&c., though both the former and latter are not unfrequently executed in plaster composition or cements. Quoin-stones are gauged and wrought blocks with parallel beds and vertical faces, placed on the angles of buildings in the Greek, Roman, and Italian styles, with the intention of adding to their beauty and strength, as in fig. 7, Plate XXI.; they are used in all kinds of walling, and are generally made to project before the face of that to which they are attached, mostly with a weathered angular joint, or with a rectangularly grooved or moulded one. The quoins are coursed with the rest of the wall if it be of stone, and are made to occupy the exact space of a limited number of courses of brick in a brick wall, or of flints where these are used. Copings in Italian work to cover walls, parapets, &c., are worked with a plain horizontal bed, two vertical faces, and an inclined or weathered back or upper surface,—either forming an acute angle with the outer and wider, and an obtuse angle with the inner and narrower face, to throw the water off, shown at *a* fig. 9, Plate XXI.; or sloping to both sides from the middle, as at *b*; the latter is technically termed saddle-back coping. In both cases they are made to project over the wall or parapet on both sides; and in the projected part of the bed under the edge or edges towards which the inclination is given, a channel or groove, called a throat, is cut, to intercept the water in its inclination to run inwards to the wall. On gables or other inclined planes the coping is neither weathered nor throated, as the water is necessarily impelled along its course to the lower end, and not over the sides. It is a curious circumstance that the mediæval designers rarely made their copings to project on the inside of a parapet, as shown in fig. 16, so that the exterior projection, which was returned up, was perhaps intended as much for effect as use. To protect the separate stones of a coping course from the danger of being displaced by high winds or other accidental causes, and to form a chain through its whole length, the stones are linked together by cramps of copper or iron let into their backs and run with lead. These metals, however, especially the iron, for the most part act very injuriously, from their exceeding sensibility to atmospheric changes, and their greater or less tendency to oxidation; indeed, the stone invariably suffers more than the work benefits from the metal cramps. Tenons, dowels, joggles, or dovetails, of stone, of hard word, or of slate set in Portland cement, applied so as to be protected from the weather, are far better, and would answer every desirable purpose sufficiently. Lead dowels, when small, are occasionally used. The value of joggling and doweling to stone-work is well exemplified in the construction of Eddystone lighthouse. Cornices are but ramified copings, and are or may be subjected to the same general laws. Care must be taken, however, in arranging them, that their centre of gravity be not brought too far forward, in the anxiety to project them sufficiently, lest they act injuriously on the wall by pressing unequally, and their own seat be also endangered. String courses economically, in contradistinction to architecturally, are meant to protect a set-off in a wall, by projecting over its lower face in the manner of a coping, as in fig. 7, Plate XXI., at *c*; the beds are worked parallel, and the outer face vertical or at right angles to them, but so much of the upper surface is weathered or sloped off as protrudes from the upper part of the wall to carry the water off; and, for the reason above stated with regard to copings, the lower bed just within the outer face is throated. A stone string course, cramped or dovetailed in the bed, forms an excellent chain round a brick wall;

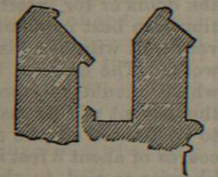


FIG. 16.—Copings.

but the part of it in the wall should be of the exact height of one, two, or more courses of brickwork. The woodcut, fig. 17, is a usual cornice or string course in the later period of mediæval art in England. A blocking course is either a very thick string projecting over or flush with the face of the lower part of the wall to cover a set-off; or it is a range of stone over a crowning cornice to bring the centre of gravity more in on the wall than it otherwise would be; in the former case it is treated exactly as a string, excepting that, if it be flush below, there is no occasion for a throat; in the latter it has a horizontal case bed, parallel vertical sides, and a weathered back or upper surface.


FIG. 17.—Cornice.

Sills. Sills are weathered and throated like the parts of a string course, Plate XXI., fig. 7, *a* and *b*; yet in mediæval work they may be seen flush with the upright of the wall. They are laid across window openings as a base to the sash-frame; distinct sills in the same line may, indeed, be considered as an intercepted string course. In the ordinary practice of building, window sills are seldom set in brick walls until they are absolutely required to set the sash-frames on; or they are set but not bedded, except at the ends. The object of this is to prevent any settlement that may occur in the piers from breaking the sills across on the unyielding part of the wall under the windows. A necessity for this, however, can only arise from bad construction; for with a good bond in the brickwork, all would settle together, and the sills might be completely bedded across at once.

Landings are platforms of stone, either over an area before a door, at the head of a flight of stairs, or as the floor of a balcony. They are made four, five, six, or eight inches in thickness, according to their extent and bearing; if not one piece of stone they are of nicely jointed pieces joggled and plugged together, and are worked on the face and edges just as their situation may demand. They should also be very carefully pinned into the walls. Fig. 18 will show the danger, should they not be so, through the full length of their insertion. If the front edge be pinned up, as at A, but a vacancy be left, as at B, the point C will become the fulcrum of a lever, and the landing have a tendency to turn at that point, and to break at the edge C. Every step and landing should have 8 inches hold in a brick wall. All landings should be well joggled; the joint joggles made as at *a*, fig. 19, is called by workmen a *he*, and that at *b* a *she* joggle. An accident at the Polytechnic Institution in London arose, no doubt, from the carelessness of the workmen, who put two landings together, in which two she-joggles were worked, as in fig. 20, and filled the open space with plaster. There happened to be a large fossil in the stone close to the wall in the landing *b*, which, having no support from the other landing *a*, gave way, and caused the destruction of the lower portion of the staircase upon which it fell.

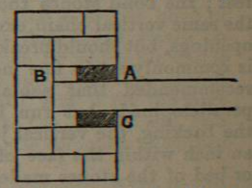


FIG. 18.—Extremity of Landing.

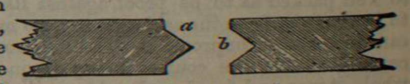


FIG. 19.—Joggles.

FIG. 20.—Joggles badly joined.

Stone pavings are prepared and laid in various ways. Ordinary paving is of self-faced or of tooled York; and for better purposes it is of rubbed Portland stone. For entrance halls, square stones, with the angles slightly cut off, the four spaces thus obtained being filled up by a small square of black or other coloured stone, makes a neat paving, which is replaced by marbles in best houses and public buildings, if a tesselated pavement be not required. Stone paving that is not exposed to the sun and air, if next the ground, should be laid on footings of brick or stone, or it will be constantly damp should the soil be close and clayey; but in yards, open areas, &c., it may be laid on the ground, bedded in sand, and jointed with mortar or cement. Stone-paved floors should be formed on brick arches, or on a timber floor prepared for the purpose; the latter, however, is a very bad mode of supporting paving, as the impression derived from the presence of the stone is, that the floor is incombustible; but if it be bedded on combustible material, the danger to human life in the event of fire is greater than if the stone paving did not exist at all. It is worked, cut, and set more or less expensively, according

Curbs. to circumstances. A curb is a range or course of thicker and stronger stone to bound a pavement, and is either flush with the paving showing as a step on its outer edge, or is raised above it to receive a balustrade, and shows on the outer side as a blocking course; in the latter situation it is generally joggled and plugged in the joints. The term

Steps. step or steps alone is usually understood to mean external steps, whether arranged in long or short flights, or the single step in a doorway into which the door-frame is tenoned. A step should have a plain horizontal bed, and a very slightly weathered tread or upper surface,—the front or riser worked plain and vertical, or with a moulded nosing, and the back sunk with a joggle or bird's-mouth joint to receive the step or landing above or behind it. Steps for areas or back courts are often made of 2 or 2½ in. stone for the tread, the riser being formed of a 4½ or 5 in. stone, both tailed into a wall at one or both ends. This is much lighter in effect. Slate is sometimes used for the treads.

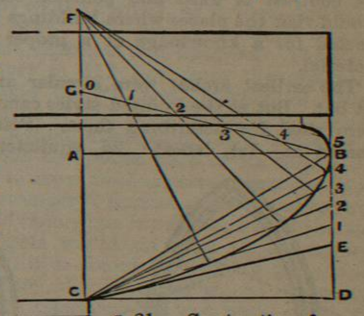
Stairs. Stairs are but a flight or combination of steps used internally, and the general principle of designing staircases, as regards the rise and tread of steps, setting out curves, curtails, landings, &c., are given in the part treating of joinery. The chief difference between these and other staircases consists in the fixing, the one being framed with wooden strings, while the other have no strings, but are supported entirely by the walls. If there be a wall at each end, they are simply built in at the time the work goes up; but if they are supported at one end only, they are called geometrical stairs, and depend entirely on their being securely wedged into the wall; on which and on the support each derives at one edge from the step below, they wholly rely. If they are square in section, they are called solid steps; but as the under side or soffit, then, is irregular, it is usual to make the steps of somewhat a triangular shape, so as to present a continued soffit. In this case they are called arris, or feather-edge steps. Care should be taken that there are no sudden or irregular changes in the curves. These may be easily avoided by the method shown in the portion relating to joinery for the easing of the curves and ramps in handrails.

Chimney-pieces. In houses built of stone the flues are usually formed in brickwork. The chimney-pieces consist of plain jambs, or boxings, or other vertical sides more or less decorated and moulded, and of the architrave or transverse covering or mantel, fig. 8, Plate XXI., with its shelf or cornice. The parts of a chimney-piece are generally put together with an adhesive plaster or cement, and affixed to the wall or chimney-breast behind with cramps, holdfasts, and plugs. The material of which chimney-pieces, if not of wood, are composed, varies from the coarsest stone to the finest marble; and the labour on them varies to a still greater extent.

Masonry to receive architectural decorations is generally worked into the walls as they are carried up; but as they are seldom homogeneous either in matter or construction, the result is mostly the converse of what it purports to be, for the work is more frequently weakened than strengthened by the decorative masonry. Stones of which columns are to be composed, whether each column is to be of one stone or more, are generally roughly boasted out before they are set, and are finished afterwards to traversing moulds and templets with a plumb-rule, whose sides are cut to the diminution obtained from the bottom and upper diameters, whatever it may be. Flutes are cut at the same time and in the same manner. The beds of the joints in columns should be worked with the greatest precision, so as to obtain parallel planes, that they may fit firmly and closely together; they must not, however, be worked hollow to make a close joint externally, or the arrises will chip off. It is considered a good plan, where the columns are large, to put a piece of thin milled lead between the beds, cut circular, and extending to within a short distance of the surface, and that the rest be filled with a fine adhesive putty, made as nearly of the colour of the stone as possible. This makes a solid bed, and protects the arrises effectually; but it will not do so well for slight columns, because it narrows the bed so materially. A joggle or dowel of hard wood, slate, or cast-iron let into the core might be a sufficient counteraction, and it would certainly add to the stability of a polylithic shaft. The other parts of a columnar composition may be sufficiently cramped and joggled together with wood and metals, according to the situation, though it may be again remarked, that neither wood nor metal should be used, unless it can be protected from access even of the atmosphere.

Greek and Roman mouldings. Sections for Roman mouldings are given in the part relating to joinery, but as those used in Grecian architecture are parts of conic sections, and not struck by compasses, we give a short problem by which they may all easily be set out. Both Roman and Grecian mouldings are shown on Plate XIII. of vol. ii.

Let an ovolo be the moulding required (fig. 21), the height of which (to the point where the moulding curves backward) is AC or BD, and the greatest projection AB or CD; and let CE be a tangent line, or line which the curve must touch but not cut. Produce CA to F, and make AF equal to AC, and AG to ED. Divide GB BE each into the same number of equal parts as 5. Draw the co-ordinates from F and C to the respective numbers, their intersections will trace the curve. If BE be more than half the whole height, the curve is an ellipse; if exactly half the height, it is a parabola; and if BE be less than half BD, the curve will be a hyperbola. All other mouldings can be drawn by this method, it being remembered that cymas, ogees, and all reflex curves, must be divided and drawn in two separate portions.



[FI]G. 21.—Construction of Ovolo.

The mouldings in mediæval architecture differ entirely from those of other styles. They are chiefly formed by a combination of curves stopped by right lines or worked into other curves and hollows. The mouldings differ in each of the several periods of the style in England, and also in the variations of the style as practised here and in each country on the Continent. We insert an outline, fig. 22, of a window jamb at Sleaford church, Lincolnshire, to show the forms and combination of an example during the Decorated period. A full description of those used in each style would exceed our limits, nor, indeed, is it a subject within the scope of this article. They are sometimes set out with the compasses, and many often appear to have been drawn by eye. We must refer our readers to the works of Professor Willis, F. A. Paley, and of J. H. Parker, for any details required about them. A very curious treatise was published by Professor Willis, called the *Architectural Nomenclature of the Middle Ages*, which goes at great length into the subject. A bead or astragal seems to have been called a bowtelle;

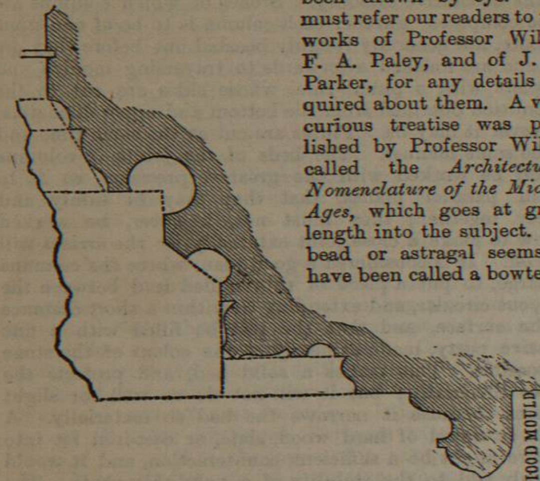


FIG. 22.—Outline of Window Jamb at Sleaford Church.

a torus, a grete bowtelle; a hollow or scotia, a casement; an ogee, a ressaunte, and so on.

The methods of working mouldings in the stones at the builder's command have been already noticed at the commencement of this section. The soft stones and marbles are easily shaped into mouldings with the chisel and the mallet, and are sawn and the surfaces even finished with a plate having a fine edge. These stones will take mouldings of minuter character than the harder stones, which have to be worked with force, and require pointed tools to form the faces. The hardest material, granite, again, has to be stunned with heavy picks to make an impression, so that only bold ornaments have a good effect; much money has been thrown away in details more suitable for softer materials. Good effect is obtained by the contrast of axed and polished surfaces. A designer should visit the places where buildings in granite have been erected for a knowledge of a proper application of that material.

The earliest arches were circular and, of course, easily set out. But as the Pointed styles came in, several methods were used for describing them. Pointed arches may be classed as—1st, lancet · 2d, equilateral; 3d, depressed;

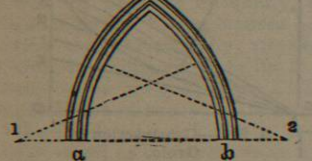


FIG. 23.—Lancet Arch.

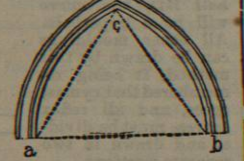


FIG. 24.—Equilateral Arch.

and 4th, four-centred or Tudor. In the first the centres, as 1, 2, in fig. 23, are outside the arch *a b*. At Westminster Abbey the arches of the choir are so acutely pointed that the distances 1*a* and 2*b* are nearly two-thirds of the entire opening *a b*. In the nave at York the points are without the arch at a distance of about one-fifth the opening *a b*. In equilateral arches the centres are exactly on the points *a b* in fig. 24, so that the apex *c*, joined to *a* and *b*, will form an equilateral triangle. The nave arches at Wells are of this description, and also those at Lincoln (see vol. ii. Plate XVIII. fig. 1). In later times the arches were of lower pitch, as fig. 25, and then, of course, the centres 1 and 2 were within the arch *a b*. At Salisbury Cathedral the distance *a*1 is one-sixth of *a b*, while in the choir at Lincoln (vol. ii., Plate XVIII., fig. 2) it is as much as two-fifths. To describe arches which shall be similar to one another throughout a building, however the openings may differ, this principle must always be borne in mind, that the centres are to be always distant from the points *a b* by some aliquot portion of the whole opening. This is the more important, as the lines of tracery will not fall into their proper places except the arches are set out upon some regular principle. If the arches are not equilateral, some distance from each point *a b* should be first determined on (say one-third the opening *a b*), and after this, whatever the span of the other arches may be, one-third its own opening is to be taken from the points *a b*, as the centres from which to strike its curves. The only exception is that, in mediæval buildings, the arches to the doorways are frequently somewhat flatter than those of the windows. In the Tudor period the arches are very frequently drawn from four centres instead of two. As there has been great misapprehension as to four-centred arches some persons treating them as parts of conic sections, whereas they are really parts of segments of circles, it is thought well to give two methods of describing these arches.

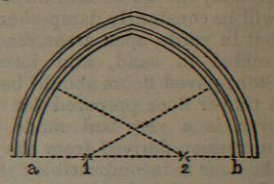


FIG. 25.—Depressed Arch.

Four-centred arches

First, when the width AB, fig. 26, of the arch, and the apex height OC, are given, and a tangent to the upper circle as CD. In this case draw AD perpendicular to AB, and set out A1 equal to AD; draw C3 perpendicular to CD, and make CE equal to AD or A1; join 1E and bisect the same as shown by a perpendicular meeting CE produced in 3; join 3 1 and produce towards F, then 1 and

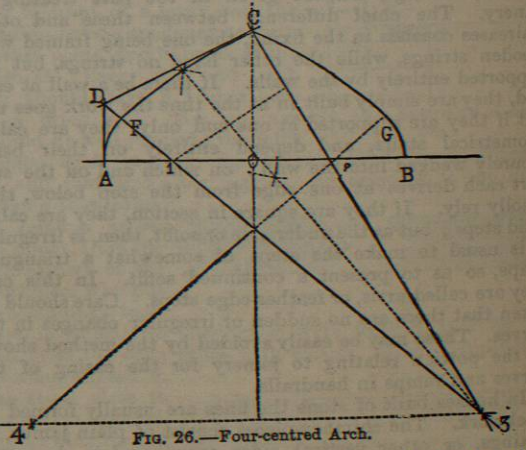


FIG. 26.—Four-centred Arch.

3 will be the centres for half the arch; and, transferring the points across, 2 and 4 will be the centres for the other half. In the second case, when the width AB and the height OC, and the centres of the small circles 1, 2, are given. Make AD equal to A1, join CD (which will be a tangent to the upper curve), draw C3 at right angles

thereto, make CE equal to A1, join 1E, bisect the same, and proceed as before. The points FG, as has before been explained, are the points where the circles will meet each other. The joints to these arches will all radiate to their respective centres.

Specimens of various sorts of the tracery which adorn the windows of the mediæval periods, and are in fact their greatest glory, are shown in Plates XVIII., XIX., and XX. of vol. ii. The designs for tracery are almost infinite, and the various methods of setting them out would fill a volume. But although they display such ingenuity and fancy that one would think the design to be quite arbitrary, it will be found that they are all, or very nearly all, set out on the principle of geometrical intersections. An example will show the principles on which the mediæval architects proceeded to describe the tracery, and also the method of finding the joints of the various pieces of stone.

Let *a b* (fig. 27) be the opening of the arch; as there are to be two mullions, divide the same into three equal parts, as *a c*, *c d*, *d b*; then determine the points from which to strike the arch. In this instance, for the sake of simplicity, we make it equilateral (as in fig. 24); *a* and *b* then are the centres for striking the main

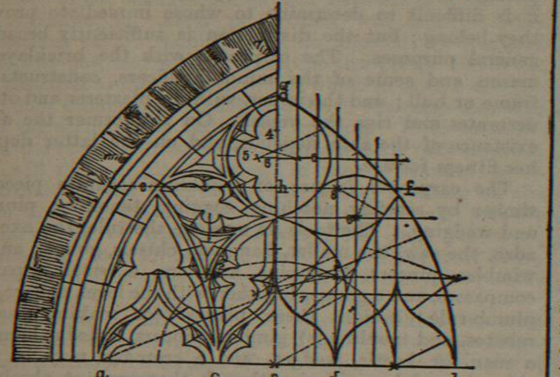


FIG. 27.—Construction of Window Tracery.

arch *a e g*, *b f g*, and the height *o g* is that of an equilateral triangle. Produce the springing line, and the same opening of the compasses through *c* and *d* will give the principal inner branches of the tracery *c e*, *d f*. From the centre *o*, with an opening extending to the middle of the lights *a c*, *d b*, strike a semicircle; raise perpendiculars from *d* and *c* to 1 and 2; draw a line through 1 and 2; on this and the springing line will be found the centres of the lower ogees; bisect the part of *g o* cut off by 1 2 in *h*, which is in fact the same thing as dividing the whole height *o g* into three; divide *h g* into three parts, at 3 and 4; through 3 draw a horizontal line, and set off from 3 distances one-third of the width *o d*, or draw the perpendicular lines as shown, which is better; then 5 and 6 will be the centres of the upper quatre-foil. From the line 1 2, on the same perpendicular as last, set down similar points, as at 7. These will be the centres for the lower subdivision as shown. Next draw *e h f* and subdivide by similar perpendiculars, and where the lines intersect, as at 8, will be the centres for the upper subdivisions. The lines thus drawn will form a species of skeleton diagram, as shown on the right side of fig. 27, which is called the *element of the tracery*, and is in fact the centre line of the mullion, as shown by *a*, fig. 28. On each side of this, using always the same centres for the same branches, draw lines, showing the face (or what the workmen call the *nose*) of the mullion, and answering to *b c*; and then others answering to the sides of the mullion, as *d e*. Any other mouldings upon their sides or faces may be drawn in like manner. Put in the cusping as shown, and the tracery is complete. The practical stone-mason will take care never to make a joint where there is an angle of any sort, as the point of a cusp. In all cases the joints must tend to the centres of the circles from which they are struck, and where the lines branch off in two directions, the joints must not be in one line, but must tend in two, or as many directions as there are branches, and each to the centre of such respective branch. When the lines are perpendicular, as at *c* and *d*, and at the joint below *h*, the joints are horizontal. A close inspection of fig. 27, where they are carefully drawn, will fully elucidate the matter. The elaborate west window at York Cathedral (see Plate XVIII. of vol ii.) is entirely set out on this principle; and so is the still more remarkable instance, the eastern window at Carlisle, which is composed of 86 pieces of stone, and the design for which is drawn from 263 centres.

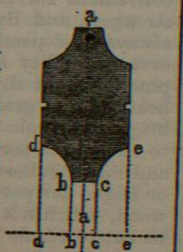


FIG. 28.—Mullion.

All the upper construction of windows and doors, and of aisle arches, should be protected from superincumbent pressure by strong relieving arches above the labels, as shown by the dark tints in fig. 27, which should be worked in with the ordinary masonry of the walls, and so set that the weight above should not press on the fair work, in which case the joints of the tracery, &c., will sometimes flush or break out.

In mediæval vaults the crowns *a b*, *c d*, are not level, but all have a slight curve or spring, as shown in fig. 29, and the filling-in between them also is slightly curved, so as to partake in some degree of the character of the dome as well as of the groined arch; and for the most part the ribs in early vaulting are not true segments of ellipses, but approximations drawn by the compasses. The triumph of mediæval stone-masonry, however, is that species of groin known as fan-vaulting. It is unlike that of any other age or time. The roofs of King's College Chapel at Cambridge and of Henry VII.'s Chapel at Westminster are eminent and late examples. The earliest are supposed to be in the cloisters of Gloucester Cathedral. It is impossible in our limited space to give demonstrations of them, and we must refer our readers to the admirable treatise on the subject by Professor Willis, published in the first volume of the *Transactions* of the Royal Institute of British Architects. The filling-in between the ribs of mediæval groins is generally of clunch, or of some soft stone, over which a layer of concrete is sometimes placed in such manner as to bind all together and to resist the thrust.

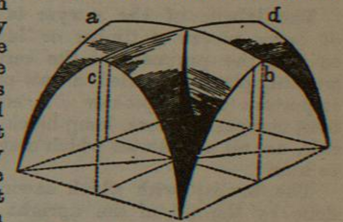


FIG. 29.—Mediæval Vaulting.

The bold and beautiful termination to mediæval towers, which we call a spire, and the French call *flèche*, is another proof of the skill of the mediæval masons. These are generally octagonal, and rise partly from the wall of the tower and partly from arches thrown angle-wise from wall to wall inside, to cut off the corners, as it were, and afford a springing to the spire. The wonder of these constructions is their extreme lightness and thinness. The top of the spire at Salisbury is 411 feet from the ground, of which the tower takes up 207 feet, leaving, of course, 204 feet for the height of the spire itself; this is only 9 inches thick at the bottom, diminishing to 7 inches, or on an average only about the 300th part of its height. It has been attempted to show mathematically that the joints of a spire would be stronger if formed at right angles to its face; but they would then slope inwards and hold the wet, which in sudden frosts would do most serious injury; practically, therefore, it is found best to lay the courses on a level bed. They should, however, be frequently doweled and cramped together, but not with metal, for the extreme thinness of the stone would soon cause it to rust and break out the stone.

The principal publications on masonry are as follows:—

English.—Moxon, *Mechanick Exercises*, 4to, 1677–93, 1700; Batty Langley, *Ancient Masonry*, fol., 1736; Nicholson, *Practical Builder*, 4to, 1823, &c.; *Practical Treatise on Masonry*, 8vo, 1828;