because the abutment of the inner part is better supported. This is certainly the case, but it supposes the whole rafter to go to the bottom of the socket, and the beam to be thicker than the rafter. Some may think that this will weaken the beam too much, when it is no broader than the rafter is thick; in which case they think that it requires a deeper socket than Nicholson has given it. Perhaps the advantages of Nicholson's construction may be had by a joint like fig. 9, No. 2.

Whatever is the form of these butting joints, great care should be taken that all parts bear alike; and the artist will attend to the magnitude of the different surfaces. In the general compression the greater surfaces will be less compressed, and the smaller will therefore change most. When all has settled, every part should be equally close. Because great logs are moved with difficulty, it is very troublesome to try the joint frequently to see how the parts fit; therefore we must expect less accuracy in the interior parts. This should make us prefer those joints whose efficacy depends chiefly on the visible joint. It appears from all that has been said on this subject, that a very small part of the cohesion of the tie-beam is sufficient for withstanding the horizontal thrust of a roof, even though very low pitched. If, therefore, no other use is made of the tie-beam, one much slenderer may be used, and blocks may be firmly fixed to the ends, on which the rafters might abut, as they do on the joggles on the head and foot of a king-post. A tie-beam may have to carry a floor or ceiling (sometimes the workshops and store-rooms of a theatre), and therefore requires a great scantling, but frequently beams have little to do, and contain an unnecessary quantity of timber. It is therefore of importance to ascertain the most perfect manner of executing such a joint, and we have directed the attention to the principles that are really concerned in the effect. In all hazardous cases the carpenter calls in the assistance of iron straps; and they are frequently necessary, even in roofs, notwithstanding this superabundant strength of the tie-beam. But this is generally owing to bad construction of the wooden joint, or to the failure of it by time.

There needs but little to be said of the joints at a joggle worked out of solid timber; they are not near so difficult as the last. When the size of a log will allow the joggle to receive the whole breadth of the abutting brace, it ought certainly to be made with a square shoulder; or, which is still better, an arch of a circle having the other end of the brace for its centre. Indeed, this in general will not sensibly differ from a straight line perpendicular to the brace. By this circular form the settling of the roof makes no change in the abutment; but when there is not sufficient stuff for this, we must avoid bevel joints at the shoulders, because these always tend to make the brace slide off. The brace in Plate XXIII., fig. 10, No. 1, must not be joined as at *b*, but as at *a*, or in some equivalent manner.

When the very oblique action of one side of a frame of carpentry does not extend, but compresses, the piece on which it abuts, there is no difficulty in the joint. Indeed a joining is unnecessary, and it is enough that the pieces abut on each other; and we have only to take care that the mutual pressure be equally borne by all the parts, and that it do not produce lateral pressures, which may cause one of the pieces to slide on the butting joint. A very slight mortise and tenon is sufficient at the joggle of a king-post with a rafter or straining beam. It is best, in general, to make the butting plain, bisecting the angle formed by the sides, or else perpendicular to one of the pieces. In fig. 10, No. 2, where the straining beam *a b* cannot slip away from the pressure, the joint *a* is preferable to *b*, or indeed to any uneven joint, which never fails to produce very unequal pressures on the different parts, by which some are crippled, others are splintered off, &c.

When it is necessary to employ iron straps for strengthening a joint, considerable attention is necessary that we may place them properly. The first thing to be determined is the direction of the strain. This must be resolved into a strain parallel to each piece, and another perpendicular to it; and then the strap which is to be made fast to any of the pieces must be so fixed that it shall resist in the direction parallel to the piece. Frequently this cannot be done; but we must come as near to it as we can. We can hardly give any general rules. Fig. 30 shows the nature of the strap or stirrup by which the king-post carries the tie-beam. The strap that we observe most generally ill placed is that which connects the foot of the rafter with the beam. It only binds down the rafter, and does not act against its horizontal thrust. It should be placed farther back on the beam, with a bolt through it, which will allow it to turn round. It should embrace the rafter almost horizontally near the foot, and should be notched square with the back of the rafter. It is represented in fig. 11, Plate XXIII. By moving round the eye-bolt, it follows the rafter, and cannot pinch and cripple it, which it always does in its ordinary form. We are of opinion that straps which have eye-bolts in the very angles, and allow all motion round them, are of all the most perfect. A branched strap, such as may at once bind the king-post and the two braces which butt on its foot, will be more serviceable if it have a joint. When a roof warps, those branched straps frequently break the tenons, by affording a fulcrum in one of their bolts. An attentive and judicious artist will consider how the beams will act on such occasions, and will avoid giving rise to these great strains by levers. In the foregoing reasoning upon the direction of straps, regard has been had especially to the economizing of their immediate strength; but it may happen that the principal purpose of the strap will be answered by its pressing the rafter firmly upon the beam, and this effect may be produced by a certain deviation from the horizontal position, with but little diminution of the strength of the strap,—a deviation which has also the advantage of allowing the strap to embrace the whole of the beam, without weakening it by driving a bolt through it. We must not, however, run the risk of crippling the end of the beam. A skilful carpenter never employs many straps, considering them as auxiliaries foreign to his art, and subject to imperfections in workmanship which he cannot discern or amend. We must refer the reader to Nicholson's *Carpenter and Joiner's Assistant* for a more particular account of the various forms of stirrups, screwed rods, and other iron-work, for carrying tie-beams, &c.

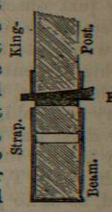

Fig. 30.

The diagrams of Plate XXIV. will illustrate the use of the before-described joints on a smaller scale in the further operations of the carpenter's work.

Ordinary scarfing is the cutting away equally from the ends, but on the opposite sides, of two pieces of timber, for the purpose of tying or connecting them lengthwise, and is done to wall-plates and bond-timber. The usual mode is by cutting about three-fifths through each piece on the upper face of the one and the under face of the other, about 6 or 8 inches from the end, as in fig. 1, Plate XXIV., transversely, making what is technically termed a *calf* or *kerf*, and longitudinally from the end, from two-fifths down on the same side, so that the pieces lap together with a sort of half dovetail. The heavy supervening weight of the wall and joists renders it impossible that they should be drawn apart without tearing the fibres asunder or lifting the weight. Nevertheless

these joints are generally spiked, and it is always required that they be made to fall in or under a pier. Notching is either square or dovetailed; it is used in connecting the ends of wall-plates and bond-timber at the angles, in letting joists down on beams or binders, purlines on principal rafters, &c. Nos. 1, 2, 3, 4, and 5, fig. 2, show varieties of notches applied as we have described. No. 1 is a simple square notch; No. 2, a dovetailed notch. No. 3 is the notch most commonly used; it is similar to No. 1, but that the ends are allowed to run on so that the one piece grasps the other, and each forms a cog to the other. No. 4 is an oblique-angled, dovetailed notch; and No. 5 shows how joists are notched or let down on beams and binders, and purlines on principal rafters. A notch is cut into the under edge of the joist or purline an inch or an inch and a half in depth, and considerably shorter than the beam, binder, or rafter is in thickness. Notches are also cut down on the upper angles of the bearing pieces, as long as the rider is thick, as deep as the notch before described of the latter is, and so far in as to leave a thickness on its own edge equal to the length of the notch in the riding joist or purline. In the diagram one joist is indicated in its place let down in the notch, and another indicates the notch in its own edge, and leaves exposed the notches in the binder. Cogging, or corking, as it is vulgarly termed, is the last-mentioned species of notch extended on one side, and leaving a narrow tooth or cog alone in the bearing-piece flush with its upper face, No. 1, fig. 3. It is used principally in tailing joists and beams on wall-plates and templets, and the cog is here made narrower, because the end of the joist or rider coming immediately beyond the plate, that part which forms the shoulder of the notch would be liable, on being strained, to be chipped off or torn away, if it were not kept as long as possible; and it is not of so much importance to guard against weakening a wall-plate which is supported along its whole length, as a beam, binder, or principal rafter, which rests on distant points alone. No. 2 of the same figure shows another mode of tailing on joists and beams by a dovetail notch, which, to distinguish it from the flat notches, Nos. 2 and 4, fig. 2, is called corking, or cogging also, though the operation certainly is not cogging. This is a good mode if the timber be so well seasoned as not to be likely to shrink more; but it would be improved by allowing the rider to take a bearing in a notch like that to No. 1 before the dovetail commenced, as at No. 3, for in the ordinary mode it is weakened in a point of great importance. Whatever notches and cogs for beams and joists are required in wall-plates and templets, should be made before they are set on or in a wall; for, as they are always bedded in mortar, anything that may break the set must be avoided. A cog-hold is best obtained through the agency of a chair of cast-iron, which should, however, be itself cogged or joggled to a stone templet laid in the wall under it, and be capped or covered by another broad flat stone, as an inverted templet, with a joggle from the chair running up into it.

Tenoning implies mortising also as a matter of course. They are the names of the two operations necessary to one result,—that of producing a connection between two pieces by inserting part of the end of one into a hole of similar size cut in the side or face of the other. A tenon is formed by cutting in on each side or edge of a piece of timber, near its end, transversely, to a certain depth, or rather, leaving a certain part of the breadth or depth uncut, and then cutting in longitudinally from the ends as far from each edge as the transverse cuts have been made in depth, thus removing two square prisms and leaving a third undivided. This is the tenon. An excavation in the side of a piece of timber, of a certain depth, in the direction of its thickness, parallel to its edges, and bounded lengthwise by lines at right angles to them, is a mortise. Tenons and mortises are made of exactly corresponding size, and are most frequently at equal distances from one or the other side or edge of the two pieces to be conjoined; and for the most part, too, every angle formed in the process of tenoning, both internal and external, is a right angle. Tenons are called joggles in some situations, when they are not intended to be borne upon, and their use is merely to keep the piece of timber to which they belong steadily in its place, without being liable to slight accidents from lateral pressure or violence. In combining timbers by means of mortises and tenons, to produce as great a degree of strength as possible, it must be obvious that the object to be kept in view is to maintain the end or tenon of the one as large and efficient as it may be, and weaken the other as little as possible in forming the mortise. For the efficiency of the mortised piece in a horizontal bearing, it is clear that as much of its thickness should be below the mortise as possible, as at *a*, fig. 4; for if it be put low, as at *b*, the superincumbent weight on the tenon would more readily split or rend it in the direction of the grain, as indicated; but the case is inverted with the tenoned pieces. With the mortise at *a* the tenon could only have the efficacy of so much of the piece to which it belongs as there is of it above its under surface, which is a very small part of its depth; whereas with the tenon at *b* it would command the power of the greatest part of the depth. To guard as much as possible against the danger of too great a mortise and too small a tenon on one side and the other, and to obviate the difficulty arising from the efficiency of one or the other of the two pieces being affected by putting the tenon too high or too low, a compound, called a tusk tenon, is used for almost all horizontal bearings of any importance, especially to joists and binders, to trimmers, beams, girders, bressummers, &c. The body of the tenon in this is a little above the middle of the end, and it runs out 2, 3, or 4 inches, or more, as the case may require. Below it the tusk protrudes, and above it the shoulder is cut down at an obtuse angle with the horizontal line, giving the strength of the whole depth of the timber above the under tusk to the tenon, and giving it a bearing in a shallow mortise, whilst a greater depth of the mortised piece than the tusk rests on receives the body of the tenon, and so protects its comparatively narrow margin from undue pressure. The diagram No. 1, fig. 5, shows the tusk tenon, with the section of a beam into which it is mortised, and No. 2 indicates perspectively the appearance of the mortise in front. Pinning is the insertion of nearly cylindrical pieces of wood or iron through a tenon, to detain it in the mortise, or prevent it from being drawn out by any ordinary force. For this purpose the pin is inserted either in the body, or beyond the thickness, of the mortised piece, as indicated at *a*, fig. 5, or at *a*, fig. 6. Wedging (see *b*, *b*, No. 2, fig. 25) is the insertion of triangular prisms, whose converging sides are under an extremely acute angle, into or beside the end of a tenon, to make it fill the mortise so completely, or bind it so tightly, that it cannot be easily withdrawn. The wedging of tenons also assists in restoring to the mortised piece of timber much of the strength it had lost by the excision of so much of its mass, which indeed the tenon itself does if it fit closely in every direction; but the assistance of the wedge renders the restoration more perfect than the tenon could secure of itself, by compressing the fibres of both, longitudinally to those of the one, and transversely to those of the other, thus removing the tendency of the mortised piece to yield in any degree in the weakened part, though it cannot make up the loss in its tenacity occasioned by the scission of its fibres.

Pinning.

Wedging.

In scarfing, cogging, and notching, the shoulders are always cut in with the saw; but the cheek is for the most part struck out with the mallet and chisel, or adze, as may be most convenient. Tenons should be made entirely with the saw. Mortises are generally bored at the ends with an auger whose diameter equals their thickness; the intervening part is taken out with a wide chisel, cutting in the direction of the fibre; and the ends are squared down with a chisel whose breadth just equals the thickness of the mortise. Wood pins must be rent to insure the equal tenacity of their whole mass. Wedges are cut with the saw, but straight-grained stuff is always preferred for them.

Bond-timbers and wall-plates should be carefully notched together at every angle and return, and scarfed at every longitudinal joint. The scarf shown at fig. 1, Plate XXIV., is sufficient; and the notch at No. 3, fig. 2, may be preferred where notching is required; neither pinning nor nailing, however, can be of great use to either the notch or the scarf. Bond-timbers are passed along and through all openings, and are not cut out until such openings are to be permanently occupied, that is, by windows with their sash-frames, &c., because they assist in preventing irregular settlements, by helping to carry the weight of a heavy part along the substruction generally, instead of allowing it to press unduly upon the part immediately under it.

It is the duty of the carpenter to supply the bricklayer or mason with wood bricks in sufficient quantity, and to direct him where they should be placed to receive the joiner's fittings, or the battening, which the carpenter himself may have to put up for the plasterer.

The carpenter makes and fixes or sets centres of all kinds, whether for single arches or niches, or even in bridge construction. Large centres are framed in distinct ribs, and are connected by horizontal ties; whilst small ones are made of mere boards cut to the required sweep, nailed together, and connected by battens notched into or nailed on their edges. Precision and stability are nevertheless equally and absolutely necessary, as it is impossible for an arch to be turned or set correctly on an incorrect or unstable centre.

Descriptions of various sorts of flooring are noticed in the earlier part of this article as for fireproof structures; and also under *Brickwork* and *Mason-work*. The timbers or framework of ordinary house and warehouse floors is called naked flooring, and it is distinguished as single, double, and framed. Of these the first, under ordinary circumstances, is the strongest.

Single flooring (Plate XXV. figs. 1, 2) consists of one row or tier of joists alone, bearing from one wall or partition to another, without any intermediate support, and receiving the flooring boards on the upper surface or edges of the joists, and the ceiling, if there be one, on the lower. Joists in single floors should never be less than 2 inches in thickness, because of their liability to be split by the brads or nails of the boards if they are thinner; and they should never be much more, because of the keying of the ceiling, which is injuriously affected by great thickness of the joists. Twelve inches from joist to joist is the distance generally allowed; that dimension, however, from centre to centre of the joists would be better. Strength to almost any extent may be given by adding to the depth of the joists, and diminishing the distance between them; and they may be made firm, and be prevented from buckling or twisting, by putting struts between them. The struts are short pieces of batten, fig. 31, which should not be less than an inch, and need not be more than an inch and a half thick, and 3 or 4 inches wide, placed diagonally between the joists, to which they are nailed, in a double series, or crossing, as indicated by the full and dotted lines in Plate XXIV. fig. 7; and they should be made to range in a right line, that none of their effect may be lost; and these ranges or rows should be repeated at intervals not exceeding 5 or 6 feet. The struts should be cut at the ends with exactly the same inclination or bevel, to fit closely. Great care should be taken, too, not to split the struts in nailing; but the trouble of boring with a gimlet is saved by making a slight nick or incision with a wide-set saw for each nail, of which there should not be less than two at each end; and the nails used should be clasp-nails. If the struts were notched into the joists, as in fig. 32, it would add very materially to their efficiency, but perhaps not in proportion to the additional labour it would involve. This strutting should be done to single flooring under any circumstances, as it adds materially to its firmness and indeed to its strength, by making the joists transmit any stress or pressure from one to another.

FIG. 31.—Strut.

FIG. 32.—Herring-bone Strutting.

The efficiency of single flooring is materially affected by the necessity which constantly occurs in practice of trimming round fire-places and flues, and across vacuities. Trimming is a mode of supporting the end of a joist by tenoning it into a piece of timber crossing it, and called a trimmer, instead of running it on or into the wall which supports the ends of the other joists generally. A trimmer requires for the most part to be carried or supported at one or both of its ends by some of the joists, which are called trimming joists, and are necessarily made stouter than if they had to bear no more than their own share of the stress. Commonly it is found enough to make the trimmers and trimming joists from half an inch to an inch thicker than common joists. In trimming, tusk tenons should be used; and the long tongue or main body of the tenon should run not less than 2 inches through, and be draw-pinned and wedged, moreover, if it do not completely fill the mortise in the direction of the length of the latter.

The principal objection, however, to single flooring is, that sound readily passes through, the attachment of the boards above and of the ceiling below being to the same joists throughout. Another objection, and one already referred to, is the necessity of making the joists so thin, not to injure the ceilings, that they with difficulty receive the flooring brads in their upper edges without splitting. A partial remedy for both these disadvantages is found in a mode sometimes adopted of making every third or fourth joist an inch or an inch and a half deeper than the intervening joists; and to these, ceiling joists are notched and nailed, or nailed alone, as shown in Plate XXIV. fig. 7. This, by diminishing the number of points of contact between the upper and the lower surface, for the ceiling joists must be carefully kept from touching the shallower joists of the floor, is less apt to convey sound from one story to another, and allows conveniently thin joists to be used for the ceiling without affecting those of the floor.

Double flooring (see Plate XXIV. fig. 8, Nos. 1 and 2, and Plate XXV. fig. 3) consists of three distinct series of joists, which are called binding, bridging, and ceiling joists. The binders in this are the real support of the floor; they run from wall to wall, and carry the bridging joists above and the ceiling joists below them. Binders need not be less and should not be much more than 6 feet apart, that is, if the bridging or flooring joists are not inordinately weak. The bridging joists form the upper tier, and are notched down on the binders with the notch No. 5, Plate XXIV. fig. 2. The ceiling joists range under the binders, and are notched and nailed as shown at No. 1, fig. 8; but the notch must be taken entirely out of the ceiling joists, for the lower face or edge of the binder may not be wounded by any means or on any account, and, moreover, no good would be gained in any other respect by doing so. When

it is an object to save height in the depth or thickness of this species of floor, the ceiling joists may be tenoned into the binders, instead of being nailed to them; in this case the latter must be chase-mortised on one side, fig. 33, for the convenience of receiving the former when they are themselves set and fixed. A chase is a long wedge-formed groove of the breadth or thickness of the mortise, of which it is indeed an elongation, so that the tenon at one end of the ceiling joist being inserted in the regular mortise in the binder prepared for it, that at the other end is driven along the chase up to its place in the mortise in the next binder. When ceiling joists are thus chase-mortised, their lower or under faces are allowed to come a little below the under face of the binders, and the space across is firred down by slips not wider than the ceiling joists are thick. No. 2, fig. 8, shows a transverse compartment, or bay, of a floor in this manner; but it is not so good a one as the preceding; for, besides the weakening of the binders, by cutting so many mortises and chases in them, it is almost impossible to give the ceiling floor the degree of firmness and consistency it possesses in the other way, besides requiring the firring down on the binders. The same space would be better gained by cutting the bridging joists so much lower down; as they may, with the sort of notch indicated above, be let down fully half their depth without great injury to either bridging joists or binder, for they can always be made to fit tightly or firmly, and very little more labour is involved in notching deeply than slightly.

FIG. 33.—Chase Mortise.

Framed flooring. Flooring is said to be framed when girders are used together with binding, bridging, and ceiling joists (see Plate XXIV. fig. 9, Nos. 1 and 2, and Pl te XXV. fig. 4).
Girders. Girders are large beams, in one or more pieces, according to the length required, and the size and strength of which timber can be procured. They are intended for longer bearings than mere binders may be trusted at, and may be strengthened by forming a built beam. The principle of constructing girders of any depth, says Tredgold, in his *Carpentry*, is the same as that of building beams, and when properly conducted they are as strong as any truss can be made of the same depth. The most simple method consists in bolting two pieces together, with keys between to prevent the parts sliding upon each other,—the upper one of hard compact wood, the lower of tough straight grained wood. The joints should be at or near the middle of the depth; the thickness of all the keys added together should be greater than one-third more than the whole depth of the girder; and if they be made of hard wood, the breadth should be about twice the thickness. They may be held together by bolts. Fig. 34 is a good form held by bands, and, if the upper timber be cut so as to be smaller towards the ends, would admit of these hoops being driven on till perfectly tight. In fig. 35 the parts are tabled or indented together instead of being keyed, and a king-bolt is added to tighten the joints. Girders may be further strengthened to almost any extent by trussing; but to be efficient, the height of the truss must always be greater than the depth of the beam itself, and the strength is increased by extending that height as the space or bearing increases. A truss is indeed a wooden arch, whose lateral thrust will of course be greater the smaller the angle subtended by it, and *vice versa*. It has been a commonly received opinion, that a truss less than the depth of a girder adds materially to its strength; but experiments have proved that very little advantage is gained by such a one, even when executed in the best manner, and that, badly executed, the beam or girder is weaker with the truss than without it. In some situations the flooring joists can be raised to a certain height to allow of the head of the truss, which is usually made of iron, being placed at a sufficient height to be truly efficient. Such is the trussed girder shown in fig. 36, intended for a great length. A common mode of strengthening a beam or bressummer, is to cut the timber in hale longitudinally, whereby any defects in the interior can be seen; then to reverse the pieces, end for end, and bolt them well together. Some additional strength is obtained by putting between the timbers a plate of wrought iron about the depth of the beam and about half an inch in thickness, and then bolting the three together, as in Plate XXIV. fig. 9, No. 3.

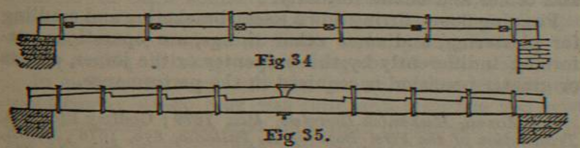

Fig 34

Fig 35.

FIGS. 34, 35.—Girders.

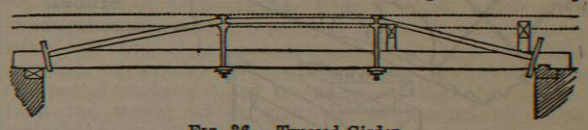

FIG. 36.—Trussed Girder.

Binders are made dependent on the girders by means of double tusk tenons, and on and to them the bridging and ceiling joists are attached as above described. Plate XXIV.
fig. 9, No. 1, shows the transverse section of a compartment or bay of a framed floor; **Plans of floors.** No. 2 the same longitudinally of the girder and of the bridging and ceiling joists, and transversely of the binders. Plate XXV. fig. 1, is the plan of a single floor of joists tailing in on wall-plates with two chains of struts, and trimmed to a fire-place. Fig. 2 is a floor similar to fig. 1, with ceiling joists nailed to deeper flooring joists at intervals, as in Plate XXIV. fig. 7. Fig. 3 is the plan of a double floor; and fig. 4 is that of a framed floor of joists, bays of which are shown in section in Plate XXIV. figs. 8, 9. It is to be observed, with reference to the diagram fig. 9, No. 1, that binders ought not to be framed into the girders opposite to one another, as they are here shown to be as a matter of convenience, since the girder is unduly weakened by being mortised on both sides at the same place. Cast-iron shoes render mortising the one forming a tenon upon the other almost unnecessary; and in like manner cast-iron shoes laid into a wall upon stone templets give a good and safe bearing to the girders; but it is not everywhere that cast-iron shoes are attainable, and mortises and tenons may be made anywhere.

Mediæval flooring. The above descriptions of the three sorts of flooring apply to floors which are to have a ceiling as in house building, or may be left open, as usual in warehouses. But in house building according to the practice of the mediæval period, these timbers would be left exposed. They would all require to be planed smooth, the girders moulded, the binders partly so, and the joists perhaps only stop-chamfered, which is done by cutting the arris of the timber to an angle along its whole length, but stopping short of the ends by a few inches, when it is returned into the arris by a cant. The underside of the joists in a framed floor may be lined with chamfered boarding or formed into panels and ornamented,—a boltel or a set of mouldings forming a frame or cornice all round against the binder. The girders would rest upon stone corbels, either moulded or decorated with foliage or figures, or all three united. Viollet le Duc, in his valuable *Dictionnaire raisonné de l'Architecture*, gives several examples of such a floor.