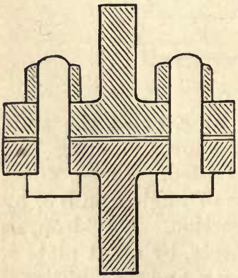


Fig. 405.

at *d* passing through the angle-iron and the wood purlin. Various other methods of forming joints in iron work will be noticed further on.

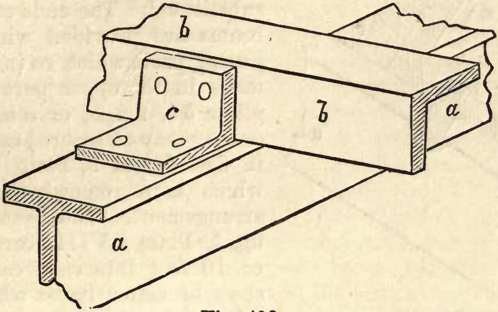


Fig. 406.

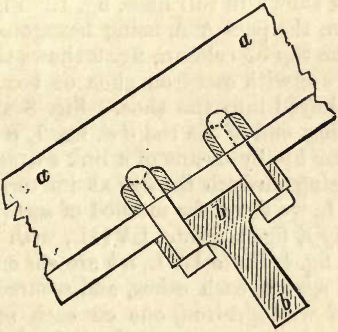


Fig. 407.

50. Iron Roofs.—In the Elementary Volume on Timber and Iron, the student will find illustrations of forms of roofs, as the "king-post" roof, which may be considered as supplementary to what we now purpose to give. In Plate LVIII. we give, in fig. 1, the outline of a shed roof, which may also be adapted to the shed illustrated in Plate LVII. The lines *b b* represent the pillars or columns placed at intervals along the sides to any desired length, the spaces between these being 17 feet. They support or carry cast-iron beams *a a*, as shown in elevation in fig. 5, and in plan, fig. 6, or open beams, as in fig. 397, may be substituted. The ends of these beams are provided with projecting parts which go into slots made in the upper part of the pillar *b b*, fig. 5, or *a a*, fig. 4, or they may be secured as shown in figs. 4 and 5, Plate LVII., which is a somewhat similar arrangement. The beams *a a*, fig. 5, Plate LVIII., carry at 8 or 10 feet intervals, cast-iron shoes or rafter boxes which receive the ends of the rafters of the truss of roof shown in full lines, fig. 1. Fig. 2 is base of pillar or column, the part A A being hexagonal as in fig. 3 plan, fig. 4 is the cap of column, fig. 9 shows the junction of principal rafter *c c*, with cast-iron shoe or box, and the end of the rod *d d*, keyed into the shoe. Fig. 8 shows another method of joining end of tie rod *d d*, fig. 1, *a a*, figs. 7 and 8, with the rafter *b b*, by means of a link *c c*, secured by bolt and nut *d e* passing through the eye at its termination. In fig. 4, Plate LVI., we show the method of securing the upper end of the rods *f f*, fig. 1, Plate LVIII., with the principal rafters *c c*. In fig. 4, Plate LVI., *a b* are the ends of the two rafters, butting against each other, and secured by a "junction plate" *c* of wrought-iron, one on each side, the bolts which pass through the eyes *e e* of the links *d d*, at the upper end of the rods, keeping the whole together. Fig. 3, Plate LVI., is the lower end of the "angle-iron" strut or brace *e e*, fig. 1, Plate LVIII. joining the tie rod *d d*, fig. 1. The tie rod *a a*, fig. 3, Plate LVI., is widened out at *b b* to receive the returned or bent end *c c* of the strut or brace *d*; the whole being secured by bolt and nut. The lower end of the rod *f*, fig. 1, Plate LVIII., is secured to the strut *d*, fig. 3, Plate LVI., as shown, or a double link as in fig. 7, Plate

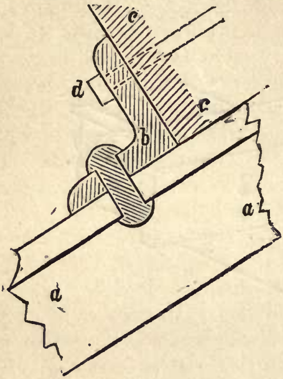


Fig. 408.

LVIII., may embrace the flange of strut *d*. Fig. 5, Plate LVI., is the junction of upper end of the strut or brace *e*, fig. 1, Plate LVIII., with the rafter *c c*; in fig. 5, Plate LVI., *a* is the brace, *b b* the rafter, *c c* the covering plate of iron secured by bolts and nuts, or by rivets passing through the holes drilled as shown. In some roofs of this kind, the strut *e e*, fig. 1, Plate LVIII., is made of cast-iron, as in fig. 6, Plate LVI., *a a* the upper part is cast with a recess, into which the rafter rib *d* passes, and is secured by bolts or rivets. The web *b b* of a cross section, as at *c c*, is terminated by a circular part *c' c'*; the ends of the "tie rod" (see *d d*, fig. 1, Plate LVIII.) *d d*, and of "suspending rod" *e*, are either dovetailed in to the circular part *c c* of strut, fig. 6, Plate LVI., as at *f f*, and then covered with covers bolted together; or the ends of the rods may be provided with eyes as at *g*; the bolts pass through the holes as shown, securing the two covers and the ends of the rod to the central part *c' c'*. The arrangement or combination of parts in fig. 6, Plate LVI., is that at *g*, fig. 1, Plate LVIII, In fig. 1, Plate LVI., we give end view of the rafter box of fig. 1, Plate LVIII., *a* being the aperture into which end of tie rod is passed, *b* slot for rib of rafter, *c c* flange of rafter; fig. 2, Plate LVI., is plan of rafter box. In Plate LIX. we give drawings illustrative of the principal parts of a railway platform, for a small way-side station roof. In fig. 1, *a a* is surface of platform, *b b* wall of station-house, *c c* the pillars or columns carrying the cast-iron beams or ornamented girders *d d*, which are secured to the upper part *e e* of pillars in the manner shown in fig. 4, sectional plan, and fig. 5 part elevation, or by the alternative method in fig. 6 sectional plan, and fig. 9 part elevation. These beams *d d* run at right angles to the railway, and at right angles to them, or parallel to the railway, and secured to the part *e e* of pillar in fig. 1, as shown in figs. 4 and 5, or figs. 6 and 9, are the ornamental beams *f f*, fig. 2, which are placed next the railway at the end *f*, fig. 1, and form the outside "principal rafter." The other principal rafters are placed at intervals between the point *f* and wall *b b*, fig. 1; being constructed with "T"-irons placed back to back as shown in section 405, while between the "principal rafters" the common rafters are placed, as at fig. 3, which gives the form of truss for both rafters. The ends of the rafters are secured to cast-iron gutters, which go into recesses at *e e*, fig. 2, or are bolted to the flat surface if no recesses are provided. This gutter, which runs parallel to the beams *d d* in fig. 1, is shown in fig. 409; in which *a a a* is the

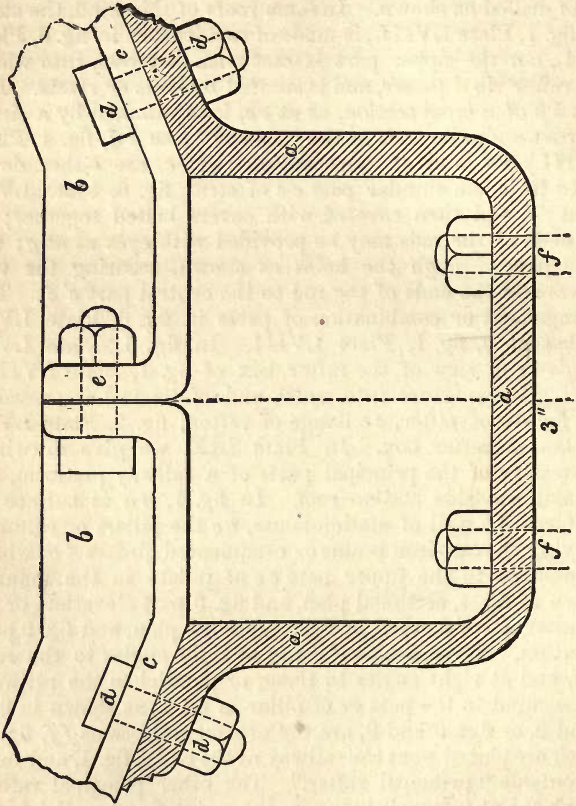


Fig. 409.

gutter, *b b* the rib of the two rafters, and bolted together at *e*; the flange *c c* of rafter being secured to the cast-iron gutter side flanges by bolts and nuts *d d*. This form of gutter may be used for a "ridge and valley" roof, the inner ends of the principal rafters of which rest upon a central wall, or upon beams supported by pillars, the gutter being secured to wall or cap of pillar by the bolts and nuts *f f*, fig. 409. Figs. 1, 2, and 3, Plate LIX., are drawn to a scale of $\frac{1}{4}'' =$ 1 foot; the details, and also fig. 409, are one-fourth full size. Fig. 7 is section on line *a b*, fig. 2; fig. 4 on line *c d*; fig. 8 is the outside single gutter which terminates the roof, and is secured to the last beam *f f*, fig. 1. In fig. 16, Plate LVI., and in fig. 410, other forms of gutters are illustrated; and in the next division, other forms adapted to zinc roof coverings will be shown. Fig. 410 shows a "double gutter" adapted to a "ridge and valley" roof, made of wrought-iron in place of cast-iron, as in fig. 409, and supported by a built beam *a a*, *b b* the right and left hand rafters of the two roofs, *c c* the gutter.

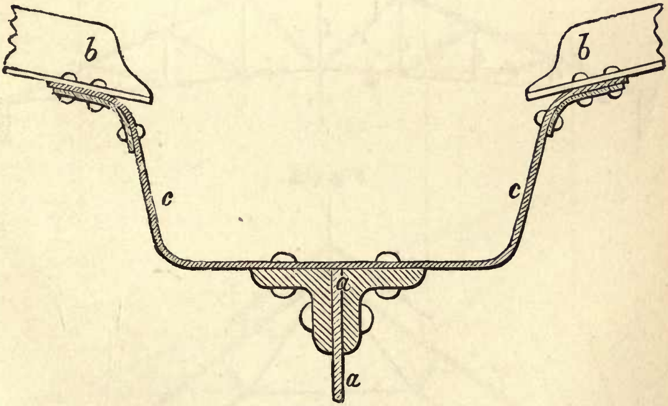


Fig. 410.

51. Iron Roof Trusses are of various combinations, some of these we have already illustrated; we give in figs 411 to 416, inclusive, diagrams showing other combinations; fig. 412 is a queen-post truss with eight bays, adapted for a fifty feet span, the principals, as in the diagram, are to be placed not

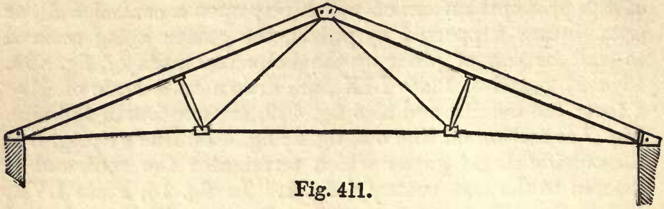


Fig. 411.

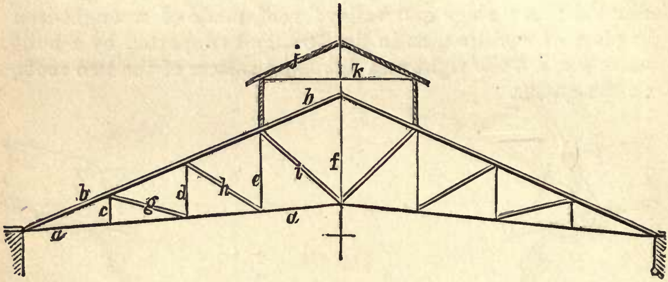


Fig. 412.

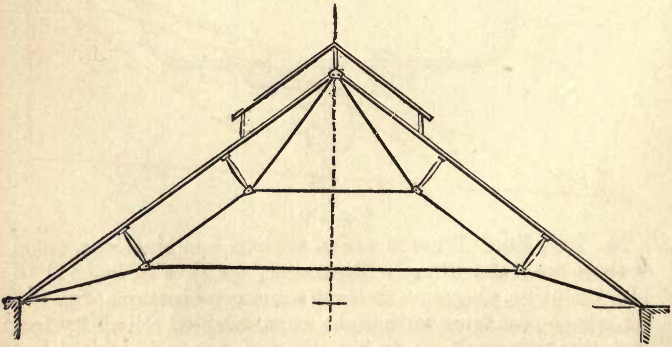


Fig. 413.

less than seven, and not more than eight feet apart. The dimensions are as follows:—"tie rod" *a a* $1\frac{3}{8}''$ diameter; rafter *b b* "T" iron, $3\frac{1}{2}'' \times 3\frac{1}{2}'' \times \frac{1}{2}''$ rib; "suspension rod," or "queen bolt," *c* $\frac{1}{2}''$ *d*, do., *d* $\frac{1}{2}''$, do., *e* $\frac{3}{4}''$, do., *f* $\frac{7}{8}''$; strut or brace *g* "angle-iron" $2\frac{1}{2} \times 2\frac{1}{2}'' \times \frac{3}{8}''$, do., *h* $3'' \times 3'' \times \frac{3}{8}''$; the

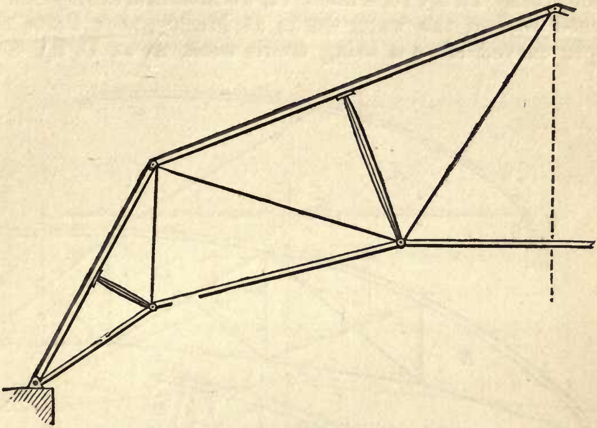


Fig. 414.

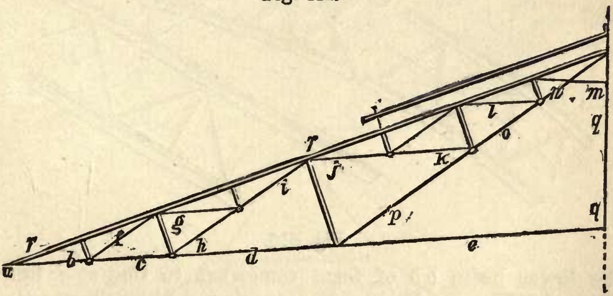


Fig. 415.

"rafter" of the "louvre ventilator," *j* $3\frac{1}{2}'' \times 3\frac{1}{2}'' \times \frac{1}{2}''$; "tie rod" *k* $\frac{1}{2}''$ diameter. The ventilator to be covered with inch boarding and zinc, the sides louvre-boarded. The truss in fig. 415 is that of one for a span of between 85 and 95 feet;

the "tie" rod *b* is $2\frac{1}{2}''$ diameter; "tie rod" *c* $2\frac{3}{8}''$, do. *d* $2\frac{3}{8}''$, do. *e* $1\frac{3}{4}''$; the "tie" *f* 1″, do. *g* 1″, *h* $1\frac{1}{8}$, *i* $1\frac{3}{8}''$, *j* $1\frac{3}{8}$, *k* $1\frac{1}{8}$, *l* and *m* 1″, *n* $1\frac{3}{4}''$, *o* $1\frac{5}{8}''$, *p* $1\frac{3}{8}''$, *q q* $\frac{1}{8}''$. The rafters *r r* are of two angle-irons $4'' \times 4\frac{1}{2}'' \times \frac{1}{2}''$. The diagrams A, B, C, and D, fig. 416, show various trusses for curved roofs; E an open beam truss. In fig. 15, Plate LV., we illustrate the segmental arched roof of the water-works at Marley, near Paris, the upper curved rib *a a* being trellis work, as at D, fig. 416;

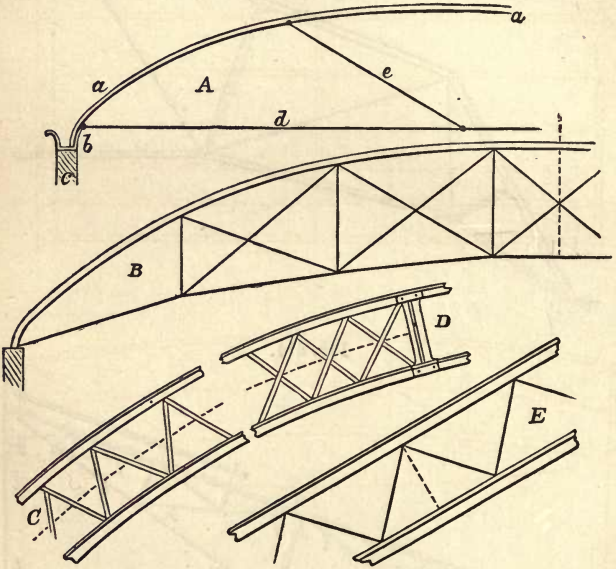


Fig. 416.

the lower beam *b b* of form somewhat to that at *j*, fig. 1, Plate LVII. In Plate LX. we give various illustrations of iron bridge work. Bridges of short span, and not requiring to be loaded with heavy weights, may be simply formed with beams of one or other of the various forms we have illustrated; the illustrations in Plate LX. refer chiefly to railway bridges, and are given with the view to illustrate some of the leading methods of joining iron plates together in work of this kind. In fig. 3, B B and C C D D is the main girder of a "box beam" bridge stretching across the opening; this carrying the cross girder I I, fig. 4, on which the rails are supported, these resting upon the wood bearers J J. Fig. 2 is a section on the line *a b* of the cross girder I I, fig. 4. Fig. 5 is the top part, fig. 8 the bottom part, of a "built beam" bridge; figs. 1 and 6, do., and fig. 3 side elevation of

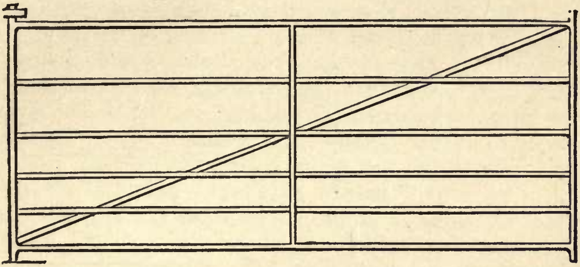


Fig. 416*a*.

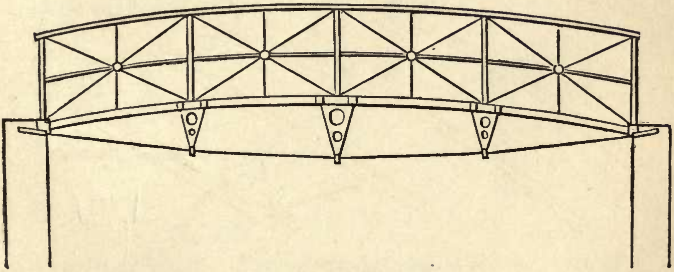


Fig. 416*b*.

fig. 1. In fig. 5, *d d* is the central plate or web of the beam, with its upper plates—in this case they are curved in outline—*a b c* secured to the web by the angle-irons *e e*, *f f* strengthening vertical plate. Fig. 7 is side elevation, with corresponding letters, a strengthening plate *g* is placed at intervals across the top plates. In fig. 8 a method of connecting the cross

girders, corresponding to the cross girder I J in fig. 4, is shown, *a a* the web of the main girder, with bottom plates *b c d* and angle-irons *e e*; *f f* are vertical strengthening angle-irons; *g g h* the cross girder resting upon the bottom plates *b c d*. In fig. 6 the section of this cross girder is shown, in which *a a* are the angle-irons corresponding to *g g* in fig. 8, *b* the web to *h* in fig. 8. Fig. 6 illustrates the cross girder carrying timber bearers *c d*. Fig. 416*a* illustrates a form of iron trussed gate, fig. 416*b* a trussed iron foot-bridge.

CHAPTER II.

WORK IN LEAD AND ZINC.

52. Lead, in building construction, is used in the form of sheets of varying thickness, and in specifications is stated as weighing so many pounds to the square foot, as "five lbs. to the foot lead." Its use is chiefly confined to the lining of cisterns and of gutters, and the formation of what are called "flushings" to gable ends and to chimney shafts. The object of a lead flushing, illustrated in fig. 417, is to keep the wet out at the junction formed by the roof covering and the vertical face of the chimney, or coping of gable, as the case may be. The flushings are strips of sheet lead varying from 8 to 9 inches in breadth. Fig. 417 illustrates a lead flushing

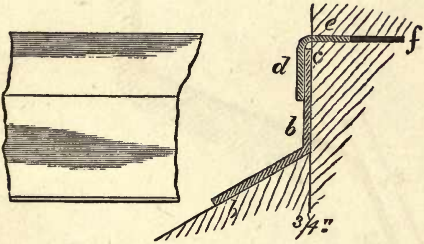


Fig. 417.

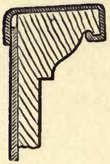


Fig. 418.

to a chimney stack. Part of the mortar is scraped out of a joint *f* in the vertical face of chimney, and a piece of lead *e* inserted and bent down at *d*, the bent part covering the other piece of lead *b c*, which is retained or bent, so as to lie against the face of chimney at *c*, and on the surface of slates at *b*. Fig. 418 represents a form of lead flushing adapted for a parapet or cornice behind which there is a gutter, as at *e* in fig. 419. In fig. 419 the lead *a c e* is turned up at *f*, so as to go under the roof covering at *g*. Fig. 420 illustrates the lead lining of a valley gutter, for a "ridge and valley" roof. The lead flushing for the ridge of a roof closely resembles in section the ridge tile illustrated in Chapter I. of the next division of this work.

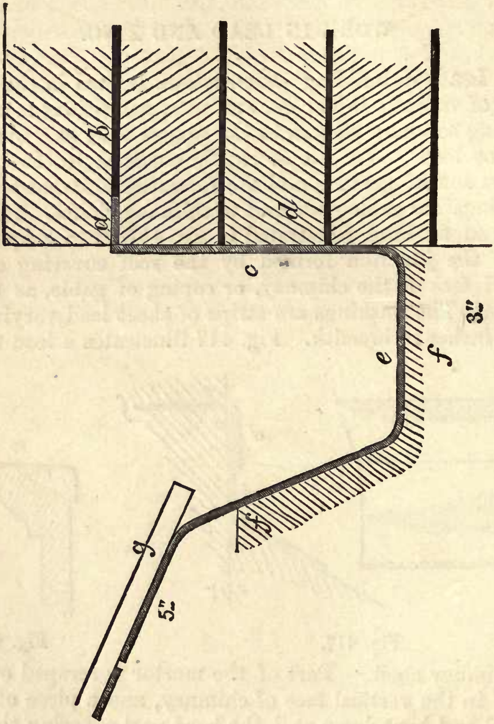


Fig. 419.

53. Zinc is much used for the covering of roofs; the various methods of using which, for this purpose introduced by the Veille Montaigne Zinc Company, whose gigantic works are near Liege, in Belgium, having done much to extend its use

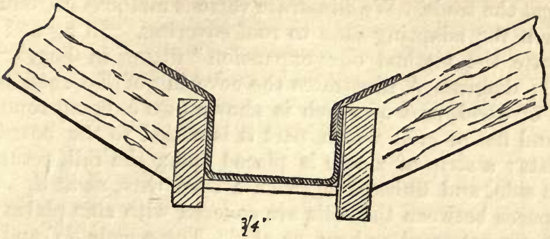


Fig. 420.

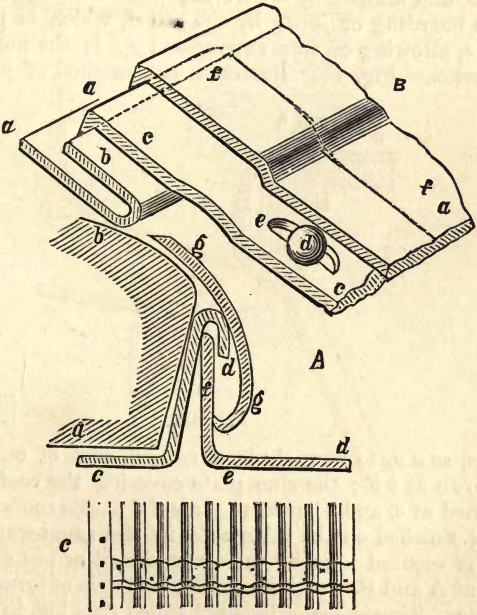


Fig. 421.

amongst the trade. We illustrate various methods introduced by them for adapting zinc to roof covering. In fig 421 we illustrate the method of "expansion" fitting in diagram A and B; diagram A illustrates the covering of flat roofs with a roll of wood, part of which is shown at *a b*, being rounded at *b* and flat at *a*, at which part it is nailed to the boarding or joists; a strip of zinc *c* is placed under the roll, returned up its side, and finished off with a bent part, as at *d*. The flat spaces between the rolls are covered with zinc plates *d e*, which are returned or bent, as at *f*. These ends *d f*, and the upper part of the roll *a b*, are protected from the rain by the cover *g g*, which is bent. By this arrangement perfect expansion is permitted. In B, fig. 421, the expansion system of covering ordinary roofs is illustrated; the plate *a a* is bent, as at *b*, and clasped by a covering piece *c c*, which is secured to the boarding or joists by the rail *d*, which is placed in a slot *e e*, allowing of free expansion; *f f* is the next plate in succession. Fig. 422 illustrates the method of joining zinc

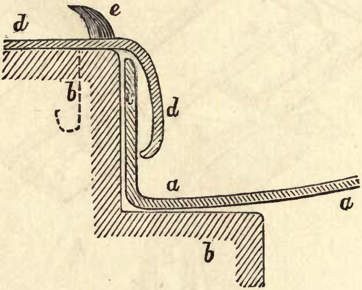


Fig. 422.

plates, as *a a*, to wrought-iron rafters, part of one of which is shown at *b b′*; the zinc plate covering the roof surface is retained at *c*, and a covering plate *d d* passes round the rafter, being finished on the other side in the same way, as at *c d*, and is secured to it by the screwed nail or pin *e b′*. In fig. 423, at A and B, we illustrate two methods of forming gutters of zinc. Zinc is generally used rolled flat, but in some cases it is used in the corrugated form, as at C in fig. 421, which illustrates the method of joining two corrugated plates with rivets. Corrugated zinc is so much strengthened by the corrugations or alternate flutings and hollows, that boarding may be dispensed with, and the sheets, bent or curved over the space to be covered, being secured only to the side walls or gutters of cast-iron, if these be used, as at C in fig. 423. In

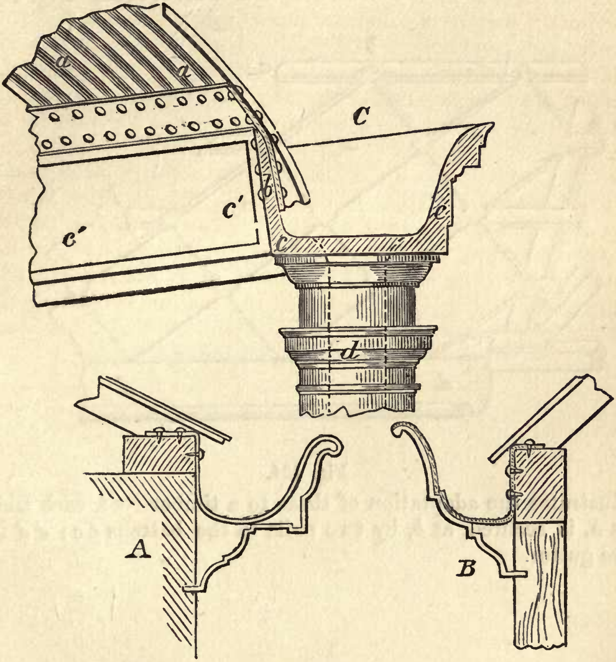


Fig. 423.

fig. 416 we illustrate part of a roof of corrugated zinc of this kind, *a a* the curved corrugated zinc plates—this curving of the plates gives additional strength to the roof—secured to the cast-iron gutter *b*, fixed to wall *c*; wrought-iron ties *d e* give additional strength to the arrangement, and strengthens it against the action of winds acting from below, as well as from the weight of the roof itself. At C, in fig. 423, we illustrate an arrangement of zinc roof of corrugated plates *a a*, which are secured, as at *b*, to the cast-iron gutter *c c*, rain from which is carried off to the drain by the hollow part of the column *d*, as shown by the dotted lines, to which the gutter is bolted at intervals. In place of sheets of zinc, so called "tiles" of the metal are used to cover roofs. Fig. 424

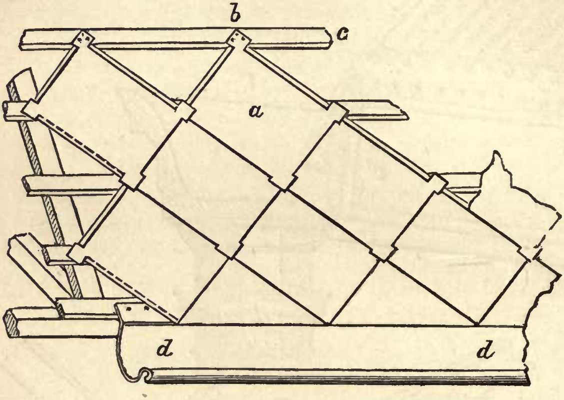


Fig. 424.

illustrates the adaptation of these to a timber roof, each tile, as *a*, is secured, at *b*, by two nails to the battens *c c*; *d d* is the gutter.

PART IV.

MISCELLANEOUS ROOF COVERINGS OF SLATE AND TILES —STAIRCASES—STRAINS UPON MATERIAL.

PART IV.

MISCELLANEOUS ROOF COVERINGS OF SLATE AND TILES —STAIRCASES—STRAINS UPON MATERIAL.

CHAPTER I.

ROOF COVERINGS OF SLATE AND TILES.

54. Slates.—Slates are of various sizes (see division on Materials), and the various parts of a slate are designated as follows :—the upper part of a slate, or that part which is seen when the roof is finished, is called the "back;" the lower or under side the "bed;" the lowest edge of a slate, as *a*, fig. 425, the "tail;" the upper edge *b*, the "head." To

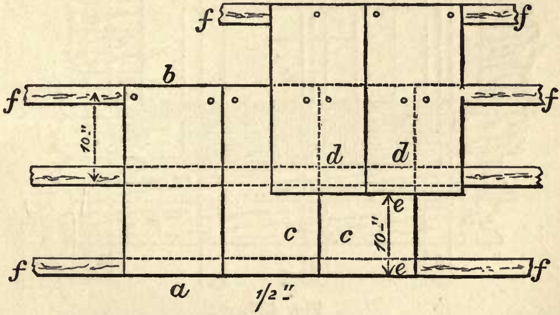


Fig. 425.

prevent the rain, etc., from gaining access under the slates they are laid so as to overlap each other, and made to "break joint," as shown in the drawing; the solid part, as *d*, of one covering the joint of the two next, as *c c*. The part of the slate in this arrangement thus exposed to view is called the "margin," as the part *e e*, fig. 425; and its depth, which varies according to circumstances, from top to bottom, as from *e* to *e*, is called the "gauge." The depth which an upper slate covers the slate below it is called the "bond" or "lap," and is measured from the line *c d* or *e f*, fig. 426 (which line running through the centre of the nail holes is called the "nail line"), to the tail or lower edge *a* or *b*. Before fixing, the slates are trimmed at the edge, and the holes punched as near to the head as possible without incurring the danger of

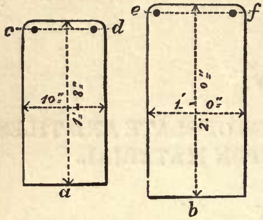


Fig. 426.

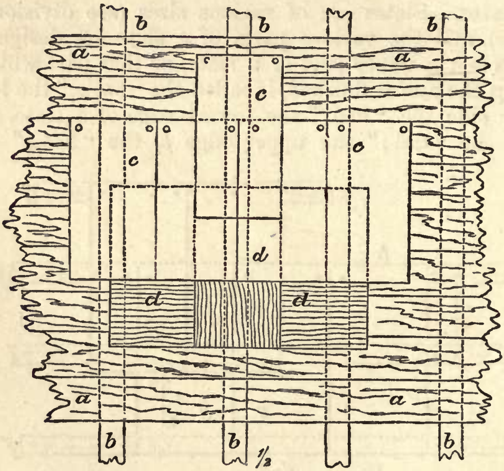


Fig. 427.

breaking the slate. The slates are fixed either to "boarding" or to "battens," these being secured at intervals to the upper edges of the rafters of the roof. Fig. 427 illustrates the mode of fixing slates to boarding—*a a a a* the board nailed to the rafters *b b b b*; *c c c* the "slates;" *d d* the "margin."

If the slates are fixed to battens, which are small timbers 2 to 3 inches wide and three-fourths of an inch in thickness, the distance from centre to centre of the battens is determined by the "gauge" or depth of the margin *e e*, fig. 427. This is found by halving the distance from the "nail line" *c d*, fig. 426, to the tail *a*, fig. 425, of the slate, deducting from this the width or depth of the "bond" or lap, and dividing the result by 2. Thus, in fig. 425, the slate *a b* is a duchess slate, 2 feet long by one foot wide. The nail line is 1 inch from

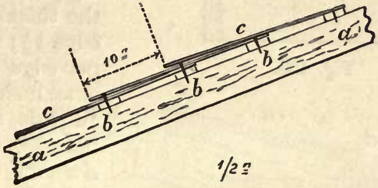


Fig: 428.

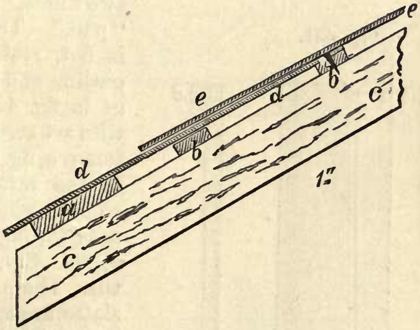


Fig. 429.

head *b*; this gives 23 inches as the distance from this to the tail *a* of the slate; the "bond" or "lap" is fixed at, say, 3 inches, which deducted from 23 gives 20, and this divided by 2 gives 10 inches as the "margin" *e e*, fig. 425, and the distance from centre to centre of the battens *f f*. Fig. 428 gives the section of the arrangement, where *a a* is the rafter;

b b the battens; *c c* the slates. In fig. 429, the "tilting piece" or "eaves board" is shown at *a*. This is feather edged, thicker at one edge than at the other, and its office is to tilt up the lower or eaves course of slates; the width of the tilting-piece *a* is 6 inches; the thickness of lower edge $1\frac{1}{2}$; and of its upper edge three-fourths of an inch in thickness. In this fig. *b b b* the battens, *c* the rafters, *d d e e* the slates.

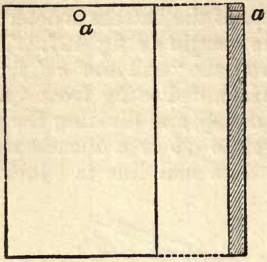


Fig. 430.

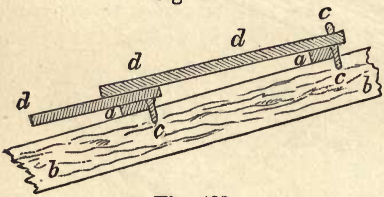


Fig. 431.

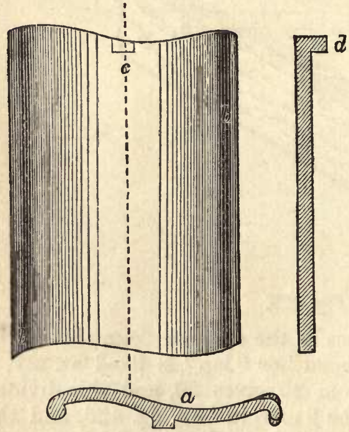


Fig. 432.

55. Tiles.—Tiles, as generally used, are of two kinds, "plain" and "pan." The "plain" is flat, rectangular in outline and in section, as in fig. 430. These tiles are secured to battens *a a*, fig. 431, nailed to the rafters *b b* by wooden pins *c c*, which pass through the hole *a*, fig. 430, at top of tile. The tiles, like the slates, are made to overlap each other, and to break joint. The "pan tile" is in cross section, as at *a*, fig. 432, in elevation at *c*, and in longitudinal section at *d*. These are hung, so to say, to the battens *a a*, fig. 433, by the projecting piece

b b (*d* in fig. 432), which is made on the lower face or bed of tile. Ornamental tiles are now made of various forms, some with their lower edges formed of semi-circles,

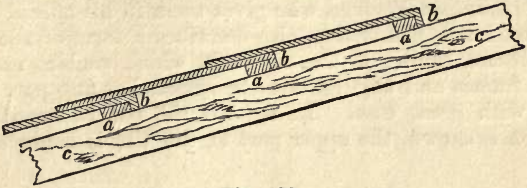


Fig. 433.

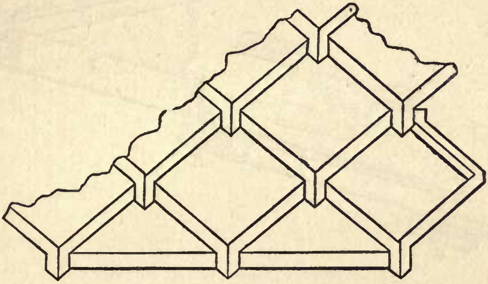


Fig. 434.

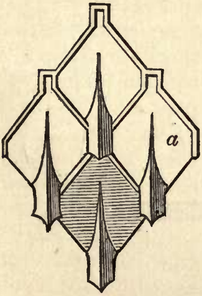


Fig. 435.

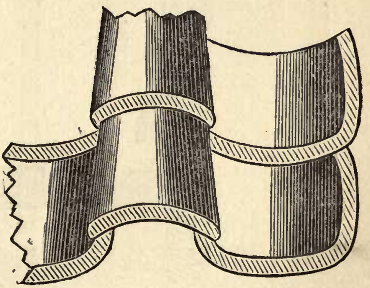


Fig. 436.

some lozenge-shaped. In figs. 434 and 435 we show two forms of Continental tiles; in fig. 435 a small ridge *a* or fillet, tapering to an edge, is placed on the upper side of the tile, which gives great strength, with thinness, and adds to the appearance; the shape of this tile is lozenge, that of fig. 434 square, placed diagonally. Fig. 436 shows the "bridge tile." Captain Fowkes, who gives them in his official report on the Paris Exhibition, also describes a form of tile made by Messrs. Muller & Co., of Paris, which enables cast-iron light frames and sky-lights to be inserted at any part of the roof with great ease. In fig. 437 the tile in longitudinal section is shown, the upper part of the tile is made as at *a*,

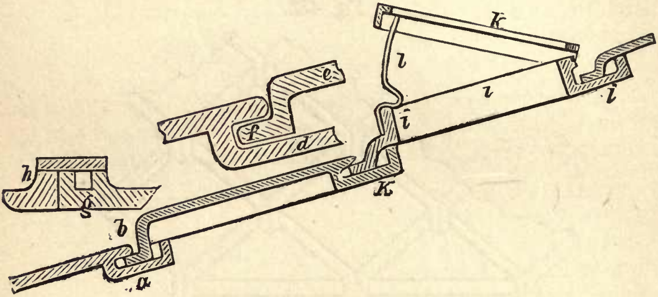


Fig. 437.

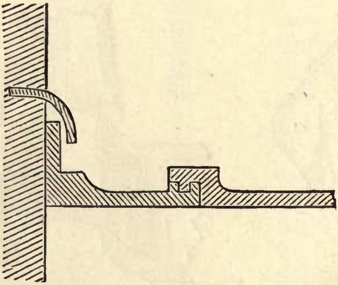


Fig. 438.

the lower part as at *b*, this going into the recess at *c* (shown on a larger scale at *d e f*). The joint longitudinally is shown at *g*, which is the lower part of one tile, this being furnished with a projecting part which goes into a hollow in the bed of the next tile lower down, as *h*. The cast-iron frame of the skylight is at *i i i*, and the easy way in which it is fitted to the tiles is there shown; *k* is the light or glass frame held open by the catch *l*. Fig. 438 shows a flushing tile made by the

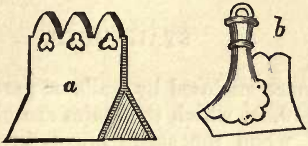


Fig. 439.

same firm and on the same principle. In fig. 439, *a* is a form of ridge tile, *b* do., but used to terminate the ridge, both being made by Messrs. Johnson & Co., of Ditchling.

CHAPTER II.

STAIRCASES.

56. The space enclosed by walls or partitions, as the space *a b c d*, fig. 440, in which the stairs are placed, is termed the "staircase;" when the stairs are external to the wall, that is, in the open air, leading, for example, to an outbuilding,

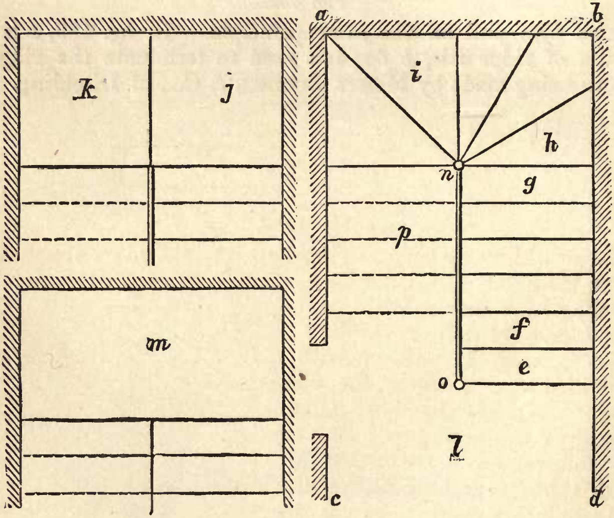


Fig. 440.

or from the door of a house to the yara or garden, they are called "outside stairs." The arrangement of the steps, of whatever kind these may be, constitutes what is called the "stairs." These are made up of "steps," "flights," and "landings." Steps, when parallel to one another, are called "flyers," as *e f g*, etc. When angular, or narrower at one end than the other, as *h*, the steps are called "winders." The series of steps between one landing or starting-point, as *a*, fig. 441, and another landing, as *b*, is called a "flight."

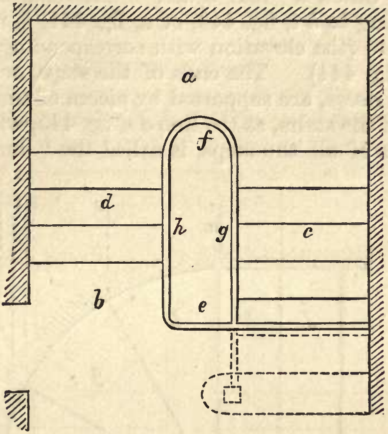


Fig. 441.

The part of a step upon which the party ascending the stairs puts his feet is called the "tread," as *b*, fig. 442; this being usually nine inches broad, and in superior work projects beyond the part *a*, and is finished with a moulded part *c* called the "nosing;" a small moulded fillet *e* connects the nosing with the face of the vertical part *a*, which is called the "riser," and the height of which is generally seven inches; a "blocking" *d* is placed underneath the tread *b* and behind the riser, this blocking is sometimes called a "rough bracket," the ends being notched or dovetailed into the face of the "rough string" (which see in succeeding sentence). The part of a stair which is wider than a step, and which is either a resting-place, as *j k*, fig. 440, or the final ending of the stair, as *l*,

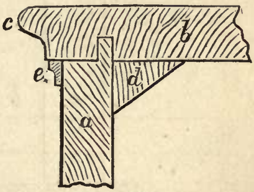


Fig. 442.

is called a "landing." If the landing is divided into two, as *j k*, the part *k* being the height of a step above *j*, the half, which is a square, as *j* or *k*, is called a "quarter space;" when the landing stretches across the whole width of the two flights, as *m*, it is called a "half space." In some cases the part corresponding to *h i*, fig. 440, or *a*, fig. 441, is made circular, as in fig. 443 (the elevation with corresponding letters being given in fig. 444). The ends of the steps, or rather of the treads and risers, are supported by pieces of timber placed at the angle of the stairs, as the line *d e*, fig. 445, which, touching the nosings of all the steps, is called the "line of nosings."

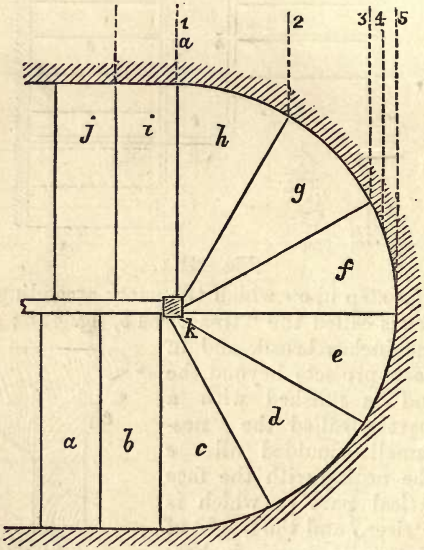


Fig. 443.

There are two strings, one next the wall *b d*, fig. 440, and which is called the "wall string," and the other outside, as *n o*, which is called the "outer string." The steps are fixed to the string *a a*, fig. 445, by one of two ways; the outer edge of the string, as *f g*, fig. 445, may have a part cut out, as *h*,

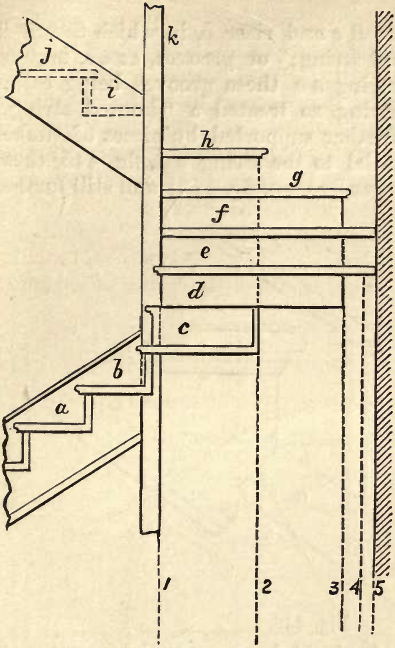


Fig. 444.

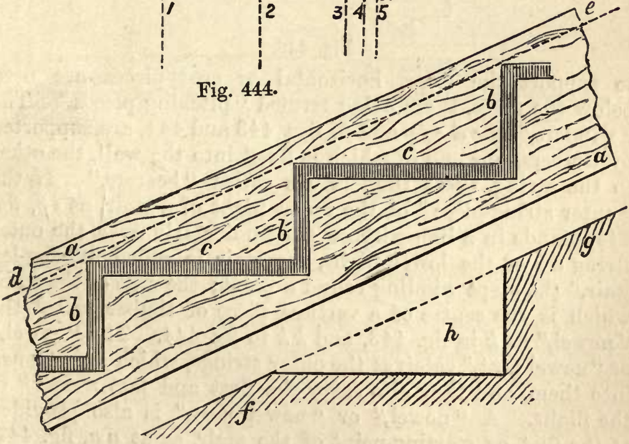


Fig. 445.

corresponding to the tread *c* and riser *b*, in which case it is called a "cut and mitred string;" or grooves, as *c b*, may be cut in the face of the string *a a* these grooves being called "housings," and the string so treated a "housed string." The steps, if long, are further supported by pieces of timber placed under them, parallel to the string *a a*, fig. 445, these are called "rough carriages," as *a a*, fig. 446; and still further

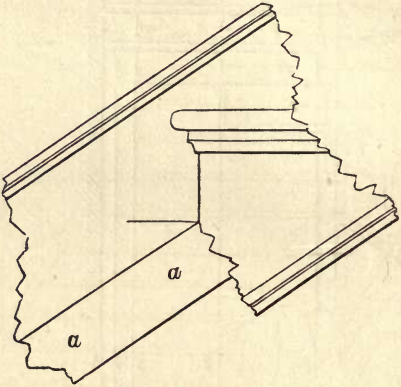


Fig. 446.

to support the steps, horizontal or cross-pieces are used below the fliers, these being termed "pitching pieces." The "winders," as *c d e f g* and *h*, figs. 443 and 444, are supported by timbers, one end of which is fixed into the wall, the other to the string, these timbers are called "bearers." If the "outer string-piece" of the upper flight of a stair, as *i j*, fig. 444, stands in a line with or perpendicularly over the outer string *a b* of the lower flight, the stair is called a "dog-leg stair," the steps winding round a point; the axis of the stair, which is the centre of a vertical piece of timber called the "newel," as *k* in fig. 443, and *k k* in fig. 444. The "newel," or "newel post," receives the outer strings, which are tenoned into them, and they also carry the first and last "riser" of the flight. A "newel," or "newel post," is also provided at the foot or starting-point of the stair, as at *a a*, fig. 447, being generally ornamented, the upper newel post is generally turned. The plan of a "newel," or "dog-leg stair," is shown in fig. 440, in which *f g* is the lower "flight" of "fliers," *h i* the "winders," and the dotted lines *p* show the position of the stairs of the upper flight terminating in the landing *o l*; *n* the "newel post;" *o* the ornamented newel post at bottom of stairs. When the upper and lower "flights," as *d* and *c*,

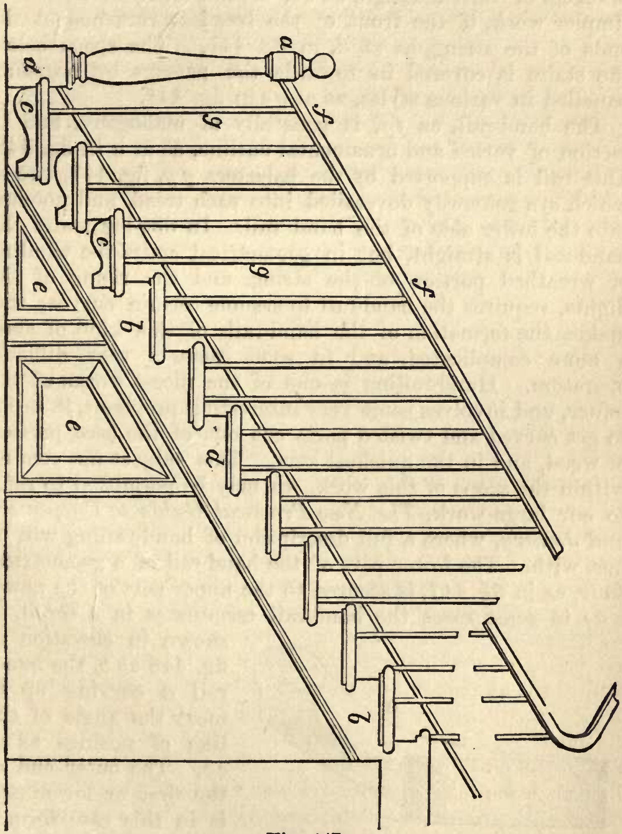


Fig. 447.

fig. 441, are not in a line, but separated by a space more or less wide, as *e f*, with no newel, as *k k*, in fig. 444, and with the outer string-piece *g*, fig. 441, winding round, as at *f*, to meet the upper string-piece *h*, the stair is said to be a "geometrical" one, and the string is said to be "wreathed." The outer string *b b*, fig. 447, is often ornamented with brackets of varied design, as *c c*, or the moulded nosing in simpler work, if the front of the tread is returned at the ends of the string, as at *d*, in fig. 447. The space below the stairs is covered in towards the passage by boarding panelled in various styles, as at *e e* in fig. 447.

The hand-rail, as *f f*, is generally of mahogany, and in section of varied and ornamental outline, as at *a* in fig. 448. This rail is supported by the balasters *g g*, fig. 447, two of which are generally dovetailed into each tread, and notched into the lower side of the hand rail. In dog-leg stairs the hand-rail is straight, but in geometrical stairs the winding or wreathed portion of the string, and the rising of the flights, requires the hand-rail to assume certain curves; this makes the formation of the hand-rails of this kind of stair a more complicated, and in some cases, a very difficult operation. Hand-railing is one of the nicest works of the joiner, and involves some very interesting problems, in order to get curved and twisted parts cut out of the least portion of wood, and in the quickest way. This subject not coming within the scope of this work, we may be permitted to refer to our large work, *The New Practical Guide to Carpentery and Joinery*, where a full description of hand-railing will be met with. The lower part of the hand-rail of a geometrical stair, as in fig. 447, is secured to the upper part of the newel *a a*; in some cases the hand-rail terminates in a scroll, as shown in elevation in fig. 448 at *b*, the hand-rail *a* curving up to meet the angle of the line of nosings as at *c c*. The outer end of the first or lower step is in this case formed with a scroll termina-

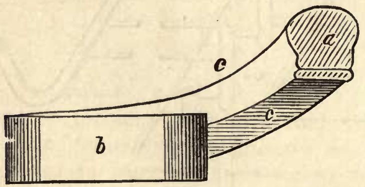


Fig. 448.

tion corresponding to the scroll *b*, fig. 448, the balasters being arranged at this part round the centre of the scrolled "curtail" step. In other cases the lower or first step of a stair is finished as at *a*, fig. 449, in which case it is called a "rounded step," or "round-ended step;" if with a scroll, as above described, the step is then called a "curtail step." Fig. 450 shows the twist of a hand-rail, as the lower part of the lower flight begins to bend or twist into the angle of the upper flight which goes in the opposite direction, as shown by the arrow *a*, *b* being the direction of lower flight, *c* a balaster. In the same figure *d* is part of the horizontal hand-rail at a level landing,

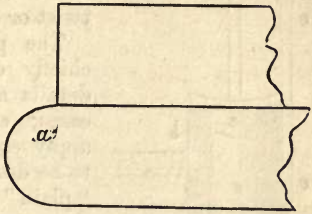


Fig. 449.

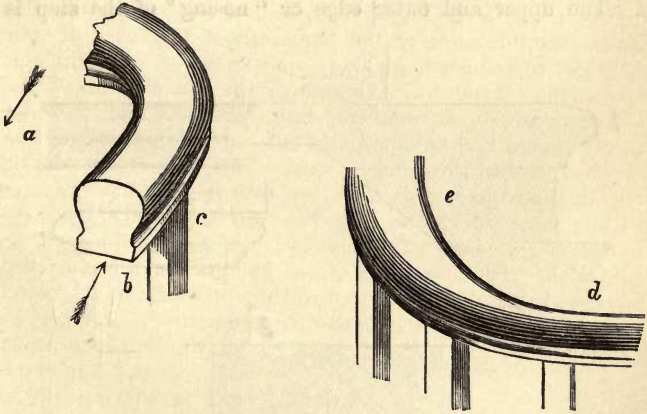


Fig. 450.

twisting into the angular part *e* of the hand-rail of next flight. Fig. 451 shows the winding or "wreathed" part of the string board *a* of a geometrical staircase at the first landing where the hand-rail twists from the angle of the lower flight (see fig. 450, *a b c*) *b b* to that of the upper flight *c c*. If the steps are ornamented, as at *c*, fig. 447, this has to follow the twist or curve of *a*, as shown at *d*.

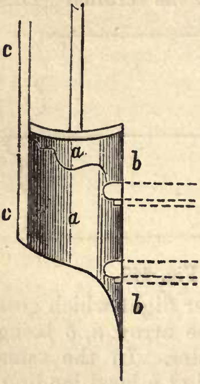


Fig. 451.

The preceding remarks have been chiefly confined, at least so far as details are concerned, to wood staircases; although many of the terms apply equally to *stone staircases*, now to be described. A stone step is either "plain" or "spandrel;" fig. 452 shows these two kinds of steps, *a* being the "plain" step; the "spandrel" is at *h f g*, in place of the upper step, as *b* in the "plain" step, simply resting upon the lower step as *a a*, and near its outer edge, as shown in the spandrel step, the junction is made as at *g*. The upper and outer edge or "nosing" of the step is

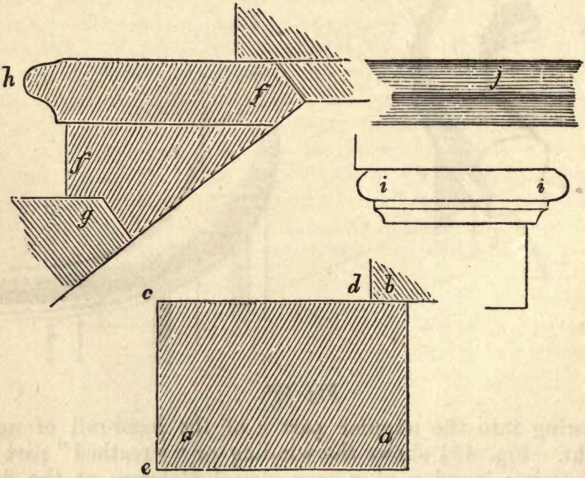


Fig. 452.

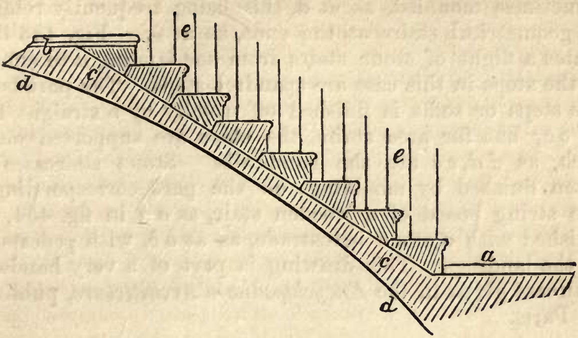


Fig. 453.

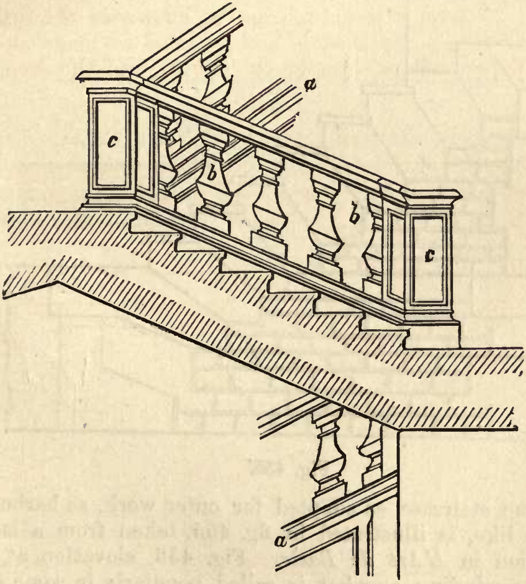


Fig. 454.

sometimes moulded, as at *a*, this being frequently retained in geometrical stairs at the ends, as at *i i*. Fig. 453 illustrates a flight of stone stairs from one landing *a* to another *b*, the steps in this case are spandrel steps. The part below the steps or soffit is finished off usually by a straight line, as *c c;* but for area stairs, the steps are supported on an arch, as *d d*, *e e* are the hand-rails. Stone staircases are often finished by mouldings on the part corresponding to the string board of a wooden stair, as *a a* in fig. 454, and finished with a stone balustrade, as at *b b*, with pedestal *c c* at the landings. This drawing is part of a very handsome staircase given in the *Encyclopediæ d'Architecture*, published in Paris.

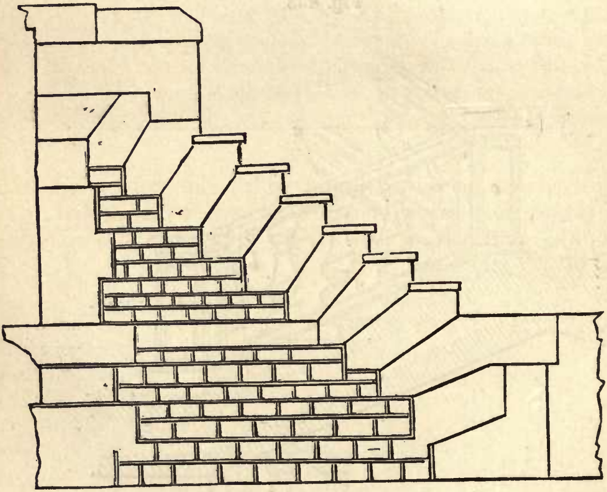


Fig. 455.

A stone staircase, as adapted for outer work, as harbours and the like, is illustrated in fig. 455, taken from a large illustration in *L'Art de Batîr*. Fig. 456, elevation at A, part of a winding, or what is called popularly in some districts, a "corkscrew" staircase; *a a* the first landing, *b b* the second landing, *c* the first flight, *d* the second, *c* the steps, *b* the railings. In same figure, at B, the plan of a winding

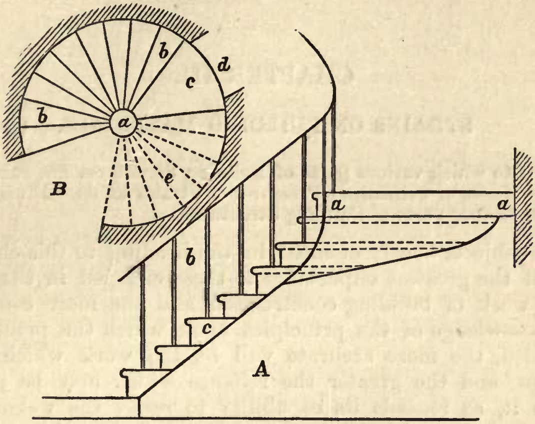


Fig. 456.

staircase, with newel *a*, round which the steps wind, and into which the narrow ends are housed, is illustrated; *c* is a landing at a door, *a e* the upper flight. In stairs of this kind all the stairs are "winders."

CHAPTER III.

STRAINS ON BUILDING MATERIALS.

Strains to which various parts of Building Structures are subjected —Modes of estimating Pressures or Strains on do.—Dimensions of various parts of Building Structures.

THE subjects briefly detailed in the heading to this chapter are of the greatest importance to those engaged in the practical work of building construction, and the more complete the knowledge of the principles upon which the practice is founded, the more accurate will be the work which they design, and the greater the reliance which may be placed upon it, as regards its capability to resist the weights or pressures to which its various parts may be subjected; in other words, the stability and the economy with which it may be erected. This latter point, although often overlooked, will be obvious on very slight consideration; for if parts are made heavier, or of larger dimensions than the necessities, so to say, of any particular point demands, then there is just so much extra material used which might have been saved; while, on the other hand, if these be made lighter or of smaller dimensions, with a view to securing the economy which alone an accurate knowledge of principles can give, then the safety of the structure is endangered, and this attempt at economising material may be carried so far that the structure cannot possibly be safe, except in the most favourable circumstances, and will, when these are unfavourable, which a variety of causes may bring about at any moment and in the most unexpected of ways, result in the entire destruction of the building, in whole or in part, thus causing heavy loss of time, labour, and material; or what may be worse, of life, a very likely occurrence, considering the uses which building structures are as a rule put to.

To a large extent in daily practice, certain empirical rules or standards of dimensions, so to call them, are in use; and while these rules, in a wide variety of instances, are found to be wonderfully successful, this arises mainly from the circumstance that they yield results in excess, rarely in deficiency, of material employed; still it is obvious that, if so, it brings about the waste of it already noticed; while it may be said with equal truth that it also involves the risk of instability and consequent damage, also above noticed; and this from the variety of circumstances connected not merely with the nature of the materials employed, but from the circumstances in which they may be placed, either as regards position, construction, or one or other of the many disturbing influences to which in all cases buildings are subjected in greater or less degree. What these are the student will have learned, with more or less fulness of detail, as space permitted of, in the various chapters and paragraphs which have been given in preceding parts of the two volumes which make up the present course. These are so varied in character, and are often so dependent upon circumstances over which the ablest designer and most careful constructor may be said to have not the slightest control; as, for example, unknown defects or flaws in materials, or from the treacherous character of some, to wit, cast-iron; so that it may be said, as has indeed not seldom been so, that the constructor who trusts to the empirical rules or standards, or that vague system described so graphically by the term "rule of thumb," is just as likely to be successful in his work, as regards its economy and safety, as he who brings to his work all the resources of the highest theoretical knowledge, as well as those derived from sound practical skill and the most careful and extended observation. But that this is not so, and that the fallacy lurking in the statement or belief is easily enough exposed, needs not to be here further gone into; it is sufficient to exemplify this by stating that the constructor trusting to the "rule of thumb" is treading upon ground, so to say, of the nature of which he really knows nothing, however much he may conjecture, as conjecture or guess he must, while he has at the same time all the elements of unknown sources of danger we have alluded to, to contend with; while he who brings to his work true principles knows what he is dealing with, and has only the chances of those unknown elements to combat, and which his superior knowledge best fits him to meet; in short, in no branch of technical work is the truth of the saying, "Knowledge is power," more strikingly employed, than in that of building construction, using this term in its widest acceptation.

The whole subject, the importance of a knowledge of which to the constructor we have thus but in the briefest manner glanced at, is one which embraces so many considerations, and the points and calculations connected with it are so diverse in character, as well as extensive in point of numbers, that to do justice to it a volume as large as the present might be written upon it without exhausting all the details. It will be obvious therefore that, within the limits of the confined space now at our disposal, we can do little more than glance at some of its leading points, and this even in the briefest fashion; and in order to the economization of space, as well as for the purposes of reference, we deem that the best way will be to give what that space admits of rather in the form of brief sentences, or what might be called notes, than in that of more formal descriptive matter or elaborate disquisitions.

The title of Strains of Materials has been chosen for the sake of brevity, although, strictly speaking, the subject involves or carries with it other departments; thus, it may be said to be divided into three great classes: "Materials used in Construction—their Characters and Peculiarities;" second, "The nature of the Strains, and the different kinds of them, to which the Materials are subjected;" and third, "Their Relative Value or Strengths, which enables them to bear certain Weights, or to resist certain Pressures or Strains to which they may be subjected." Following these, however, and as their natural result, come what may be called two other classes: first, the methods in use by which the direction and value of the pressures or strains are ascertained; and, lastly, the various formulæ upon which the rules used in practice, to determine the dimensions of the parts of materials designed to resist these pressures or meet these strains, with the maximum of efficiency and the minimum amount of weight of material.

The first of the classes named above—the characteristics of the materials used in construction—having, in the volume of this "Advanced Series," which embraces construction in stone and brick, been dwelt upon as fully as the space at disposal admitted of, we refer the student to that volume, and proceed to consider the strains or pressures to which these materials are subjected. These we give in the following brief paragraphs or sentences, which, although in most cases have reference to timber beams, apply also directly, with certain modifications which shall be noticed in due course, to those of iron in its two forms of cast and wrought.

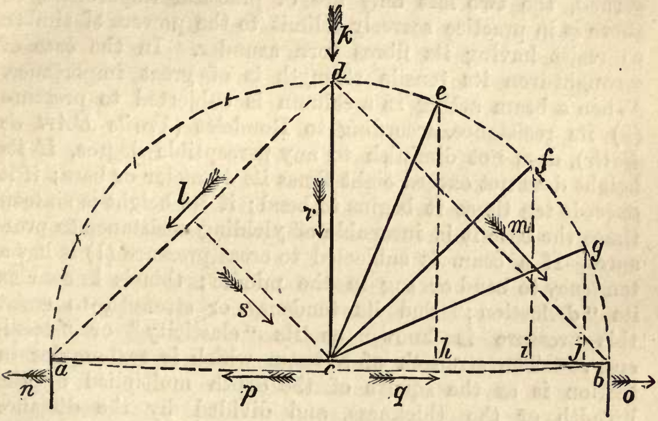


Fig. 457.

57. The strains to which materials are subjected, in the construction of framework, are as follows—(1) "transverse" or "cross strain." When a timber beam is supported at both ends, as the beam *a b*, fig. 457, and pressed upon by weights at its upper surface, in the direction of the arrow *r*, it is said to be acted upon by a cross or transverse strain, and this effect or strain is equally produced if the weights act from below, being suspended from the beam. (2) If the beam be acted upon by strains which operate in the direction of the arrows, *n o*, fig. 457, it is said to be subjected to a "tensile strain," and its power to resist this is stated to be its "resistance to

tension." (3) If the beam be placed vertically, like a column or pillar *d c*, and it be placed under a pressure acting in the direction of the arrow *k*, fig. 457, it is said to be subjected to a "compressive strain" or "force," and its resistance to that is stated as its "resistance to compression." The first (1) of these strains act in the direction of right angles to the fibres of the timber, tending to break them across; the second (2) in the direction of the fibres, with a tendency to tear them asunder; and the third (3) also in the direction of the fibres, but with a tendency to crush them together. Of these three, so far as timber beams are concerned, the two last only are of practical importance, as there is in practice scarcely a limit to the powers of timber to resist having its fibres torn asunder. In the case of wrought-iron its tensile strength is of great importance. When a beam acting as a column is subjected to pressure (3) its resistance, according to Rondelet (*Traite L'Art de Batîr*), does not diminish to any perceptible degree, if its height does not exceed eight times its diameter or base; if it exceeds ten times it begins to bend; if its height is sixteen times the base it is incapable of yielding resistance to pressure. If a beam is subjected to cross pressure (1) it has a tendency to bend or sag in the middle; this is known as its "deflection;" and its tendency or strength to resist this pressure is known as its "elasticity" or "resiliency." The strength of a beam which is rectangular in section is as the square of the depth multiplied by the breadth or the thickness, and divided by the distance between the points of support, as *a b*, fig. 457, or by the "span." Hence the strength of a beam is more economically increased by increasing the depth than by increasing the breadth; thus, a beam having its depth doubled, the thickness remaining the same, has four times the strength than before; but if its thickness or breadth be doubled, the depth remaining as before, its strength is only doubled. The best proportion of depth to thickness or width, in the face or edge of a beam, "is as the square root of 2 to 1." It is thus seen, as simply stated, that the strength is increased as the square of their depth, and directly as the breadth. A beam therefore, which is rectangular in section, is stronger when laid upon its edge than when laid upon its side, in the proportions as now stated. Ignorance of this simple fact, and of the principle upon which it is based, has led to some strange errors in construction. The strength of beams is also influenced by their length—the longer the weaker; or, stated thus, the strength is inversely as the bearing or span, or distance between the supports. The strength of a beam is also influenced by the way in which the load is distributed over its surface; if it be concentrated in the centre, as at the point *c*, fig. 457, it will only bear half the weight which it will do if the load be distributed over its surface. As will be presently shown, the strength of a beam increases as the load approaches its points of support, so that a beam uniformly loaded may be reduced in depth as it approaches the points of support without reducing its strength, if so lessened in depth from the centre to the ends. A parabolic curve is the best outline to give the under side, allowing flat places at the end for the bearings on the wall. A beam or cantalever, projecting from a wall and uniformly loaded, is as strong if the under half be cut away, the outer end being reduced to a point, the inner end of the normal depth of the beam, as the beam would be if kept the full depth from point to bearing. And as in the case of a beam supported at both ends, this cantalever will support twice the weight, if uniformly loaded, which it would do if loaded at the end only. A beam supported at both ends, but not loaded, if of great length, has a tendency to sag or bend in the centre, just as if it was loaded on the surface. In all calculations, therefore, respecting beams, the weight of the beam itself must be taken into account. The fibres of a beam supported at both ends, and subjected to cross pressure, are placed under different kinds of strains. Thus, the upper fibres are subjected to a strain of compression, while the under are under tension. In a beam or cantalever supported at one end, and subjected to a load at one end or distributed over the surface, the upper fibres are under compression and the lower under tension. In the former case the point is pretty well illustrated if the student will suppose the beam, supported at both ends, to be considerably bent; he will then understand how the fibres towards the centre of the upper side *g*, fig. 458, are crushed together, while those of the lower *h* side are extended. By taking a piece of thick vulcanised india-rubber and bending it, he will have the point visibly illustrated.

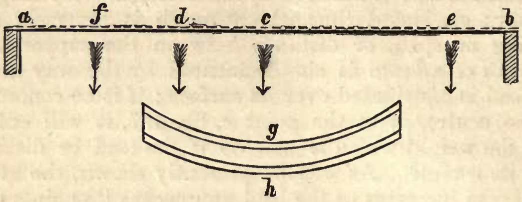


Fig. 458.

The resistance of a horizontal beam to cross strain increases, as we have said, as the shortness of the distance between the supports or bearings, as *a b*, fig. 458; the horizontal position being the weakest in which a beam can be placed, the vertical the strongest. The point at which the pressure or cross strain is applied to a beam, influences also its power to resist strain; and it follows from what we have said that the nearer this pressure is applied to any one of its bearings the greater will its power to resist strains be. Hence, as already stated, a beam will support twice the weight if that weight be uniformly distributed over its surface, which it would do if applied at its centre. Hence, also, the varying pressure as the distance from the bearings at which the pressure is applied is increased or diminished. At the point *c*, fig. 458, as we have shown, the pressure is just twice the amount which it would be if the same weight was distributed over the whole surface of the beam, as illustrated by the dotted line. The proportion of pressure to that borne at the centre *c*, which a given weight exercises at any other point may be ascertained thus: let the distance between the bearings *a* and *b* be 30 feet, and the pressure applied at the point *d*, say 10 feet from the point *a*, and 20 feet from *b*; then multiply these two together, which gives 200; next square the distance *a c*, or *c b*, which is $15 \times 15 = 225$; so that the proportion of pressure which the same weight exercises at the two points d and c is as 200 to 225. If the pressure was applied at e, 5 feet from the support or bearing b, then $e\,b \times e\,a$ or $5 \times 25 = 125$; and $a\,c^2$ or $c\,b^2 = 225$, gives the proportion which the pressure at the point e exercises, namely 125, as compared with that at c, namely 225. To find the strain to which the beam is subjected at the points of support $a\,b$, by any given weight pressing at a point as d: let the weight be 450 lbs., and the distance $a\,d$, as above stated, 10 feet; then multiply the distance $b\,d = 20$ by the weight 450, and divide by the span or distance between $a\,b$ as 30, the quotient will be the pressure at the point b. To find that at a, multiply the distance $a\,d = 10$ by the weight 450, and divide by 30 (the span $a\,b$) the quotient is the pressure at the point a. The pressure sustained at other points, as e and f, while that at e and its distance from a is known, may be thus ascertained. Let the distance $e\,b$ be 5, and $a\,f$ 7 feet. To find the pressure at the point f, multiply weight at e (450) by the distance $a\,d = 10$, then multiply the product by the distance $b\,e = 5$, and divide by the distance or span $a\,b = 30$. To find the pressure at the point e, multiply 450 (the weight at d) by $b\,e = 5$, and the product by distance $a\,f = 7$, and divide by span $a\,b = 30$; the quotient will be the pressure at the point $f = 10$. As the pressure thus decreases from the centre c, the reason will now be seen for the statement previously made, namely, that the depth of a beam may decrease from the centre towards the ends. We have said that a beam is the weakest when laid horizontally, as $a\,b$ at fig. 457, and strongest vertically, as $c\,d$; its strength, when in an inclined position, will evidently be in proportion to its angle of inclination from the vertical line $c\,d$. The proportion may be ascertained geometrically, as in fig. 457, where the distances $a\,b\,c\,d$ are laid down from a scale of equal parts. From c as a centre, with $c\,a$ or $c\,b$ as radius, describe the semi-circle $a\,d\,b$. From the points where the inclined beams as $c\,e$, $c\,f$, or $c\,g$ cut this, drop perpendiculars cutting $c\,b$ in points, as at h, i, and j; then the strength of $c\,f$ will diminish in the proportion as $c\,i$ is greater than $c\,h$, or $c\,j$ greater than $c\,i$. By adding two inclined beams, as shown by the dotted lines $a\,d$, $b\,d$, to the vertical beam $d\,c$, to the horizontal one $a\,b$, we obtain what is called technically a "truss," and an arrangement which is the strongest possible one we can get. Theoretically the truss is perfect without the vertical piece, when the pressure is vertical, as by the arrow *k*; in this case the pressure is transmitted along the inclined beams *d a*, *d b*, in the direction of the arrows *l m*, and is a pressure or strain of compression; this has a tendency to bulge or force the walls *a b* out in the direction of the arrows *n o*; but this is overcome by the beam *a b*, technically called a "tie beam," the strain or pressure upon which is that of tension acting in the direction of the arrows *p q* tending to pull its fibres asunder. But in the case of a roof, in which the inclined beams (or rafters), as *d a*, *d b*, are loaded along their whole surface, the pressure is changed from the purely vertical one as at *k*, and has therefore to be provided for. To do so, the vertical piece *d c* is added, the strain upon which is that of tension in the direction of the arrow *r*. The junction of the foot of this member (technically called a "king post," or if of wrought-iron, which may be substituted for timber, as the strain is tensional, a "king bolt" or "king rod") affords a butting place from which other members spring to relieve the pressure upon the inclined pieces (rafters) *a d*, *a b*. This is illustrated by the inclined piece *c l* (which is called a "strut" or "brace"), and the strain upon which is that of "compression" in the direction of the arrow *s*.

58. Having thus briefly stated the strains and pressures to which beams placed vertically and horizontally are subjected, we now turn our attention to those which affect beams *inclined* to the horizontal, these forming, as the student now knows, the most important members of trussed framework. Two points require to be ascertained in determining the strains to which the parts of trussed framework are subjected; first, the direction in which the pressure is communicated to the part; and, second, the amount or value of the pressure. These can be ascertained by calculation; but the simplest, and that perhaps most generally employed, is by geometrical construction, this being based upon the well-known problem, the "parallelogram of forces," by means of which we can find two pressures or forces, which, acting in two different directions, can counterbalance or be equal to one pressure or force acting in a certain direction, this being called the "resolution of forces or pressures;" or we can, on the other hand, or converse of the above, find the value and direction of one pressure or force, which will counterbalance or be equal to two forces or pressures acting in two directions, this latter process being called the "composition of forces;" thus, by means of construction, we can find the strains to which different parts of trussed framework are subjected. The "parallelogram of forces" may be illustrated by the following diagram: let *a*, fig. 459, be supposed to be a ball discharged from a cannon in the direction *b c*, as indicated by the arrow;

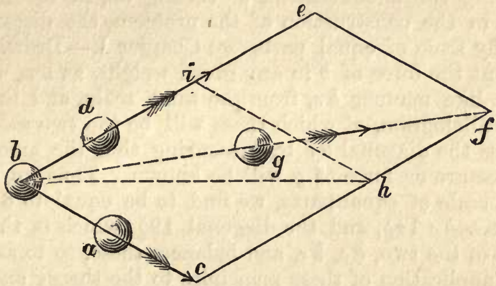


Fig. 459.

and *d* another ball, propelled in the direction *b e*; both would travel if acted upon singly, in these directions. But suppose a single ball, as *b*, to be acted upon by *two* forces, one tending to send it forward in the direction *b c*, the other in the direction *b e*, the ball would follow neither of these directions, but would take another and different course, and would go off in the direction of the diagonal, as at *g*, towards *f*. This diagonal evidently represents the amount or *result* of the two forces, *b c* and *b e*, as it is made up of these, and is therefore called the "resultant" of these two compound forces, or "component forces" *b c* and *b e*. Should the force or pressure sending the ball *b*, fig. 459, in the direction *b c*, be equal to that sending it in the direction *b e*, the diagonal would be *b h*, or of a square, as *b c h i*; but if the force sending the ball *b*, in the direction *b e*, was twice that sending it in the direction *b c*, the diagonal would be that of a rectangle, the length of which would be equal to twice the breadth; as, for example, *b f* is the diagonal of the rectangle *c b e f*. The finding of the amount of the pressure of the diagonal ball *g*, which will balance, so to say, the two pressures *a* and *d*, *i.e.*, one pressure acting in one direction, as *b f*, to be equal to two acting in two different directions, *b c*, *b e*, is called the "composition of forces," or pressures; while the converse of this finding, the amount of two pressures, as *bc*, *be*, which shall be equal to one pressure, *b f*, is called the "resolution of forces." These, as we have said, can be found geometrically. Thus, by taking the measurement, or setting off, in the first instance, in the construction of the problem, the distance *b c* from any scale of equal parts (*see* Chapter I.—Drawing), to represent the force of *b* in any given weight, as lbs. or tons, and in like manner *b e*, from the same scale, and finishing the parallelogram, of which these will be the two sides, and drawing the diagonal *b f* by measuring this, the amount of the pressure or force of *g* will be known. Thus *b c*, from a certain scale of equal parts, we find to be equal to $8\frac{1}{2}$—say $8\frac{1}{2}$ cwts.—*b e* $14\frac{1}{4}$, and the diagonal $19\frac{3}{4}$, which is the component of the two, *b c*, *b e*, and balances these, so to say.

The application of these principles to the theory and practice of framework, will now be illustrated and described. The pressure or strain exerted by any given weight, acting upon or being hung from the apex of two inclined beams, as *a b*, *a c*, fig. 460, increases as the inclination. To find what this pressure is, proceed as follows: Find the centre lines of the beams, and from the point *a* of their intersection at the apex drop a perpendicular *a b*. Let the amount of the pressure of the ball *a* be supposed to be 8 cwt. Then, from any scale of equal parts, make *a b* equal to eight of these parts. From *b* draw *b c* parallel to the opposite beam *a d*, and *b d* parallel to *a c*. Measure off the distance *a c* on the compasses, and apply it to the same scale of equal parts as that from which the distance *a b* was taken, and it will be found to be $5\frac{1}{2}$, and as the beams are equally inclined, the pressure on *a d* will be same as on *a c*; so that by doubling $5\frac{1}{2}$ we obtain the amount of united pressure which the two beams sustain, namely, 11, 8 being that at the point *a*. To simplify the constructions, and to prevent errors in the measurements, it is better to construct all problems with simple lines, as in fig. 459. The various points of intersection will thus be more clearly seen. The united

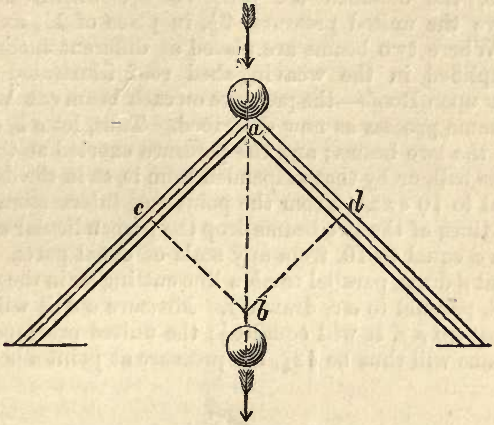


Fig. 460.

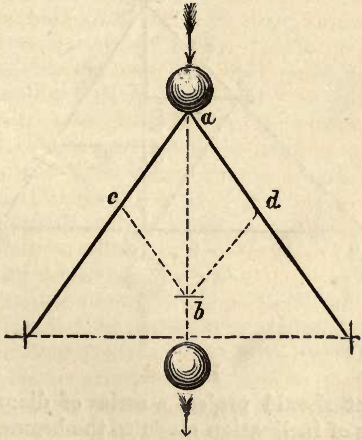


Fig. 461.

pressure of two beams, varying in their inclination, is illustrated by fig. 461, in which the inclination is less than in fig. 460; by proceeding as in fig. 460, making *a b* equal 8, the distance *a c* will be $4\frac{3}{4}$, which, doubled, will give the united pressure, $9\frac{1}{2}$, in place of 11, as in fig. 460. Where two beams are placed at different inclinations —exemplified in the weaving-shed roof illustrated in the Chapter upon Roofs—the pressure on each beam can be found by the same process as now described. Thus, let *a b*, *a c*, fig. 462, be the two beams; and the pressure exerted at the apex *a*, by the ball, or by that suspended from it, as in the diagram, be equal to 10 cwt. From the point *a* of intersection of the central lines of the two beams drop the perpendicular *a d*, and make *a d* equal to 10, from any scale of equal parts. From the point *d* draw, parallel to *a b*, a line cutting *a c* in the point *e*. From *d*, parallel to *a c*, draw *d f*. Measure *a e*, it will equal $7\frac{1}{4}$; measure *a f*, it will equal $5\frac{1}{2}$; the united pressure of the two beams will thus be $12\frac{3}{4}$, the pressure at point *a* being 10.

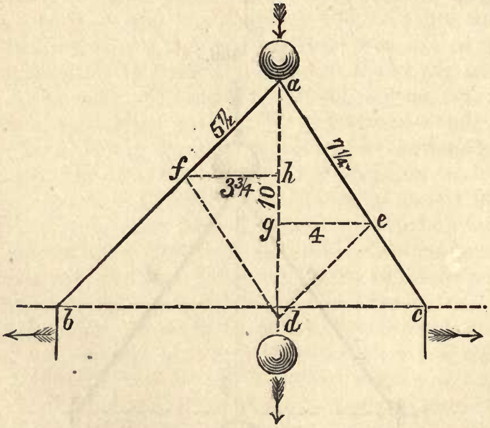


Fig. 462.

The student should project a series of diagrams with different degrees of inclination given to the beams, and marking in the figures, as in fig. 462. If we have two beams acting in two different directions, as the beams *a b*, *a c*, fig. 463, and if we know the force or pressure acting on these, we can find the direction in which a third beam should be placed to meet these two, and also ascertain the pressure which this third piece sustains, by proceeding thus: Let *a b*, *b c*, fig. 463, be the two inclined beams, the pressure *a b* 6, and on *c b* 11 cwt., and the direction in which these pressures act shown by the arrows; continue these directions, indefinitely, to *e* and *d*, and make *e* equal to 6 and *b d* equal to 11, from any scale of equal parts; from *e*, parallel to *d b*, draw a line, and from *d* another parallel to *b e*, intersecting in the point *f*, thus completing the parallelogram *b e f d*. Draw the diagonal *b f*. The line *b f* will be the direction in which a third piece should be placed to balance or equal the two pieces *a b*, *c b*; and the amount of pressure which that piece, as *f g*, has to sustain will be found by measuring the diagonal *f b* from the scale of equal parts, and which will be 14½. This is a problem in what we have shown to be called the "composition" of forces, in which a third force is found to counterbalance or resist two other forces acting in different directions. As stated in a preceding paragraph, when treating of Roofs generally, the tendency of two inclined beams *a b*, *a c*, fig. 464, acted upon by pressures or forces, represented by the balls and arrows, is to force the parts or walls *f g* upon which the feet of the beams rest apart, in the direction of the arrows *d e*. The amount of the thrust or force thus exercised may be

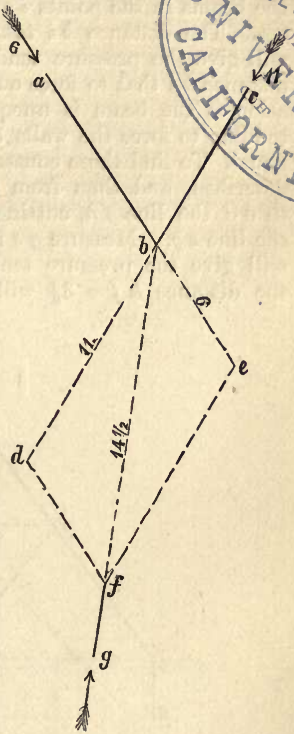


Fig. 463.

ascertained thus: From the point *a* drop a perpendicular, as *a h*, and make *a h* equal to the weight *a*, say 10 cwt.; from *h*, parallel to the two beams *a b*, *a c*, draw lines cutting the beams in the points *i* and *j*; join *i* and *j* by a line cutting *a h*. The distance *k i* taken from the scale of equal parts will give the pressure tending to force out the wall *c f*, and distance *k j* that to force out the wall *b g*. Where the inclination of the beam is unequal, as in fig. 462, the pressures tending to force the walls *b* and *c* outwards will also be unequal. To find these construct the diagram, as already there described, and then from the point *f* draw at right angles to *a d* the line *f h*, cutting *a d* in *h*, and from the point *e* the line *e g*. Measure *g e* from the scale of equal parts, this will give the pressure tending to force out the wall $c = 4$; the distance $h f = 3\frac{3}{4}$ will be the pressure on the wall *b*.

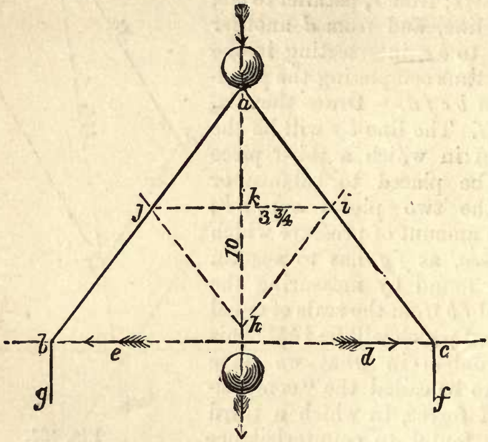


Fig. 464.

The pressure of beams upon walls, as in fig. 464, is made up of two kinds, one horizontal, the other vertical. To make the pressure of the beams on the walls as vertical as possible—which is the direction in which they are best calculated to sustain a pressure—the member of a truss, known as a tie beam, connecting the feet of the two beams, as the line *b c*, fig. 464, is used. The angle at which there is the least oblique pressure exerted by two inclined beams uniformly loaded on their surface is found to be 35·16. The pressure tending to tear asunder or rend the tie beam *c b*, fig. 462, will be equal to $f h + g e$, or $3\frac{3}{4} + 4 = 7\frac{3}{4}$. The amount of horizontal thrust or pressure upon the wall *c* will, as already stated, be equal to the distance *g e*; upon wall *b*, distance *f h*. The distance *f a* will be the measure ($5\frac{1}{2}$ cwt.) of the pressure upon the point *b*, the distance *ae* that on the point *c*. The direction of the pressure on these points being *a b*, *a c*. But in the case of roofs, the pressure is not exerted when on the apex of the inclined beam, as in figs. 462 and 464; but the roof covering being spread over the surface of the beams, from top *a* to bottom *b*, fig. 464, the direction of the pressure on the beams is out of the lines of their length. To find the direction proceed thus: Let *a b*, fig. 465, be one of the beams, and *c* its centre of gravity; from *a* drop a perpendicular *a d*,

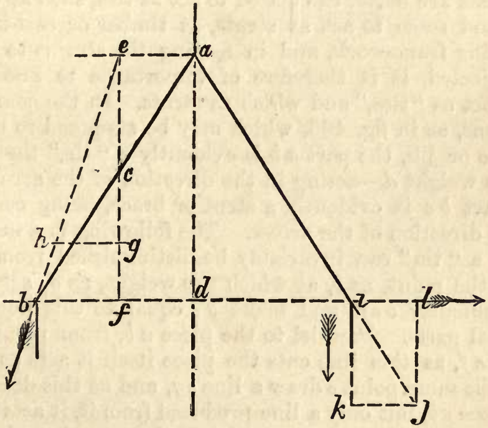


Fig. 465.

and parallel to this, through *c*, draw a line *c e f*, and from *a*, a line at right angles to *a d*, cutting *e f* in the point *e*, join *e b*; *e b* is the direction in which the thrust or pressure acts upon the beam *a b*. To ascertain the amount of pressure exerted on the wall; from *e* set off from a scale of equal parts a distance *e g* equal to the weight sustained by the beams, and from *g*, parallel to *a e*, draw the line *g h*; the distance *g h* gives the pressure. To ascertain the amount of horizontal and vertical thrusts or pressures at the foot of a beam, as at the point *i*, produce the line *a i* to the point *j*, and make *i j* equal to the weight placed on the beam, as, say, 5. From *j*, parallel to *d a* and *e a*, draw lines *j l*, *j k*, and from *i* draw *i k*; the distance *i l* gives the amount of horizontal, the distance *i k* the amount of vertical pressure, at the foot of the beam at *i*.

We have already stated, while treating upon beams and the strains to which they are subjected, that "ties" are subjected to the strain of tension tending to draw their fibres asunder, while struts or braces are subjected to a strain of compression tending to press or crush their fibres together; and further, that this leads to the practical point that some materials are better calculated to act as ties, such as wrought-iron, and some to act as struts, as timber or cast-iron. In designing framework, and in finding the strains to which it is subjected, it is therefore of importance to know which parts act as "ties," and which as struts. In the combination of beams, as in fig. 466, which may be supposed to represent a crane or jib, the part *a b* is evidently a "tie," the strain—by the weight *d*—acting in the direction of the arrow, while the part *b c* is evidently a strut or brace, being compressed in the direction of the arrow. The following is a method by which a "tie" can invariably be distinguished from a strut. From the point, as *b*, at which the weight, as *d*, acts, drop a perpendicular *b e d*, and make *b e* equal to this from a scale of equal parts. Parallel to the piece *a b*, from point *e*, draw a line *e f*, as this line cuts the piece itself it acts as a strut; from the same point *e* draw a line *eg*, and as this does not cut the piece *ab*, but only a line produced from it, it acts as a tie; if, therefore, when lines parallel to the two pieces be drawn, if the lines cut a piece within the parts of the framing, that piece acts as a strut; if it cuts a line produced without the framing, that piece so produced performs the office of a tie. Another method is this—when the parallelogram is completed, as at *b f e g*, draw its diagonal *f g*; then from the point *b*, at

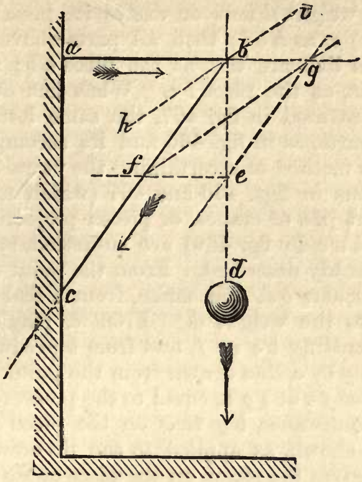


Fig. 466.

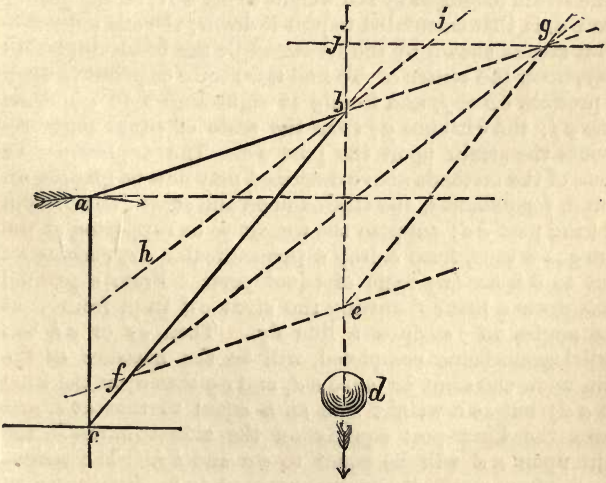


Fig. 467.

which the weight *d* acts or exerts its pressure, draw a line parallel to *f g*, as *h b i*; then all parts above or in the upper side of this line are ties, as the piece *a b*; all pieces below it are struts, as the piece *b c*. What has now been said is further illustrated in fig. 467, the same letters referring to the same parts, as in fig. 466 and its accompanying description. The method of ascertaining the "strains" to which the combinations in figs. 466 and 467 (which may be supposed to represent jibs or cranes, or pieces projecting from a wall, as the wall *a c* in fig. 466) are subjected, is much the same as that already described. From the point *b*, fig. 466, drop a perpendicular *b d*, and make, from a scale of equal parts, *b e* equal to the weight *d*. From *e*, parallel to *a b*, draw a line *e f*, cutting *b c* in *f*, and from *b* produce *a b* to *g*, and cut this in *g* by a line drawn from the point *e* parallel to *b c*. The distance *f b* or *f g* is equal to the pressure upon the piece *b c*, and the distance *b g* that on the piece *a b*. The same method is shown, as applied to the jib crane in fig. 467, in which *b g* gives the strain on the piece or tie *a b*, the distance *g e* that on the piece or strut *b c*.

The strain exercised by the weight *d*, fig. 467, on the post or pillar *c a*, is that calculated to pull it down; the end *a* describing an arc, as shown by the arrow, while the beam rotates, so to say, upon the centre *c*. To find this strain or pressure upon *a c*, produce *e b* to *j*, and from *g* at right angles to *a c*, draw a line *g j*; the distance *g j* from the scale of equal parts represents the strain upon the post *c a*. The application to trusses of the methods above described may now be glanced at. To find, for example, the strains upon the strut *c d*, fig. 468, and king post *a d*; suppose the weight to be supported at the point *c* is 3 tons, from *c* drop a perpendicular *c e*, making *c e* equal to 3 from any scale of equal parts. From *e* parallel to *a b*, draw a line *e f*, cutting the strut *c d* in *f*, from *f* at right angles to *c e*, draw a line *f g*. Then *c f* or *e i*, the parallelogram being completed, will be the measure of the strain upon the strut or brace *c d*, and *c g* that upon the king post *a d*; but as a weight acts at *h* equal to that at *c*, and presses the king post equally on the side towards *h*, the strain upon *a d* will be equal to *c g* and *h j*. The weight upon a rafter, as *a b*, is usually supposed to be distributed in equal proportions between the points of support, so that one-third would be at *b*, the second third at *c*, and the remaining

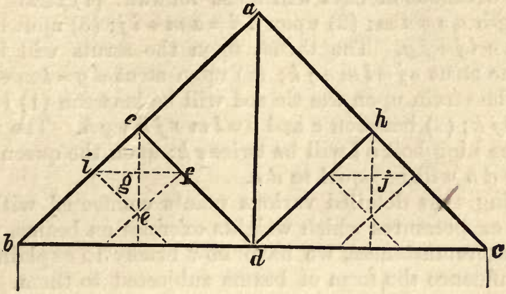


Fig. 468.

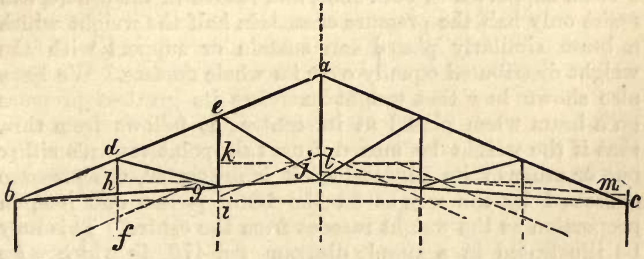


Fig. 469.

third at *a*. In fig. 469 the weight on *a b* would on this principle be distributed at four points *b*, *d*, *e*, and *a*. This diagram illustrates the method given by Mr. Molesworth in his excellent *Pocket Book of Useful Formulæ and Memoranda for Civil and Mechanical Engineers*, to find by construction the strains upon the parts of iron roofs; the principle, as will be seen, is the same as that already described. From the point *d* drop a perpendicular *d f*, and make *d f* equal to the weight (*w*); from *f* parallel to *a b*, draw *f g*, cutting the strut *d g* in *g*; from *g* at right angles to *d f*, draw *g h*, cutting *d f* in *h*. From *e* make *e i* equal to (*w*) plus *d h*, and draw *i j* parallel to *a b*, and *j k* parallel to *g h*. From *a* make *a l* equal to (w) plus $e\,k$, and from l, parallel to the tie rod $j\,c$, draw a line $j\,m$; then the thrust upon the rafter $a\,b$ at its various divisions or bays will be as follows: (1) strain upon the length $a\,e = a\,m$; (2) upon $e\,d = a\,m + i\,j$; (3) upon length $d\,b$, $a\,m + i\,j + f\,g$. The thrust upon the struts will be (1) upon the strut $e\,j = l\,m + j\,k$; (2) upon strut $d\,g = l\,m + j\,k + g\,h$. The strain upon the tie rod will be between (1) j and $i = l\,m + j\,k$; (2) between c and $b = l\,m + j\,k + g\,h$. The strain upon the king bolt $a\,l$ will be twice $e\,k$; upon the queen bolts $e\,i$, and $d\,h$ will be equal to $d\,h$.

Having thus detailed various points connected with the strains or pressures which weights exercise on beams, under various circumstances, we have now briefly to explain how these influence the form of beams subjected to them. In a special diagram in the present chapter we have shown that a beam supported at both ends, and loaded in the centre, can resist only half the pressure or sustain half the weight which a beam similarly placed can sustain or support with the weight distributed equally over its whole surface. We have also shown how that weight exercises its greatest pressure on a beam when placed at its centre; it follows from this, that if the weight be moved from this point towards either one or other of its ends, where it is supported, the pressure exercised by the weight on the beam is less and less, in proportion as the weight recedes from the centre. This may be illustrated in a simple diagram, fig. 470, in which $a\,b\,c$ represents a beam, supported at its ends by the walls $d\,e$, the arrow $b\,f$ representing the weight at the centre, and therefore exercising its greatest pressure, while other weights represented by arrows, as $g\,h\,i\,j\,k\,l\,m$ and n, may be taken as illustrating the gradual decrease of the various pressures at different points receding from the centre; or, in other words, the shorter arrows may represent the different positions to which the central weight $f\,b$ is moved along the beam. As the pressure at the point h or g is less than that at the point $b\,f$, and j or i less than that at g or h, it follows that it is simply a waste of material to make the beam of the same depth at the points g or i, as at b, and as the pressures gradually decrease towards the points of support a and c, so that it may decrease on either side of the point b, towards *a* and *c*; this is illustrated by the curved dotted line *m n*. This curve gives of course apparently the decrease on the upper part of the beam, but for obvious reasons, in convenience of building, etc., the flat side, as *o q*, is placed uppermost, the curve *p q* being at the lower edge of the beam; again, as the narrow points of the curves—a parabolic one being the best, as *o q*—present obvious inconveniences, the ends are finished off with a flat surface, as at the points *r* and *s* in elevation and plan, these being built into the wall *t*, or the end may be finished with a curved part *u* secured to the wall by a bolt and nut *v*.

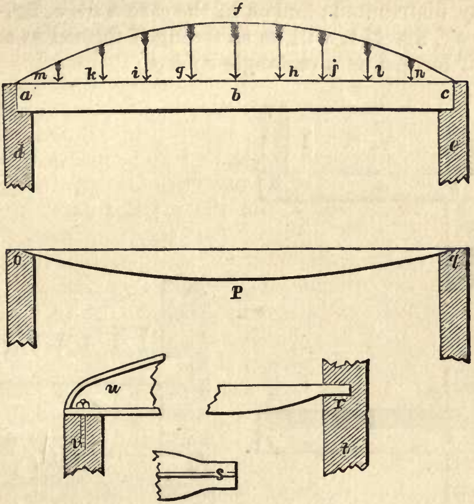


Fig. 470.

Again, in the case of beams projecting from a wall built into or supported by this, as the beam *a*, fig. 471, at point *b*; the pressure sustained by the beam is greatest at the point *b*, in the case where the weight, as *c*, is supported at the end *d* of the beam, inasmuch as the leverage which the weight *c* exercises on the beam decreases in its fracturing capacity towards the end *d*; this is illustrated in fig. 472, after the manner used or employed in fig. 470, showing also that as the tendency of the weight *c*, fig. 471, to fracture the beam diminishes towards the end *d*, the beam will be as strong as when in the form of *a b c*, fig. 472, as when of the form *a b d c*. To find the strain at *b*, fig. 471, when so far as the beam itself is concerned, not taking into account any weight to which it may be subjected, multiply the weight of the beam by half its length. As in the case of beams supported at both ends, so in that of beams supported at one end; a beam, as *b a d*, fig. 471, loaded at its end by a weight *c* will support only half the weight of a beam similarly placed, as *e f*, over the surface of which the weight represented by the lines *g h* is uniformly distributed; and as in the case *a b d c*, fig. 472, the beam, as *e f*, fig. 471, will be as strong if formed as a triangle *e f g*, as if formed as a rectangle *e f h g*.

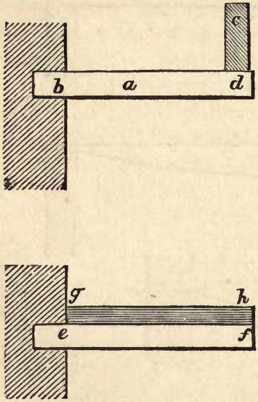


Fig. 471.

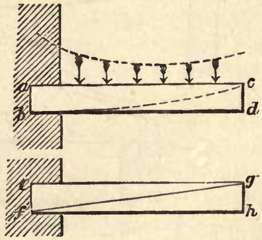


Fig. 472

These points as yet named, with relation to the form of beams, have had reference to their outline considered as elevations, or the appearance they present when viewed from either side; we have now to take up the form as presented when looked at at right angles to the side or front view; in other words, their cross or transverse section. We have just seen that the side elevation of a beam in the improved form, as detailed by results of scientific observation and repeated experiments, varies according to circumstances, and indeed the ideas or taste of the designer; but so far as regards the cross or transverse section is concerned, a form and proportion have been decided upon and adopted by the best practitioners, as that which gives the maximum of strength with the minimum of material. That form and these proportions were only arrived at by long and patient observation, and by a series of experiments of the most elaborate and painstaking character.

Of those who devoted themselves to this important work —while many could be named who have done good service in connection with it—the name of one stands prominently and pre-eminently forward and first, Mr. Hodgkinson of Manchester and London. This gentlemen brought to the task the accomplishment of mathematical knowledge of a profoundity rarely met with, and which has perhaps never been excelled, at least in modern times; together with a remarkable skill in applying this to circumstances which were altogether novel, many of which might be said to be created by him to meet the peculiar wants and necessities of the investigations he entered upon, and all of which were characterised by difficulties of no common order; and further by the exercise of a wonderful patience in observing and recording, and by the application of new methods of investigation and experimenting, he succeeded in so placing the whole subject of strength of material in such a thoroughly practical position, and deducing formulæ and rules so easily applied and so applicable to almost every variety or kind of practice, that it may be said he left little or no work for others to do who might follow after him. In connection with the labours of this distinguished scientist, it is impossible to omit naming one, who partly in the same field of mathematical investigation, but more immediately in that which may be called the practical, namely, William Fairbairn, whose reputation is world-wide as a mechanical engineer. The value of such labours cannot be over-estimated, for apart from the importance of being able to design parts of structures which have to support heavy weights or to sustain great pressures, with the least expenditure of material, and thus effect in most cases a considerable, but in some extensive works a very large saving in money, the fact is too often overlooked that the mere weight of a beam, for example, so badly designed and its proportions so carelessly calculated—if calculated at all—that its material is greatly in excess of what is really required, endangers the stability of the building, nay, has a tendency to weaken the part itself by throwing, by this extra weight, a pressure upon it which it should not be required to bear; so that the "rule of thumb" principle, which is said to be the safest, because it errs generally in making the parts too strong, in order to be "sure of them," as the phrase goes, introduces the very element of danger which it is supposed to avoid. Such remarks are not out of place here nor devoid of practical value, as they touch points often overlooked, which exercise an important influence in sound and economical construction.

Coming now to the subject of the cross section of beams, the rectangular section, if applied in the form of timber, could be made of such dimensions, by the adoption of one or other of the methods we have illustrated, as to bear great weights, such as merely by increasing the dimensions, as depth *ab*, breadth *cd*, fig. 474 (see succeeding paragraph); but it is obvious that this increase, as the weights they had to bear increased, would give such scantlings, so to say, that the mere weights of the beams would of themselves have no small influence on their breaking weight. To alter the form of the section would obviously, with such a material, involve no small manual labour. The case, however, was different with cast-iron, which could be run into sections or forms, such as scientific investigations or practical experience showed to be the best. The last, for a long time, was the girder; and the best section, and for long—and indeed yet—continued by many practical men to be the best, was that known as the "I" girder, in which the flanges at top and bottom are equal; and these and the central web at or about the same thickness. But the experiments, just above alluded to, conducted by Mr. Hodgkinson, showed that the strongest beam was that illustrated in a previous section, in which the sectional area of the top flange is one-sixth of that of the lower (see preceding illustration). This section is that now used in all cases where care is taken to secure the safest results, but, as just stated, many constructors, either indifferent to the indications of science or ignorant of what these have been, and are, still continue to use the old forms, and often, moreover, in the worst possible conditions. The calculations in connection with the improved section will be found further on.

59. Having thus described the strains by which various materials are influenced, the methods of ascertaining the amounts of these to which the parts of framing are subjected, and the direction in which these act, and alluded to the improved forms or sections of beams now generally approved of, we proceed to give a series of sentences containing a variety of practical details, which we trust will be useful to the student connected with the different departments of practical construction. We shall take the materials in what may be called their natural order.

60. In making the calculations respecting the pressure sustained by buildings and parts of buildings, it is necessary to know the weight per cubic foot of the *stones*, etc., most generally used throughout the country. The following list, which for obvious reasons is not complete, will, however, convey a fair amount of information useful to the student. We divide or classify the building stones of the kingdom thus—*sandstones*, first of England, second of Scotland; next the *limestones*, and of these, first the magnesium, and second the oolitic.

Taking first the *English Sandstones*, and of these the Abercame, from the quarries in Monmouthshire, we find the weight per cubic foot to be nearly 168 lbs.; of Ball Cross, Derbyshire, nearly 159 lbs.; of Barbadoes Quarry, in Monmouthshire, 146$\frac{3}{4}$ lbs.; of Bevis's Quarry, Wiltshire, 111 lbs.; Bolton's Quarry, Yorkshire, 126$\frac{3}{4}$ lbs. Bromley Hall, Yorkshire, 142 lbs. 3 oz.; Culverley, in Kent, 118 lbs.; Duffield Bank, Derbyshire, 132 lbs. 14 oz.; Gathally Moor, Yorkshire, 135 lbs. 13 oz.; Galton, Surrey, 103 lbs. 1 oz.; Heddon, in Northumberland, 130 lbs. 11 oz.; Hollington, Staffordshire, 133 lbs. 1 oz.; Lindley, Red Quarry, Nottingham, 148 lbs. 10 oz.; Lindley White Quarry, 149 lbs. 9 oz.; Morley

Moor, Derbyshire, 130 lbs. 8 oz.; Osmotherly Quarry, Yorkshire, 160 lbs.; Park Quarry, do., 160 lbs.; Park Quarry, Staffordshire, 124 lbs. 9 oz.; Park Spring, Yorkshire, 151 lbs. 1 oz.; Penshee Quarry, Durham, 134 lbs. 5 oz.; Shaw Lane Quarry, Derbyshire, 135 lbs. 15 oz.; Darley Dale Quarry, Derbyshire, 148 lbs. 3 oz.; Stanley Quarry, Shropshire, 146 lbs.; Slenton Quarry, Durham, 142 lbs. 8 oz.; Tulacre and Gweslyr Quarry, Flintshire, 150 lbs. 4 oz.; Victoria Quarry, Yorkshire, 145 lbs. 3 oz.; Viney Hall Quarry, Gloucester, 155 lbs. 11 oz.; Warwick Quarry, Yorkshire, 148 lbs. 10 oz.; Wheatwood Quarry, Yorkshire, 143 lbs.; Whitby Company's Quarry, Arlasby, Yorkshire, 126 lbs. 11 oz.

The Scottish Sandstones—Auchray Quarry, Forfarshire, 158 lbs. 14 oz.; Binnie Quarry, Linlithgowshire, 140 lbs. 1 oz.; Cat Crag Quarry, do., 141 lbs. 11 oz.; Craigleith Quarry, Edinburgh, 145 lbs. 14 oz.; Crawbank, Linlithgowshire, 129 lbs. 2 oz.; Glammis Quarry, Forfarshire, 161 lbs. 2 oz.; Humbie Quarry, Linlithgowshire (white stone), 140 lbs. 3 oz.; do. (grey stone), 135 lbs. 13 oz.; Loch, Forfarshire, 159 lbs. 3 oz.; Lochee Quarry, 158 lbs. 11 oz.; Longannet, Perthshire, 131 lbs. 11 oz.; Munlochy, Ross-shire, 169 lbs. 9 oz.; Mylnefield Quarry, Perthshire, 160 lbs.; President Quarry, Dumbartonshire, 134 lbs. 5 oz.; Pigotdikes, Forfarshire, 162 lbs. 8 oz.

We now come to the limestones of the two groups, of which we take the *magnesium* first,—Bolsover, Derbyshire, 151 lbs. 11 oz.; Birdsworth, Yorkshire, 133 lbs. 10 oz.; Cadeby, Yorkshire, 126 lbs. 9 oz.; Huddllestone, Yorkshire, 137 lbs. 13 oz.; Park Hook Quarry, Yorkshire, 137 lbs. 3 oz.; Roche Abbey, Yorkshire, 127 lbs. 8 oz.; Shrawse do., Yorkshire, do. do. Taking next the *oolitic* limestones, we come first to those of the limestone quarry, Lincolnshire, a cubic foot of which weighs 139 lbs. 4 oz.; Bath Lodge Hill Quary, Somerset, 116 lbs.; Bath Baynton Quarry, Wiltshire, 123 lbs.; Haydon, Lincolnshire, 133 lbs. 7 oz.; Kelton, Rutlandshire, 128 lbs. 5 oz.; Portland (Vern St. Quarry), 134 lbs. 10 oz.; Portland (Waycroft Quarries), 135 lbs. 8 oz.; Portland (Grove Quarry), 145 lbs. 9 oz.

61. Although cast-iron, for the purposes of columns to support heavy weights, has greatly, indeed almost wholly,

superseded the use of stone, in some cases, however, this latter material is still used. When so, the length should never be greater than twelve times the diameter of the column at the base; nor should the load which the column has to support exceed one-tenth of the estimated weight or pressure which it takes to crush or disintegrate the particles of the stone of which the column is built. According to the best experiments which have been made, it appears that granite can stand a pressure of 500 tons per square foot before fracture is caused; marble, 400; sandstone, 350; Craigh Leaf freestone, 200; magnesian limestone, 100; brick of the best quality, 70; of ordinary, 40; while fire-brick is as high as 75. A brickwork column, set with lime joints, takes a pressure of 20 tons per square foot before it crushes or breaks; if the bricks are set with cement, the pressure is increased to 30 tons; while a rubble masonry column, with lime setting, is of the same strength as one of brickwork with lime joints, namely, 20. Of the two cements chiefly used, the following gives the cohesive strength when used in setting bricks. "Roman pure;" 467 lbs., one part cement and one sand, 420½ lbs. "Portland pure," 152 lbs.; one part cement, three of sand, 420 lbs. Of the weights, etc., of *soils*, a cart-load averages 2½ tons. A cubic yard is otherwise and generally designated a "load." An ordinary sized wheelbarrow is estimated to hold a tenth of a cubic yard, or in other words, ten wheelbarrow loads make an ordinary load of a cubic yard. Soils, when dug take up greater space than when *in situ;* thus ordinary soil increases as much as 25 per cent. in bulk, so that three wheelbarrow loads in its natural condition will form four. Sand and gravel increase one-twelfth, chalk a third. The absorptive power of soils vary very considerably; thus 100 lbs. of pure sand will absorb one-fourth of its weight of water; pure clay, 70; chalk, 45. White pure clay is the most cohesive of ordinary soils, and is therefore taken as the standard, or say 100, ordinary soil is 33, sandy soil 57, loamy clay 68; while pure sand, which is wholly, or nearly, destitute of cohesive powers, is taken at zero. Soils when thrown up in a loose condition have a tendency to slide down, and assume the horizontal position; there is, however, a limit to this, and there is an angle at which they will remain quiescent, this technically is called the "angle of repose," and is for various materials as follows: for ordinary soil the angle of repose is 28°; gravel, 40°; dry sand, 38°; sand in its normal condition, 22°; undrained clay, 16°; drained clay, 45°.

62. *Brickwork* is measured by the square rod of 30¼ square yards, or in round numbers 272 feet; in the North it is measured by the square yard. What in England, where brickwork is carried out to a much larger extent than it is in Scotland, is called the "standard" thickness, is 14-inch or brick-and-half work, a rod of which is equal to 306 cubic feet, or 11⅕ cubic yards; this with the mortar, which on an average will make 71 feet, will give a weight of 15 tons. A cubic foot of brickwork weighing somewhere about from 100 lbs. to 1 cwt., according to the quality or density of the bricks; of stock bricks four courses high will take 4352 to make a rod, 4533 four courses high; the weight of a brick averages 5 lbs. The weight per cubic foot of machine-made bricks — Platts, 123·57; of another class, which is the highest of which we have a record, 118·75; of hand-made bricks the lowest average gives 111·65 lbs. to the cubic foot, the highest 113·69. Of the above-named bricks, and in their order as given, the weight of water absorbed was 180·93 oz., 127·62, 150·29, and 144·6. The crushing weight of a brick, average hardness or density of the best quality, is nearly 1100 lbs.; that of an ordinary brick of poor quality may be taken at nearly 900 lbs. Of roofing or pan tiles the weight may be taken, on an average, of 5¼ lbs.; plain tiles 2¼ lbs.

63. The following give the proportions of the various peculiarities of different classes of "*timber*," as stiffness, elasticity, transverse strength, etc., according to the strains which we have already named. The first is the "stiffness," English oak being taken as the standard, and put down as 100 :—American oak, 114; beech, 77; ash, 89; elm, 78; sycamore, 59; larch, 79; chestnut, 67; cedar, 28; Riga fir, 98; Memel fir, 114; Scotch fir, 55; white American spruce, 72; yellow pine, 95; pitch pine, 73; Honduras mahogany, 93; Spanish do., 92; walnut, 49; poplar, 44; teak, 126.

64. Proportions of Elasticity or Resiliency.—American oak, 64; beech, 138; ash, 160; elm, 86; sycamore, 111; larch, 134; chestnut, 118; cedar, 106; Riga fir, 64; Memel fir, 56; Scotch fir, 65; white American spruce, 102; yellow pine, 103; pitch pine, 92; Honduras mahogany, 99; Spanish do., 61; poplar, 57; walnut, 111; teak, 94.

65. Proportions of Transverse Strength.—American oak, 86; beech, 103; ash, 119; elm, 82; sycamore, 81; larch, 103; chestnut, 89; cedar, 62; Riga fir, 80; Memel fir, 80; Scotch fir, 60; white American spruce, 86; yellow pine, 99; pitch pine, 82; Honduras mahogany, 96; Spanish do., 67; walnut, 73; poplar, 50; teak, 109.

66. Number of Cubic Feet of Various Timbers to make 1 Ton in Weight.—Oak (English), 38; do. (American), 53; beech, 45; ash, 43; elm, 53; sycamore, 59; larch, 72; chestnut, 59; cedar, 68; Riga fir, 48; Memel fir, 66; Scotch fir, 68; white American spruce, 66; yellow pine, 80; pitch pine, 54; Honduras mahogany, 40; Spanish do., 50; walnut, 42; poplar, 34; teak, 46.

67. Weight of a Cubic Foot in Pounds of different Woods.—Oak (English), 58; do. (American), 42; beech, 48; ash, 52; elm, 42; sycamore, 38; larch, 31; chestnut, 38; cedar, 33; Riga fir, 47; Memel fir, 34; Scotch fir, 33; white American spruce, 34; yellow pine, 28; pitch pine, 41; Honduras mahogany, 40; Spanish do., 50; walnut, 42; poplar, 34; teak, 46.

68. Specific Gravities of Various Timbers.—1. *Oaks*—English, 829; Memel, 727; Dantzic, 720; Italian, 796; American white, 779; American red, 952; African live, 1160; 2. *Firs*—American white pine, 432; American red do., 576; American yellow do., 508; pitch do., 740; Archangel do., 551; Dantzic, 649; Memel, 601; Prussian, 596; Riga, 654; spruce, American, 772, 503; Mar Forest, 698; Norway spar, 577; Deal, Christiania, 689. 3. *Ashes*—English, 760; American, 626; American swamp, 925; do., black, 533. 4. *Beeches*—English, 696; American, white, 711; do., red, 775. 5. *Birches*—English, 711; American, black, 670; American, yellow, 756. 6. *Elms*—English, 579; Canada rock, 725. 7. *Cedars*—Lebanon, 330; Bermuda, 748; American, white, 354; Guadaloupe, 756. 8. *Miscellaneous*—Larch, 556;

lignum vitæ, 1082; teak, 729; iron-wood, 879; green heart, 985; Honduras mahogany, 608; soft maple, 675; acacia, 710; hickory (American), 831; hemlock, 911; Canada balsam, 548. Carpentry work, as interior, or of limited area, is measured by the square foot or the square yard; where the area or extent is large, as in roofs, it is measured by what is called the "square" of a hundred square feet.

69. The following is the bearing value of various timbers, the numbers representing the "constant" used in calculating the breaking weight of beams:—pitch pine, 629; red pine, 467; Baltic pine, 444; yellow pine, 358·5; English oak, 1079·5; American do., 653·5; English elm, 595·25; American do., 631·5; ash, 517·75.

70. If it is required to find the dimensions of a rectangular post, pillar, or column of timber, square the length, and multiply the weight in pounds which it has to support by this, and the product of the two by ·0015, if the post is of oak; by ·00152, if of Riga fir; by ·00133, if of Memel; and by ·00142, if of spruce timber. Divide the product obtained by the number of inches in the breadth of the post, and the thickness will be equal to the cube root of the quotient. If the pillar or post is to be square, the product obtained by the multiplying of the weight (in pounds) by the square of the length in feet, is to be multiplied by four times the "constants" above named (·0015 being that for oak, etc.); the fourth root of the product will give the length in inches of the diagonal of the square. We have stated that practically the tensile strength of timber beams does not often enter into calculations, as the force required to tear asunder the fibres is very great. The experiments made in order to find the tenacity of various timbers have shown great discrepancies, so that not much reliance can be placed upon them. The following is a rule to find the sectional area of a beam subjected to a certain tension or tensile strain of so many pounds weight, taking for oak 10,000, and for fir 12,000; divide the weight of either of these numbers, as the case may be, four times the quotient will be the area required; or if the dimensions are given, multiply the area of section by the numbers, as above, either for oak or for fir, and the result will be the resistance in pounds which the beam will oppose to the tensile strain. As before, the factor of safety should be not less than one-third of the results obtained by calculation.

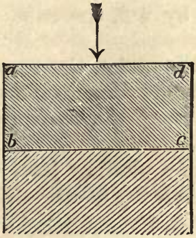


Fig. 473.

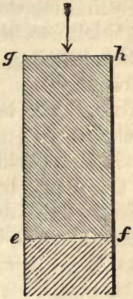


Fig. 474.

When a rectangular beam of timber, as *a b*, fig. 473, is loaded in the centre *c*, while supported at both ends *e f*, the number of pounds which it will bear without breaking may be found by the following rule:—Find the sectional area of the beam in inches (by multiplying the depth *a b*, fig. 473, by the breadth *d a*), which call (*a*), and reduce the length of the beam or span in feet to inches, which call (*i*), and the depth of the beam also in inches (*d*), (*s*) the "constant;" for oak 1181, red pine 1341, pitch pine 1631, fir (Riga) 1108, Memel 1731; then multiply (*a*) by four times (*d*) and by (*s*), and divide the result by (*i*); the quotient will give the highest number of pounds which the beam will bear in the centre, or twice this equally distributed. One-third of this —some authorities give a broader factor of safety, and say one-fourth of the weights thus found—will be the safe load for the beam. The best proportion of breadth, *e f*, fig. 474, to depth *g e* in a rectangular beam is 6 (*d c*) to 10 (*a b*), when the beam is fixed at one end and loaded at the other or outer extremity. Taking the letters to represent certain values, as above, then multiply (*a*) by (*s*) and by (*d*) and divide by *l*; the quotient will be the breaking weight of the beam. The following will be found useful in calculating the dimensions of the various members of a roof, etc.

To find the breadth of a pine girder, where the bearing or distance between the walls and the depth is given—Take the square of the bearing in feet, and divide by the cube of the depth, and multiply the result by 74.

To find the depth of a pine girder, the bearing and breadth and thickness being given—Divide by the breadth the square of the bearing, then multiply by 4·2, the cube root of the quotient.

To find the breadth of a binding joist, the bearing in feet, or the length and depth in inches being given—Cube the depth, and divide by it the square of the bearing, and multiply the result by 40.

To find the depth in inches of a binding joist, the bearing in feet and the breadth in inches being given—Divide by the breadth the square of the bearing, and multiply the cube root of the result by 3·42.

To find the depth in inches of a tie beam of pine, in which the bearing in feet and the breadth in inches are given—Take the cube root of the breadth and divide the bearing by it, and multiply the result by 1·47.

To find the depth of a beam supported at both ends, to sustain a given weight, the length and thickness or breadth of which is given—The weight multiplied by the square of the length, and this by ·011, and the result divided by the thickness, gives a quotient, the cube root of which is the depth for pine.

To find the thickness of a beam, the weight, length, and depth being given—The weight, multiplied by the square of the length, and the result multiplied by ·011, gives a quotient, which divided by the cube of the depth in inches, gives the breadth or thickness required. In both these rules, the weight to be supported must be in pounds.

To find the diameter of a round post of red pine, to sustain a given weight—Weight in pounds multiplied by 17, multiplied by ·0021; multiply the square root of the result thus obtained by the height in feet, and the square root of the product is the diameter required. The length should not exceed ten times the diameter.

To find the depth of a rectangular post of red pine, the breadth or thickness of which is given—Take the square of the length of the post in feet, multiply this by the weight in pounds which the post has to sustain; multiply the quotient by ·0021 and divide by the breadth in inches, the cube root of the quotient will be the depth of the beam.

The following, giving the dimensions of various parts of king-post and queen-post roofs, may be useful for ready reference. We classify the various parts according to the positions which the timbers assume, such as horizontal, vertical, and inclined, as this may make the references perhaps still more easily available. We shall take the vertical timbers first, these being comprised of two members only; the king posts and queen posts.

King Posts.

Span, or distance from Wall to Wall.	Dimensions, or Scantling in Inches.
18	4 × 3.
20	5½ × 3.
22	4 × 3½.
24	4½ × 3½.
26	5 × 3½.
28	5 × 4.
30	5½ × 4.

Queen Posts.

30	4½ × 4.
32	5 × 4.
32	5½ + 4.
36	5½ × 4½.

King-Post Roofs.

Tie Beams.

18	7½ × 3.
20	8 × 3.
22	8½ × 3½.
24	9 × 3½.
26	9½ × 4.
28	10 × 4.
30	10½ × 4.

Pole Plates.

Span, or Distance from Wall to Wall.	Dimensions, or Scantling in Inches.
18	4 × 3½.
20	4 × 4.
22	4 × 4.
24	4 × 4.
26	4 × 4.
28	4 × 4.
30	4 × 4.

Wall Plates.

18	4 × 3.
20	4½ × 3.
22	4½ × 3.
24	5 × 3.
26	5 × 3.
28	5 × 3.
30	5 × 3.

Purlins.

18	6 × 3½.
20	6½ × 3½.
22	7 × 3½.
24	7½ × 3½.
26	8 × 4.
28	8½ × 4.
30	8½ × 4½.

Queen Posts.

Tie Beams.

30	5 × 3.
32	5 × 4.
34	5 × 4.
36	5 × 4.

Wall Plates.

Span, or Distance from Wall to Wall.	Dimensions, or Scantling in Inches.
30	9 × 4.
32	9½ × 4.
34	10 × 4½.
36	10 × 5.

Purlins.

30	7 × 3½.
32	7½ × 3½.
34	8 × 4.
36	8 × 4.

Straining Pieces.

30	7 × 4.
32	7½ × 4.
33	8 × 4.
36	8 × 4.

Straining Sills.

30	4 × 4.
32	4½ × 4.
34	5 × 4.
36	5 × 4½.

KING POSTS.

Principal Rafters.

18	5 × 3.
20	5½ × 3.
22	6 × 3.
24	6 × 3½.
26	6½ × 3½.
28	6½ × 4.
30	7 × 4.

Common Rafters.

Span, or Distance from Wall to Wall.	Dimensions, or Scantling in Inches.
18	3½ × 2.
20	3½ × 2.
22	4 × 2.
24	4 × 2.
26	4½ × 2½.
28	4½ × 2½.
30	5 × 2¾.

Braces or Struts.

18	3 × 2½.
20	3½ × 2½.
22	3½ × 3.
24	4 × 3.
26	4½ × 3.
28	4½ × 3½.
30	5 × 3½.

QUEEN POSTS.

Principal Rafters.

30	5½ × 4.
32	6 × 4.
34	6½ × 4½.
36	6½ × 4½.

Common Rafters.

30	4 × 2.
33	4 × 2½.
34	4½ × 2½.
36	5 × 2½.

Braces or Struts.

30	4 × 3.
32	4 × 3½.
34	4½ × 3½.
36	5 × 3½.

71. As already stated, *cast-iron* is almost universally used for metal columns, to sustain heavy weights, its greatest strength being shown in its resistance to crushing powers. It is, however, a very uncertain, indeed treacherous material, being

liable to break suddenly at and in unexpected times and situations. It is ill calculated to bear sudden shocks or blows, its power to resist tension is comparatively feeble, that of compression being generally estimated at four tons per square inch.

Wrought-iron is seldom used for columns, although its resistance to crushing powers is high; still it is liable, from its flexibility, to be bent or forced out of the perpendicular line, and weakened to a very great extent. Its cohesive powers, however, constitute its most valuable feature, hence for beams, tie rods, etc., which are subjected chiefly to tensile strain, it is most extensively used; seven tons per square inch being generally allowed as the safe tensile load. The following gives the strength of some of the leading qualities of cast-iron to resist the crushing strain, as, for example, that to which iron columns are subjected per square inch of section. Low Moor, 28·809 tons; Clyde, 41·249; Coltness, 44·723; Plaen War, 40·562; Brymha, 33·399; Ystalyfera anthracite, 44·6610. A quality of iron which may be said to be *sui generis*, and which is not a pure cast-iron, having a portion of wrought-iron in its composition, and which was patented by Mr. Morris Sterling, shows in its best quality the highest strength of the samples experimented upon in Mr. Hodgkinson's series of trials, being as high as 70·824 tons per square inch of section; the lowest quality being 53·329. The mean breaking weight of cast-iron varies of course according to sample, as our readers will all probably know. Cast-iron is now smelted chiefly by the hot-blast plan; that is, by the use of air of a very high temperature, in contradistinction to the old plan, in which cold air was used. Cast-iron prepared on these two plans are known respectively as "hot" and "cold blast iron." The following gives the mean breaking (in pounds) weight of some of the leading qualities, giving the highest first, hot and cold blast will be here classed separately, taking the cold-blast first. Ponkey, 581 lbs., this in colour is whitish-grey, and of hard quality; Cleator, 537 lbs., white colour and hard; Low Moor, 472 lbs., dark-grey and soft; Carron, 444 lbs., grey and soft; Blaina, 448 lbs., bright grey colour and hard; Coed—Tallon, 413 lbs., grey and rather soft in quality. Coming now to the hot-blast irons we take the Devon, which has a mean breaking weight in pounds of 537, and is white in colour and hard in quality; Carron, 527 lbs., whitish-grey and hard; Butterley, 502 lbs., dark-grey and soft; Beaufort, 474 lbs., dull-grey and hard; Gartsherrie, 447 lbs., light-grey and soft; Muirkirk, 418 lbs., bluish-grey and soft. As already stated, beams supported at both ends, and either loaded, or in virtue of their own weight, have a tendency to bend or get depressed below the line of level of their supporting points, this is known as their "deflection." The following gives the rate of the deflection of cast-iron bars 4 feet 6 inches long:—Ponkey, cold-blast (*c. b.*), 1·747 inch; Cleator (*c. b.*), 1·001; Low Moor, 1·852; Blaina, 1·726; Coed-Talon, 1·470; Devon, hot-blast (*h. b.*), 1·09; Carron, 1·36; Beaufort, 1·51; Gartsherrie, 1·557. Cast-iron beams placed in the circumstances named in last sentence are sometimes subjected to blows or sudden shocks, their power to resist these is known as their "resistance to impact." The following are examples of the strength of the leading qualities we have named in two previous sentences to resist impact: Ponkey (*c. b.*), 992, the bars being 4 feet 6 inches long; Cleator, 537; Low Moor, 855; Blaina, 747; Carron, 593; Coed-Tallon, 600. All these are cold-blast iron. The following are hot-blast (*h. b.*):—Devon, 589; Carron, 710; Butterley, 889; Beaufort, 729; Gartsherrie, 998; Muirkirk, 656. The ratio of power which cast-iron has to resist tension and crushing strain, may be stated in round numbers to vary from 1 to $4\frac{1}{2}$ of the lowest, of 2, $6\frac{3}{4}$ of the highest qualities named in the above sentences.

Wrought-iron is chiefly used in construction for parts subjected to a tensile strain, or that calculated to tear the fibres asunder, as in the case of the tie rod of a roof. The following gives the result of a few bars out of several experimented upon by Mr. Hodgkinson; the length of the bars being 10 feet, the cross section one square inch. With a weight of 3785 lbs., extension of the bar was ·01690 in., the set of the bar being ·0005 in.; with a weight of 6309 lbs., the extension was ·02772 in., the set being ·0007 in.; with a weight of 13,880 lbs., the extension was ·05950, the set being ·007; with a weight of 26,499 lbs., the extension was ·1240, the set being ·00680.

The following are some examples showing the resistance of wrought-iron to a cross or transverse strain, as in the case of a bar supported at both ends, stretching across a void space, the length of the bar being 14 feet 7½ inches, the depth in the direction of the pressure 1·585 in., breadth of the bar, or its thickness, 5·523 in., the distance between the supports or the span being 13 feet 6 inches. With a weight of 28 lbs. applied and acting horizontally, the deflection after five minutes was ·051 in.; with a weight of 56 lbs., the deflection was ·112 in.; with a weight of 112 lbs., the deflection was ·232 in.; with a weight of 224 lbs., the deflection was ·458 in.; with a weight of 448 lbs., the deflection was ·916 in.; with a weight of 1008 lbs., the deflection was 2·044 in. Wrought-iron, as already stated, is seldom used in constructions for parts subjected to direct compression, as a column or pillar. The student will find further on, while giving a few calculations on columns, some remarks of the resistance of wrought-iron to compression when used in this form.

With reference to the strength of wrought-iron plates, Mr. Hodgkinson says, "that the resistance of plates of the same length and breadth, but varying in thickness, was nearly as a cube of the thickness, or more nearly as the 2·878 power of it. Thus a plate of double the thickness of another would resist flexure or buckling with seven or eight times the force applied in the direction of its length." The mean breaking weight of wrought-iron plates in the direction of the fibre, in tons per square inch, may be taken from a series of experiments made by the above authority as 19·563 for the lowest, and 25·770 for the highest quality. The mean breaking weight across the fibre, in tons per square inch, being respectively 21·010 and 27·490. The tensile strain of wrought-iron plates, according to Mr. Fairbairn, was as follows :—With a thickness of plate of 1½ inches, the mean breaking strain per square inch in tons was 24·453, where the plate was 3 inches thick the strain was 25·031. The compressive strain of plates of the above dimensions show a mean ultimate pressure per square inch in tons of 90·967, and the mean ultimate compression per unit of length was ·513 and ·511.

As already stated, wrought-iron is not often used in the form of columns to resist compression, Mr. Hodgkinson states that the strength of square pillars of wrought-iron, long enough, became bent without the material being much crushed, is nearly as the 3·59 power of the lateral dimensions, or as d 3·59, where d is the side of the square, the length being constant. The law of resistance of wrought-iron is not widely different from that arrived at in my experiments with cast-iron pillars, the mean from pillars of this material being 3·6 nearly. From numerous experiments in the comparative strength of wrought and cast iron to bear pressure in the direction of the length, to determine the pressure which wrought-iron would bear as a column, "I find," says Mr. Hodgkinson, "that beyond 12 tons per square inch, it was of little or no use in practice." The experiments further show that cast-iron was decreased in length about double what wrought-iron was, of the same weight; but the wrought-iron sank to any degree with little more than 12 tons per square inch, whilst cast-iron required twice, or perhaps three times, the weight to produce the same effect.

We have in a preceding chapter given illustrations of the different forms of iron beams now generally used; we now give a formula adapted for calculating the breaking weight, of the form in which the lower flange is of greater breadth than the upper is that given by Mr. Hodgkinson, in which the "constant" was taken at 25, a representing the sectional area of the bottom flange in square inches, d the depth of the beam in inches, and l the length of the span or the bearing of the beam on the opening, also in inches, and W the breaking weight in the centre; $W = \frac{a \times d \times C}{l}$; in the approved form the sectional area of the top flange is equal to $\frac{1}{6}$ of that of the bottom. A good proportion between the span or length of the beam, between the bearing and its depth, is $\frac{1}{12}$. The following is given by a high authority as a sound practical rule for proportioning the parts of iron beams:—"Take the breaking weight at from two to three times the weight estimated to be carried by the beam, then assume the depth of the beam at about $\frac{1}{16}$th part (we have above stated it at $\frac{1}{12}$th) of the distance between the supports for ordinary cases, and the sectional area of the bottom flange may then be found by the following proportion: as the depth, in feet, of the beam in the middle is to the distance between the supports, in feet, so is the $\frac{1}{26}$ part of the breaking weight, in tons, to the sectional area of the bottom flange, in square inches. Make the thickness of the bottom flange $\frac{1}{12}$th the depth of the beam, and find the breadth by dividing the area by the thickness. Make the area of the top flange $\frac{1}{5}$th part (we have above stated it to be $\frac{1}{6}$th) of the area of the bottom flange, and half its breadth. Make the thickness of the web of the beam rather more than half the thickness of the bottom flange for the beam when cast, that the pattern may be made somewhat thinner.

As the breaking weight of a beam at the centre is double that when distributed over its whole surface, and as we have in a special diagram illustrated how the pressure on a beam decreases as the weight from the centre increases, the depth of beams in practice may be made to decrease from the centre to the ends; the line, where this is adopted, of the upper edge of beam being a parabolic curve, a good proportion being for the ends, two-thirds of the depth of the middle. But as in buildings beams are generally made to carry materials above them, they are formed of equal depth throughout; but the breadth of the beam may be reduced where circumstances will admit of it, the ends being one-half the breadth of the middle, the outline assuming the form of a parabolic curve, which gives to the breadth of the bottom flange a direct proportion to the strength of the beam at any point. The thickness of the web of beams is about equal to that of the bottom flange, practically a little less at the point where it joins the latter, which it is made to do with a slight curve; the web, however, is not uniformly thick, but tapers as it approaches the upper flange, at the junction of which it is a trifle less in thickness than that of the latter, and to which also the junction is made by slight curves at the sides. Such is the improved arrrangements in the form of beams, that a saving of nearly one-third in the material is effected as compared with the old forms.

We have stated that the breaking weight of a beam at the centre is double that when the weight is distributed over its whole surface; but as some of our readers may not know why this is so, we may state this in the words of an authority: "The centre of gravity of each half span of a uniformly distributed weight is but half as far from its corresponding support at the end of the beam as is the centre of gravity; if a weight suspended at the middle, and the effect of a given weight upon a beam, is necessarily and directly as the distance of its centre of gravity from the point of support." The formula used for finding the area, in square inches, of a cast-iron beam or cantilever, which projects from a wall, in which it is supported at one end, and over which the weight is uniformly distributed, as in the case of a flagstone for the landing of an outside stair, is as follows: where a represents the area of the flange, in square inches; W the weight to be supported; l the length of the cantilever, measured from the surface of wall to its extremity; and d its depth in inches, the length also is taken in inches: $a = \frac{W \times l}{12 \times d}$; where the weight is placed at the outer extremity of the cantilever, the formula is the same as above, only the divisor is six times the depth in place of twelve. In calculating the dimensions of wrought-iron beams, the usual form of which for spans, of what may be called ordinary length, and known as built beams, is shown in a preceding section. The constant used is ·75 generally, although in the form of solid wrought-iron beams, of the section shown in a preceding paragraph, a constant as high as double this amount has been proved by the result of experiments made in the case of beams rolled at Belgian iron-works, which, singular to say, have long excelled ours in the production of this class of beams. The formula for finding the breaking weight is the same as that for cast-iron, the constant, however, being ·75 instead of ·25, as there stated; or the constant may be higher according as the experiments of any given section or form manufactured by any particular firm may indicate. The rule may be, however, here more particularly stated. Take the sectional area of the bottom flange in inches, and multiply the depth of the girder by this, the depth being also in inches; multiply the result by ·75, divide the product by the bearing or the span, taken in inches; the result will be breaking weight in tons at the centre of the beam. But if the load is to be distributed over the surface of the beam it will bear twice the amount, as shown by the above rule. To save the trouble attendant upon the calculation, as per above rule—we give here a statement of a few sizes of beams and the load which they will bear, with this (the load) uniformly distributed. To avoid repetition in the following statement, let the student note that the spans or bearings of the beams increase two feet in each case, the span in all the cases beginning at 6 and ending with 30 feet. The figures marked (*s. d.*) denote the sectional dimensions of each beam, and this is followed by the spans or bearings of the beams, thus:—

(*s.d.*) $12'' \times 5'' \times 5''$—36—27—$21\frac{12}{20}$—18,

Would read thus—Sectional Dimensions, 12 inches by 5 inches by 5 inches—36 tons with a span of 6 feet—27 tons with a span of 8 feet and—$21\frac{12}{20}$ with a span of 10 feet, the span, as before stated, increasing two feet in each case stated.

(*s.d.*) $12 \times 5 \times 5$—36—27—$21\frac{12}{20}$—18—$15\frac{8}{20}$—$13\frac{10}{20}$—12—$10\frac{16}{20}$—$9\frac{16}{20}$—9—$8\frac{5}{20}$—$7\frac{5}{20}$—$6\frac{10}{20}$.

(*s.d.*) $10 \times 5 \times 5$—$27\frac{10}{20}$—$20\frac{12}{20}$—$16\frac{10}{20}$—$13\frac{10}{20}$—12—$10\frac{5}{20}$—$9\frac{2}{20}$—8—$7\frac{2}{20}$—$6\frac{10}{20}$—$5\frac{12}{20}$—5—$4\frac{8}{20}$.

(*s.d.*) $8 \times 5 \times 5$—$18\frac{10}{20}$—$13\frac{15}{20}$—11—$9\frac{2}{20}$.

(*s.d.*) $7\frac{16}{20}$—$6\frac{15}{20}$—6—$5\frac{8}{20}$—5—$4\frac{12}{20}$.

(*s.d.*) $4\frac{5}{20}$—$3\frac{18}{20}$—$3\frac{12}{20}$.

In the case of trussed or latticed beams, which we have elsewhere illustrated, and which have no central web, as in the case of built or solid rolled beams; and supposing the top and bottom flanges to have equal powers of resistance respectively to compression and extension; "then the constant, whatever it is ascertained to be, is exactly four times the breaking weight per square inch of the bottom flange, the weight being taken in tons. Thus, where the beam fails, by tearing across the bottom flange, a constant of 80 will show that the breaking weight of the iron is 20 tons per square inch, a constant of 90 shows $22\frac{1}{2}$ tons, etc. In this case the beam is supposed to fail only by breaking the bottom flange, and sinking vertically. Most forms of beams, excepting box beams, are double trussed, held together side by side, are much weakened however by lateral flexure; or, in other words, by twisting out of shape, instead of sinking at the middle of their length. In this case—the almost invariable case with single beams—the real breaking strength may be more than is represented by one-fourth of the constant; that is, with a constant of 80, the real breaking strength of the material, instead of being 20 tons only, may be perhaps 22 or 25 tons. It need scarcely be said, however, what we have elsewhere in a preceding paragraph stated, that much of the strength of a beam, other than a solid rolled one, depends not only upon its design, but upon its construction, the punching or drilling of the rivet holes, and the accurate adjustment of these to one another, the riveting itself, and the disposition of the angle-irons, covering or butting plates, etc.

The above statement, as regards the relation of the breaking strain of the bottom flange to the constant, is shown by the following formula:—Thus, to find the sectional area of the bottom flange in square inches, let a represent the area, W the breaking weight, l the length, C the constant (·75), d the depth of beam, then—

$$a = \frac{W \times l}{C\,(\cdot 75) \times d}$$

As in a preceding paragraph in this chapter we have given dimensions of various parts of timber roofs of spans of a useful variety, we now do the same office for wrought-iron roofs; on the trusses illustrated in fig. 475—"king post" and in fig. 476, "queen post." We shall take the king post roof in fig. 475 first; in this the trusses are from 6 to 10 feet apart, according to circumstances. The rafters *ca*, *cd*, are of the form, and placed in the position illustrated in fig. 476.

KING BOLT ROOFS OR TRUSSES.

Rafters.

Span.	Width of Upper Flange *c d*.	Thickness of do. *e b*.	Total Depth of Rafter *a b*.	Thickness of Rib or Web A, as *g h*, fig. 475.
18	$1\frac{3}{4}''$	$\frac{3}{16}''$	$2\frac{1}{4}''$	$\frac{5}{16}''$
20	$2''$	$\frac{1}{4}''$	$2\frac{1}{2}''$	$\frac{3}{8}''$
22	$2\frac{1}{4}''$	$\frac{5}{16}''$	$2\frac{3}{4}''$	$\frac{7}{16}''$
24	$2\frac{3}{8}''$	$\frac{5}{16}''$	$2\frac{7}{8}''$	$\frac{1}{2}''$
26	$2\frac{1}{2}''$	$\frac{3}{8}''$	$3''$	$\frac{9}{16}''$
28	$2\frac{5}{8}''$	$\frac{3}{8}''$	$3\frac{1}{8}''$	$\frac{9}{16}''$
30	$2\frac{3}{4}''$	$\frac{7}{16}''$	$3\frac{1}{4}''$	$\frac{9}{16}''$

Struts or Braces *b f*, or *b c*, fig. 476.

Span.	Width of Upper Flange *c d*.	Thickness of do. *e b*.	Total Depth of Rafter *a b*.	Thickness of Rib or web A, as *g h*, fig. 455.
18	$1\frac{3}{16}''$	$\frac{3}{16}''$	$1\frac{3}{16}''$	$3\frac{1}{16}''$
20	$1\frac{1}{4}''$	$\frac{1}{4}''$	$1\frac{1}{2}''$	$\frac{1}{4}''$
22	$1\frac{1}{2}''$	$\frac{5}{16}''$	$1\frac{9}{16}''$	$\frac{1}{4}''$
24	$1\frac{3}{4}''$	$\frac{5}{16}''$	$1\frac{3}{4}''$	$\frac{1}{4}''$
26	$1\frac{7}{16}''$	$\frac{7}{16}''$	$1\frac{7}{8}''$	$\frac{5}{16}''$
28	$2''$	$\frac{7}{16}''$	$2''$	$\frac{3}{8}''$
30	$2\frac{1}{8}''$	$\frac{7}{16}''$	$2\frac{1}{8}''$	$\frac{7}{16}''$

Tie Rod.

Span.	Diameter.
18	$\frac{7}{8}''$
20	$\frac{3}{4}''$
22	$\frac{7}{8}''$
24	$1''$
26	$1\frac{1}{8}''$
28	$1\frac{1}{8}''$
30	$1\frac{3}{16}''$

King Bolt.

Span.	Diameter.
18	$\frac{7}{16}''$
20	$\frac{3}{4}''$
22	$\frac{7}{8}''$
24	$1''$
26	$1\frac{1}{8}''$
28	$1\frac{1}{8}''$
30	$1\frac{3}{16}''$

QUEEN BOLT ROOFS OR TRUSSES.

RAFTERS *e d*, fig. 477.

Span.	Width of Upper Flange *c d*.	Thickness of do. *e b*.	Total Depth of Rafter *a b*.	Thickness of Rib or Web A, as *g h*.
32	$2\frac{5}{8}''$	$\frac{3}{8}''$	$3''$	$\frac{7}{16}''$
34	$2\frac{3}{4}''$	$\frac{3}{8}''$	$3\frac{1}{4}''$	$\frac{7}{16}''$
36	$3''$	$\frac{7}{16}''$	$3\frac{1}{2}''$	$\frac{1}{2}''$
38	$3\frac{1}{8}''$	$\frac{3}{8}''$	$3\frac{3}{4}''$	$\frac{9}{16}''$
40	$3\frac{1}{4}''$	$\frac{1}{2}''$	$4''$	$\frac{5}{8}''$

STRUTS OR BRACES, as *a c*, fig. 476.

Span.	Width of Upper Flange *c d*.	Thickness of do. *e b*.	Total Depth of Rafter *a b*.	Thickness of Rib or Web A, as *g h*.
32	$1\frac{3}{4}''$	$\frac{1}{4}''$	$2\frac{1}{4}''$	$\frac{3}{8}''$
34	$2\frac{1}{8}''$	$\frac{1}{4}''$	$2\frac{1}{2}''$	$\frac{3}{8}''$
36	$2\frac{1}{4}''$	$\frac{1}{4}''$	$\frac{1}{4}''$	$\frac{3}{8}''$
38	$2\frac{3}{8}''$	$\frac{5}{16}''$	$\frac{5}{16}''$	$\frac{7}{16}''$
40	$3\frac{1}{2}''$	$\frac{3}{8}''$	$\frac{3}{8}''$	$\frac{1}{2}''$

TIE ROD, as *c e*, fig. 476.

Span.	Diameter.
32	$1\frac{1}{8}''$
34	$1\frac{1}{8}''$
36	$1\frac{3}{16}''$
38	$1\frac{3}{16}''$
40	$1\frac{1}{4}''$

KING BOLT, as *c d*, fig. 476.

Span.	Diameter.
32	$\frac{7}{8}''$
34	$\frac{7}{8}''$
36	$\frac{15}{16}''$
38	$1''$
40	$1\frac{1}{8}''$

QUEEN BOLT, as *c b*, fig. 476.

Span.	Diameter.
32	$\frac{5}{8}''$
34	$\frac{5}{8}''$
36	$\frac{3}{4}''$
38	$\frac{3}{4}''$
40	$\frac{13}{16}''$

Iron roofs may be covered with any of the usual materials, they are frequently, however, in the case of sheds, etc., covered with galvanised iron or zinc; a square foot of galvanised sheet-iron, No. 16 Birmingham wire gauge, weighs 40 oz., the thickness being $\frac{1}{16}$th of an inch; No. 22, same gauge, which is the thirty-second part of an inch, weighs 16 oz. to the square foot; a square, that is 100 superficial feet of zinc, No. 16 Birmingham wire gauge, weighs 2 cwt.; 6 lbs., of No. 22, same gauge, 1 cwt. 4 lbs. Unless where the zinc is corrugated or curved it is usually placed on boarding, a square of which weighs $2\frac{1}{2}$ cwt. Where pan tiles are used

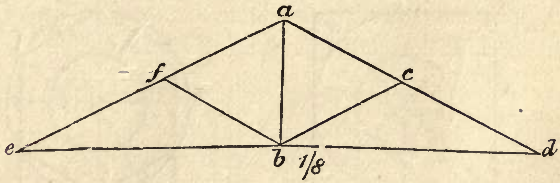


Fig. 475.

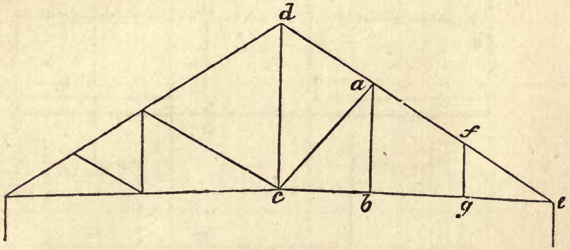


Fig. 476.

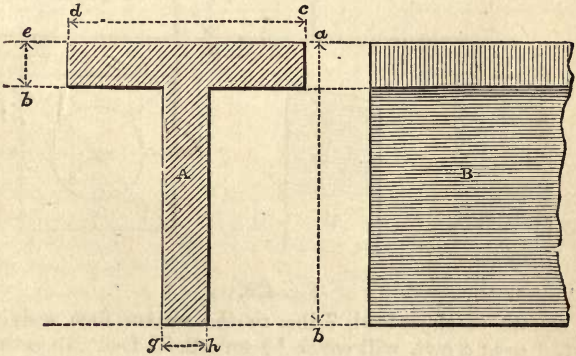


Fig. 477

it takes 180 of 10-inch gauge to make a square, and the weight of each tile is 75 oz.; that of a plane tile is 37; a square of pan tiling weighs 7 cwt. 2 qrs.; of plain tiling, 14 cwt. 2 qrs.; of "Queen's" slates a square weighs $7\frac{1}{2}$ cwt.

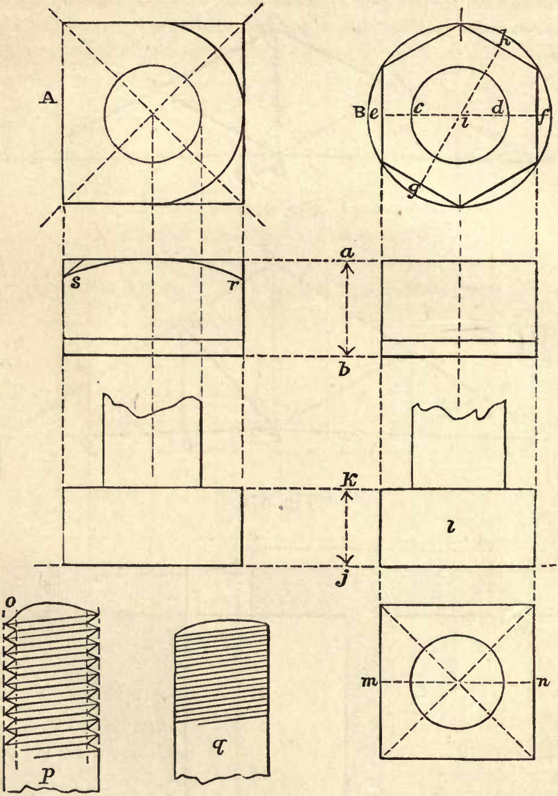


Fig. 478.

A square of sheet-lead, 7 lbs. to the square foot, weighs 6 cwt. 1 qrs.; a cwt. will cover 16 superficial feet. In estimating the pressure of weights to which roofs are subjected, in addition to the materials employed, it is usual to allow for the pressure of the wind 36 cwt.; or, say, in round numbers, 2 tons to the square. In a preceding paragraph we have given illustrations and descriptions of the methods used to connect and secure the various parts of iron framing, as roofs, etc., such as bolts and pins; we now give a remark or two on the subject of projecting or delineating bolts and nuts.

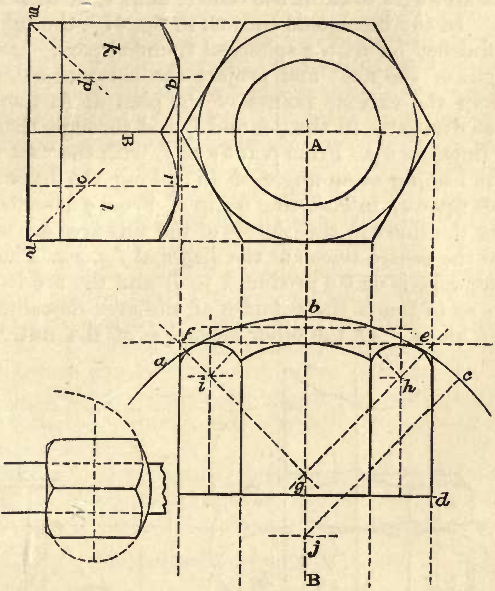


Fig. 479.

Nuts are generally of two classes, square as at A, fig. 478, or hexagonal as at B. In the latter the height or the thickness of the nut, as *a b*, is equal to the diameter *c d* of the bolt. The width across the flat sides of the nut, as *e f*, or *g h*, is to be equal in fifths of inches, as there are eighths of inches in the diameter of the bolt. The head of the bolt, as *l*, is square, even with hexagonal nuts; the height, as *j k*, equal to half the width *e f*, or *g h* of nut; the side of the square *m n*, equal to *g h*, or *e f*. In delineating or setting out the forms of screws, whether with threads square or angular, the process is somewhat complicated (see vol. in this series on *Machine Construction and Drawing*); but on the small scale the screw thread of the bolt may be shown, as at *o p*, or still more simply at *q*. The upper surfaces of square nuts are often left quite flat; but in some cases the corners are filed down at an angle towards the centre, as at *s*, or with a curve, as at *r*. In the hexagonal nut, as in fig. 479, the upper surface is finished off with a spherical rounded part. Let *e d* be the height of the nut; and project the sides, as *c d*, etc., by lines from the various points of the plan at A, then bisect the three divisions in the *g h* and *i*, and through them draw central lines, as *b g*. From point *e* or *f*, with the "set square" draw the line *f g* at an angle of 45° (along the hypothenuse of the set square), intersecting *b g* in *g*. From *g* describe an arc touching the line *e f*; the centres of the side arcs are at *h* and *i*, where the centre lines cut the diagonal *f g*, *e g*. The centre of the arc *a b c* is on *b g* produced to *j*; and the arc is of such a radius as to touch the outsides of the arcs described from centres *h* and *i*. In the other elevation of the nut A, as at

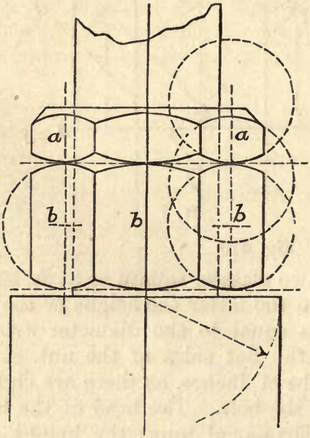


Fig. 480.

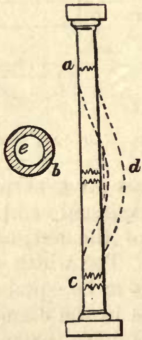


Fig. 481.

B, the projection is taken as before, by producing (shown by the dotted lines) the points of A, and bisecting the two sides *k l*, and drawing the central lines—lines from the points *m* and *n* at the angle of 45°, cutting these central lines on points *o* and *p* will give the centres *o* and *p* of the arcs *q* and *r*, touching the line *q r*. Fig. 480 shows an arrangement known as the "lock nut," or "jamb nut," on which a second nut *a a* is placed above or below the first nut *b b*; both are hexagonal.

As already stated, cast-iron is generally used in the construction of pillars or columns, this material being calculated to bear a high strain of compression, which tends, as shown in fig. 481, to crush or break the particles, as at the points *a*, *b*, and *c*; wrought-iron, although in one sense stronger, being more liable to bend, as shown by the exaggerated dotted lines *d*. The strongest form or section of cast-iron columns is a hollow cylinder, as at *e*, and this is that generally adopted—with the exception of columns of diameter of 4 inches or less, which are solid—for those of 5 to 6 inches external diameter, the thickness of metal should be from $\frac{6}{8}$ to $\frac{7}{8}$ of an inch, and for those from 8 to 10 inches diameter, 1 inch to $1\frac{1}{8}$. In another part of this section we have given various points connected with columns, as, for example, the influence which the length has upon the strength, or the resisting powers; we now give the formula for finding the dimensions.

According to Hodgkinson, the strength of cast-iron columns is found by using the following formula:—The ends being flat and fixed for solid columns, the breaking weight—$W = 44 \frac{D\ 3{\cdot}6}{l\ 1{\cdot}7}$; for hollow columns $W = 44 \frac{D\ 3{\cdot}6 - d\ 3{\cdot}6}{l\ 1{\cdot}7}$, in which D is the diameter exterior in inches of solid columns, *d* the internal diameter of hollow do., *l* length in feet, W crushing weight in tons. When *l* exceeds the D 30 times the thickness of metal in hollow columns should not be less than one-twelfth of the diameter.

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