before 1825, it is only of late years that this scaffold has been much used. A couple of planks are secured side by side to form a platform, which is guarded by a railing all round to prevent the workmen falling off. To iron bands are secured pulleys and ropes, passing over other pulleys made fast to two or more beams projecting out of the upper windows, or secured to the roof-timbers, by means of which the workmen employed can raise or lower the scaffold to any position where it is wanted to get access to the work to be done.

Brickmaking.—The manufacture of bricks forms the subject of a separate article. See p. 279 of the present volume.

Mortars and Cements.—A few observations on the composition of mortars and cements for bricklaying will be necessary here. Mortar is of two kinds,—common mortar, or that mixture of lime and sand ordinarily used in building; and hydraulic mortar, or that which will set under water. Cement is a name given to the produce of certain argillaceous stones, after calcination, which will set rapidly in the air, becoming a hard adhesive substance in a short time, and will also set under water, both without admixture of any other substance. The name is given, too, to certain artificial imitations of these substances, possessing the same properties; and besides, to various bituminous or oleaginous compositions, used in building for similar purposes.

Lime.

Pure lime, which is an oxide of a metal called calcium, does not exist in a natural state. It is, however, found abundantly in the conditions of carbonates and subcarbonates, in chalk, and in the various other descriptions of limestones. Its chemical qualities and analysis will be described under the proper headings in this work. Limes are generally classed, since the publication of the work of Vicat, as—(1) rich limes, (2) poor limes, (3) limes slightly hydraulic, (4) hydraulic limes, and (5) eminently hydraulic limes. In treating of mortar we have to deal with the first two of this division. The first operation is to drive off the water, which all limestones contain in a greater or less degree, and the carbonic acid gas, which is done by calcining or burning in a kiln at red heat; this must be kept up for several hours, care being taken to avoid any approach to vitrification. By this process it is slightly diminished in bulk, loses nearly half its weight, and becomes caustic lime. The lime is next converted into a hydrate by a process called "slaking," or throwing pure water over it from time to time till it hisses and cracks with considerable force and some noise, gives off a large quantity of hot vapour, and falls into a powder. The rich limes, which are the purest oxides of calcium, increase to double their bulk in the process. The poor limes swell to a much less degree. The hydrates thus formed absorb water, and easily take the form of a paste. They contain rather less than one-third water to two-thirds lime. In this state, if treated with pure water, frequently renewed, every particle of the rich limes, and very nearly the whole of the poor limes, will be taken up in solution. In the process of slaking too much water should not be used, as it "drowns" the lime, according to the expression of the workmen. When in the form of paste it begins to absorb carbonic acid, which is always present in air in considerable quantities, and gradually to crystallize again, and so to harden. If the air be excluded from the hydrate of pure lime, it may be kept for almost any length of time. Alberti (lib. ii. cap. 11) says that he once discovered some in an old ditch, which from certain indications must have been there 500 years, and was as soft as honey or marrow, and perfectly fit for use.

The rich limestones give a white lime, which easily slakes, and increases in bulk; but it is curious that though the stones differ so much in outward appearance and in texture, the lime, if they be well burned, is the same. The softest chalk and the hardest rag-stone or marble yield an equally good lime, the calcium which they contain being the same mineral. But as chalk generally contains water, irregularly distributed in some places and not in others, and as it does not exhibit the change that marble or stone does, it is frequently unequally burned, and therefore slakes imperfectly. It is said by Higgins (*Mortars and Cements*, p. 29), however, that lime made from chalk absorbs carbonic acid more rapidly than that made from stone; but experience does not seem to warrant this conclusion. Poor limestones are those which contain silica, magnesia, manganese, or metallic oxides. In consequence of this they are more liable to vitrify in burning, and do not slake so freely. The lime is generally of a browner colour than that from rich limestones, which is said to be a proof of the presence of the above-named metallic oxides. If, however, they be ground so as to facilitate the slaking of every particle, and if used immediately being made up, poor limes produce a mortar which becomes harder than that from the rich limes, and which resists water better. In fact, works where the latter have been used have been found to fail entirely by the action of running water, which, as before has been said, will continue to remove the whole of a rich lime particle by particle.

Sands.

It is found that the mixture of some kind of hard matter in particles or granules facilitates the setting of mortar, and renders it harder and more adhesive than when used alone, besides the saving of limestone and expense of burning. The harder this material and the sharper the particles the better, as the brick or stone has always some irregularities on the surface, into which these angles or sharp points may enter, and form what is called a key. The substance most generally used is sand, which is classed as river-sand and pit-sand. The former is usually preferred, as it is more free from earthy matters, particularly soft loams or clay. Mortar made with sand containing one-seventh or one-eighth part of fat clay moulders in winter like marl,—a circumstance which proves the propriety of freeing from clay the sand used in mortar. If pit-sand be used it should be well washed. Scarcely any material is better than crushed quartz, or flint, from the sharpness of the angles of the particles; in fact, it is said that very sharp sand, with an inferior lime, will make a more adhesive mortar than soft sand with the best lime. The practical mixing of mortar will be noticed further on.

Other materials. Burned clay.

Where sand is scarce, other materials are sometimes used, the principal and cheapest of which is burned clay. The Romans used this extensively in the form of pounded tile. At present the custom is to throw up clay mixed with fuel in loose heaps, to burn it slowly, and then to grind it in a mill with a proper quantity of lime. The French writers at one time asserted that burned clay, if not equal to pozzuolana, was very nearly so; and large quantities were used as hydraulic mortars at various public works. Where the water was fresh, as at Strasburg, the work stood very well; but where these mortars were exposed to the action of sea-water, they failed and went to powder in three or four years. Vicat gave great attention to the subject; and though he attributed much of the fault to the imperfect carbonization of the materials, it appears with but little doubt there is some inherent difference between the pozzuolanas and other volcanic products and those produced artificially. After long investigation, Vicat was of opinion that this failure was due to the quantity of hydrochloride of magnesia always present in sea-water; but in what way this affected the burned clay and not the volcanic products he was unable to explain.

A very excellent mortar, much used by engineers in

tunnels, is composed of one part of moderately hydraulic lime, one part of coal ashes, one part of burned clay, and two parts of sharp sand. The vitrified refuse of furnaces, called slag, and the scoriæ from the iron-works, have also been crushed and used instead of sand; and with lime, slightly hydraulic, produce good mortar. The former is preferred to the latter, as having sharper and harder particles, and containing much less iron. Coal cinders have been used, and seem to have some hydraulic properties; they should, however, be employed with caution, for it is considered they make the lime "short." Wood cinders are too alkaline to be used with safety.

The vitrified and calcined products of volcanoes make most excellent materials for mortars, particularly where required to be eminently hydraulic. The principal of them is the pozzuolana, which abounds in Italy. It is called so from being found in great abundance at Pozzuoli, near Naples, and is, in fact, the basis of all the best Roman mortars, ancient as well as modern. It is usually sent to England from Civita Vecchia. It varies in colour from reddish brown to violet red, and is sometimes greyish; it has a roughly granulated appearance, and sometimes resembles a cinder in texture, and has frequently a spongy appearance. Acids have little effect on it, and it is not soluble in water. A similar earth is found in the centre of France. But one long known in this country comes from the village of Brohl, near Andernach, on the Rhine; this is called tarrass or trass. These materials have a wonderful effect in rendering even the rich limes eminently hydraulic, and in less proportions improving the hydraulic limes. Vicat says, these mortars begin to set under water the first day, grow hard in the third, and in twelve months are as hard as the bricks themselves. The mixture of common lime with these materials, according to the French writers, should be 1 of pounded lime to 2½ of pozzuolana, or to 2 of trass; or 1 of lime to 1 of sand and 1 of pozzuolana.

In addition to the hydraulic limes, which have been thus described, there is a peculiar class of stones, which, when burned and pulverized, may be used as mortar, without admixture of sand or any similar substance; and which will not only set rapidly under water, but will acquire an unusual degree of hardness and tenacity. These are called natural cements. Mr Parker is supposed to have been the inventor; at any rate, that gentleman took out a patent about sixty years ago for what he called Roman cement. His materials were the argillo-calcareous nodules, or septaria, found in the Isle of Sheppey, and commonly called bald-pates. They contain about 70 per cent. of carbonate of lime, about 4 per cent. of oxide of iron, 18 per cent. of silica, and 6 or 7 per cent. of alumina. The process is simply to break the stones into small pieces, and burn them in running kilns with coal or coke; they are then ground to a powder, and headed up into casks for use. The success of Parker's cement led to experiments in other places, and the same process was carried on with other argillo-calcareous nodules, as the septaria at Hawick; those in Yorkshire, which produce the cement called Atkinson's; and those in the Isle of Wight, which produce the Medina cement. Similar substances were also discovered, and the same processes carried on in France and in Russia. All these cement-stones effervesce with acids, and lose about one-third of their weight in burning. Parker considered that the more the stones were burned short of absolute vitrification the better; but this is not the practice in the present day, though, no doubt, sound in theory. When taken from the kiln these stones will not slake without being pulverized; and if kept dry, and not exposed to the air, the cement will be good almost any length of time; but it rapidly absorbs both water and carbonic acid if not carefully closed up, and falls back into a state of subcarbonate, from which it is said it may be recovered by fresh burning, but it is doubted whether it is ever so good as on the first calcination. The great utility of these cements, and the expense of obtaining the stone, induced manufacturers to endeavour to discover some method of making an article by artificial means which should resemble the natural cements. Mr Frost seems to have been the first who attempted it on a large scale; but though he was assisted by the science of General Pasley, the results did not come up to the expected standard. Of course, the object was to produce an argillo-calcareous substance containing the same chemical qualities as the natural nodules, which might be burned in kilns as they are. The attempt to combine argil in the form of burned clay, to be mixed with lime instead of pozzuolana, had partially failed, as has been stated above. The experiments conducted by General Pasley, and by Vicat at Meudon in France, were all based on the principle of mixing together, in a mill, with a quantity of water, masses of chalk and clay, just as the brickmakers do for the production of malm bricks, but in the proportion of about four of the former to one of the latter. The fluid mixture is run out into shallow receivers, and when dry is cut into small blocks or lumps, and burned exactly as the natural nodules are. The difficulty was to give the materials the full degree of calcination short of vitrification.

Portland cement.

A successful result seems to have been at last attained by the inventors of the Portland cement, so called from its near resemblance to Portland stone in its colour. It not only possesses the property of setting more quickly, and has greater powers of cohesion than the natural cements, but it may be used with a superabundance of water in the form of grout, which they cannot be; above all, it seems to resist the action of sea-water beyond all others; and it is proof against water when used as a mortar in setting brickwork, and in the composition of concrete for foundations. It also forms a very superior cement for plasterer's work.

Westmacott's patent.

A prepared patent carbonate (Westmacott's patent) is used in combination with chalk, grey, and all other limes. All the carbonic acid being removed from the lime in its burning, 75 per cent. of this acid is restored by its mixture with the prepared patent carbonate, and its induration immediately commences, instead of the lime gaining the carbonic acid by atmospheric influence through a lengthened period. It is used as a quick stucco for rapid plastering; and as a carbonated lime for external use it is in the course of a few days converted into a stone mortar.

Scott's selenitic mortar.

Selenitic mortar is the name given to a composition lately invented by Major-General Scott. He was the first to observe, about eighteen years ago, that a limestone capable of conversion by burning into a hydraulic lime might furnish a good cement by simply allowing a small portion of sulphuric acid gas to pass into the kiln during the burning of the lime. Having found difficulty in carrying out this process, he now mixes with the water used in the preparation of the mortar a small quantity of sulphate of lime (*i.e.*, plaster of Paris, or gypsum) or green vitriol. It has the advantage, when used for plastering, of allowing the setting coat to be applied in forty-eight hours after the first coat has been put on. This mortar is said to save half the lime, is four times as strong, and sets in one quarter of the time required by common mortar. The lime will take six parts of sand, and is said to be an excellent substitute for Portland cement for concrete at less cost.

Asphalt, or mineral pitch (see ASPHALT), has lately come into extensive use for paving, for covering the backs of arches, or rendering the walls of basements where wet is likely to soak through, also as a damp-course over the footings of walls to prevent the rise of damp, and for lining cisterns and tanks to prevent the escape of the fluid. The best qualities are the Val de Travers and the Seyssel, both obtained from France. In using asphalt for paving, a bed of concrete, made of the best hydraulic lime, is first prepared, and made fair at top by a rendering of similar mortar. The asphalt will not dissolve with heat by itself, but will calcine in the caldron. A small quantity of pure mineral pitch is therefore first put in; when this is hot the asphalt is added, and soon dissolves; a quantity of powdered stone-dust is then stirred in, and a small portion of quicklime. The mixture in its melted state is then laid on the bed of concrete (which must be quite dry), and spread close and fair, some sand being sprinkled over the top and well trowelled in. The best proportions are said to be about 2 pints of mineral pitch to 10 ℔ of asphalt and one-fourth bushel of stone-dust. Another method of forming a paving is to place on the concrete a layer about 3 inches in thickness of hot asphalt in powder, and then to ram it down with hot iron rammers, until it has come to its proper consistency; it is then finished as usual. This has been lately much used for roadways in the city of London and elsewhere. The same material has been compressed into tiles about 6 inches square, and these laid on a good foundation. A very inferior imitation is made by mixing a quantity of sharp sand with gas-tar, heated in a caldron, and then adding some quicklime. This may do for rendering walls, &c., to keep out wet, but it is of very little use as paving. Gravel coated with tar, and then laid and set in tar, rammed down, and sanded over, makes a very good pavement for ordinary footpaths.

Mortar making.

As before noticed, particular attention must be paid to cleansing the sand to be used for mortar of every particle of clay or mud that may adhere to or be mixed up with it. Sea-sand is objectionable for two reasons: it cannot be perfectly freed from a saline taint, and the particles are moreover generally rounded by attrition, caused by the action of the sea, which makes it less efficient for mortar than if they retained their natural angular forms. Lime should not be slaked until the moment it is to be mixed up with the sand in mortar, but the sooner that is done after it is burnt the better. The proportion of lime to sand generally taken, and the best, is one to three; but if both the materials be of good quality, that is, if the lime slake freely, and become a fine pungent impalpable powder, perfectly clear from argillaceous or any other foreign matter, and the sand be clean and sharp, one part to four is enough; more is injurious. The ingredients should be well mixed together, and with just as much water as will suffice to make the compound consistent and paste-like. Of late years, in lieu of sand, burned clay, as above noticed, has been much used in localities where it is difficult to obtain the former material. This is ground up with lime in a mill, but unless very great care is taken in its manufacture the result is a very poor substitute for sand and lime mortar; and brick and lime rubbish have also been used in like manner, with an equally inferior result. Rain or other soft water should be used for the purpose of making mortar, and not spring or hard water, though any other may be preferred to what is brackish even in the slightest degree. Higgins recommended that lime-water should be used in preference to pure water. A quick-setting cement, such as those which are commonly used in building in England, and known as Parker's or Roman cement, and Portland cement, can only be mixed or gauged as it is required for use. A bricklayer will keep a labourer fully employed in gauging cement for him alone. It is mixed with sand in the proportion of from about two or three to about five or six of sand, to one of the cement, according to the quality of the latter; and the labourer as he gauges on one board supplies the mixture to the bricklayer fit for use on another board, a spadeful at a time; it must then be applied within half a minute, or it sets and is spoiled and wasted, for it should never be worked up again.

The average size of bricks in England is a fraction under 9 inches long, $4\frac{1}{2}$ inches wide, and $2\frac{1}{2}$ inches thick; and in consequence of this uniformity of size, a wall of this material is described as of so many bricks in thickness, or of the number of inches which result from multiplying 9 inches by any number of bricks; a 9-inch or one-brick wall; a 14-inch or one-brick-and-a-half wall ($13\frac{1}{2}$ inches would be more correct, in fact, for although a joint of mortar must occur in this thickness, yet the fraction under the given size of the brick is enough to form it); an 18-inch or two brick wall, and so on.

The great art in bricklaying is to preserve and maintain a bond, to have every course perfectly horizontal, both longitudinally and transversely, and perfectly plumb (which last, however, may not mean upright, though that is the general acceptation of the term, for the plumb-rule may be made to suit any required inclination, as inward against a bank, for instance, or in a tapering tower); and also to make the vertical joints recur perpendicularly over each other, which is vulgarly and technically called keeping the *perpends*. By bond in brickwork is intended that arrangement which shall make the bricks of every course cover the joints of those in the course below it, and so tend to make the whole mass or combination of bricks act as much together, or as dependently one upon another, as possible. The workmen should be strictly supervised as they proceed with it, for many of the failures which have occurred may be referred to their ignorance or carelessness in this particular. The object of bonding will be understood by reference to the diagram, fig. 1, Plate XX. **Plate XX.** Here, it is evident, from the arrangement of the bricks, that any weight placed on *a* would (supposing, as we are obliged to suppose, that every brick bears equally, throughout its whole length, a stress laid on every part of it) be carried down and borne alike in every course from *b* to *c*; in the same manner the brick *d* is upborne by every brick in the line *e f*, and so throughout the structure. But this forms a longitudinal bond only, which cannot extend its influence beyond the width of the brick; and a wall of one brick and a half or two bricks thick, built in this manner, would, in effect, consist of three or four half-brick-thick walls, acting independently of each other, as shown in the plan at *i* in the diagram under fig. 1. If the bricks were turned so as to show their short sides or ends in front, instead of their long ones, certainly a compact wall of a whole brick in thickness would be produced; but the longitudinal bond would be shortened one-half, as at *g c h*, and a wall of any greater thickness, in the same manner, must be composed of so many independent one-brick walls, as at *k* in the plan before referred to. To obviate this, to produce a transverse, and yet preserve a true longitudinal bond, the bricks are laid in alternate courses of headers and stretchers, or of ends and sides, as shown in fig. 2, thus combining the advantages of the two modes of arrangement *a b c* and *g c h* fig. 1, in *a b c* fig. 2. Each brick in fig. 2 showing its long side in front, or being a stretcher, will have another lying parallel to it, and on the same level, on the other side, to receive the other ends of the bricks showing as headers in front, which in their turn bind, by covering the joint between them, as shown in the end of such a wall at *d*. Thus a well-bonded 9-inch or one-brick wall is produced. The end elevations of the same wall at *e* and *f* show how the process of bonding is pursued in walls of one and a half and two bricks thick, the stretcher being abutted in the same course by a header,—thus, in a 14-inch wall, inverting the appearance on the opposite sides, as seen at *e*, and producing the same appearance in an 18-inch wall, as at *f*. In the diagram

under fig. 2, at *g*, is the plan of a 14-inch wall, showing the headers on one side, and the stretchers on the other, and at *h* is the plan of the course immediately above it, in which the headers and stretchers are inverted; at *k* and *i* are shown in the same manner the plans of two courses of an 18-inch wall. This is called English bond. Thicker walls are constructed in the same manner by the extension of the same principle.

But a brick being exactly half its length in breadth, it is impossible, commencing from a vertical end or quoin, to make a bond with whole bricks, as the joints must of necessity fall one over the other. This difficulty is obviated by cutting a brick longitudinally into two equal parts, which are called half headers. One of these is placed next to a whole header, inward from the angle, and forms with it a three-quarter length between the stretchers above and below, thus making a regular overlap, which may then be preserved throughout; half headers so applied are technically termed closers, and are shown next the upright angle of the wall fig. 2, and the first joints inwards from the square ends by the headers in the plans at *g* and *h*. A three-quarter stretcher is obviously as available for this purpose as a half header, but the latter is preferred, because, by the use of it, uniformity of appearance is preserved, and whole bricks are retained on the returns. In walls of almost all thicknesses above 9 inches, to preserve the transverse, and yet not destroy the longitudinal bond, it is frequently necessary to use half bricks; but it becomes a question whether more is not lost in the general firmness and consistence of the wall by that necessity, than is gained in the uniformity of the bond. It may certainly be taken as a general rule, that a brick should never be cut if it can be worked in whole, for a new joint is thereby created in a construction, the difficulty of which consists in obviating the debility arising from the constant recurrence of joints. Great attention should be paid to this, especially in the quoins of buildings, in which half bricks most frequently occur; and there it is not only of consequence to have the greatest degree of consistence, but the quarter bricks used as closers are already admitted, and the weakness consequent on their admission would only be increased by the use of other bats, or fragments of bricks.

Flemish bond.

Another mode of bonding brickwork, which may be supposed to have arisen from the appearance of the ends of a wall according to the former mode of arrangement (see *e* and *f*, fig. 2), instead of placing the bricks in alternate courses of headers and stretchers, places headers and stretchers alternately in the same course, fig. 3. The plans below this at *c* and *d* are of two courses of a 14-inch wall, with their bond, showing in what manner the joints are broken in the wall horizontally as well as vertically on its face. This is called Flemish bond. Closers are also necessary to this variety of bond; half bricks also will occur in both, but what has been said with reference to the use of them in the former applies even with more force to the latter, for they are more frequent in Flemish than in English, and its transverse tie is thereby rendered less strong. Their occurrence is a disadvantage which every care should be taken to obviate. The arrangements of the joints, however, in Flemish bond, presenting a neater appearance than that of English bond, it is generally preferred for external walls when their outer faces are not to be covered with some composition; but English bond should have the preference when the greatest degree of strength and compactness is considered of the highest importance, because it affords, as we have already noticed, a better transverse tie than the other.

Mr W. Hosking was the first to notice (in the last edition of this work) that what is in England called Flemish bond is unknown in Flanders, and is practised in the British Isles alone. In Flanders, Holland, and Rhenish Germany, which are bricklaying countries, no kind of bond is found but what is known in England as English bond. But it has lately been noticed that the mediæval brick buildings in the north-east of Germany are worked in Flemish bond, or as it is there called "cross-bond;" and it is also to be seen at Brussels in work of about the end of the 18th century. Many of the buildings designed by Inigo Jones in England, and perhaps all of those by Sir C. Wren, are executed in Flemish bond, which name, it has been suggested, might have been derived from the word "flemishing" used by workmen, and thus applied to brickwork as meaning work better "finished off" than the other kind.

It has been attempted to improve the bond in thick walls by laying raking courses in the core between external stretching courses, and reversing the rake when the course recurs. This obviates whatever necessity may exist of using half bricks in the heading courses, but it leaves triangular interstices to be filled up with bats, as is shown in Plate XX. fig. 4. This represents the plan of 36-inch or three-brick wall with raking courses at *a*, between external ranges of stretchers, and lying on a complete course of headers, and at *b* a wall of the same thickness herring-boned; courses of headers would bed and cover this also, and, in the second course above, the raking or herring-boning would be repeated, but the direction of the bricks reversed. It will be seen that the latter demands, in addition to the triangular filling in bats at the outer ends of the diagonally placed bricks, half bricks to fill up the central line of interstices, rendering herring-boning more objectionable in that particular, though it has some advantages over simply raking, or thorough diagonal courses in other points. Neither mode should, however, be had recourse to for walls of a less thickness than three bricks, and that indeed is almost too thin to admit of any great advantage from it.

Walls to be vertical and level.

Not second in importance to bonding is, that the brickwork be perfectly plumb, or vertical, and that every course be perfectly horizontal, or level, both longitudinally and transversely. The lowest course in the footings of a brick wall should be laid with the strictest attention to this latter particular; for the bricks being of equal thickness throughout, the slightest irregularity or incorrectness in that will be carried into the superimposing courses, and can only be rectified by using a greater or less quantity of mortar in one part or another, so that the wall will of course yield unequally to the superincumbent weight, as the work goes on, and perpetuate the infirmity. To save the trouble of keeping the plumb-rule and level constantly in his hands, and yet to insure correct work, the bricklayer, on clearing the footings of a wall, builds up six or eight courses at the external angles (Plate XX. fig. 5), which he carefully plumbs and levels across, and from one to the other. These form a gauge for the intervening parts of the courses, a line being tightly strained from one end to the other, resting on the upper and outer angles of the gauge bricks of the next course to be laid, as at *a* and *b*, and with this he makes his work range. If, however, the length be great, the line will of course sag; and it must therefore be carefully set and propped at sufficient intervals. Having carried up three or four courses to a level, with the guidance of the line, the work should be proved with the level and plumb-rule, and particularly with the latter at the quoins and reveals, as well as on the face. A smart tap with the end of the handle of the trowel will generally suffice to make a brick yield what little it may be out, while the work is so green, and not injure it. Good workmen, however, take a pride in showing how correctly their work will plumb without tapping. In work which is circular on the plan, both the level and the plumb-rule must be used, together with