Civil & Mechanical Engineers' Society.

MEETING OF SOCIETY

HELD AT

7, WESTMINSTER CHAMBERS,

On THURSDAY, MARCH 1, 1877

The President (R. M. Bancroft, Esq.) in the Chair.

Minutes of the last Meeting were read and confirmed.

Mr. Henry Adams then read his paper on

"JOINTS IN WOODWORK."

Mr. President and Gentlemen,

In the following paper the form and arrangement of some of the principal Joints in Woodwork, and the methods in common use for securing them, will be considered, together with a few incidental matters pertaining to the material employed.

Although wood is used much less than formerly in permanent structures it is still of sufficient importance to warrant a careful study of its nature, properties, and uses. This subject is seldom treated in a sufficiently systematic manner in the text-books used by the junior members of the profession, especially as among Engineers iron is looked upon as the staple material of construction, the properties and economical uses of which receive, in consequence, an almost exclusive share of their attention.

All trees are divided by botanists into three classes: Exogens, or outward-growers; Endogens, or inward-growers; and Acrogens, or summit growers; according to the relative position in which the new material for increasing the substance of the tree is added; viz., whether towards the outside, the inside, or the top. Typical trees of each class would be the oak, the palm, and the tree-fern. We have to deal with the exogenous class only, as that furnishes the timber in general use for construction, the term "timber" including all varieties of wood which, when felled and seasoned, are suitable for building purposes.

If the stem of an exogenous tree be cut across, it will be found to exhibit a number of nearly concentric rings, more or less distinct: and, in certain cases, radial lines intersecting them. These rings represent the annual growth of the tree which takes place just under the bark. Each ring consists of bundles of woody fibre or vascular tissue, in the form of long tapering tubes, interlaced, and breaking joint with each other, having a small portion of cellular tissue at intervals. Towards the outer edge of each ring the woody fibre is harder, more compact, and of a darker colour than the remaining portion. The radial lines consist of thin, hard vertical plates formed entirely of cellular tissue, known to botanists as "medullary rays," and to carpenters as "silver grain." Fig. 1 shews the woody fibre as seen in a magnified vertical section, Fig. 2 the cellular tissue, and Fig. 3 a typical section of the stem of a young tree, *a* being the woody fibre, *b* the pith, *c* the medullary rays, and *d* the bark: the three latter consisting of cellular tissue and enclosing the woody fibre in wedge-shaped portions. As the tree advances in age, the rings and rays become more irregular, the growth being more vigorous on the sunny side, causing distortion. The strength of wood "along the grain" depends on the tenacity of the walls of the fibres and cells, while the strength "across the grain" depends on the adhesion of the sides of the tubes and cells to each other.

Tredgold proposed a classification of timber according to its mechanical structure, this, as modified by Professor Rankine, is given in the following table.

Class I.—Pine-wood (coniferous trees),—pine, fir, larch, cowrie, yew, cedar, &c.

Class II.—Leaf-wood (non-coniferous trees), Division I. with distinct large medullary rays.

Sub-division I.—Annual rings distinct,—oak.

Sub-division II.—Annual rings indistinct,—beech, alder, plane, sycamore, &c.

Division II.—No distinct large medullary rays.

Sub-division I.—Annual rings distinct,—chestnut, ash, elm, &c.

Sub-division II.—Annual rings indistinct,—mahogany, teak, walnut, box, &c.

Specimens of several of the above-named trees are lying on the table for inspection. A personal examination is necessary to obtain a clear conception of the differences between them, which are so minute, and at the same time so varied, that no verbal description can convey a sufficiently accurate idea of their nature.

Having glanced at the microscopical structure of the wood, we shall be in a position to understand the process of seasoning, and the shrinking incidental to that operation. While wood is in a growing state there is a constant passage of sap, or nutritive fluid, which keeps the whole of the interior of the tree moist, and the fibres distended, but more especially towards the outside. When the tree is cut down, and exposed to the air, the moisture gradually evaporates, causing the fibres to shrink according to certain laws: this is the natural process of seasoning. There are various methods of seasoning timber artificially, in each case the object in view is to expedite the process of evaporation. The shrinkage in length is very slight, and need not therefore be considered; but the shrinkage transversely, is so great, that it is necessary to look closely into the nature of it, as the question of jointing is affected considerably thereby. The behaviour of timber in shrinking was demonstrated by Dr. Anderson in one of the Cantor Lectures at the Society of Arts, which the author of this paper had the pleasure of hearing, and of which he has availed himself to some extent.

If Fig. 4 be taken as representing the section of a newly-felled tree, it will be seen that the wood is solid throughout, and on comparing Fig. 5 with this the result of the seasoning will be apparent. The action is exaggerated in the diagrams in order to render it more conspicuous. As the moisture evaporates, the bundles of woody fibres shrink and draw closer together; but this contraction cannot take place radially, without crushing or tearing the hard plates forming the medullary rays, which are unaffected in size by the seasoning. These plates are generally sufficiently strong to resist the crushing action, and the contraction is therefore compelled to take place in the opposite direction, *i.e.*, circumferentially;

the strain finding relief by splitting the timber in radial lines, allowing the medullary rays in each partially severed portion to approach each other in the same direction as the ribs of a lady's fan when closing. The illustration of a closing fan affords the best example of the principle of shrinking during seasoning, every portion of the wood practically retaining its original distance from the centre. If the tree were sawn down the middle, the cut surfaces, although flat at first, would in time become rounded, as in Fig. 6; the outer portion shrinking more than that nearer the heart on account of the greater mass of woody fibre it contains, and the larger amount of moisture. If cut into quarters each portion would present a similar result, as shown in Fig. 7. Figs. 8 to 12 show the same principle applied to sawn timber of various forms, the peculiarities of which are perhaps indicated more clearly in Fig. 14. If we assume the tree to be cut into planks, as shown in Fig. 13, it will be found, after allowing due time for seasoning, that the planks have altered their shape, as in Fig. 14. Taking the centre plank first, it will be observed that the thickness at the middle remains unaltered, at the edge it is reduced, and both sides are rounded, while the width remains unaltered. The planks on each side of this are rounding on the heart side, hollow on the other, retain their middle thickness, but are reduced in width in proportion to their distance from the centre of the tree; or, in other words, the more nearly the annual rings are parallel to the sides of the planks the greater will be the reduction in width. The most striking result of the shrinkage is shown in Figs. 15-17. Fig. 15 shows a piece of quartering freshly cut from unseasoned timber; in Fig. 16 the part coloured black shows the portion lost by shrinkage, and Fig. 17 shows the final result. These remarks apply more especially to oak, beech, and the stronger home firs. In the softer woods the medullary rays are more yielding, and this slightly modifies the result; but the same principles must be borne in mind if we wish to avoid the evils of shrinking which may occur from negligence in this respect.

The peculiar direction which "shakes" or natural fractures sometimes take is due to the unequal adhesion of the woody fibres, the weakest part yielding first. In a "cup-shake," which is the separation of a portion of two annual rings, the medullary rays are deficient in cohesion; several cup-shakes will be observed in the sample of Quebec pine exhibited to you. The same fault sometimes occurs in Dantzic fir, and has been attributed to the action of lightning and of severe frosts. So far we have considered the shrinking only as regards the cross section of various pieces. Turning now to the effect produced when we look at the timber in the other direction, Fig. 18 represents a piece of timber with the end cut off square; as this shrinks, the end remains square, the width alone being affected. If, however, the end be bevelled as in Fig. 19, we shall find that in shrinking it assumes a more acute angle, and this should be remembered in framing roofs, arranging the joints for struts, &c., especially by the carpenters who have to do the actual work of fitting the parts. If the angle be an internal one or bird's-mouth, it will in the same way become more acute in seasoning. The transverse shrinkage is here considered to the exclusion of any slight longitudinal alteration which might occur, and which would never be sufficient to affect the angle of the bevil. When seasoned timber is used in positions subject to damp, the wood will swell in exactly the reverse direction to the shrinkage, and induce similar difficulties unless this point has also received due attention. Of course it will be seen from a study of the cross sections illustrated in the diagrams that the pieces might be selected in such a way that the shrinkage and expansion would take place chiefly in the thickness instead of the width, and thus leave the bevil unaltered. In this consists the chief art of selecting pieces for framing; but in many instances motives of economy unfortunately favour the use of pieces on stock, without reference to their suitability for the purpose required.

We may now leave the question of shrinkage, and proceed to a consideration of the more immediate object of the paper. In the following table, an attempt has been made to classify timber under the different terms by which it is known, according to its size, and other accidental characteristics. This is only a rough approximation, as no definite rule can be laid down; but it may be of some assistance to those who have occasionally to deal with workmen using the terms.

CLASSIFICATION OF TIMBER ACCORDING TO SIZE.

(Approximate).

Balk	12″ × 12″ to 18″ × 18″
Whole timber	9 × 9 to 15 × 15
Half timber	9 × 4½ to 18 × 9
Scantling	6 × 4 to 12 × 12
Quartering	2 × 2 to 6 × 6
Planks	11 to 18 × 3 to 6
Deals	9 × 2 to 4½
Battens	4½ to 7 × ¾ to 3
Strips and laths	2 to 4½ × ½ to 1½

Pieces larger than planks are generally called timber, but when sawn all round, are called scantling, and when sawn to equal dimensions each way, are called die-square. The dimensions (width and thickness) of parts in a framing are sometimes called the scantlings of the pieces. The term "deal" is also used to distinguish wood in the state ready for the joiner, from "timber" which is wood prepared for the use of the carpenter. A "log" or "stick," is a rough whole timber unsawn.

The use of wood may be discussed under the two heads of carpentry and joinery. The former consists principally of the use of large timbers, either rough, adzed, or sawn, and the latter of smaller pieces, always sawn, and with the exposed surfaces planed. The carpenters' work is chiefly outdoor; it embraces such objects as building timber bridges and gantries, framing roofs and floors, constructing centreing, and other heavy or rough work. The joiners' work is mostly indoor; it includes laying flooring, making and fixing doors, window sashes, frames, linings, partitions, and internal fittings generally. In all cases the proper connection of the parts is an essential element, and in designing or executing joints and fastenings in woodwork, the following principles, laid down by Professor Rankine, should be adhered to, viz.:—

1st. To cut the joints and arrange the fastenings so as to weaken the pieces of timber that they connect as little as possible.

2nd. To place each abutting surface in a joint as nearly as possible perpendicular to the pressure which it has to transmit.

3rd. To proportion the area of each surface to the pressure which it has to bear, so that the timber may be safe against injury under the heaviest load which occurs in practice and to form and fit every pair of such surfaces accurately in order to distribute the stress uniformly.

4th. To proportion the fastenings so that they may be of equal strength with the pieces which they connect.

5th. To place the fastenings in each piece of timber so that there shall be sufficient resistance to the giving way of the joint by the fastenings shearing or crushing their way through the timber.

To these may be added a 6th principle not less important than the foregoing ; viz., To select the simplest forms of joints, and to obtain the smallest possible number of abutments. The reason for this is that the more complicated the joint, or the greater the number of bearing surfaces, the less probability there will be of getting a sound and cheaply-made connection. To ensure a fair and equal bearing in a joint which is not quite true, it is usual, after the pieces are put together, to run a saw-cut between each bearing surface or abutment, the kerf or width of cut being equal in each case, the bearing is then rendered true. This is often done, for instance, with the shoulders of a tenon or the butting ends of a scarf, when careless workmanship has rendered it necessary. When the visible junction of two pieces is required to be as close as possible, and no great strain has to be met at the joint, it is usual to slightly undercut the parts, and give clearance on the inside, as in Fig. 20, which shows an enlarged view of a tongued and rebated heading joint in flooring. In pattern-making, the fillets which are placed at the internal angle of two meeting surfaces, are made obtuse angled on the back, in order that when bradded into place the sharp edges may lie close, as shown in Fig. 21. The prints used by pattern-makers for indicating the position of round-cored holes are also undercut by being turned slightly hollow on the bottom, as shown in Fig. 22. The principle is adopted in nearly all cases where a close joint is a desideratum. Clearance must also be left in joints of framing when a settlement is likely to take place, in order that after the settlement, the abutting surfaces may take a fair bearing to resist the strain.

The various strains that can come upon any member of a structure are—

Tension: Stretching or pulling.
Compression: Crushing or pushing
Transverse strain: Cross strain or bending.
Torsion: Twisting or wrenching.
Shearing: Cutting.

But in woodwork, when the latter force acts along the grain, it is generally called "detrusion," the term shearing being limited to the action across the grain. The first three varieties are the strains which usually come upon ties, struts, and beams respectively. The transverse strain, it must be observed, is resolvable into tension and compression, the former occurring on the convex side of a loaded beam, and the latter on the concave side, the two being separated by the neutral axis or line of no strain. The shearing strain occurs principally in beams and is greatest at the point of support, the tendency being to cut the timber through at right angles to the grain; but in nearly all cases if the timber is strong enough to resist the transverse strain it is amply strong for any possible shearing strain which can occur. Keys and other fastenings are especially subject to shearing strain, and it will be shown in that portion of our subject that there are certain precautions to be adopted to obtain the best results.

The following tables will serve as an introduction to the remaining portion of the paper:—

Classification of Joints in Carpentry.

Joints for lengthening ties, struts, and beams:

Lapping, fishing, scarfing, tabling, building-up.

Bearing-joints for beams: Halving, notching, cogging, dovetailing, tusk-tenoning, housing, chase-mortising.

Joints for posts and beams: Tenon, joggle, bridle, housing.

Joints for struts with ties and posts: Oblique tenon, bridle, toe joint.

Miscellaneous: Butting, mitreing, rebating.

Classification of Fastenings in Carpentry.

Wedges.	Pins: { Treenails, screws, bolts.
Keys.	Straps.
Pins: { Wood pins, nails, spikes.	Sockets.

And for joinery must be added glue.

We will consider these joints in the order given above. One of the first requirements in the use of timber for engineering purposes is the connection of two or more beams to obtain a greater length. Fig. 23 shows the method of lengthening a beam by lapping another to it, the two being held together by straps and prevented from sliding by the insertion of keys. Fig. 24 shows a similar joint, through-bolts being used instead of straps, and wrought-iron plates instead of oak keys. This makes a neater joint than the former, but they are both unsightly, and whenever adopted the beams should be arranged in three or five pieces in order that the supports at each end may be level, and the beams horizontal. This joint is more suitable for a cross strain than for tension and compression. Fig. 25 shows the common form of a fished beam adapted for compression. If required to resist tensile strain, keys should be inserted in the top and bottom joints between the bolts. Fig. 26 shows a fished joint adapted for a cross strain, the whole sectional area of the original beam taking the compressive portion of the cross strain, and the fishing-piece taking the tensile portion. Fig. 27 shows a fished beam for the same purpose, in which a wrought-iron plate turned up at the ends takes the tensile strain. Tabling consists of bedding portions of one beam into the other longitudinally. Occasionally the fishing pieces are tabled at the ends into the beams to resist the tendency to slip under strain, but this office is better performed by keys, and in practice tabling is not much used. The distinction between fished beams and scarfed beams is that in the former the original length is not reduced, the pieces being butted against each other, while in the latter the beams themselves are cut in a special manner and lapped partly over each other; in both cases additional pieces of wood or iron are attached to strengthen the joint. Fig. 28 shows a form of scarf adapted to short posts. Here the scarf is cut square and parallel to the sides, so that the full sectional area is utilized for resisting the compressive strain. When the post is longer and liable to a bending strain the scarf should be inclined, as in Fig. 29, to allow of greater thickness being retained at the shoulder of each piece, the shoulder being kept square. In this joint a considerable strain may be thrown on the bolts from the sliding tendency of the scarf, if the shoulders should happen to be badly fitted, as any slipping would virtually increase the thickness of the timber where the bolts pass through. The width of each shoulder should be not less than one-fourth the total thickness. Joints in posts are mostly required when it is desired to lengthen piles already driven, to support a superstructure in the manner of columns. Another form of scarf for a post put together without bolts is shown in Fig. 30, the parts being tabled and tongued, and held together by wedges. This is not a satisfactory joint, and is moreover, expensive because of its requiring extra care in fitting; but it may be a suitable joint in some special cases, in which all the sides are required to be flush. Fig. 31 shows the common form of scarf in a tie-beam. The ends of the scarf are bird's-mouthed, and the joint is tightened up by wedges driven from opposite sides. It is further secured by the wrought-iron plates on the top and bottom, which are attached to the timber by bolts and nuts. In all these joints the friction between the surfaces, due to the bolts being tightly screwed up, plays an important part in the strength of the joint; and as all timber is liable to shrink, it is necessary to examine the bolts occasionally, and to keep them well tightened up. Figs. 32 and 33 show good forms of scarfs, which are stronger but not so common as the preceding. Sometimes the scarf is made vertically instead of horizontally, and when this is done a slight modification is made in the position of the projecting tongue, as will be seen from Fig. 34, which shows the joint in elevation and plan. The only other scarfs to which attention need be called are those shown in Figs. 35 and 36, in which the compression side is made with a square abutment. These are very strong forms, and at the same time easily made. Many other forms have been designed, and old books on carpentry teem with scarfs of every conceivable pattern; but in this, as in many other cases, the simplest thing is the best, as the whole value depends upon the accuracy of the workmanship, and this is rendered excessively difficult with a multiplicity of parts or abutments.

In building-up beams to obtain increased strength the most usual method is to lay two together sideways for short spans, as in the lintels over doors and windows, or to cut one down the middle and reverse the halves, inserting a wrought iron plate between, as shown in the flitch-girder, Fig. 37. The reversal of the halves gives no additional strength, as many workmen suppose, but it enables one to see if the timber is sound throughout to the heart, and it also allows the pieces to season better. A beam uncut may be decayed in the centre, and hence the advantage of cutting and reversing, even if no flitch-plate is to be inserted, defective pieces being then discarded. When very long and strong beams are required, a simple method is to bolt several together so as to break joint with each other, as shown in Fig. 38, taking care that on the tension side the middle of one piece comes in the centre of the span with the two nearest joints equidistant. It is not necessary in a built beam to carry the full depth as far as the supports; the strain is, of course, greatest in the centre, and provided there is sufficient depth given at that point, the beam may be reduced towards the ends, allowance being made for the loss of strength at the joints on tension side. A single piece of timber secured to the underside of a beam at the centre, as in Fig. 39, is a simple and effective mode of increasing its strength. It will be observed that the straps are bedded into the sides of the beams; they thus form keys to prevent the pieces from slipping on each other. This weakens the timber much less than cutting out the top or bottom, as the strength of a beam varies only in direct proportion to the breadth, but as the square of the depth. The addition of a second piece of timber in the middle is a method frequently adopted for strengthening shear legs and derrick poles temporarily for lifting heavy weights.

We now come to the consideration of bearing joints for beams, the term "beam" being taken to include all pieces which carry or receive a load across the grain. The simplest of these is the halving joint, shown at Fig. 40, where two pieces of cross bracing are halved together. This joint is also shown at Fig. 41, where the ends of two wall plates meet each other. When a joint occurs in the length of a beam, as at Fig. 42, it is generally called a scarf. In each of these examples it will be seen that half the thickness of each piece is cut away so as to make the joint flush top and bottom. Sometimes the outer end of the upper piece is made thicker, forming a bevelled joint and acting as a dovetail when loaded on top. This is shown at Figs. 43, and 44. When one beam crosses another at right angles, and is cut on the lower side to fit upon it, the joint is known as single-notching, shown in Fig. 45. When both are cut, as in Fig. 46, it is known as double-notching. These forms occur in the bridging and ceiling joists shown on the diagrams of double and double-framed flooring. When a cog or solid projecting portion is left in the lower piece at the middle of the joint it is known as cogging, cocking, or caulking, and is shown in Fig. 47. Figs. 48 and 49 show two forms of the joint occurring between a tie-beam and wall plate in roofing. Dovetailing is not much used in carpentry or house-joinery, owing to the shrinkage of the wood loosening the joint. Two wall plates are shown dovetailed together at Figs. 50 and 51; in the latter a wedge is sometimes inserted on the straight side to enable the joint to be tightened up as the wood shrinks. Tredgold proposed the form shown in Fig. 52, which is known as the "Tredgold notch;" but this is never seen in practice. Tusk-tenoning is the method adopted for obtaining a bearing for one beam meeting another at right angles at the same level. Fig. 53 shows a trimmer supported on a trimming joist in this manner; this occurs round fire-places, hoistways, and other openings through floors. Fig. 54 shows the same joint between a wood girder and binding joist, it is also seen in the diagram of double-framed flooring. The advantage of this form is that a good bearing is obtained without weakening the beam to any very great extent, as the principal portion of the material removed is taken from the neutral axis, leaving the remainder disposed somewhat after the form of a flanged girder. When a cross piece of timber has to be framed in between two beams already fixed, a tenon and chase-mortise (Fig. 55), is one of the methods adopted. If the space is very confined, the same kind of mortise is made in both beams, but in opposite directions; the cross-piece is then held obliquely, and slid into place. Occasionally it is necessary to make the chase-mortise vertical, but this is not to be recommended, as the beam is more weakened by so doing—it is shown in Fig. 56. Ceiling joists, fixed by tenons and chase-mortises, are shown on the diagram of double flooring. In some cases, a square fillet is nailed on, as shown in the same diagram, to take the weight of the joists without cutting into the beam. While speaking of floors, the process of firring-up may be mentioned; this consists of laying thin pieces, or strips, of wood on the top of joists, or any surfaces, to bring them up to a level. Firring-pieces are also sometimes nailed underneath the large beams in framed floors, so that the under side may be level with the bottom of the ceiling joists to give a bearing for the laths, and at the same time allow sufficient space for the plaster to form a key. Brandering is formed by strips about one inch square, nailed to the under side of the ceiling joists at right angles to them; these strips help to stiffen the ceiling, and being narrower than the ceiling joists, do not interrupt the key of the plastering so much—this is also shown on the diagram of double flooring. Housing consists of letting one piece of wood bodily into another for a short distance, or, as it were, a tenon the full size of the stuff. This is shown in the diagram of staircase details, where the treads and risers are seen housed into the strings, and held by wedges. Housing is likewise adopted for fixing rails to posts, as in Fig. 57, where an arris rail is shown housed into an oak post for fencing. The most common joint, however, between posts and beams, is the tenon and mortise joint, either wedged or fixed by a pin; the former arrangement is shown in Fig. 58, and the latter in Fig. 59. The friction of the wedges, when tightly driven, aided by the adhesion of the glue or white lead with which they are coated, forms, in effect, a solid dovetail, and the fibres being compressed, do not yield further by the shrinking of the wood. In the diagram of a framed door will be seen an example of the application of this joint, and in the adjacent diagram will be seen the evils produced by careless fitting, or the use of unseasoned material When it is desired to tenon a beam into a post, without allowing the tenon to show through, or where a mortise has to be made in an existing post fixed against a wall, the dovetail tenon, shown in Fig. 60, is sometimes adopted, a wedge being driven in on the straight side to draw the tenon home and keep it in place. In joining small pieces, the foxtail tenon, shown in Fig. 61, has the same advantage as the dovetail tenon of not showing through; but it is more difficult to fix. The outer wedges are made the longest, and in driving the tenon home, these come into action first, splitting away the sides, and filling up the dovetailed mortise, at the same time compressing the fibres of the tenon. This joint requires no glue, as it cannot draw out, should it work loose at any time, the only way to tighten it up would be to insert a very thin wedge in one end of the mortise. Short tenons, assisted by strap bolts, as shown in Fig. 62, are commonly adopted in connecting large timbers. The post is cut to form a shoulder so that the beam takes a bearing for its full width, the tenon preventing any side movement. When a post rests on a beam or sill piece, its movement is prevented by a "joggle," or stub-tenon, as shown in Fig. 63; but too much reliance should not be placed on this tenon, owing to the impossibility of seeing, after the pieces are fixed, whether it has been properly fitted, and it is particularly liable to decay from moisture settling in the joint. For temporary purposes, posts are commonly secured to heads and sills by dog-irons or "dogs," Fig. 64; the pieces in this case simply butt against each other, the object being to avoid cutting the timber, and so depreciating its value, and also for economy of labour. Other forms of tenons are shown in Figs. 65 and 66. The double tenon is used in framing wide pieces, and the haunched tenon when the edge of the piece on which the tenon is formed is required to be flush with the end of the piece containing the mortice. Examples of both these will be found in the diagram of framed door. In Figs. 67 and 68 are shown two forms of bridle joint between a post and a beam. Tredgold recommended a bridle joint with a circular abutment, but this is not a correct form, as the post is then equivalent to a column with rounded ends, which it is well known is unable in that form to bear so great a load before it commences to yield. A strut meeting a tie, as in the case of the foot of a principal rafter in a roof truss, is generally tenoned into the tie by an oblique tenon, as shown in Fig. 69; and the joint is further strengthened by a toe on the rafter bearing against a shoulder in the tie. Tredgold strongly advised this joint being made with a bridle instead of a tenon, as shewn in Fig. 70, on account of the abutting surfaces being fully open to view. A strut meeting a post as in Fig. 71, or a strut meeting the principal rafter of a roof-truss (Fig. 72) is usually connected by a simple toe-joint. The shoulder should be cut square with the piece containing it, or it should bisect the angle formed between the two pieces. It is sometimes made square with the strut, but this is incorrect, as there would in some cases be a possibility of the piece slipping out. In ledged and braced doors or gates this joint is used, the pieces being so arranged as to form triangles, and so prevent the liability to sag or drop, which is so difficult to guard against in square framed work without struts or braces. When a structure is triangulated, its shape remains constant so long as the fastenings are not torn away, because, with a given length of sides, a triangle can assume only one position; but this is not the case with four-sided framing, as the sides, while remaining constant in length may vary in position. The diagram of a mansard roof shows various examples of a toe-joint; it shows also the principle of framing king-post and queen-post roof trusses each portion being triangulated to ensure the utmost stability. Among the miscellaneous joints in carpentry not previously mentioned the most common are the butt joint, Fig. 73, where the pieces meet each other with square ends or sides; the mitre joint, Fig. 74, where the pieces abut against each other with bevelled ends, bisecting the angle between them, as in the case of struts mitred to a corbel piece supporting the beam of a gantry; and the rabetted or "rebated" joint, Fig. 75, which is a kind of narrow halving, either transverse or longitudinal. To these must be added in joinery the grooved and tongued joint, Fig. 76; the matched and beaded joint, Fig. 77; the dowelled joint, Fig. 78; the dovetailed joint, Fig. 79, and other modifications of these to suit special purposes. The application of several of these joints is shown on the various diagrams before you of flooring, &c. To one of these it may be desirable to call particular attention—viz., the flooring laid folding. This is a method of obtaining close joints without the use of a cramp. It consists of nailing down two boards, and leaving a space between them rather less than the width of, say five boards, these boards are then put in place, and the two projecting edges are forced down by laying a plank across them, and standing on it. This may generally be detected in old floors by observing that several heading joints come in one line, as shown on the diagram, instead of breaking joint with each other. It is worthy of notice that the tongue, or slip feather, shown in Fig. 76, which in good work is formed generally of hard wood, is made up of short pieces cut diagonally across the grain of the plank, in order that any movement of the joints may not split the tongue, which would inevitably occur if it were cut longitudinally from the plank.

With regard to fastenings, the figures already given show several applications. Wedges should be split or torn from the log, so that the grain may be continuous; or if sawn out, a straight-grained piece should be selected. Sufficient taper should be put on to give enough compression to the joint, but too much taper would allow the possibility of the wedge working loose. For outside work, wedges should be painted over with white lead before being driven, this not being affected by moisture, as glue would be. In scarf-joints the chief use of wedges is to draw the parts together before the bolt-holes are bored. Keys are nearly parallel strips of hard wood or metal; they are usually made with a slight draft, to enable them to fit tightly. If the key is cut lengthways of the grain, a piece with curled or twisted grain should be selected, but if this cannot be done, the key should be cut crossways of the log from which it is taken, and inserted in the joint with the grain at right angles to the direction of the strain, so that the shearing stress to which the key is subject may act upon it across the fibres. In timber bridges and other large structures cast iron keys are frequently used, as there is with them an absence of all difficulty from shrinkage. Wood pins should be selected in the same way as wedges, from straight-grained, hard wood. Square pins are more efficient than round pins, but are not often used, on account of the difficulty of forming square holes for their reception. Tenons are frequently secured in mortises, as in Fig. 59, by pins, the pins being driven in such a manner as to draw the tenon tightly into the mortise up to its shoulders, and afterwards to hold it there. This is done by boring the hole first through the cheeks of the mortise, then inserting the tenon, marking off the position of the hole, removing the tenon, and boring the pin-hole in it rather nearer the shoulders than the mark, so that when the pin is driven it will draw the tenon as above described. The dowelled floor shown in Fig. 78 gives another example of the use of pins.

Nails, and their uses, are too well known to need description; it may, however, be well to call attention to the two kinds of cut and wrought nails, the former being sheared or stamped out of plates, and the latter forged out of rods. The cut nails are cheaper, but are rather brittle; they are useful in many kinds of work, as they may be driven without previously boring holes to receive them, being rather blunt pointed and having two parallel sides, which are placed in the direction of the grain of the wood. The wrought nails do not easily break, and are used where it is desired to clench them on the back to draw and hold the wood together. The following table gives the result of some experiments on the adhesion of nails and screws:—

ADHESION OF NAILS (Experiments by Mr. Bevan.

Description of Nails used.	No. to the lbs. Avoir.	Inches long.	Ins. forced into wood.	Lbs. Pressure to force in.	Lbs. pressure to extract.	
				Dry Christ. Deal	Dry Christ. Deal.	Dry Elm.
Fine Sprigs	4560	0·44	·40	—	22	—
,,	3200	0·53	·44	—	37	—
Threepenny brads	618	1·25	·50	—	58	—
Cast-iron nails	380	1·00	·25	—	72	—
Sixpenny nails	73	2·50	·50	24	—	—
,,	,,	,,	·50	76	—	—
,,	,,	,,	1·00	235	187	327
,,	,,	,,	,,	end grain.	87	257
,,	,,	,,	1·50	400*	327	—
,,	,,	,,	2·00	610	530	—
,,	,,	,,	,,	end grain.	257	—
Fivepenny nails	139	2·00	1·50	—	320	—

*Or 4 blows by weight of 6·275 lbs. falling freely through 1 foot.

SUMMARY.

	Across grain.		With grain.
Adhesion of nails in Deal	2	to	1
„ „ Elm	4	to	3

Entrance to extraction is as 6 to 5.

Common screw ·2″ diam. = 3 times the adhesive force of a sixpenny nail.

Spikes are nearly of the same form as nails, but much larger and are mostly used for heavy timber work. Treenails are hard wood pins used in the same way as nails. In particular work, with some woods, such as oak, they are used to prevent the staining of the wood, which would occur if nails were used and any moisture afterwards reached them. Compressed treenails are largely used for fixing railway-chairs to sleepers, as they swell on exposure to moisture, and then hold more firmly. Screws are used in situations where the parts may afterwards require to be disconnected. They are more useful than nails, as they not only connect the parts, but draw them closer together, and are more secure. For joiners' work the screws usually have countersunk heads; where it is desired to conceal them, they are let well into the wood, and the holes plugged with dowels of the same kind of wood, with the grain in the same direction. For carpenters' work the screws are larger and have often square heads; these are known as coach-screws. The bolts, nuts, and washers used in carpentry may be of the proportions given in the following table—an example is shown in Fig. 80 :—

Thickness of nut	$=1$	diar. of bolt
" head	$=\frac{3}{4}$	"
Diar. of head or nut over sides ...	$=1\frac{3}{4}$	"
Side of square washer for fir	$=3\frac{1}{2}$	"
" " oak... ...	$=2\frac{1}{2}$	"
Thickness of washer	$=\frac{1}{2}$	"

The square nuts used by carpenters are generally much too thin; unless they are equal in thickness to the diameter of the bolt, the full advantage of that diameter cannot be obtained, the strength of any connection being measured by its weakest part. The best proportion for nuts is shown in the diagram of a Whitworth standard hexagon nut. A large square washer is generally put under the nut to prevent it from sinking into the wood and tearing the fibres while being screwed up, but it is also necessary to put a similar washer under the head to prevent it sinking into the wood. This is, however, often improperly omitted. Straps are bands of wrought-iron placed over a joint to strengthen it and tie the parts together. When the strap is carried round one piece, and both ends secured to a piece joining it at right angles, as in a king post and tie-beam, it is known as a stirrup, and is tightened by means of a cotter and gib-keys, as shown in Fig. 81. When straps connect more than two pieces of timber together, they are made with a branch leading in the direction of each piece; but they are usually not strong enough at the point of junction, and might often be made shorter than they are without impairing their efficiency. Sockets are generally of cast-iron, and may be described as hollow boxes formed to receive the ends of timber framing.

With regard to the use of glue for securing joints, it has been found that the tensile strength of solid glue is about 4,000 lbs. per square inch, while that of a glued joint in damp weather is from 350 to 360 lbs. per square inch, and in dry weather about 715 lbs. per square inch. The lateral cohesion of fir wood is about 562 lbs. per square inch, and therefore in a good glue joint the solid material will give way before the junction yields.

The author has confined himself principally to those joints which are used in general construction; many others might have been mentioned, but, not being required in ordinary practice, they have been omitted, to avoid extending the paper to an undue length. He cannot conclude without acknowledging the assistance he has derived from the works of Tredgold, Rankine, and others, which contain valuable tables and information relating to the subject under consideration.

His thanks are also due to the Council of the City of London College for the loan of a set of 50 models of joints, which are exhibited. Other joints are illustrated by a few larger models, and one of these, a quadruple dovetail, may be referred to as a curiosity of jointing.

The author trusts that he has been able to treat the question in a sufficiently practical manner to be of some value to the members of this society in the exercise of their profession, and that the various debateable points will be freely discussed by the meeting.

At the conclusion of the Paper, a discussion took place as to the best forms of joints for taking the strains in the various positions to which timber in engineering works especially is subjected, and notice was taken of the necessity for periodically tightening the nuts in cases where timber is bolted together.

Mr. Adams having replied to the different questions which raised discussion, a vote of thanks was proposed by Mr. Herbert, who expressed the hope that a reduced copy of the numerous diagrams by which the paper was illustrated would be issued with the society's proceedings.*

*The reduced figures, published herewith, include all those referred to by number in the paper the remainder were principally larger diagrams shewing the application of the various joints.

The vote having been seconded by Mr. J. Love was carried unanimously.

The Chairman announced that Mr. Duncan would be unable to read his paper, through absence from London, at the meeting of the 15th inst. and that Mr. John Dixon had kindly promised to read on that evening a paper "On the means of Transport from Egypt and Erection in London of Cleopatra's Needle."

Mr. H. P. Worssam was declared duly elected a member of the society.

The meeting was then dissolved.