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SAWYER-WORK.

The labour of the sawyer is applied to the division of large pieces of timber or logs into forms and sizes to suit the purposes of the carpenter and joiner. His working-place is called a saw-pit, and his almost only important tool a pit-saw. A cross-cut saw, axes, dogs, files, compasses, lines, lamp-black, black-lead, chalk, and a rule, are all accessories which may be considered necessary to him.

The facility with which sawing whole timber is now done by the aid of the upright saw-frame, and smaller timber by the circular-saw bench, has in large factories and workshops caused the saw-pits to be out of date; timber after it has been cut at the mills can be again reduced into sizes and scantlings at a rapid rate, and with great exactitude and little labour. In some country parts, however, the saw-pit is still used. Unlike most other artificers, the sawyer can do absolutely nothing alone; sawyers are therefore always in pairs,—one of the two standing on the work, and the other in the pit under it. The log or baulk of timber being carefully and firmly fixed on the pit, and lined for the cuts which are to be made in it, the top-man standing on it, and the pit-man below or off from its end, a cut is commenced, the former holding the saw with his two hands by the handle above, and the other in the same manner by the box handle below. The attention of the top-man is directed to keeping the saw in the direction of and out of winding with the line to be cut upon, and that of the pit-man to cut down in a truly vertical line. The saw being correctly entered, very little more is required than steadiness of hand and eye in keeping it correctly on throughout the whole length. In the operations of the carpenter and joiner much depends on the manner in which the sawyers have performed their part. The best work on the part of the carpenter cannot retrieve the radical defects in his materials from bad sawing; and although the joiner need not allow his work to suffer, bad sawing causes him great loss of wood and immense additional and otherwise unnecessary labour. Planks or boards, and scantlings, on coming from the saw-pit, should be as straight and true in every particular, except mere smoothness of surface, as if they had been tried upon the joiner's bench; and good workmen actually produce them so. Saw-mills, too, by the truth and beauty with which they operate, show the sawyer what may be effected; for though he can hardly hope to equal their effect, he may seek to approach it.

CARPENTRY.

Carpentry or carpenter's work has been divided into three principal heads, namely, *descriptive*, *constructive*, and *mechanical*. The first shows the lines or methods for forming every species of work by the rules of geometry; the second comprises the practice of reducing the timber into particular forms, and joining the forms so produced so as to make a complete whole according to the intention or design; and the third displays the relative strength of the timbers and the strains to which they are subjected by their disposition. Here, we have merely to describe the practical details of carpenters' work in the operations of building. The carpenter works in wood, which he receives from the sawyer in beams, scantlings, and planks or boards, which he cuts and combines into bond-timbers, wall-plates, floors, and roofs. He is distinguished from the *joiner* by his operations being directed to the mere carcass of a building—to things which have reference to structure only. Almost everything the carpenter does in and to an edifice is absolutely necessary to its stability and efficiency, whereas the joiner does not begin his operations until the carcass is complete; and every article of joiners' work might at any time be removed from a building without undermining it or affecting its most important qualities. Certainly, in the practice of building, a few things do occur regarding which it is difficult to determine to whose immediate province they belong; but the distinction is sufficiently broad for general purposes. The carpenter, with the bricklayer or mason and some of the minor artificers, constructs the frame or hull; and the joiner, with the plasterer and others, decorates and rigs the vessel. On the former the actual existence of the ship depends, and on the latter depends her fitness for use.

Tools.

The carpenter frames or combines separate pieces of timber by scarfing, notching, cogging, tenoning, pinning, and wedging. The tools he uses are the rule, the axe, the adze, the saw, the mallet, hammers, chisels, gouges, augers, wimbles, pincers, hook-pins, a square, a bevel, a pair of compasses, and a gauge, together with the level, square, and plumb-rule; besides these, planes (for making grooves, rebates, and mouldings), gimlets, pincers, a sledge-hammer, a maul or beetle, wedges, and a crow-bar, may be considered useful auxiliaries, though they are not absolutely necessary to the performance of works of carpentry. Planing and other machines are used to diminish the great manual labour of working the surface of planks and boards, and of moulding, tenoning, and other similar operations; and so elaborate are some of these machines, that a four-panelled door can now be made complete in a couple of hours, which formerly was considered a good day's work for a man. Circular-saws are employed for working up larger timbers; and for ripping up boards or scantlings of moderate thickness, they are now used in all workshops.

Timber.

The fir timber in general use is imported from Memel Riga, Dantzig, and Sweden. Memel timber is the most convenient for size, Riga the best in quality, Dantzig the strongest, and Swedish the toughest. Riga timber can always be depended upon. Red pine may be used wherever durability and strength are objects; Quebec yellow pine for light dry purposes. In selecting timber, spongy heart, porous grain, and dead knots are to be avoided; the brightest in colour, and where the strong red grain appears to rise on the surface, are the best to be chosen. For joists and main timbers, the best woods are from Dantzig, Memel, or Riga; for partitions and minor timbers, American red wood, which not being so strong as the Baltic timber, must be cut to a little larger size. For sleepers, window-sills, and some parts of a roof, oak is used; for framing, Christiania deals or battens; for panelling, Christiania white deal or American yellow pine; for upper floors, Dram or Drammen and Christiania whites; for ground floors, Stockholm and Gefle yellows; for warehouse floors and staircases, Archangel and Onega planks; for best floors, St Petersburg, Onega, Dram, and Christiania battens. American deals should not be used for floors, as they are softer; and Swedish deals are bad for framing, as they warp. For interior finishings generally, Baltic red and white woods, and the American red and yellow pine, are to be preferred.

We must first proceed to consider the means by which form in the work of the carpenter is to be secured, and the connections by which the various strains are excited and communicated. The following practical remarks on various *joints* are abridged from the article by Prof. Robison in the former editions of this work.

The joinings practised in carpentry are almost infinitely various, and each has advantages which make it preferable in some circumstances. Many varieties are employed merely to please the eye. We do not concern ourselves with these; nor shall we consider those which are only employed in connecting small works, and can never appear on a great scale; yet even in some of these, the skill of the carpenter may be discovered by his choice; for in all cases it is wise to make every, even the smallest, part of his work as strong as the materials will admit. He will be particularly attentive to the changes which will necessarily happen by the shrinking of timber as it dries, will consider what dimensions of his framings will be affected by this and what will not, and will then dispose the pieces which are less essential to the strength of the whole in such a manner that their tendency to shrink shall be in the same direction with the shrinking of the whole framing. If he do otherwise, the seams will widen, and parts will be split asunder. He will dispose his boardings in such a manner as to contribute to the stiffness of the whole, avoiding at the same time the giving them positions which will produce lateral strains on truss beams which bear great pressures; recollecting, that although a single board has little force, yet many united have a great deal, and may frequently perform the office of very powerful struts.

Our limits confine us to the joinings which are most essential for connecting the parts of a single piece of a frame (when it cannot be formed of one beam, either for want of the necessary thickness or length), and the joints for connecting the different sides of a trussed frame.

Building up beams.

Much ingenuity has been bestowed on the manner of building up a great beam of many thicknesses, and many singular methods are practised; but when we consider the manner in which the cohesion of the fibres performs its office, we see that the simplest are formed on the same principles as the most refined, and they are less apt to induce false notions of the strength of the assemblage. Thus, were it required to build up a beam for a great lever or a girder, so that it may act nearly as a beam of the same size of one log, it may either be done by plain joggling, as in Plate XXII. fig. 1, A, or by scarfing, as in B or C. If it is to act as a lever, having the gudgeon on the lower side at C, we believe that most artists will prefer the form B and C. We may frequently gain a considerable accession of strength by this building up of a beam, especially if the part which is stretched by the strain be of oak, and the other part be fir. Fir being so much superior to oak as a pillar, and oak so much preferable as a tie, this construction seems to unite both advantages. But much better methods of making powerful levers, girders, &c., are obtained by trussing. Observe that the efficacy of both methods depends entirely on the difficulty of causing the piece between the cross joints to slide along the timber to which it adheres. Therefore, if this be moderate, it is wrong to make the notches deep; for as soon as they are so deep that their ends have a force sufficient to push the slice along the line of junction, nothing is gained by making them deeper; and this requires a greater expenditure of timber.

Scarfings of beams are frequently made oblique, as in Plate XXII. fig. 2; but this seems a bad practice. It begins to yield at a point where the wood is crippled and splintered off, or at least bruised out a little. As the pressure increases, this part, by squeezing broader, causes the solid parts to rise a little upwards, and gives them some tendency, not only to push their antagonists along the base, but even to tear them up a little. For similar reasons we disapprove of the favourite practice of many artists to make the angles of their scarfings acute, as in fig. 3. This often causes the two pieces to tear each other up. The abutments should always be perpendicular to the directions of the pressures. This law is also to be extended to the abutments of different pieces of a frame, and the artist must even attend to the shrinking of the timbers by drying. When two timbers abut obliquely, the joint should be most full at the obtuse angle of the end; because, by drying, that angle grows more obtuse, and the beam would then be in danger of splintering off at the acute angle.

Wedging.

It is evident that the nicest work is indispensably necessary in building up a beam. The parts must abut on each other completely, and the smallest play or void takes away the whole efficacy. It is usual to give the abutting joints a small taper to one side of the beam, so that they may require moderate blows of a maul to force them in, and the joints may be perfectly close when the external surfaces are even on each side of the beam. But we must not exceed in the least degree, for a very taper wedge has great force; and if the pieces be driven together by very heavy blows, the whole is left in a state of violent strain, and the abutments are perhaps ready to splinter off by a small addition of pressure. It is not unusual to leave some abutments open enough to admit a thin wedge reaching through the beam. Nor is this a bad practice, if the wedge is of material which is not compressed by the driving or the strain of service. Iron would be preferable for this purpose, and for the joggles, were it not that, by its too great hardness, it cripples the fibres of timber to some distance. In consequence of this it often happens, that in beams which are subjected to desultory and sudden strains (as in the levers of reciprocating engines), the joggles or wedges widen the holes, and work themselves loose; therefore skilful engineers never admit them, and indeed admit as few bolts as possible, for the same reason; but when resisting a steady or dead pull, they are not so improper, and are frequently used.

Beams are built up, not only to increase their dimensions in the direction of the strain (which we have hitherto called their depth), but also to increase their breadth, or the dimensions perpendicular to the strain. Sometimes the breadth of girder is doubled, if it is thought too weak for its load, and when the thickness of the flooring must not be increased.

The mast of a great ship of war must be made bigger athwartship, as well as fore and aft. This is one of the nicest problems of the art; and professional men are by no means agreed in their opinions in regard to it. We shall content ourselves here with exhibiting the different methods. The most obvious and natural method is that shown in Plate XXII. fig. 4. It is plain that (independent of the connection of cross bolts, which are used in them all when the beams are square) the piece C cannot bend in the direction of the plane of the figure without bending the piece D along with it. This method is much used in the French navy; but it is undoubtedly imperfect. Fig. 5 exhibits another method. The two halves of the beam are tabled into each other in the same manner as in fig. 1. It is plain that this will not be affected by any unequal swelling or shrinking, because this is insensible in the direction of the fibres; but when bent in the direction *a b*, the beam fig. 4 is weaker than bent in the direction *c f.* Each half of fig. 4 has, in every part of its length, a thickness greater than half the thickness of the beam. It is the contrary in the alternate portions of the halves of fig. 5. When one of them is bent in the direction AB, it is plain that it drags the other with it by means of the cross butments of its tables, and there can be no longitudinal sliding. But unless the work is accurately executed, and each hollow completely filled up by the table of the other piece, there will be a lateral slide along the cross joints sufficient to compensate for the curvature; and this will hinder the one from compressing or stretching the other in conformity to this curvature.

The imperfection of this method is so obvious that it has seldom been practised; but it has been combined with the other, as is represented in fig. 6, where the beams are divided along the middle, and the tables in each half are alternate, and alternate also with the tables of the other half. Thus 1, 3, 4 are prominent, and 5, 2, 6 are depressed. This construction evidently puts a stop to both slides, and obliges every part of both pieces to move together. *a b* and *c d* show sections of the built-up beam corresponding to AB and CD. No more is intended in this practice by any intelligent artist, than the causing the two pieces to act together in all their parts, although the strains may be unequally distributed on them. Thus, in a built-up girder, the binding joists are frequently mortised into very different parts of the two sides. But many seem to aim at making the beam stronger than if it were of one piece; and this inconsiderate project has given rise to many whimsical modes of tabling and scarfing.

The practice in the British dockyards is somewhat different from any of these methods. The pieces are tabled as in fig. 6, but the tables are not thin parallelopipeds, but thin prisms. The two outward joints or visible seams are straight lines, and the table 1 rises gradually to its greatest thickness in the axis. In like manner, the hollow 5, for receiving the opposite table, sinks gradually from the edge to its greatest depth in the axis. Plate XXII., fig. 7, No. 1, represents a section of a round piece of timber built up in this way, where the full line EF, GH is the section corresponding to AB of fig. 6, and the dotted line EG, FH is the section corresponding to CD. This construction, by making the external seam straight, leaves no lodgment for water, and looks much fairer to the eye; but it appears to us that it does not give so firm a hold when the mast is bent in the direction EH. The exterior parts are most stretched and most compressed by this bending; but there is hardly any abutment in the exterior parts of these tables. In the very axis, where the abutment is the firmest, there is little or no difference of extension and compression. But this construction has an advantage, which, we imagine, much more than compensates for these imperfections, at least in the case of a round mast; it will draw together by hooping incomparably better than any of the others.

Joggles of elm are sometimes used in the middle of the large tables of masts; and when sunk into the firm wood near the surface, they must contribute much to the strength. But it is very necessary to employ wood not much harder than the pine, otherwise it will soon enlarge its bed and become loose, for the timber of these large trunks is very soft.

The most general reason for piecing a beam is to increase its length. This is frequently necessary, in order to procure tie-beams for very wide roofs. Two pieces must be scarfed together. Numberless are the modes of doing this, and almost every master carpenter has his favourite nostrum. Some of them are very ingenious; but here, as in other cases, the most simple are commonly the strongest. We do not imagine that any, the most ingenious, is equally strong with a tie consisting of two pieces of the same scantling laid over each other for a certain length, and firmly bolted together. We acknowledge that this will appear an artless and clumsy tie-beam, but it will be stronger than any that is more artificially made up of the same thickness of timber. The next simplest and most obvious scarfing is that represented in Plate XXII., fig. 8, Nos. 1 and 2. If considered merely as two pieces of wood joined, it is plain that, as a tie, it has but half the strength of an entire piece, supposing that the bolts (which are the only connections) are fast in their holes. No. 2 requires a bolt in the middle of the scarf to give it that strength, and in every other part is weaker on one side or the other. If the bolts were sufficiently numerous and sufficiently firm, so as to produce a great degree of adhesion or of friction between the parts, this joint might be made almost as strong as the entire beam, since there is nothing to prevent the co-operation of each side with the other throughout its extent; but much of the strength would be lost if the bolts became loose, even in an inconsiderable degree. But the bolts are very apt to bend by the violent strain, and require to be strengthened by uniting their ends by iron plates,—in which case it is no longer a wooden tie. The form of No. 1 is better adapted to the office of a pillar than No. 2, especially if its ends be formed in the manner shown in the elevation No. 3. By the sally given to the ends, the scarf resists an effort to bend it in that direction. Besides, the form of No. 2 is unsuitable for a post, because the pieces by sliding on each other by the pressure are apt to splinter off the tongue which confines their extremity. Figs. 9 and 10 exhibit the most approved form of a scarf, whether for a tie or for a post. The key represented in the middle is not essentially necessary; the two pieces might simply meet square there. This form, without a key, needs no bolts (although they strengthen it greatly), but, if worked very true and close, and with square abutments, will hold together, and will resist bending in any direction. But the key is a very great improvement, and will force the parts together with perfect tightness, but it must not be over driven. The form of fig. 9 is by far the best (it is sometimes said to be tabulated, that is, to render the joints as close as possible, and the juncture more independent of any bolts which might be placed similarly to those in fig. 8, No. 1),—because the triangle of fig. 10 is much more readily splintered off by the strain or by the key than the square wood of fig. 9. It is far preferable for a post, for the reason given in speaking of fig. 8, No. 1 and No. 2. Both may be formed with a sally at the ends equal to the breadth of the key. In this shape fig. 9 is well suited for joining the parts of the long corner posts of spires and other wooden towers. Fig. 9, No. 2 differs from No. 1 only by having three keys; the principle and the longitudinal strength are the same. The long scarf of No. 2, tightened by the three keys, enables it to resist bending much better.

None of these scarfed tie-beams can have more than one third of the strength of an entire piece, unless with the assistance of iron plates; for if the key be made thinner than one-third, it has less than one-third of the fibres to pull by We are confident, therefore, that when the heads of the bolts are connected by plates, the simple form of fig. 8, No. 1, is stronger than those more ingenious scarfings. It may be strengthened against lateral bending by a little tongue, or by a sally, but cannot have both.

Fishing beam.

The strongest of all methods of piecing a tie-beam would be to set the parts end to end, and grasp them between other pieces on each side, as in Plate XXIII., fig. 1. This the ship-carpenter calls fishing a beam; it is a frequent practice for occasional repairs. Perronet used it for the tie-beams or stretchers by which he connected the opposite feet of a centre, which was yielding to its load. and had pushed aside one of the piers above 4 inches

Where the beams stand square with each other, and the strains are square with the beams and in the plane of the frame, the mortise and tenon is the most perfect junction. A pin is generally put through both in order to keep the pieces united, in opposition to any force which tends to part them. Every carpenter knows how to bore the hole for this pin, so that it shall draw the tenon tight into the mortise, and cause the shoulder to butt close, and make neat work; and he knows the risk of tearing out the bit of the tenon beyond the pin, if he draw it too much. We may just observe, that square holes and pins are much preferable to round ones for this purpose, bringing more of the wood into action, with less tendency to split it.

Ship-carpenters have an ingenious method of making long wooden bolts, not passing completely through, which take a very fast hold, though not nicely fitted to their holes, which they must not be, lest they should be crippled in driving. They call it fox-tail wedging. They stick into the point of the bolt T, Plate XXIII., fig 2, thin wedges of hard wood, so as to project a proper distance; when these reach the bottom of the hole by driving the bolt. they split the end of it, and squeeze it hard to the side. This may be practised with advantage in carpentry. If the ends of the mortise are widened inwards, and a thin wedge be put into the end of the tenon, it will have the same effect, and make the joint equal to a dove-tail; but this risks the splitting the piece beyond the shoulder of the tenon, which would be unsightly, and may be avoided by two *very* thin wedges *a* and *c* being struck in near its angles, projecting equally; at a very small distance within these are to be placed two shorter ones *b*, *d*, and more within these if necessary. In driving this tenon, the wedges *a* and *c* will take first, and split off a thin slice, which will easily bend without breaking. The wedges *b*, *d* will act next, and have a similar effect, and the others in succession. The thickness of all the wedges taken together must be equal to the enlargement of the mortise towards the bottom.

When the strain is transverse to the plane of the two beams, great care must be taken by the artist in placing his mortise A mortise in a girder for receiving the tenon of a binding-joist of a floor should be as near the upper side as possible, because the girder becomes concave on that side by the strain. But as this exposes the tenon of the binding-joist to the risk of being torn off, we are obliged to mortise further down. The form in Plate XXIII., fig. 3, generally given to this joint is extremely judicious. The sloping part *a b* gives a very firm support to the additional bearing *e d*, without much weakening of the girder. This form should be copied in every case where the strain has a similar direction

The joint that most of all demands the careful attention of the artist is that which connects the ends of beams, one of which pushes the other very obliquely, putting it into a state of extension. The most familiar instance of this is the foot of a rafter pressing on the tie-beam, and thereby *drawing* it away from the other wall. When the direction is very oblique (in which case the extending strain is the greatest), it is difficult to give the foot of the rafter such a hold of the tie-beam as to bring many of its fibres into the proper action. There would be little difficulty if we could allow the end of the tie-beam to project to a small distance beyond the foot of the rafter; but, indeed, the dimensions which are given to tie-beams for other reasons are always sufficient to give enough of abutment when judiciously employed. Unfortunately this joint is very liable to fail from the effects of the weather. It is much exposed; and frequently perishes by rot, or becomes so soft and friable that a very small force is sufficient either for pulling the filaments out of the tie-beam, or for crushing them together. We are therefore obliged to secure it with particular attention, and to avail ourselves of every circumstance of construction.

One is naturally disposed to give the rafter a deep hold by a long tenon, but it has been frequently observed in old roofs that such tenons break off. Frequently they are observed to tear up the wood that is above them, and push their way through the end of the tie-beam. This in all probability arises from the first sagging of the roof, by the compression of the rafters and of the head of the king-post. The head of the rafter descends, and the angle with the tie-beam is diminished by the rafter revolving round its step in the tie-beam. By this motion the heel or inner angle of the rafter becomes a fulcrum to a very long and powerful lever much loaded. The tenon is the other arm, very short; and being still fresh, it is therefore very powerful. It therefore forces up the wood that is above it, tearing it out from between the cheeks of the mortise, and then pushes it along. Carpenters have therefore given up long tenons, and give to the toe of the tenon a shape which abuts firmly, in the direction of the thrust, on the solid bottom of the mortise, which is well supported on the under side by the wall-plate. This form, represented in Plate XXIII., fig. 4, has no tendency to tear up the end of the mortise. The tenon has a small portion *a b* cut perpendicular to the surface of the tie-beam. and the rest *b c* is perpendicular to the rafter.

But if the tenon is not sufficiently strong and it is not so strong as the rafter, which is thought not to be stronger than is necessary), it will be crushed, and then the rafter will slide out along the surface of the beam. It is therefore necessary to call in the assistance of the whole rafter. It is in this distribution of the strain among the various abutting parts that the varieties of joints and their merits chiefly consist. We can only mention a few here that have met with most general approval.

Various forms of joints.

The aim in fig. 5, Plate XXIII., is to make the abutments exactly perpendicular to the thrusts. The action is the same as against the joggle on the head or foot of a king-post. This is a very effectual joint; it is not, however, much practised. It is said that the sloping seam at the shoulder lodges water; but the great on seems to be a secret notion that it weakens the tie-beam. Fig. 6 exhibits a form that is more general, but certainly worse. The shoulder-joint is sometimes formed like the dotted line *a b e d c f g* of fig. 6. This is much more agreeable to the true principle, and would be a very perfect method, were it not that the intervals *b d* and *d f* are so short that the little wooden triangles *b e d*, *d c f* will be easily pushed off their bases *b d*, *d f*. Fig. 7, No. 1, seems to have the most general approbation, but we fail to perceive its peculiar merits. It is the joint recommended by Price, and copied into books of carpentry as the *true joint* for a rafter foot. The visible shoulder-joint is flush with the upper surface of the tie-beam. The angle of the tenon at the tie nearly bisects the obtuse angle formed by the rafter and the beam, and is therefore somewhat oblique to the thrust. The inner shoulder *a c* is nearly perpendicular to *b d*. The lower angle of the tenon is cut off horizontally as at *e d*. Fig. 8 is a section of the beam and rafter foot, showing the different shoulders. Fig. 7, No. 2, is a simpler, and in our opinion a preferable joint. We observe it practised by the most eminent carpenters for all oblique thrusts; but it surely employs less of the cohesion of the tie-beam than might be used without weakening it, at least when it is supported on the other side by the wall-plate. Fig. 7, No. 3, is also much practised by the best carpenters. Fig. 9, No. 1, is proposed by Mr Nicholson as preferable to fig. 7, No. 3.