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THE STONEMASON

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Practical Details and Drawings Illustrating the Various Departments
of the Industrial Arts of

MASONRY AND BRICKLAYING

WITH

NOTES ON THE MATERIALS USED: STONES, BRICKS, TILES, LIMES, MORTARS, CEMENTS AND CONCRETES

BY

VARIOUS PRACTICAL WRITERS

EDITED BY

THE EDITOR OF "THE INDUSTRIAL SELF-INSTRUCTOR"

WITH 11 FOLDING PLATES AND 224 ILLUSTRATIONS IN THE TEXT

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ERRATA.

Page 27, line 17, *for* fig. 27 *read* fig. 26.
„ 31, lines 11 and 21, *for* Plate III. *read* Plate I.
„ 219, lines 18, 22, 32, and 35, *for* Plate II. *read* Plate IV.
„ 251, line 5, *for* Plate III. *read* Plate II.
„ 251, line 8, *for* fig. 7 *read* fig. 6.
„ 251, lines 9, 15, 18, and 22, *for* Plate IV. *read* Plate III.

PREFACE.

LIKE the companion volumes in the present series of works, designed for Home Study or Self-Instruction in the various departments of Industrial Work, the matter forming the major portion of the present volume appeared originally in the well-known serial entitled "The Industrial Self-Instructor," under the two heads of "The Stonemason" and "The Bricklayer." The leading departments of the two constructive arts were fully described and largely illustrated by a wide and extended range of diagrams in the text, supplemented with a series of full-page plates; but while of necessity many of the textual illustrations were only diagramatic in character, these amply meeting the requirements of description of various points and principles of work—the illustrations for the most part were working drawings—reduced and arranged from drawings and designs used in actual construction. These gave, therefore, an amount of practical information calculated to be of great value to the student. These have nearly all been reproduced in the present volume.

In the original work the shortness of the space at the command of the Editor compelled him to leave out those departments of the subjects which concern themselves with the *materials* used in actual construction. But this point has been looked to in the preparation of the present volume; and a series of paragraphs form its last section, which take up and discuss, in the same thoroughly practical way which distinguishes the other section, the leading points connected with building-stones, limes, mortars, cements and concretes. In addition to these paragraphs another series is devoted to the practical points connected with the important subject of Foundations in the various classes of building soils or sites; and, to make the volume in every way complete, illustrations are given of the most important appliances used by the builder in the erection of his work—such as cranes, steam-cranes, and the like. At one time it was contemplated to give a separate volume to each of the two subjects—one being devoted to the work of the Stonemason, the other to that of the Bricklayer. But, amongst the many advantages flowing from the embodiment of the two arts of Building Construction in one and the same volume, the consideration of which led to this arrangement being the one finally adopted, was this other: namely, That not a few of the departments of work in masonry and in bricklaying are so closely connected with—overlap, so to say—each other, that they may be said so to belong to both subjects, that a practical advantage is clearly to be gained by having them discussed under one cover, so that ready reference can be made from one to the other, and such comparative observations made as are likely to carry with them points of practical value. This arrangement, then, which has been adopted, will meet, we doubt not, with the approval of the home student, as will also the profusion of drawings, both diagramatic and working in character, which is given in order to make both sections thoroughly practical and suggestive. Advanced as those claims to the favourable notice of the home student are, the Editor ventures to hope that the nature of the information met with in the following pages will fully justify their being now made.

THE EDITOR.

March 1891.

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STONE MASON AS A TECHNICAL WORKER.

Introductory.

Of the early history of the art of Masonry nothing positive is known. There is but little to be met with on which what might be called reasonable conjecture can be based as to what constituted the earlier works of the mason. When we come to the period in the history of man's civilization in which regular structures of stone begin to appear, we find the details very much mixed up with the progress of the sister, or, as we should perhaps call it, the mother, art of Architecture.

In tracing the details of the work of the mason as a handicraftsman, we may succeed in tracing the steps by which what may be called the rough and ready-to-hand methods were, by careful observation of the effects of different methods at command, gradually brought to that position in which perfection has been attained in the art of working stones and its practice has become based on fixed and accepted principles. Those principles have thus raised it to the dignity of a science; so that from the art or handicraft skill in working stones and placing them in position in the structures in which they are used, we shall arrive at that point at which we have a science of masonry, properly so called.

Leading Divisions of the Subject.

It is our purpose to give to our readers a series of diagrams, drawings, and descriptions illustrative of masonry considered as both an art and a science. This naturally divides our subject into two parts. The first of them will take up the various kinds or classes of walls in the formation of which as a rule, with few exceptions, the work known as the mason's is employed; the kind of stones, or more properly the physical form, shape, or configuration in which the stones are used, and the methods by which these stones are built up into the wide variety of structures known as buildings in stone, or masonry. The second part concerns itself chiefly with what may be called the science of masonry, in which theory gives its aid to practice in affording rules and methods by which the various forms of stones required in the more complicated stone structures, such as arches, niches, vaults, etc., can be obtained with rigid accuracy. The forms or configurations of the stones composing these are more or less complicated or varied, but all require to be shaped and cut according to the positions they are to occupy in the structures for which they are designed. And this shape or form is dependent upon the employment of certain methods of what is called "projection," by which graphic representations are obtained to scale of the form required. In these methods the science of geometry plays an important part, and the labours of the draughtsman are necessitated for this department of the work of masonry. Proceeding under this briefly expressed plan of arrangement of subjects, we take up first what may be called the handicraft part of masonry, inasmuch as its work chiefly depends upon the skill of those who have been brought or bred up to the mechanical working of stone.

Definition of the Term Masonry—The Distinction between it and Bricklaying.

Masonry has been defined—to follow the principle laid down by an eminent authority—as a bulk or mass of stone, either cut to regular shapes or forms, or taken as they are brought from the quarry or dug up from, or found on the surface of, the soil, of irregular shapes and sizes; those being either bonded, held together or connected by mortar or cement, or simply by resting on each other, or interlocking, so to say, more or less completely with each other, no mortar or cement being employed.

According to this authority, brick is a material which comes properly within the domain of masonry. In this country, however, the trade or business of bricklaying is distinct from that of the stone mason, each being, as a rule, carried on quite independently of the other. But the method of placing or superimposing bricks upon one another to form a wall or structure demanding a peculiar method of working, known technically as "bonding" (which term, so far as masonry is concerned, will be presently explained), and the employment of different, though less complicated appliances and apparatus —takes, as we think, the art of bricklaying within a category at least somewhat different from that of masonry. So that we deem it advisable to divide the two, giving a special paper or papers devoted to the bricklayer's work, just as we devote the series of chapters of which the present is one to the art and science of masonry.

Other Materials used in Wall Construction.

There are, however, methods of constructing walls which may be considered the typical forms of artificial structure, other than with stone or with brick. The materials employed in these other systems are first soil or clay worked up under the system of "*pisé*"; second, "concrete," which may be called a species of artificial stone. Of those two materials and methods, *pisé*—using soil or clay—is still occasionally employed, and is useful in colonies and remote districts where skilled labour to work up stones or make bricks and to build them is either very dear or cannot be had. Of the second, or concrete system, it may be said that from its use presenting so many advantages, it is being largely and still more successfully employed. There should be no reason why the carrying out of these two methods should be made to lie within the province of the mason any more than that they should be taken up by the bricklayer. In point of fact, both trades are quite competent to carry out both methods, and often in point of fact do so; although concrete building has lately received such an impetus that it has almost become a special trade or calling. But as both systems must receive some notice at our hands, we shall give what space can be spared to their description within the range of the present series of papers, this forming an integral part of it.

The Typical Form of Masonry the Wall—Its General Features.

All stone structures—and the same holds equally true of brick—or as they are popularly designated, "buildings," are spaces of ground enclosed by walls of greater or less length, height, and thickness—those three dimensions, which go to make up the solid wall, varying according to circumstances. There are a few exceptions to this rule, such as in the vast masses of great breadth and length employed in the construction of harbour, and in some classes of railway work, in the formation of floors of tanks, and the like; but these are nearly all but apparent exceptions, and might be safely classed as walls only of unusual dimensions or bulk or built upon unusual positions or sites. For the same method of construction is adopted; and even in the last-named exception, a floor may be in one sense said to be a wall, only posed or placed horizontally. All walls do not, however, enclose spaces. They often skirt or bound the side or end only of a space of ground, and are termed bounding or boundary walls; while others are built up against the face of a bank of earth, and are called retaining walls. The various forms they assume will be explained hereafter. Meanwhile we proceed to describe the methods by which they are built up, and the various forms which the materials employed assume. In one sense walls might be considered at first as divisible into two parts—first, the conditions or forms in which the stones forming them are met with in practice; and second, the way in which they are superimposed one upon another, held and tied together. This method will, in point of fact, be here and there adopted; but it so happens that the two are so intermixed with each other that it is difficult to separate the consideration of the stones themselves, and that of the way in which they are built up to form a wall. This, however, is observable in the early stages of the question, or in the simple forms of walls. We shall reach a point shortly in which we get the dual position of the two more distinctly marked, when we shall take up each separately.

The Simplest Forms of Walls.

Following the features of what may be called the natural system of building, by which the art of masonry arose, we take the simplest of all the methods of forming walls. In the earliest times the first walls, or attempts at erections like walls, would probably be made by taking such stones as could be found most ready to hand. Those would be found lying in the field, cropping up on its surface; or would be dug more or less easily from its soil; or they might be found in larger or smaller heaps and collections in the beds or channels of torrents and rivers. Such stones are generally more or less rounded, as at *a*, *b*, *c*, and *d*, in fig. 1, and this from the action of flowing or running water. This is the case even in the stones found on field surfaces or dug up from their soils. For it is to be remembered that those soils are for the most part deposits, laid by the action of water, or subsiding from them. Frequently also, when the rocks to which they belong are different from the soil in which they are found, having been brought from a distance by icebergs or glaciers, they have, when the ice has melted, been deposited *in situ*. To form walls of those stones with rounded surfaces would to the early builder be a matter of some difficulty, from their tendency to roll upon one another. This difficulty, which in course of time would with us be designated technically as their giving bad "bedding" stones—that is, stones which would not lie readily at rest when placed upon each other or in a heap—would be easiest got over by mixing up the stones with clay or soil somewhat in the fashion shown in fig. 2.

This method closely resembles what is known as "Kentish ragstone work," only that the stones used are not rounded, at least not large, as in fig. 2; but are selected more on account of their comparative thinness and flatness; the former about the thickness of a brick, and somewhat of the shape as at *f*, or possibly at *g*, in fig. 1.

When walls are constructed of the kind of stones such as *a*, *b*, *c*, *d*, in fig. 1, and connected together not with clay, but with strong sound mortar, poured in thinnish condition between them, a good strong,

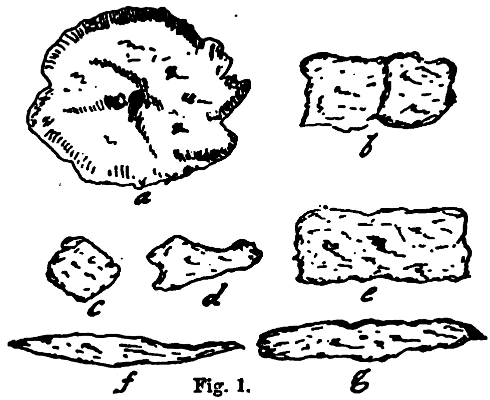


Fig. 1.

lasting, and economically constructed wall can be obtained. In many districts excellent specimens of this method of building exist, which may be classed as the simplest, as it was probably the earliest adopted.

Fig. 2.

Rubble Stones and Rubble Walls—Random Rubble.

When stones are not obtained of the kind or class described in the two last paragraphs, but are got in what may be called the natural condition in which they are quarried, the walls formed of them are called "rubble." Rubble stones are of various forms and sizes: from the "splinters," such as at *f* in fig. 1, obtained from the dressing and squaring of the large blocks used in the higher class of work known as "ashlar," presently to be described, up to blocks of stone of more regular forms, as at *a*, *b*, *e*, and *g* in fig. 1. Splinters, however, or as they are often termed "shivers," are generally used for filling in the central parts of walls, on which practice we shall have yet more to give. Walls formed of "rubble" work are of two kinds. First, what is called "random rubble," which is simply putting the stones in place to form the desired thickness, and in such a way as to keep them perfectly vertical. These points are secured without any attempt to lay the stones in even or horizontal courses parallel to each other more or less; the result being very similar to that shown in the upper sketch in fig. 3; supposing the stones to be larger and not so round as those shown, somewhat like the arrangement shown in

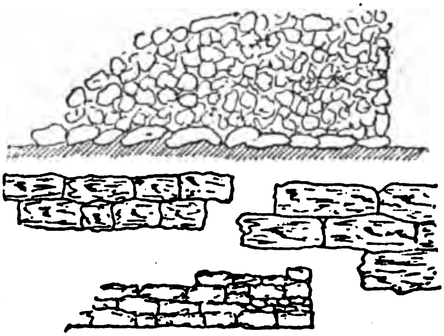


Fig. 3.

fig. 4 at *a a*. Rough as walls of this kind would be at first, when quarrying would be done in the roughest of ways and with the simplest of tools, in process of time, as the quarrymen succeeded in breaking up the rock into larger masses, those of the largest size would naturally be placed at the bottom of all, as at *b b* in fig. 4, so as to form a kind of bearing surface on the ground. This would

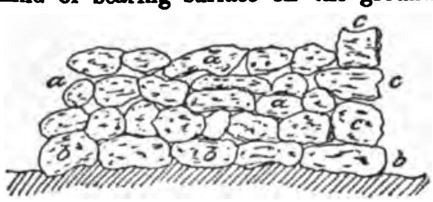


Fig. 4.

especially be done in cases where the soil was softish and liable to yield to the pressure of the weight of wall above it.

Broad Bearing Surfaces in Building Stones.

For the value of a broad bearing surface of stone would be quickly learned. The same might be done at the sides at *c c*, in fig. 4, or as shown in larger scale at the lower sketch in fig. 3. The sketch in fig. 9, p. 8, may be taken as illustrative of an early style of building a wall, in cases where an abundance of small-sized stones could be had, with only comparatively few large-sized ones. These latter would be taken to enclose the small-sized ones—those too small to be placed upon each other or to bed upon one another. And if the whole were cemented together with good mortar, a very strong wall would be obtained. This would be an advance upon the method shown in fig. 2, where the mortar, clay, or binding material was largely used. This mode of construction was, indeed, frequently adopted, and such examples of it as have come down to our own time show how very lasting are structures built in this way. The knowledge of the value of bearing surfaces would soon lead to the choice of such stones as turned up in the quarry operations possessing flat sides, if not flat ends. Those would, for superior work, be preferred, not only on this account, but also as looking better or at least more uniform when the wall was completed.

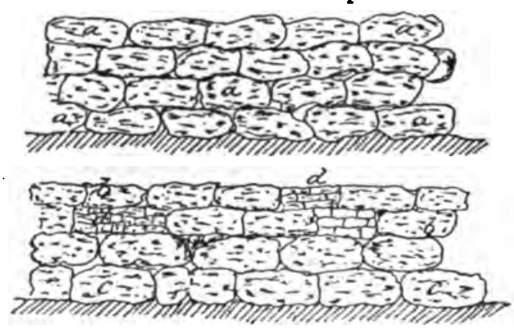


Fig. 5.

Rubble Walls—"Coursed Rubble."

This would lead to the use of an advanced style of masonry work in wall construction. This is now known technically as "coursed rubble," and is constructed with stones which receive a partial dressing in or at the quarry, so as to give them faces more or less square, or with those selected with some care, of as uniform a size and shape as possible. The first elements of this coursed rubble work are shown in the central sketches in fig. 3; a partial combination of rough or random rubble being shown at the corner of the lower sketch of this central group in fig. 3.

Fig. 5 illustrates coursed rubble work in a wall in which the stones are of pretty equal thickness (as at *a a*) and length, so that a degree of external uniformity is obtained. This would not be always so, as stones of this character could not be always obtained in the great numbers frequently required. In this case the thinner stones, as at *b b* in the lower sketch, would be used in the upper part of the

Fig. 6.

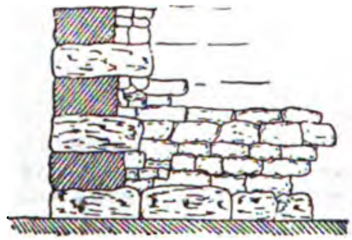


Fig. 7.

wall, superimposed upon the thicker and heavier, as *c c*, the best place for which would obviously be nearer the ground. Very thin

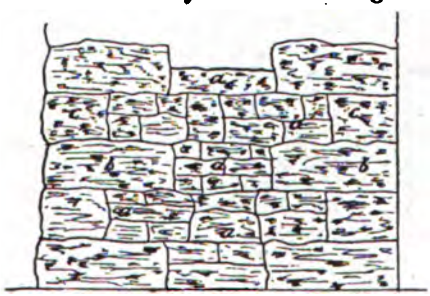


Fig. 8.

stones would be best used at places in the wall in the manner indicated at *d d*. Fig. 6 illustrates part of a wall in cross section—in

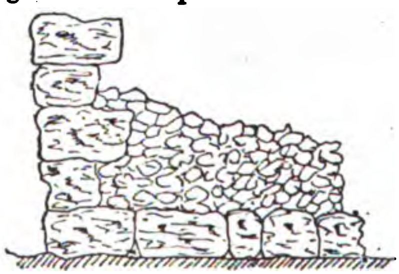


Fig. 9.

coursed rubble work in which the system of using stones of various sizes is adopted; the thin and smaller-sized stones being of course placed in the interior of the wall, but still laid together in as uniform a manner as possible. Fig. 7 illustrates also in cross section, giving the thickness of the walls, the combination of thick and thin, and also long and short stones; the inner thin stones, placed also on the coursed rubble system, being disposed or put in place as evenly as possible. In fig. 8 another combination is shown, the outer foundation stones or lower courses being of uniform length and thickness; the outer face stones in the courses above being alternately long and short, as at *b* and *c* (shown also in fig. 7), while the inner and thin stones at *a* are made up in courses also. In fig. 9, small stones (as at *c c*) on the random or rough rubble system are used to fill in the central part of the wall, being thrown in at random and held or cemented together by thin mortar, termed "grouting," poured in amongst them. In this section of wall, also, long and short stones are used after the first or foundation course. As to the effect of this

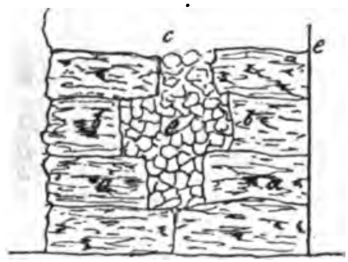


Fig. 10.

combination we shall have presently more to say, when we describe the method of obtaining greater strength in walls by the system known as "bond" or "bonding."

Ashlar Work.

Meanwhile we proceed to describe the next method of preparing and disposing stones, which is known as "ashlar." We have said that in coursed rubble work the stones are chosen as uniform in size and thickness as possible, just as they are quarried—that is, without being subjected to tool working. Although this is the rule, the stones for coursed rubble work are often partially dressed or tooled, so as to give faces as uniform as possible, as at *a a* in fig. 10. When the front face is tooled or dressed, so as to give a straight or even surface, and the top or bottom—that is the bedding surfaces—are left rough as they come from the quarry, the work when finished gives to the outer or exposed surface of the wall a smooth face. Coursed rubble work of this kind is called technically "snecked," and when the stones selected are pretty uniform in dimensions, affords the nearest approach to "ashlar" work, in which all the faces are at right angles to each other.

Ashlar-built Walling—Dimensions and Proportion of Stones.

In this all the stones are blocks of considerable dimensions; the least thickness or depth—reckoned vertically as the stone lies in bed or in the course—being twelve inches. The stones for the best class of work should be carefully proportioned, the length, depth, and breadth having what is called a harmonious relation to each other, and the breadth, as *a b*, fig. 11, or length from front face *e a* to back

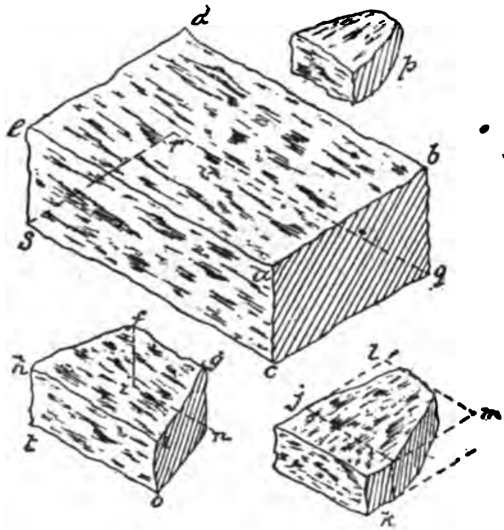


Fig. 11.

face *b d*, never less than the depth or thickness of the block, as *a c*. If the length, as *a e* or *b d*, fig. 11, be from twice to thrice the depth or thickness of the block, as *e s* or *a c*, or two and a half times, and the width or breadth, as *e d* or *a b*, twice or double the depth or thickness, *e s* or *a c*, the block may be looked upon as well proportioned, or having its surfaces in harmonious relation to each other.

False Ashlar—Defective Forms of Stones.

It is very defective ashlar work, and always gives unsound or unstable results proportionate to the extent to which the bad system is carried out, to have the block cut so that the length of the back face, as *f g*, fig. 11, is less than that of the front face, as *h i*. This work is but a shade removed from that utterly bad system of cutting an ashlar block when there is a certain depth of the block cut square in all directions, giving only in reality a narrow rectangle or parallelogram of the proper dimensions, as shown by the dotted line *j k*, in place of the full and proper rectangle of upper face shown by the dotted lines *j, k, l, m*. This is false ashlar, and is in reality a block of rough or random rubble with merely a false face, as at *j k*; and is well entitled or classed as veneered or "sham" ashlar. Blocks so cut will give still worse work in the wall in which they are used if in place of having the depth at back, as *g n*, the same as the depth at front, *i o*, it is less, as at *p*. With stones cut as shown, *h i o n g*, and rounded at bottom, as at *p*, no properly *bedded* and *bonded* work can be obtained; and, as we shall see presently, upon good bedding and bonding all sound or stable ashlar work depends.

Technical Terms or Names of Parts of Ashlar Blocks or Stones.

The faces of an ashlar block have different technical names. Thus the term "bed" is applied to both the upper and lower surfaces, supposing the block to lie in the same position as when in its proper place in the wall of which it is to form a part. But the lower surface—that is, on which the block rests on the stone or course immediately below it—as the surface shown by the partly full and partly dotted lines *s, c, g, r*, in fig. 11, is called the "bottom bed"; the upper surface, as *a b d e*, being the "top bed," on which the next block of course immediately above rests. The vertical surface which is exposed in the wall, or forms the front or visible surface, as *a e s c*, is called the "face" of the block; the part shown in full and dotted lines, as *f g n i*, the "back."

Polished or Rubbed Ashlar Blocks or Stones.

All the faces of true ashlar blocks are tooled and dressed to form a cubical block, with all its faces at right angles. And to further ensure good bedding and a good joint in mortar, the faces are all "rubbed" so as to give perfectly smooth surfaces. This rubbing is done generally by means of a piece of the same stone, the rubbing down being aided by the use of water; although dry stone rubbing may be resorted to, especially to finish off the surface when dry after wet rubbing. In large blocks two stones may be placed face to face upon each other, and the upper block dragged to and fro over the surface of the lower one, water being used to facilitate the rubbing. Ashlar blocks so finished are termed "polished," sometimes "rubbed" ashlar work.

Tooled or Dressed Ashlar Blocks or Stones—Different Methods in Use: Straight-lined or Plain Tooling—Rusticated Work.

In place of having the "faces" or exposed surfaces of ashlar blocks smooth by being polished or rubbed, they are frequently "tooled"

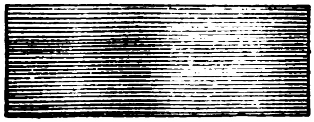


Fig. 12.

or "dressed" in one of a variety of ways. Those are very numerous, and go by a great many technical names; many of which, although indicating the same class of work, are known by names prevalent

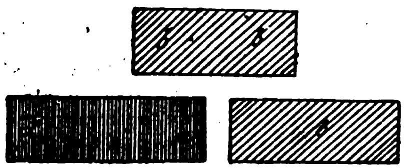


Fig. 13.

only in one district or part of the country, and not used in other districts or parts. The surface may be tooled with a sharp-pointed chisel so as to present a series of lines extending all over it. These

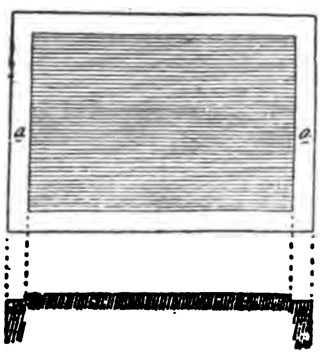


Fig. 14.

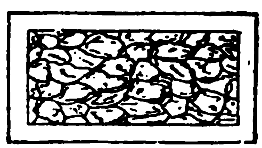


Fig. 15.

may run horizontally along the length of the block, as in fig. 12, or vertically across the breadth, as at *a a*, fig. 13, or diagonally, as at *b b* and *b*, same figure. In place of having the rowing or lining to extend over the whole surface of the "face," a margin is sometimes left all round the lined part, as at *a a*, fig. 14, in front view of face, and in sectional view at foot of sketch. The surface of this margin may itself be lined, but in a different way; or, as is generally the case, left smooth. But it is generally rowed or lined where the surface is purposely left rough, as shown in fig. 15, which illustrates in front or face view what is called "rusticated work." In this the greater part of the face is tooled so as to present a series of projections or knobs of varied outline and size, the general effect desired to be attained being regulated by the size of the block and the position it occupies in wall or structure. There are different modifications of rusticated or rough-faced wall, known as "rough-faced," "frosted," and "sparrow-pecked" work, etc., etc.

Other Methods of Finishing the Faces of Ashlar Blocks or Stones.

In place of having the face of the stone flat, it is often finished with a rising part sloping off, as at A in fig. 16. All the sides of the projecting part slope inwards, of course; they may meet at a point, as in A and B, B being the end view, A the side view of block, and as at the right-hand side of the diagram C, to the right of the dotted centre line, this being a plan or top view of the face. Or they may meet in a point only at the sides, the end sloping part stopping short at some distance from the centre line, shown dotted. In this figure the diagram D is a side sectional view, showing at the left-hand side of the centre line how the end sloping surface stops short of the centre point of the block face. The appearance thus presented of the surface of a wall built with blocks tooled and dressed in this fashion, is very much like that of a series of roof-sloping surfaces in miniature. The sloping surfaces do not start from the extreme edges of the face of block, but a margin is left all round, as shown in C, the surface of which may be called the true face of the block, the sloping part being as it were only an addition or projection, supposed by those who use it to be ornamental.

Forms of External Joints in Ashlar Stone Walling.

In ordinary "polished," "rubbed," or "tool rowed or lined" ashlar work, the joints formed by the superimposing of one course above another, show only straight lines, as at top and bottom of stone *a a* in fig. 13; the fineness, or rather closeness, of the joints depending upon the style of the workmanship of the mason in laying the blocks. In the best work the joints show very close, the layer of mortar between the beds being very thin. Mortar of the best quality is, of course, in this class of work only used. In some cases, while the actual joints, that is the bedding surfaces, are in good work very close, the apparent joint, as viewed in looking at the general surface of the wall, is very open or wide. On looking closely at an example of this the reader will perceive that in some examples of open joint work the sides of each joint slope inwards at such an angle that they meet at a point in line. This line is placed centrally between

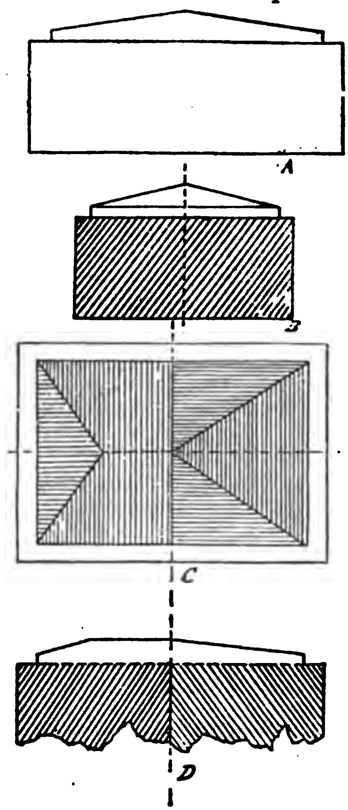


Fig. 16.

the upper and lower line of the joint; and the effect is produced by cutting the edges of the "face" of block all round at an angle, as shown in diagram E, fig. 17; so that when two stones so treated are placed "on bed" they form in section two angles, as shown in the sketch at the right hand of diagram E; that to the left being a front view. When four stones, as *a*, *b*, *c*, *d*, in diagram G, are placed together, the meeting of their angular edges gives the appearance as in sketch. Open joints, where the appearance they give looks like a series of grooves or channels, as in front view in sketch F, fig. 17, with rectangular sides and flat bottom, are produced by cutting a rebate or marginal part all round, as shown in the sectional sketch in

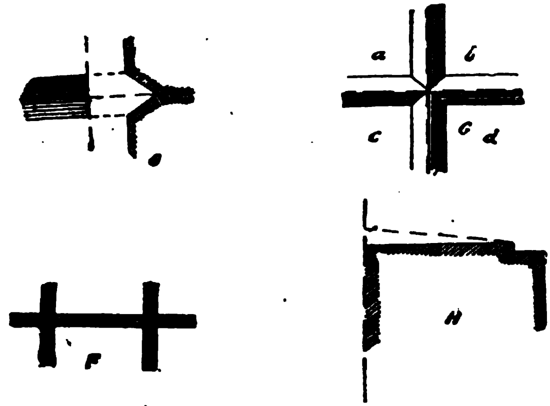


Fig. 17.

H. Figs. 18 and 19 illustrate courses of parts of walls in polished or rubbed ashlar work, with open joints above described; fig. 18 illustrating the form of joint obtained by cutting the edges of face of block in the manner illustrated at sketches E and G in fig. 17; fig. 19 the form of the marginal cutting as in H.

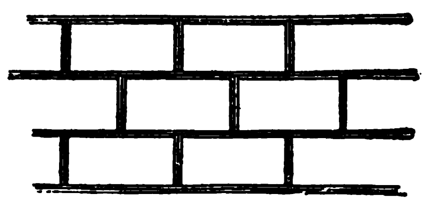


Fig. 18.

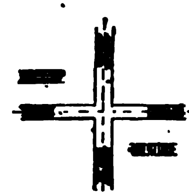


Fig. 19.

"Bond" in, or "Bonding" of Stones in Walls; Its General Principles and Importance.

The practical work of masonry consists not merely in the selecting and cutting, dressing or tooling the individual blocks or stones, so as to give to them certain solid forms or shapes; but in the way in which these stones are placed together and superimposed one upon another. We have seen that on the nature of the bedding faces of stones, used in the building, say of a wall, much of the stability of the structure will depend. If the bedding surface or "top bed" (as *a b d e*, fig. 11) of the block be perfectly flat, much of the advantage obtained from this flat surface will obviously depend upon the nature of the "bottom bed" (*s r g c*, same fig.) of the stone which is to form part of the course immediately above. If this bottom bed be very uneven or rough, and especially if its thickness, as *n g*, varies, so that the "back" face, as *f g n i*, is of less depth than the depth *i o* of the face *h t o i*, the upper stone will tend to "rock" or sway to and fro upon the face of the other or lower stone. The vacant space formed between the two stones thus placed may be filled or jammed up with smaller stones, or with thick mortar; but it is evident that this style of treatmont—often, however, adopted in practice—is only an endeavour to get rid of the evils which careless workmanship has brought into existence. It is clear that the most perfect joint between two stones, one resting upon the other, will be that in which the surfaces of both stones are so even and regular that the greater part of the two surfaces will touch each other. This cannot be the case, of course, in "rough rubble," or even in "coursed rubble" stones. Still in the latter a certain good bed is often obtained, and consequent joint, by the interlocking, so to say, of the two surfaces, the projecting parts or knobs of one going into the depressed parts or hollows of the other. And in the case of "rough or random rubble" work this interlocking or dovetailing, so to say, of one stone with another, can be secured to a considerable extent by careful selection and adjustment of the stones. Admirable examples in abundance are met with of "dry stone" wall work in Yorkshire and districts of England where rubble or rough stones can be easily and plentifully had, or in Scotland, where work of this kind is carried out extensively. They afford excellent examples of the skill of the masons, who are indeed bred to, and only practise, this species of masonry.

Theoretical and Practical Conditions of a Wall—Courses in Walling—Joints in Walls, formed by the Courses Vertical and Horizontal.

But the stability or strength of a wall or structure depends not only upon the form which each stone considered by itself possesses, or has by special tooling and working given to it; it depends also, as we have said, upon the manner in which the number of stones making up the structure are disposed in its bulk or mass. Each coursed rubble or ashlar wall is theoretically considered as a solid mass throughout, being defined as a solid prism or parallelopipedon, standing on a rectangular base of much greater length than breadth. But practically this solid is made up of a series of layers parallel to the base and to each other, each layer being as a rule of equal thickness or depth throughout the wall. The technical name given to each of these horizontal layers is a "course"; and as the courses are independent of each other, one resting upon the surface of the one immediately below—being separated only from each other by the mortar used to cement them together—a series of joints are formed along the lines of heights of stones. But there are vertical joints also. That is, two are formed by the end of one stone "butting" up against, or being placed in contact with the one or nearest end of the stone placed next to it on the right; the other end with the stone to the left. A third joint is formed by the back face of the stone if it butts up against the face of another in the same course. In fig. 11 the horizontal joints are on the lines *e a*, *s c*—the vertical on the lines *e s*, *a c*—the back vertical joint being on line *b g*. This back joint is not present, of course, in cases where a stone is of length sufficient to form the full thickness of the wall, as in the case of what is called a "through" stone, presently to be described and illustrated. In this case there is no back vertical joint, as the two faces or ends of the "through" stone are exposed, one to the front or outer, the other to the back or inner face of wall.

Function or Uses of Joints in the Courses of a Wall.

Those "joints" formed by the contact of faces of adjacent stones afford surfaces by which the different stones are obviously kept together or from separating by being connected or glued together, so to say, by a mortar or other binding and cementing material. The very friction, indeed, between the two rough surfaces—rough enough even in the case of polished or rubbed ashlar faces—would tend to keep stones superimposed upon and placed in contact with each other in the courses or layers. And this friction between the stones, or the "grip" which one stone takes of the one above or below it, forms an element in the construction of a "dry-stone wall," referred to in the last paragraph; but one which must not be lost sight of in estimating the strength of a wall of this kind. An element of higher value than some might be disposed to assign to it; who conclude that it is from the interlocking of the stones between the stones as referred to, that a dry stone wall alone derives its strength and stability. But this merely adventitious or artificial binding of the stones together, in the case of walls in which mortar was used, would be unsafe to trust to, in endeavouring to secure a stable wall capable of resisting strains or sustaining pressures calculated to force the stones asunder or to separate them. The full advantage of the cementing or binding power of mortar or of special cements (see succeeding paragraph on "Limes, Mortars and Cements") is not here undervalued by saying the above. There is great binding or cementing power exercised by mortar when it is good in quality, and judiciously applied—for in this, as in all other work, there is a bad and a good way of employing mortar, which we shall in due place notice. Mortar made by the ancient builders, and even by those at the very early part of the present or late in the preceding century, was in very truth mortar. Being of the best quality, it hardened like stone in process of time, and set indeed so fast that it formed in itself a kind of artificial stone in many cases much harder and more durable than the original stones it bound together. So hard and firm that it was, and is to this day, no uncommon thing for extensive areas of walls to fall or be forced over, and to fall to the ground in a solid mass, not in the slightest degree shattered or broken up. No modern-built wall, certainly very few walls, could stand a test of this kind; mortar as now used by but too many builders—falsely so called, for they do not build in the true sense of the term—being a lime cement or true mortar but in name only, that is, a composition in which sand plays an all too important part. And this sand, it is worthy in this connection of being here noted, is of itself sometimes not of the quality to give a good mortar. For as there is lime and *lime*, so there is sand and *sand*; on both of which points we shall have something hereafter to say.

Principle and Illustration of "Bond" between, or "Bonding" on Stone Walling.

In addition, then, to the full binding power of a mortar or lime "cement," the science of masonry has devised a method by which, in carrying out the art of setting the stones it uses, a mechanical arrangement is given which binds the individual stones together, forming a coherent and largely solid mass. This arrangement is technically termed "bond," and stones set in a wall or structure properly are said to be "well and truly bonded." What the principle of this "bond" is we shall endeavour to illustrate and explain.

Let us suppose that two stones lying on a flat surface, as the ground (as *a* and *b*, fig. 20), are placed together, so that the joint formed by the juxtaposition and contact of the two is formed at *a b*. If they be simply placed in contact, should any force act in the direction of the arrow *c*, so as to tend to cause the stone *c* to slide away from the stone *d*, the two would clearly be separated, and the joint *a b* would open up or widen, and contact between

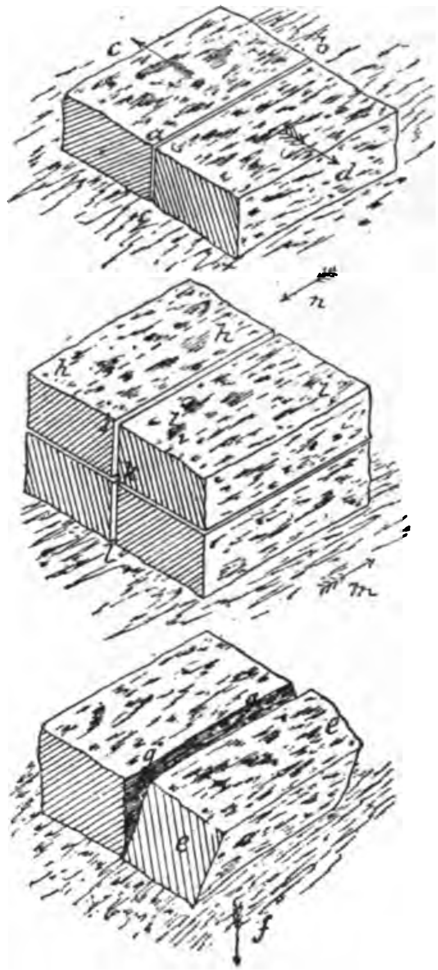


Fig. 20.

the two would, if the movement went far enough, be obviously destroyed. The tendency to separate the two stones would be all the greater if another force acting in the direction opposite to *c* operated in the line indicated by the arrow *d*. The same result of separation of the two stones would take place if the one stone, as *e e* in the lowest diagram, rested upon soft or treacherous ground or soil: it might sink down towards the side *f*, and in the direction of the arrow at that point. The result, so far as the integrity of the "joint" *g g* is concerned, is shown in the illustration. As

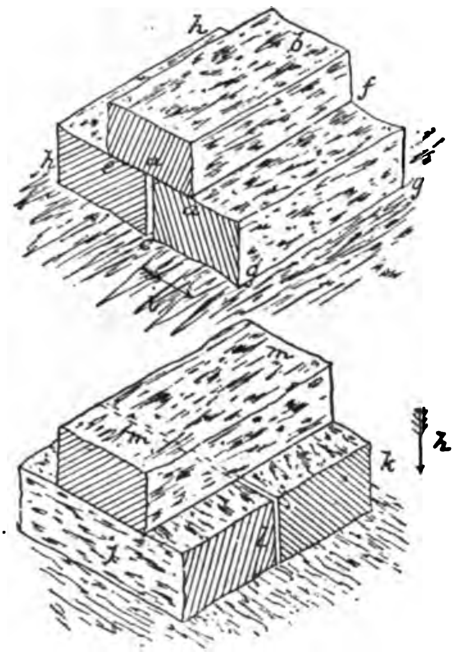


Fig. 21.

between the two stones originally placed at *c d*, joining at *a b*, the keeping of the two in contact might be in some degree ensured by placing two stones above them, as shown at *h i* in central diagram in fig. 20. But this would only be by increasing the cementing surfaces if mortar, or the frictional surfaces if placed without mortar or cement. Any pressure acting either as at *c d* or *m*, in the two first sketches of the figure, would still have the tendency to separate the joint between them; for the joint represented by the line *j k* in central diagram runs in line with that, *k l*, of the two lower stones.

Analysis of the Principle of Bonding of Stones.

The pupil will have a simple exercise, yet one which will serve to give him some useful hints, if he works out mentally the different results of pressures exerted upon the stone in the illustration in fig. 20; those pressures being exerted by the arrows as *c*, *d*, *f*, and additional pressures acting in the directions as at *m* and *n*. If he

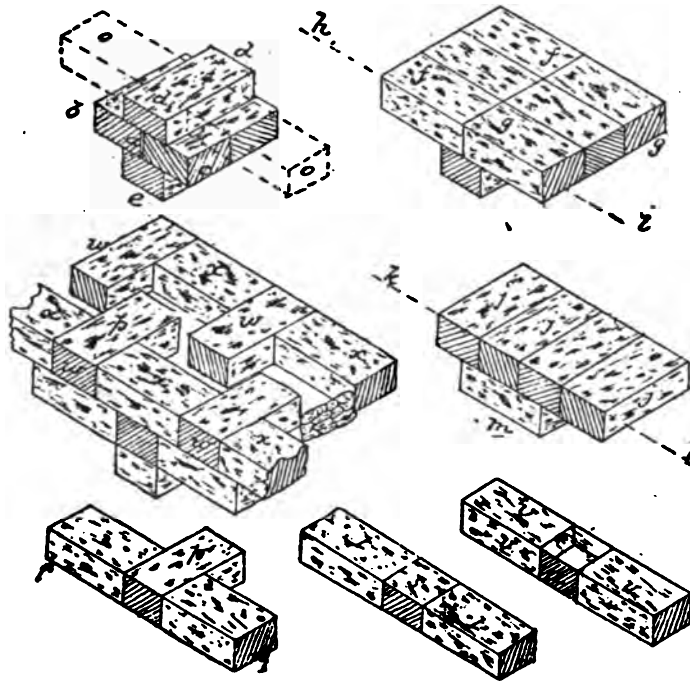


Fig. 22.

does so, he will not be long probably in perceiving that the condition of the joint *a b* would be materially altered if, in place of superimposing upon it two stones, as at *h h* and *i i*, one stone, as *a b*, fig. 21, were placed as there shown. Let the pupil study the position we have now arrived at. He will see that the solid part *a* of the stone *a b* lying on the upper surface or part of the surfaces of the two stones under, is centrally over the joint *a c* of those two stones. Let him suppose that by a bed or stratum of mortar the "bottom bed" of *a b* is connected closely and firmly to part of the upper beds of the two stones *g g*, *h h*. Suppose now that a pressure acting in the direction of the arrow *i* has a tendency to move the stone *g g* towards the right hand, while the stone *h* remains firmly fixed in or on the soil, and has no pressure corresponding to that at *i* acting upon it. To resist this pressure there is now not merely the strength of the mortar or cement, as in the case before considered in connection with fig. 20, but there is also, in addition to this, the resistance of the cement or mortar to be overcome, which is spread over the half of the bed of the block *a b* resting on the block *h*. In this case we do not here take into account such resistance as would be offered by the mortar joint on the half of *a b* resting upon the block *g g*, which is under the pressure. But this resistance would be just so much the more in favour of the two stones *g g*, *h h*, being separated by the rupture of the joint at *a c*—that is, the joint would be all the stronger by the mortar between the edges of the two blocks.

Take again the case of the two blocks *j*, *k*, jointed at *l*, and the joint partly covered, not wholly so, as in the case of the block *a b* in the other sketch in this figure. Suppose a pressure to be exerted on the brick *k* in the direction of the arrow *n*, and at the corner nearest it, and that the soil under *k* was soft and yielding. Here the result, as shown at *g g* in fig. 20, would not be so likely to happen, for not only, as there, is the cementing resistance of the mortar of the joint the only force to resist rupture; but in fig. 21, in addition to this at the joint *l*, is the resisting power of the mortar joint under the bed of the whole of the under side of the block *m m*. So that before the block *k* would yield to the pressure put upon it, as at arrow *n*, and would be forced into the yielding soil, the block *j*, which we suppose to be on firm ground, would be raised like a lever, the fulcrum of which would be the corner nearest *n* of the block *l*. And this resistance of the block *j* to the pressure exercised at *n* would only cease when the cementing power of the bed of the block *m* was overcome by the rupture of the joint of its bed. In those two cases represented in fig. 21, we have two resisting powers to any pressure tending to rupture the joint, as *a c*, or *l*, of any two blocks cemented together by mortar: first, the cemented joint, *a c* or *l*, itself; and second, that afforded by the bed joint of blocks *a b* and *m* resting on and cemented to the top beds, or part of them, of the two blocks *h g* and *j k*.

"Breaking Joint" an Essential Feature of Bond.

It is obvious that by thoughtful arrangement of the blocks of stone the joints of any course in the construction of a wall may be so arranged that they may be covered by the solid parts of the blocks of the courses above and below them. Thus the joint *a* of the two blocks *b* and *c*, fig. 22, is covered by the solid parts of the blocks *d d* and *c*. This is technically called "breaking joint," and the principle is adopted in more than one branch of the constructive arts, mechanical as well as building. These arrangements of blocks to secure this sound principle in construction technically constitute "bond," or in other words that by which the individual blocks are bound or tied together. If the blocks were all of the same length, and placed invariably in the same relation to each other as the blocks *f f*, *g g*, either parallel in the sense of their length to the line *h i* of face of wall, or at right angles to it, as *j j* to the line *k l*, while "breaking joint" could still be carried out by proper arrangement of the blocks as shown at *m* and below *f* and *g*, this mode of disposition or "placement," to use the technical expression, would not give the greatest or strongest form of "bond." In practice, if the blocks are of the same dimensions—as in the case of bricks—they are disposed so that part are placed in the wall parallel to the line of its face, as at *f*, and part at right angles to it, as at *j j*, fig. 22; so that, although of similar length considered in relation to the breadth or thickness of the wall, they may be looked upon, to use a familiar phrase, as being "longs and shorts."

"Longs" and "Shorts," "Headers" or "Stretchers" in Bonding of Stones.

Thus the block *d d* in fig. 22 is a "long," considered in relation to the breadth or thickness of the wall; and the block *o o* a "short," as it only reaches across a part of the thickness or breadth of the wall. When blocks are thus placed, as at *o o*, *f f*, or *g g*, fig. 22, to run along the length of the wall, they are technically called "stretchers." If they are placed so as to run across the thickness or breadth of the wall, or at right angles to its line of length, as at *d d* or *j j*, they are termed "headers." A wall, therefore, is built up with a series of "headers" and "stretchers," so disposed in relation to each other that they "break joint" in the way already explained and illustrated. The way in which they are thus disposed varies according to circumstances, and constitutes what is a particular bond, which goes by its special name—as, for example, in brickwork the kinds of bond termed "Flemish" and "Old English." In stonework the blocks are not always of the same length, but the length of the shortest is, or should always be, greater than the breadth of the longest—as the block in the centre of the lowest diagram to the left of fig. 22, being larger than the breadth of the blocks on each side of it, projects beyond those, as shown. This projection is obviously necessary to secure "bond" with other blocks; and this would not be obtained if the short blocks were equal in length to the breadth of the long blocks, as the block *s* to the blocks on each side of it in centre of lowest diagrams in fig. 22. The case would be worse if the short blocks were less in length, as at *u*, than the breadth of the long block *v v*. But when the stone blocks are of unequal length, they are still disposed in a wall or structure on the same principle of "longs and shorts" alternately.

System of Interlocking of Stones of Different Lengths secured by "Bond"—"Throughs" or "Through Stones."

The complete way in which the individual blocks composing or making up the solidity of a wall are interlocked, so to say, with each other, or bound or "bonded" together, is partially illustrated

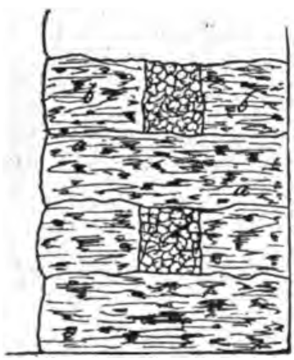


Fig. 23.

in fig. 22, in the sketches at top of diagram. That to the left may be taken as part of a solid wall of blocks, either "ashlar" or rough hammer-dressed coursed rubble work. The block *d d*, although a "header," is termed specially in the technical language of masonry a "through," inasmuch as it goes completely through the thickness or breadth of the wall; its two ends showing at each side of it, interior and exterior. The blocks *o o* and *b c* are "stretchers." The top sketch in fig. 22, to the right, may be taken as an illustration of a composite wall, or made up of solid blocks, or of "ashlar" or of "coursed rubble" work; those blocks being placed or disposed so as to form the outside faces of the wall, inner and outer, while the central part of it is filled up with small stones or "rough or random rubble" work. But the blocks, although of equal length, are disposed as "longs or shorts," or as "headers" and "stretchers," as in the lower diagram to the left. In fig. 23 *a a* is a "through."

Bond in Coursed Rubble-work Walls.

In the last figure (23) in preceding paragraph we illustrated what is termed a "through" or "through stone." This figure, taken in conjunction with next figure here given (24), illustrate the way in

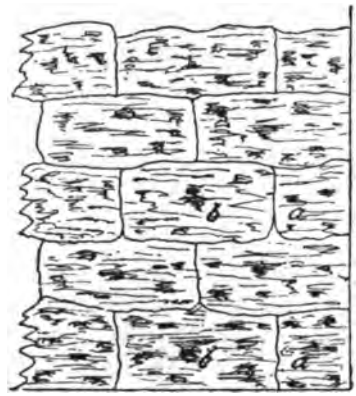


Fig. 24.

which bond is obtained in "coursed rubble work" by setting the blocks as "headers" and "stretchers," the "header" *a a*, in fig. 23, being in this case a "through." The sketch in fig. 24 shows an elevation, and how the blocks all "break joint." Fig. 7 (*ante*, p. 8) illustrates the cross section of a wall in coursed rubble work in

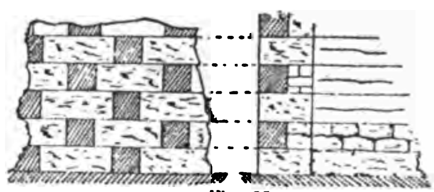


Fig. 25.

which no "throughs" are employed—but only "longs and shorts," the interior of the wall being made of rough or random or small-sized blocks of various dimensions, as shown. Fig. 9 illustrates another section of a wall of coursed rubble work in which no "throughs" are employed, but only "longs and shorts," forming in the elevation "headers" and "stretchers." In this illustration the interior or "heart" of the wall is made up with "rough or random rubble" well grouted with mortar. Fig. 8 shows in elevation how "breaking joint" is obtained work partially employed. Fig. 18 illustrates in coursed rubble in the centre of the wall, the blocks being of varied dimensions, and rough or random, the disposition or placement of blocks in polished or rubbed or tool-jointed

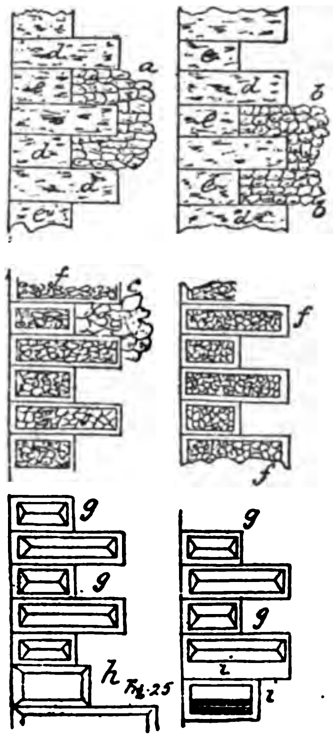


Fig. 26.

work, in elevation showing how the blocks break joints; the corresponding vertical joints in the alternative courses all run, it will be observed, in the same line. Fig. 25 is intended to illustrate more closely the relation between "headers" and "stretchers," the "headers" being shown as in section, with cross lines, or "hatched," as the technical term in wood engraving is.

Position of Bonding Stones—"Longs" and "Shorts" at the Corners of Buildings—"Quoins."

The pupil will perceive that, as illustrated in fig. 26, the blocks which appear in the elevation to the left as "headers," in the elevation to the right at the corner, or as it is technically called "the return" of the wall, appear as "stretchers." On the contrary, the blocks which appear as "stretchers" in the section appear as "headers" in the elevation, and *vice versâ*. A little thought will enable the pupil to understand how this result is a necessity arising from the disposition of the blocks of one face of a wall as "longs" and "shorts," or "headers" and "stretchers," the breadth of a block in the one face acting as a "stretcher," obviously showing as the end of a "header" in the other face.

This disposition at the corner of a wall is the invariable result of employing "stretchers and headers" in its construction. And the stones at this part of the "return" of a wall are technically called

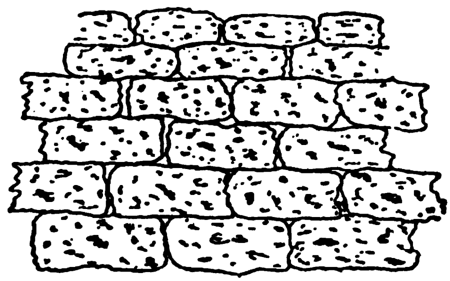


Fig. 27.

"quoins," various forms of which are illustrated in fig. 27. The term is clearly a corruption, or rather the simple substitution of a "qu" for a "c," in the spelling of the French word *coin*—a corner. Shakespeare speaks of the "coigne of vantage," meaning thereby that one who stands at or possesses the corner of a building or wood commands or can sweep with his artillery the two sides of it. "Quoins" are in civil architecture, public buildings, and domestic structures, generally so arranged as to form a distinguishing or ornamental feature in the design. If the body or bulk of a wall be constructed in coursed rubble work as at *a* in fig. 27, or in rough or random work at *b*, or in irregular rubble where the stones are purposely dressed to form odd and various shapes, as at *c*, the quoin stones are usually of polished or rubbed ashlar blocks; or if only hammer-dressed, are more carefully tooled than usual. The object in both cases is to give a distinctive because different character to the quoin blocks, to distinguish them from the rubble work of the body of the walls. This their mere size would also do. When the whole of the wall is thus formed of rubble work one or other of the ways, as at *a b c*, the quoins are left plain generally in surface—*i.e.* not rusticated, etc.—and the joints also are plain, as at *d d*, *e e e*. When the body of the wall generally is built in polished ashlar work, the "quoin" stone surfaces are either rusticated, as at *f f*, with tooled margins rowed or smooth (see fig. 14), or the surfaces are finished as at *g g*, after the manner illustrated in fig. 16. And in place of having the joints plain, as in those methods now described, they are "wrought"—to use the technical term for worked or tooled —after the manner illustrated in fig. 16 (see also *i*)—this disposition

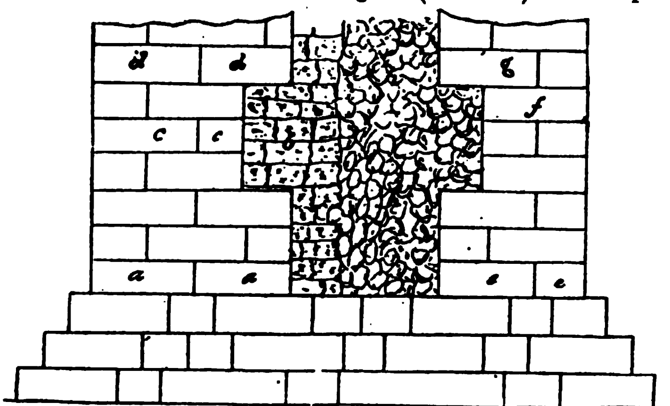


Fig. 28.

being shown at *h h*. The pupil will, in these sketches of "quoins," see another illustration of the disposition of "headers and stretchers" at the return or corner of a wall: the long quoin in the sketch, on the one face of the wall to the left, appearing as a short quoin stone in the sketch to the right, which is the other face, and *vice versâ*.

"Block in Course" Walling.

We have still, in addition to the varieties of disposition of stones in the formation of walls, to illustrate a modification of coursed rubble work, or what in reality is a compromise, so to call it, between coursed rubble work and ashlar work. This is illustrated in fig. 27, and is known as "block in course." The courses are not all of equal thickness or depth throughout, but generally the thickest stones are used at the lower courses, the thinner at the upper courses, the courses often gradually merging into ordinary coursed rubble work. The depth or thickness of the thickest stones is, as a rule, less than the average or minimum depth or thickness of ashlar blocks.

Stone combined with Brick in Walling.

Stonework is often combined with brickwork; the brickwork generally forms the outer facing of the wall, as at *a a*, *e e*, *c c*, *d d*, fig. 28, the interior or heart of the wall being filled with random rubble work, or, if desired, with coursed rubble work—generally rough rubble is employed. Combined brick and stone work is, however, the reverse of this arrangement; the outer facings being built in coursed rubble, as at *a a*, fig. 29, the heart of the wall being filled in with brickwork, as *b b*. In all combinations of different kinds of work or materials, such as brick with rubble work, as in fig. 29, or with ashlar and rubble work—of which latter, by supposing the

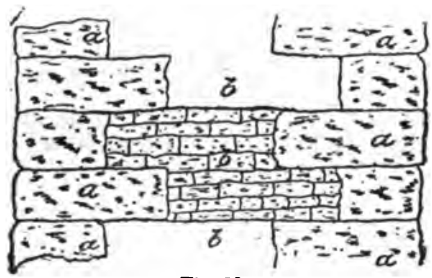


Fig. 29.

outsides or faces to be in ashlar or straight-outlined blocks in place of rough, as shown, fig. 7 may be taken as an illustration—the greatest care should be taken with the "bonding" of the different materials, so as to prevent rupture of the courses by uneven settlement of the walls, or by irregular pressure on them.

Ashlar and Coursed Rubble Work combined in Windows.

In fig. 30 we illustrate another combination of ashlar work with coursed rubble. This shows the disposition of stones in a wall in which there is a window opening, as *a a*. Technically, all openings, as doors or windows, are called "voids"—that is, empty spaces or vacuities, by which the continuity of the wall is interrupted. The void or opening is "spanned," or, so to say, bridged over, by a long flat-surfaced single stone, *b b*, called a "lintel," the corresponding stone *c c* at foot being called the "cill." The "ashlar" quoin blocks are at *d d*, the interior filling between them being of coursed rubble work at *e e*. Another void—the arrangement of window being known as a "two-light"—is shown in fig. 31, the wall or "pier" between them being in ashlar work. In place of coursed rubble, as at *b*, the

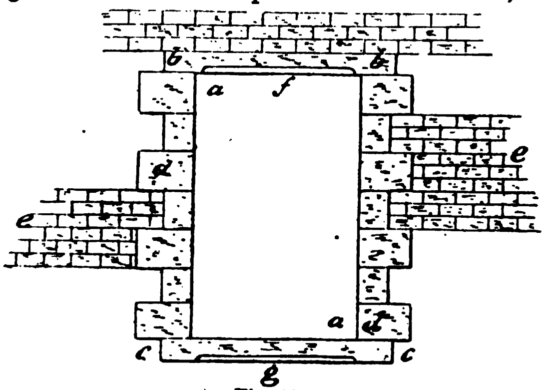


Fig. 30.

wall may be formed of irregularly shaped stones, as at *c*, and each stone very carefully "pointed,"—for which operation see a succeeding paragraph.

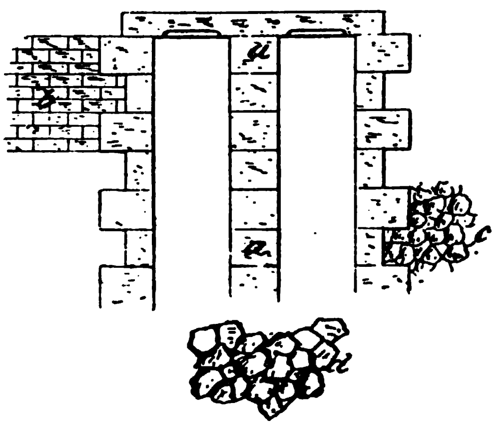


Fig. 31.

Chamfered Work in Stone Lintels, Cills, etc., etc.

The lintel *f* in fig. 30 and the cill *g* are shown with a double line at the bottom edge. This does not continue along the whole length of the lintel edge, but is seen to stop short of the cills, being terminated by curves. This method of finishing the edge of a block is called technically a "chamfer," and how it is done requires further illustration. When two sides of a block meet at right angles, the corner or sharp edge formed is called an "arris." Taking the arris off a block, either by way of making a sharp corner into an easy rubbing surface, as at the side posts of a door, or for giving the variation to the outline, more or less ornamental as it is supposed

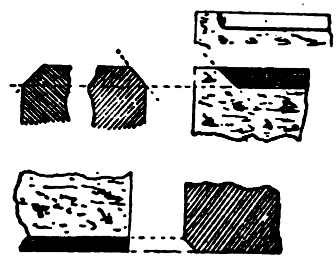


Fig. 32.

to be, is simply cutting a part of the corner off by paring, planing or sawing, in the case of wood, or by the chisel in case of stone. A corner so treated is shown at *a* in fig. 6, Plate III., in section, and at *b* in elevation. This "taking off the arris" from a block is sometimes otherwise called "bevelling" or "splaying," generally a "chamfer." In some cases the bevelled portion continues to the end of the block, as at *b*. But if it stops short of the end, as at *c*, it is

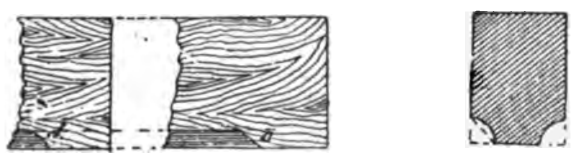


Fig. 33.

called a "stop chamfer," and may be finished as there shown. It may terminate with a curved line, as is done when the "bevel" or "splay" is straight-faced, as in fig. 32; but if the arris be taken with a curved face, as shown in the sketch to the extreme right of fig. 33, the "stop chamfer" terminates with a curved line, as at *d*. In fig. 6, Plate III., *e e* shows in plan the stop chamfer curved in face, as in the section at right of fig. 33. Fig. 32 further illustrates plain and curved-faced chamfers.

"Weathered" and "Throated" Window Sills.

The "sill" of a window, as at *c* in fig. 30, is generally cut or wrought in a peculiar way. This is illustrated in fig. 34. The sill is not made flat-surfaced, with the top parallel to the bottom line—that is, with the front face of the same depth as at back—but slopes downwards from a certain point to the front edge, the slope having as its height the distance as shown by the dotted lines in fig. 34. This slope is given to the upper surface, part of which projects beyond the line *d* of wall, in order that the rain may pass away from the top of the sill, and running down the front face, drop to the ground as at arrow *c*. This sloping surface, shown in complete sill at *ff*, fig. 34, is what is technically termed "weathered." But a little consideration will show the pupil in masonry that when the rain passes down the front face of the sill, on reaching the corner it will be apt by the force of capillary attraction—or may be blown inwards

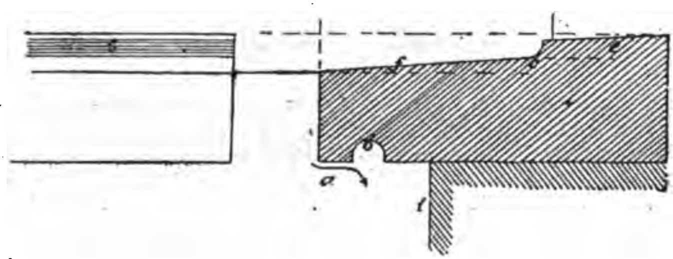


Fig. 34.

by the wind, in, towards and along the under surface, and by this means—to pass to the wall, as indicated by the arrow *b*, fig. 35. Now, it is an object of importance to keep all rain "drip" from reaching a wall. This is prevented in the case of the sill by cutting in the under side of it near the wall a groove, as *d*, running along from end to end. On the water or "drip" reaching to the outside edge of this, it cannot of course pass across the opening of groove or upwards within the groove, and therefore drips to the ground.

Coping Stones, "Weathered" and "Throated."—Angle Quoins.

Enclosing walls are generally finished at the upper part or top course with a line of stone blocks. These are sometimes weathered on one side—that is, they have the sloping surface to shed off the rain on one side only, as in the diagram to the left in the upper part of fig. 35. Usually, and in good work, the coping stones are weathered or sloped on both sides, as shown in the diagram below. The sides are usually plain, as the side *b* to the right of centre line. They are sometimes curved with an ogee curve, as at side *e*. In this diagram the coping stones are "throated," as at *d d*. When window or door voids are arched over in place of having a flat lintel, as in fig. 30, and are dressed with quoins at the sides, the quoin block at the top of each side of opening is cut with an angular face to serve as an abutment for the springing arch at top. This may be, as at *c* or *d*, to the right of fig. 35, or the blocks may be cut as at *a* and *b* in diagrams above the last-named, part serving for the vertical part of the quoin, and part for a portion of the springing arch.

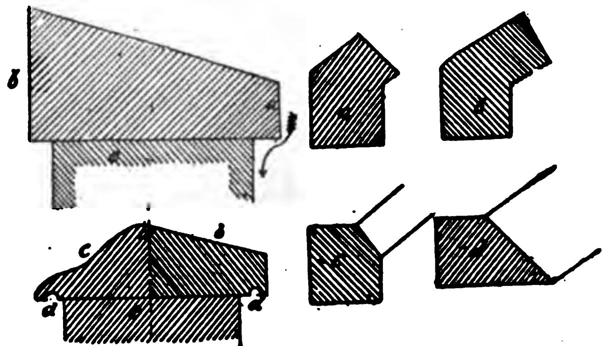


Fig. 35.

Methods of Bonding or Joining Stones other than those already described—Connecting Stones Mechanically—Description of Various Methods with Details.

Before proceeding to illustrate the various forms into which stones are cut in order to serve as part of buildings, domestic or otherwise, it will here be necessary to go further into the subject of "bond." This, however, only so far as methods other than the principle of bonding the stones of a structure together which we described in the latter part of the preceding chapter. That principle of placing or disposing the stones of a structure so that they shall interlock, so to say, with one another, constitutes what is "true bonding." There are other methods which are more purely mechanical, inasmuch as some of them demand a special treatment or cutting of the stones so as to form special interlocking or dovetailing parts by which the stone are mechanically held together. In other methods special appliances purely mechanical, and for the most part formed of iron or wood (chiefly iron), are used. All the methods comprised under those two classe may be termed methods of bonding stonework supplementary to what we have called the true principle of bond, or "mechanical bonding." This "true bonding" here referred to may also be termed the natural method, being intrinsic, so to say, to, or purely characteristic of the stones themselves; each as affording the means to bond with its neighbour according to its placement or disposition in the wall or general structure.

Bond secured between Stones by cutting them into Certain Forms—The Ordinary "Joggle" for Stones on the Flat.

Of the foregoing methods of this supplementary or mechanical style

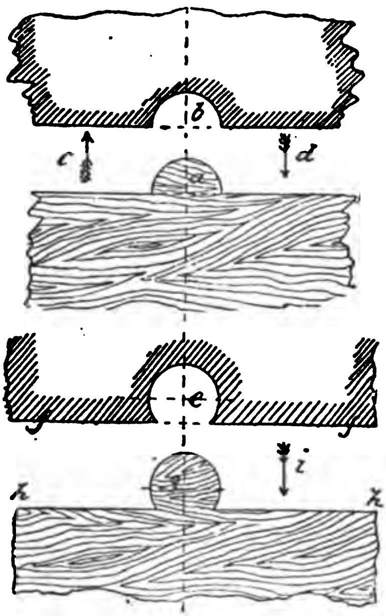


Fig. 36.

or class of bonding stonework, let us now glance at the first—namely, that in which the stones are specially treated or cut. A simple way of keeping two stones, lying on the flat, bonded together, is by cutting a circular projection, as *a*, fig. 36, on one edge of the stone, with a corresponding indentation, *b*, on the other. But while this would keep the stones together, pressing in the direction of arrow *d*, there would be no tendency in the joint formed by *a* passing into *b* if the pressure acted in the opposite direction, as in the arrow *c*, inasmuch as the projection *a* could easily slip out from the indentation *b*. This would be prevented by giving the indentation the form of more than a semicircle, as at *b*, such as is shown at *e*, cut in the edge of stone

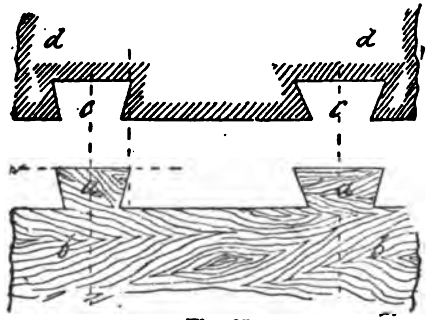


Fig. 37.

f f; the projection *g* in *h h* would be of the corresponding shape, and would of course require to be lifted and passed endways into

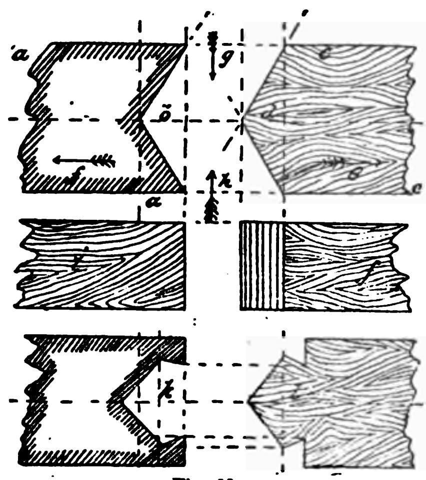


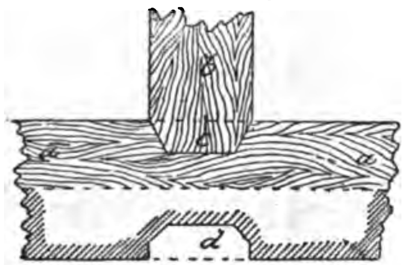
Fig. 38.

the indentation, as it could not be passed in edgeways. This form of bonding or binding joint is called a "joggle," and the method is termed "joggling," or the stones so joined are said to be "joggled."

The principle is carried out in more ways than one. Another and a more common method is illustrated in fig. 37.

The Dovetail Joggle for Joining Stones on the Flat.

The joggles *a, a,* are of the dovetail or fantail form, and are cut out of the solid on the edge of the stone *b b*. These pass in or are lifted into the corresponding indentations, *c, c,* on the edge of stone *d d,* or what may be called mortise holes, to borrow a term from the sister art of carpentry. Another method of joggling stones, and a simpler, is shown in fig. 38, in which the joggle extends across the whole width of the stone *a a,* having an angular indentation, *b,* cut in its end, the stone *c c* having its projecting end similarly formed.



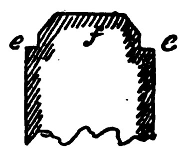


Fig. 39.

This method affords no bond preventing the separation of the stones by pressures acting in the direction of the arrows *e, f,* although it provides for pressures acting in the direction of the arrows *g, h*. The pressure in the direction of *e f* on the stones *c c, a a,* is met by giving the joggle the form of *k* and *l*; *i* and *j* are side elevations of it. A modification of the joggle in *b d* in the last figure is shown in fig. 39, by which the stone *a a* is connected with a stone *b* at right angles to it by the joggle *c*. This joggle may be modified as at edge *d*, the joggle *f* having two butting shoulders at *e e*.

Joggles for Stones in Positions other than the Flat.

All these joggles are used for stones in the flat, lying in the same plane. We now illustrate joggles used for stones lying in different planes, as stones or blocks lying one upon another, and those at right angles to each other. The first of those we illustrate are joggles used to connect horizontal stones together, in which a more perfect

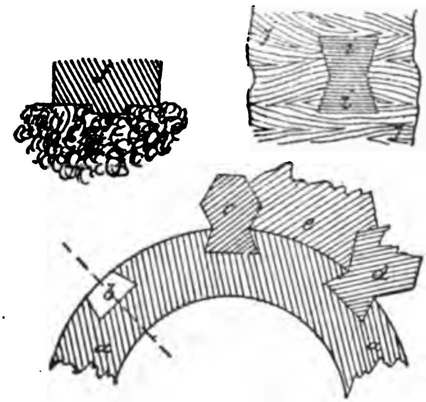


Fig. 40.

bond is required than can be obtained by the ordinary bonds we have described in preceding paragraphs. This more perfect bond—in addition to the connecting force obtained by the use of cement between or on the beds of the stones—is often required in stonework

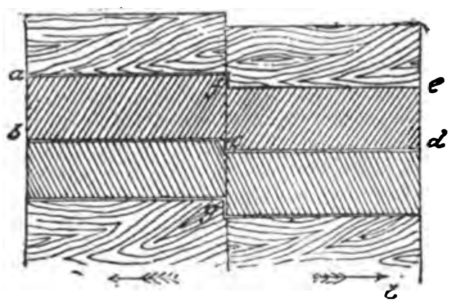


Fig. 41.

exposed to great pressures and severe shocks, as in lighthouse work, marine or harbour works, etc., etc. The principle upon which the methods proceed is that of the dovetail joint, of which we have already given an example or two in connecting stones lying on the same plane. A very celebrated example of the joggling or dovetailing of stones together lying on the same plane, but the principle of which was also applied to bond successive courses of blocks lying upon one another and rising vertically, is the Eddystone lighthouse, lately in Plymouth Sound, erected from the designs of the father of modern civil engineering, Smeaton, and which has been re-erected on the ground known as The Hoe, at Plymouth, as a monument to that great engineer. This may be illustrated by fig. 40, in which blocks as *c*, *e*, *d*, are united to the central part *a a* by dovetails cut as at *b*. The relation of any two blocks, as *c* and *d*, also give rise to another dovetail joint, by which the piece *e* is firmly bonded to those and to the central part. It is obvious that by carefully adjusting the positions a series of dovetail joints can be arranged over the whole surface of the structure—which was done with admirably designed forethought by Smeaton. In the new lighthouse, recently erected as a substitute for the old one—the foundation rock of the latter giving signs of evident and dangerous decay and weakness—this principle of interlocking was carried out still more completely throughout the structure, not applied merely to the courses placed and resting upon the rock as a foundation; the first course has, we believe, been dovetailed to the rock itself. The principle of this is also illustrated in fig. 40, in which the block, as *f*, is provided on its lower surface with a projection, as *g*, which passes into a hole cut in the face of the rock *h h* itself. The form which this might assume is illustrated as *i i* in the plan of rock *j j*.

Uniting or Joining Blocks of Stones to lie in Vertical Courses.

A method of uniting blocks in successive courses is shown in fig. 41, in which the blocks are cut to a peculiar form, the outline of which is at *a b c d e f*. This shows the section or end view of the block, but the same form is maintained in the side—that is, the length running in face of structure. The pupil should "project" a drawing of the structure in side elevation, showing the position of the zigzag lines of courses which the peculiar shape of the stones would give. As the foundation or first-course stones would not have a fair bed if formed as in fig. 41 in section, to be used as the blocks for the length of the wall, the blocks for the first course are cut with the lower bed at *a* in straight line, as at *a b* in fig. 42, the upper bed as shown to correspond with the shoulders of the blocks formed as at fig. 41.

In examining fig. 41, the reader will perceive that a shoulder is formed at the points *f*, *c*, and *g*. In the wall of which the diagram is a cross-section, pressure put on the sides, either in the direction of the arrow *h* or *i*, would have a tendency to force the block asunder sideways. The block *g* to the left, if acted upon by a pressure in the direction of the arrow *i*, might leave the shoulder at *g*; or the block *b c d e f a* above it might be forced aside if the pressure acted in the direction of the arrow *h*. No doubt the tendency to leave the shoulder *g* would be counteracted by its coming in contact with the shoulder *c* of the block *a b c d e f*, supposing this block to be steadily

Fig. 42.

secured. But it would probably be liable to the same pressure as put upon the block *g*, and in the same direction. Any pressure, in fact, acting in the direction of the arrow *i* would have little tendency to be resisted by the shoulders, at *f*, *c*, and *g*, as they all "give" in the same direction. A more perfect locking or bonding can be secured, as by the method shown in illustration, fig. 43: in this one stone, *c c*, has a part *a b* cut out, as at *g* in the stone *f f*, the stone

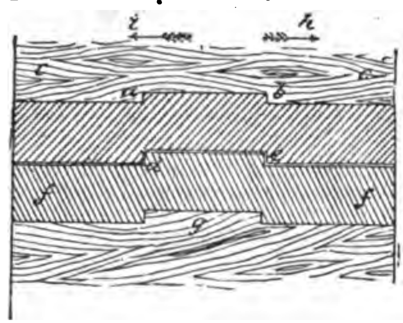


Fig. 43.

below it being provided with a corresponding projection, as *d e* of the stone *f f*. As two shoulders are thus provided, as at *a b* and *d e*, pressures in the direction of arrows *h* and *i* would be both counteracted. We do not at present go further into the subject of pressures, nor show how they can be met further than by methods connected with the bonding or interlocking of the blocks; but it is obvious that as a mere locking or bonding contrivance that in fig. 43 is of a higher class than that in fig. 41.

Another Example of the Class of Joggling described in Last Paragraph.

We now come to another example of the same class of joggling, suitable for the binding together of the various blocks in the vertical courses of a structure, this being illustrated in fig. 44. Here the

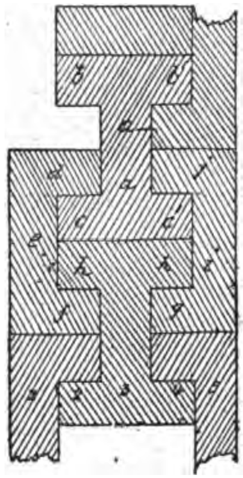


Fig. 44.

blocks are flat on both beds, and have no projecting or hollow parts, as in figs. 41 and 43. The bond is secured between the blocks in any one course only, wholly by the peculiar form into which they are cut. This form has no influence in bonding a course with the

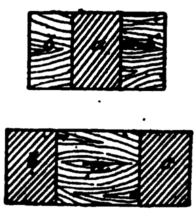


Fig. 45.

next one above or below it; the connection between the several courses being obtained, as in ordinary bond, by the mortar or cement between the binding faces. Any bond between the courses vertically, other than this, must be secured, if secured at all, by the three methods of supplementary bond yet to be described—namely, "dowels," "cramps," and "bolts." As seen from fig. 44, the shape of the central block is precisely like the letter I—the web, or central part, *a a*, being finished at each end by cross pieces of equal length, as *b b'*, *c c'*. The outside blocks are, on the other hand, shaped like the letter E without the central projection, or like part of a central block with the projecting parts *b c'* cut off. The space between the "lugs" or "ears" of the outside blocks, as *d e f*, is such as admits the easy insertion of the ends, as *c c'*, *h h'*, of two central, or I, blocks placed in contact, as shown in diagram. Those ends are embraced or locked by the

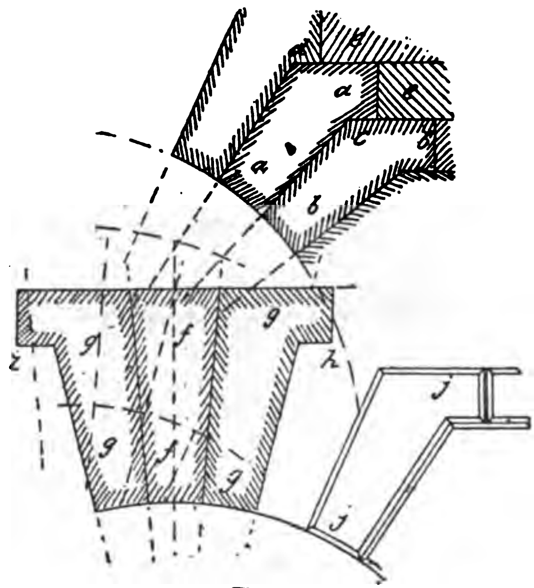


Fig. 46.

hollow parts of two outside, or E, blocks, as *d e f*, *g i j*, one on each side. The breadths of all the parts are equal, so that when the blocks are placed in position, or *in situ*, as the technical term is, the thickness of the wall is made up by them all, as by the five parts 1, 2, 3, 4, 5, all of which are equal in breadth or width. The pupil will see how completely interlocking this somewhat elaborate method of preparing stones or blocks is. Fig. 45 gives at top a section of the I or central block in fig. 44, through a line at *a a*, *a* being the section of centre part or web, *a a*, fig. 44; *b b*, fig. 45, being the inner sides of the corresponding parts in fig. 44. In the lower sketch, fig. 45 is a section through the points *b c* or *b' c'*, fig. 44, as is elevation of inside of block; *a a*, *b c*, being sections of parts *b* and *c*, fig. 44.

Interlocking or Binding of Stones in Arches and in Stairs.

The principle of interlocking blocks with each other is further illustrated in fig. 46, which shows the forms given to the blocks forming an arch, as in a bridge. The blocks *a a*, *b b*, are part of the series of arch blocks near the piers, and are so cut that, while their lines converge to the centre of the arch, shoulders are made at *c* and *d*, into which the horizontal stones forming the courses of the wall or faces of the bridge between the arches lie or butt, as shown. In the lower part of the diagram, *f f* is the "key stone" of the arch, *g*, *g*, side stones, with shoulders *h*, *i*. The sketch *j j* shows how the joints, in place of being plain, are formed as in figs. 17 and 25.

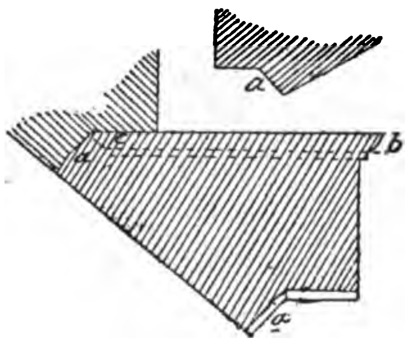


Fig. 47.

The diagram in fig. 47 shows how the steps of a stone staircase are cut in cross section, to afford a bearing or interlocking surface, as at *a*. The dotted lines at *b c* show the "return" of the moulding *b*, at the end elevation—for the sketch is in section—of the step. The moulding at *b* runs along the whole length of front of steps; the point *b* is called a "nosing."

"Joggling" or Joining of Stones Vertically.

We now take up the methods of joining blocks placed at right angles to each other, or vertical pieces resting upon one another. Figs. 48 and 49 show two methods—the projecting part *g*, fig. 48, on block *a* passing into the hollow *h* in the lower block *b*. In fig. 49, the parts, as *e e*, are tapering at different angles, corresponding hollows being made in the under blocks *d f*. Fig. 50 represents how part of a cylindrical stone column *a a* may be secured to the lower part *b b*, by a joggle *c* passing into it. Or a hole may be made in each part, and a circular or square block of hard stone or of iron inserted, as at *e*; or this may be made square, as at *f*. Fig. 51 shows how a cornice block or cope stone may be secured to the sloping surface of a pediment or gable of a house, shown in part *a a*, by leaving a projecting part on its surface, as at *b*; this, of course, going

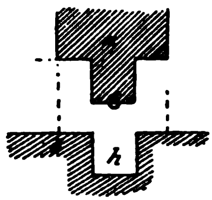


Fig. 48.

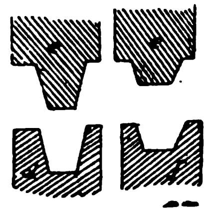


Fig. 49.

into a corresponding hole cut in the lower bed of the cornice block or coping stone. In a course of "cope" stones forming the last or upper course of a gable, the connection may be made, as at *e* in fig. 50, by a square or round pin of hard stone.

Joining of Blocks of Stone by "Dowels."

These last methods are, indeed, illustrations of the methods of effecting supplementary or additional bond, to which the name of

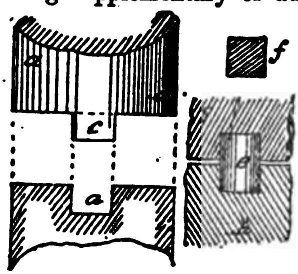


Fig. 50.

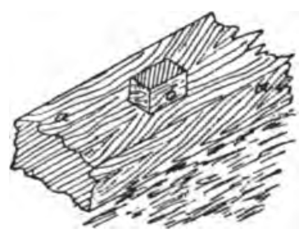


Fig. 51.

"dowelling" is given. The parts corresponding to *e* and *f* in fig. 50, or *b* in fig. 51, of a pin are known as "dowels," and may be made either of stone or iron. "Dowels," if of stone, are small blocks of greater or less length, square in section or rectangular, which are let into holes or apertures cut in the edges of the two stones to be secured together. The size of the aperture or "slot" is a little larger than the size of "dowel" or small "key" or block, so that it can slip easily in when the stones are put in place, or "*in situ.*" The length or depth of each slot cut into the stone is half the length of the "dowel." In fig. 52 the two stones *b*, *c*, bedded on the course *a a*, are shown secured together by the "dowel" let into the hole

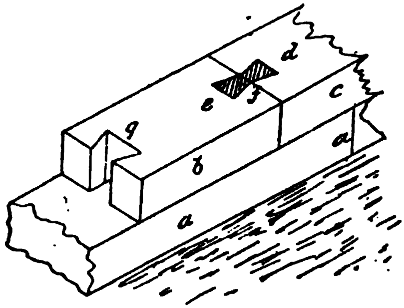


Fig. 52.

formed by the junction of the two stones, half of the length of which is cut on each stone, as the part *g*, which corresponds to the hole into which the end *d* of the "dowel" *d e* slips. If the stone is very broad, two "dowels" may be put in at the joint, spaces being laid out equally across the face. The form of "dowel" shown at *a* in fig.

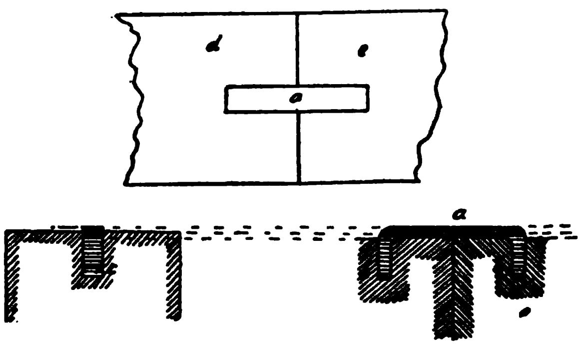


Fig. 53.

53 or at *b* in fig. 54, joining the two stones *d* and *e* is sometimes used; but it is obvious that this section, or the square "dowel" *c* in fig. 54, does not take so firm a grip of both stones as the dovetailed shape at *a* in this figure, or at *d e* in fig. 52.

"Dowels" of Iron as well as of Stone—Best Sections of, or Forms for, Dowels to resist Great Pressures, to which Masonry is so Frequently Subjected.

The "dowels" may be made of iron—but this, rusting rapidly, is not so durable as a dowel of hard stone. The rusting also tends to discolour the stone. They may, whether of hard stone, as granite or trap, or of iron, be of various shapes, or rather sectional forms; but it is clear that, as the object is to keep the stones in contact, to prevent them under pressure slipping away from each other, there are certain sections better calculated to secure this end than others. And all pressures should be provided for, however unlikely it may be that some of them may ever have an existence in practice. A section of dowel, then, which can meet a strain or pressure coming on it in any direction should, if possible, be obtained, for it is

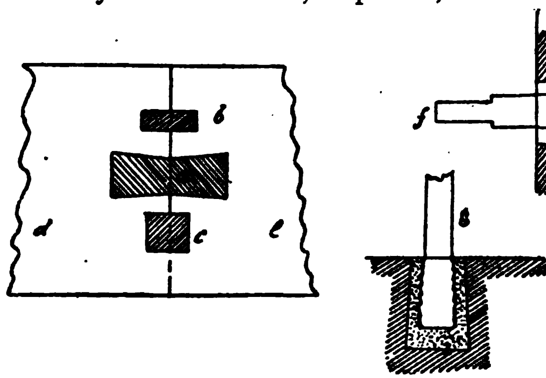


Fig. 54.

exceedingly difficult to predicate that that strain will never exist. In marine work, for example, one has to deal with a power, or rather with powers—that of the wind and that of the waves—not only of enormous force, but which are exerted in the most uncertain, or, if the expression be preferred, in the most capricious of ways. Of the mere force exerted both by wind and wave, the majority of people have literally not even the faintest of conceptions. It requires one to have opportunities, and those often repeated—and to be possessed of powers of observation and reflection, without which all opportunities, however striking, will be useless—to give one an idea of what gigantic power winds and waves possess, and of the strange work of destruction they can with such apparent ease perform. We could cite cases, many of them derived from personally obtained experience—not always by any means safely gained—of such work, to which the popular mind would give so little credence that it would almost without hesitation set our statements down as the mere hallucination of an excited and all-too-credulous mind. Yet the actual facts exceed even what those best acquainted with the effects of winds and waves would expect from the mighty power they exercise.

Let the pupil conceive of the effect of a pressure upon a body, even of the strongest kind, equal in amount to between two and three tons on every square inch of its surface. And yet even the maximum of these pressures named has been known to be exerted by waves. Calculate the surface of a large block of stone exposed to wave force (which may be considered as a compound force of wind and wave), multiply every inch—and even but a small block will give hundreds of inches—by the pressure on each inch, and the pupil will have some conception of the wild work on the structures reared by man which the waves of an angry sea, that may have received the stormy impulse of high winds over scores of miles of open water, may do. The marvel, indeed, is not that so much of the laborious and expensive work of man on sea margin or on lonely rock far out at sea should be destroyed, but that any of it can be reared at all, and when reared kept in existence.

Importance of the Study of the Pressures to which Stones are subject, or likely to be subject.

We have purposely here alluded to this subject of pressure exerted upon stonework, as it is one which closely concerns the practice of the stone mason. For although we have specially illustrated its importance by reference to two great sources of pressure, the pupil must not suppose that the effects of a powerful pressure are confined to works of the marine mason only. In structures on the "firm set land," with which the mind is apt to associate ideas of perfect stability, pressures, and those of a most potent kind, come into existence in a way often wholly unlooked for, and are exercised in a way as uncertain and as apparently capricious as those we have seen to be exercised by the winds and waves. In works of any extent or magnitude there are always sources of pressure the existence of which cannot always be predicated, and which are therefore not in the first instance provided for. In the well-conducted affairs of daily life no wise and prudent man ever trusts to a chance or contingency of danger or loss not coming into existence and acting prejudicially to his interests. He takes care, knowing that the chance or likelihood of mischief does exist, that it shall not injure him, simply because he provides against it, or, better still, gets rid of the chances against him. And if he does not absolutely know that they exist, or if they do in what direction they will operate, he tries hard to find out, if possible, all about them. A man forewarned is forearmed. Just so in the world, so to call it, of practical construction, be it of the mason, the carpenter, or the machinist. The wise and prudent designer and artificer tries his very best to provide against all chances or contingencies of loss or of evil to his structure. If he knows that a chance of loss or danger exists, the action of which is so remote that in the calculation of probabilities it is not likely to occur, he nevertheless wisely determines, since it *may* come into evil operation, to do his best that it shall not operate prejudicially. And in like manner he tries to conceive of possibilities of danger to his structure arising, none of which may show on the face of his work as he first designs it. What is likely to happen is, with the wise and prudent constructor, as carefully provided for as that which his knowledge and experience tell him will positively arise. No apology at all is needed either for the character or the length of these remarks; for as it is our duty to point out to the reader what, from their obvious character, may be called the open secrets connected with structures of stone, so it is no less our duty to point out the direction or probable direction in which the occult or hidden secrets or causes of danger or loss exist. What lies on the surface may or not be picked up by the pupil, but its acquirement is comparatively easy; it is another thing for him to imitate the conduct of the wise man, who does not conclude that all that exists is only all that which is seen. He looks below the surface, and this looking is invariably the result of thinking over the subject. One of the first, as it is in truth the most important, of all the lessons which the technical student has to learn, is the value of thought. The writer, who has had a wide and as varied as wide experience of work and of workers, does not hesitate to say that the great obstacle to the progress of working-men in their several callings is their lack of thought; or, to put it in a paradoxical way—which, like most paradoxes, conveys a vital truth—their determined thinking that no thinking is required of them.

In carrying on—for we have not, although some may think we have, interrupted—the consideration of the subject of contrivances to bind or bond blocks of stone together to resist pressure, we now come to notice the next class of appliances for securing bond supplementary to the ordinary methods of obtaining it, and which in preceding paragraphs we have illustrated and described.

The "Cramping" Method of Joining Blocks of Stone.—Cramps with Plain Ends.

This class of securing stones together is known as "cramping," the appliances being styled "cramps." These are constructed of iron, generally (almost universally) of the kind known as malleable, or more widely as wrought iron, and are of various forms and applied in different ways. A good idea of "cramping" and of the general form of a "cramp" may be obtained from an inspection of the sketches in fig. 55. The "cramping" is the bonding or tying together of two adjacent blocks of stone, *a*, *b*, by the "cramp," the upper surface or top of which is shown at *c c*. This is not merely flat, and of a certain thickness, let into a groove or depression cut in the surface of the two stones to receive it, and so that its surface be in the same level or line—technically called "flush"—with that of the stone surfaces. If so made, it would more properly be classed as a "dowel." But the ends are bent downwards, or "returned"—to use the technical term—in the manner shown at *h*, *i* being part of

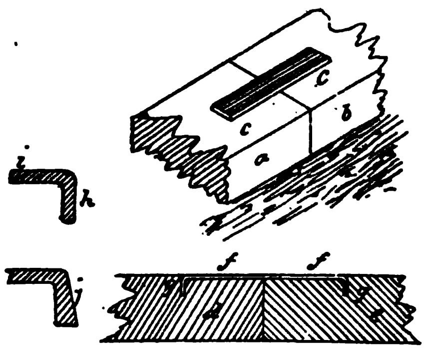


Fig. 55.

the horizontal piece which lies flat on the stone surface, as at *e*. The primary length of the piece of wrought iron is such, of course, as will, when the ends are returned, as at *h*, be the proper length which will give the "cramp" sufficient horizontal hold (as at *c c*) of each stone, as at *a b*. In the lower sketch we give to the right hand a sectional view of two stones, as *d*, *e*, secured together by the "cramp" *f f*, with its two "returned" ends, *g g*, one of which is let into the stone *d*, the other into the stone *e*.

"Cramps" with Dovetailed Ends.

A much faster grip of the stones will be taken by the "cramp" if, in place of the "returned" ends being of equal thickness throughout, as at *i* in preceding figure, they are formed dovetail fashion, as at *j*. For it is clear that, while the "cramp," as *f f*, if made with "returned" ends as at *i*, could be lifted up by a pressure, or "prised out"—to use the technical term—by a sharp-edged tool acting as a lever, this could not be done with a "cramp" with "returned dovetail" ends, as at *j*, unless the stone was broken which rested above the sloping or bevelled side, at *j*. If the "returned" end was made with a double, or rather a true or complete dovetail, as in the lower sketch in fig. 56, there would be still greater difficulty in withdrawing the "cramp" from out of contact with the stones. This sketch in fig. 56 shows how the lower surfaces of the ends of the "cramp" shown in plan in the sketch at top of diagram may be formed, in order to get this greater grip of the stones. The plan in the upper sketch in the figure shows also a form sometimes given to the outline of a "cramp," by which it will be perceived that with equal length between the ends the horizontal contact with or grip of the stones is increased. It is obvious that cramps with dovetailed ends, as at *j* in fig. 55, and in lower diagram

Fig. 56.

in fig. 56, cannot be let into the spaces or voids cut in the stones to receive them, inasmuch as the upper parts of the voids or spaces will be narrower than the width or thickness of the lower edge of dovetailed end of the cramp. Such cramps have therefore to be passed into their spaces in the stone from the sides or edges, at or near which the cramps are placed. But square holes may be cut in the stones to receive from their upper surfaces or sides cramps having dovetailed ends of any width, by adopting the method next described.

Securing the Ends of Cramps, etc., to the Stones by Lead—Various Methods of "Leading."

All the advantages of a solid iron dovetail grip by the returned ends may be obtained by "leading" the ends into the stone. A wrought-iron bar or stanchion is said to be "leaded" into a stone when the aperture or void in which its end is inserted into the body of the stone is made not straight-sided, but with sloping sides, as at *h* or *i* in fig. 54 (*ante*). To make the hold all the firmer, the end of the bar may itself be formed in dovetailed fashion, as shown in sketch at *g*, in place of being left straight, like the remaining part of the bar. The end of the bar *g* being inserted in the dovetailed hole in the stone, as at *i*, melted lead is then poured in, which envelopes or embraces the end of the rod *g*, and filling up the hole, *i*, in the stone, forms a solid wedge-like block of lead, in which the end of bar *g* is firmly gripped. To increase the "bite" or "grip" of the lead on the end of bar, the surface of this is often, and should be, chisel-notched, so as to form a series of saw-like teeth.

All bars in "leading" into stones should be chisel-notched. To enable these to take the fastest hold of the lead, and to resist the breaking-out tendency which the bar may have by pressure or strain put upon it, care should be taken that the direction of the notches should be such that the teeth, so to call them, formed by the notches will open upwards, that is, against the line of strain tending to pull the bar *g* out of the hole in the stone, or rather out of the lead wedge-block *i*, fig. 54. The pupil will learn from this illustration the value of thinking, even in a matter apparently so trifling as a simple cramp, so that all chances of loss or danger to the work may be avoided as completely as possible. He should ever remember that *no detail of construction is trifling*. He ought to bear in mind that the strength of a structure lies in its weakest point: it may be that this weakest point lies in a bolt, a cramp, or a dowel, or what some would call a trifling detail. This, one of the most important axioms in construction, should never be lost sight of; its lessons are simply invaluable to the constructor. The method of "leading-in" iron bars into stones we have described and illustrated, as in fig. 54 at *g i*, is applicable to all positions of bars. Thus *f h*, in same figure, illustrates how it is applied to a horizontal bar. In "leading-in" horizontal or inclined bars, means must be taken to prevent the melted lead from running out as fast as it is poured in. In point of fact, it could not be poured into the horizontal hole as at *h* in fig. 54. To get over the difficulty a very simple plan is adopted. Well kneaded plaster clay is taken and stuck up and secured against the face of the wall or stone into which the horizontal bar is to be "leaded," the clay being so shaped or moulded by the hand as to form a species of cup open at top, into which the melted lead is poured, which is of course conducted to all parts of the dovetail hole, as at *h* in fig. 54. When the lead is "set" or cold, the clay cup be taken down, and the mass of solid lead left outside, the hole is cut away with the cold chisel, and left smooth on surface and flush with the surface of stone or wall in which the iron bar is leaded.

Further Illustrations of the Practice of Cramping by Joining Blocks of Stone together with Iron.

In fig. 53 (*ante*) the use of a "cramp" for securing stones together, as *d e*, is further illustrated by different views; the upper sketch being in plan, the lower to the right, a section in the direction of the length of the stones, the lower sketch to the left being a cross or transverse section in the direction of the breadth of the block. A further illustration of the use of "cramps" is given in fig. 57. In this, which shows a "cornice block," *a a*, crossing a wall *b*, which we suppose to be further secured by a stone "dowel" at *c*, the block is secured by the cramp *d d*, of which front view is at *e e*. In place of terminating at a point below the top surface of block, as shown at *d d*, the cramp at upper end may be extended further up, and have a double returned end, as at *f*. This may have a greater or less horizontal hold of the upper surface of block *a a*; in the illustration this hold is very short. Fig. 58 illustrates another method of using

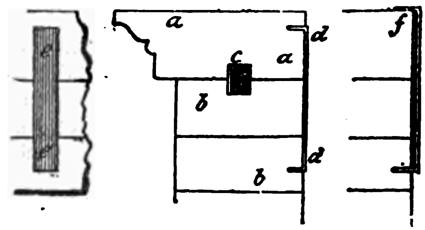


Fig. 57.

cramps. In this two "header" blocks, *a b*, in the cross section of a wall in "coursed rubble work," are secured together to provide for a pressure or strain tending to force them apart, or to cause the wall to bulge out. The "cramp" is at *c c*.

Securing or Binding Blocks of Stone together by means of Iron Bolts and Keys or Cottars.

We now come to the last of the methods of supplementary bonding—namely, bolts, and bolts and ties, or bars. And first as to bolts. These are of different forms, and are employed in a variety of ways, the general direction of the bolts being either vertical or horizontal. Both of these are illustrated in the sketches in fig. 59. Bolts are secured in position by two methods—either by flat keys or wedges, or by having screwed ends and nuts. The first of these methods is illustrated at *a b*, showing how the stones *c, c*, are secured by the vertical tie of the bolt, which passes through a hole made in each stone. This hole is made a little longer than the diameter, if circular, as at *d*; on the side, if square, in section as at *e*,—so as to admit of the easy passing down of the bolt, and of its expansion, which may take place. The lower end of the bolt is passed into a vacant space, as *b*, left in the stonework, to admit of the fastening being put in. This consists of a "key," or wedge, made of flat bar iron, as at *f f*, this being passed through a slot or rectangularly-shaped opening, as *g*, made at the end of the bolt. The position of this slot is such that

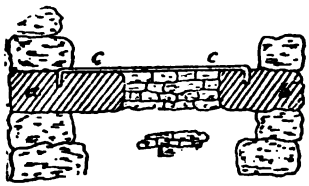


Fig. 58.

when the key *f f* is passed into it, the upper edge of the key will press against the lower surface of the stone. The sketches at *f f* and *g*—the first being a view at the side, the second a view of the edge of the bolt and wedge—illustrate the bolt as secured at the *top* or uppermost stone block of the series of blocks, as at *c c*. The position at the bottom of the bolt, as at *b*, is the same in detail, only reversed. This arrangement, although often adopted, is so far faulty that it affords no good bearing surface for the retaining wedge or key *f f*.

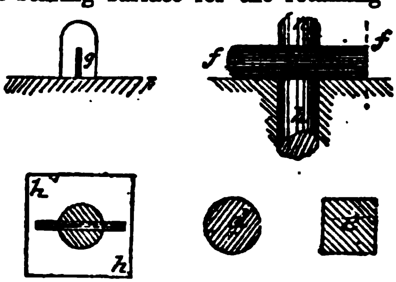


Fig. 59.

This presses on the stone only through the medium of its narrow edge. If the stone block be of a soft nature, this edge is apt, under pressure put upon it, to cut into the stone. This fault can be overcome by giving a broad bearing surface of iron, the same material as the bolt and wedge, or key, this surface being simply a flat and thickish plate of iron. As the pressure to which this is subjected is chiefly that of compression, it may be made of cast iron, which form of the metal is well calculated to resist a strain of this kind. Or the "bearing plate" may be made of a piece of boiler plate. The surface of this should be considerable, so as to distribute the pressure over as large a surface of the stone as possible. The arrangement is shown in plan at *h*.

Securing or Binding Blocks of Stone together by means of Iron Screw Bolts and "Nuts."

The method of securing bolts in stonework by screwed ends and "nuts," as at *i j* (fig. 59), is further explained in detail in fig. 60.

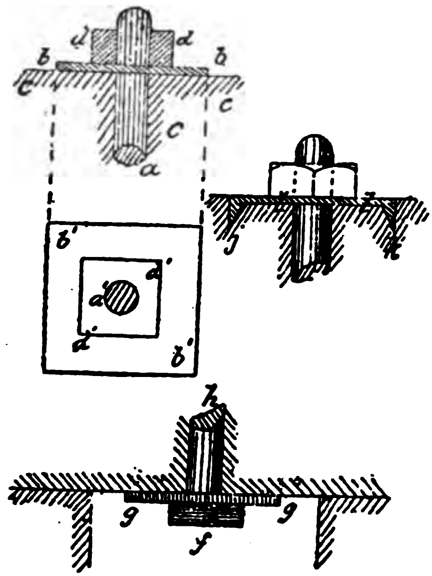
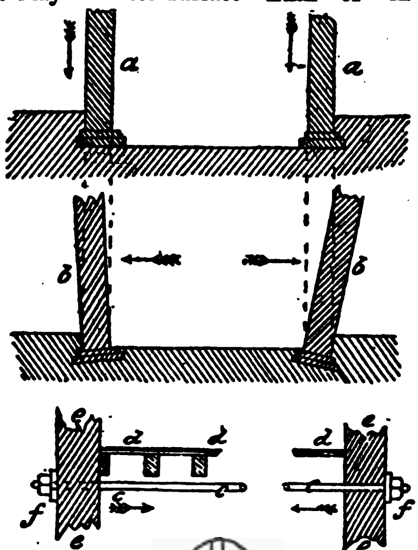


Fig. 60.

The upper part of the bolt *a a* is screwed, and passes, or should pass, through a "bearing plate," *b b*, bearing or pressing upon the surface, *c c*, of the stone block. A screwed nut, *d d*, passes over and embraces the bolt *a a*, and by turning it, it is pressed down upon the bearing plate *b b*, and by tending to pull the bolt upwards, it tightens down the whole upon the stone surface *c*. But to do this the tendency of the bolt *a a* to be pulled upwards must be resisted. This is done by giving to the lower or opposite extremity of the bolt a bearing surface, as *f*, this part of the bolt being called the "head." As the bearing surface of this is small for the comparatively soft material of stone, this should itself bear upon a "bearing plate," as *g g*, through a hole in the centre of which the bolt "shank" or "tail" *h* passes, the upper end of which is shown, with its connections, in the upper sketch, to the left in fig. 60,—the plan being below with corresponding letters accented. In place of the bearing plates, as that at *b b*, lying on the surface of the stone, and projecting from it in proportion to its thickness, it may have its surface "flush" or "in line" with the



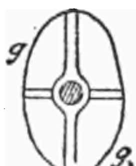


Fig. 61.

surface of stone by being let into the stone as at *i*; and if the bearing plate have two of its edges "returned," as at *j* and *k*, all the advantages of a "cramp," more or less modified, may be obtained by the arrangement.

Securing or Strengthening Buildings by means of Iron Tie-Rods and Bearing Plates.

Bolts or iron tie-rods with heads and screwed ends and nuts, as now illustrated, are often applied to buildings the floors of which sustain heavy weights, as granaries. Through some defect in construction, either in the walls themselves, unequal settlement of the same, or through defective framing in floors, partitions and roof, the walls, in place of remaining vertical as at *a a*, fig. 61, have a tendency to, and often do, push outwards, as at *b b*. To bring them to the vertical again, or to retain them in this the only stable position, wrought-iron screwed bolts, bearing plates, and nuts are used, as at *c c*. The bolts (*c*, *c*) are passed right through the apartment from side to side, being most conveniently placed below the flooring, *d d*, and then passed through holes made in the walls, *e e*, and secured by bearing plates and nuts, as at *f*, in the same way as shown in fig. 60. If used

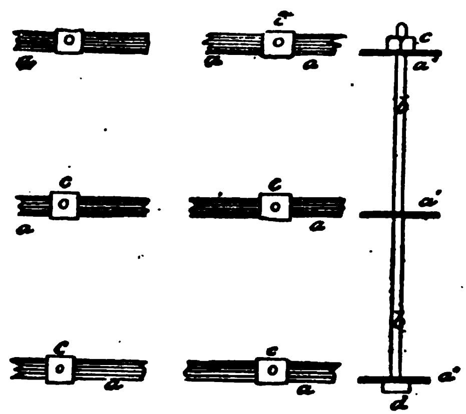


Fig. 62.

as a preventive of the walls bulging out, the nuts are at first screwed loosely up till settlement of the walls has taken place, when they are tightened. If the method is adopted after the walls have begun to bulge out, they can be brought back to the straight, after fixing the bolts and screwing the nuts up as tightly as may be; then by heating the body of the bolt it is expanded, and the consequent lengthening presses the nuts outwards away from the bearing plates, which can now be screwed tightly up against them again. By doing this with care and judgment the walls bulging out, as at *b b*, can be brought vertically up, as at *a a*. A front view of a form of bearing plate is shown at *g g* in fig. 61. It is usually made of cast iron, and as it is seen on the outside of wall it is made more or less ornamental.

Binding together Blocks or Courses of Stone by Flat Iron Tension Bars and Screw Bolts and Nuts.

We now notice the last of the methods of supplementary bond to stone structures. In this flat bars—called technically "ties" or tension bars—are used in conjunction with screwed bolts and nuts. These tension bars or ties are laid flat between and bearing upon the beds of the courses of blocks in number and disposition as desired or deemed necessary to secure a certain efficiency in the bond which they give. These bars are shown at *a a* in plan in fig. 62, and in elevation at *a a'*. They are punched or drilled at intervals, to afford holes for the bolts, as *b b*, passing through; and these are secured by

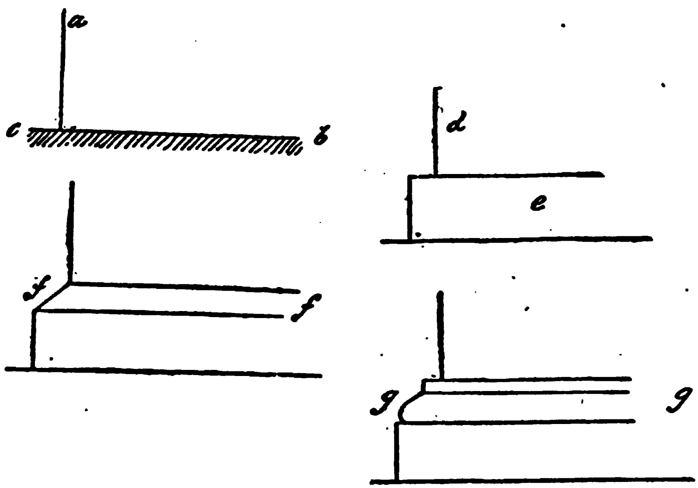


Fig. 63.

nuts in the way already described in connection with fig. 60 (*ante*). These nuts are shown at *c c* in plan.

The Shape or Configuration of Stones as forming Part of the Architectural Style or Design of a Structure.

We have in the early paragraphs of this paper traced the steps, supposed or conjectural, which were taken by the early workers, starting with the rudest collections of stones, in leading up to the systematic and more or less complicated method of arranging stones in walls under what is termed "bond." In doing so we have had of necessity much to do with the form, shape, or configuration of the stones employed in building walls of various kinds. When

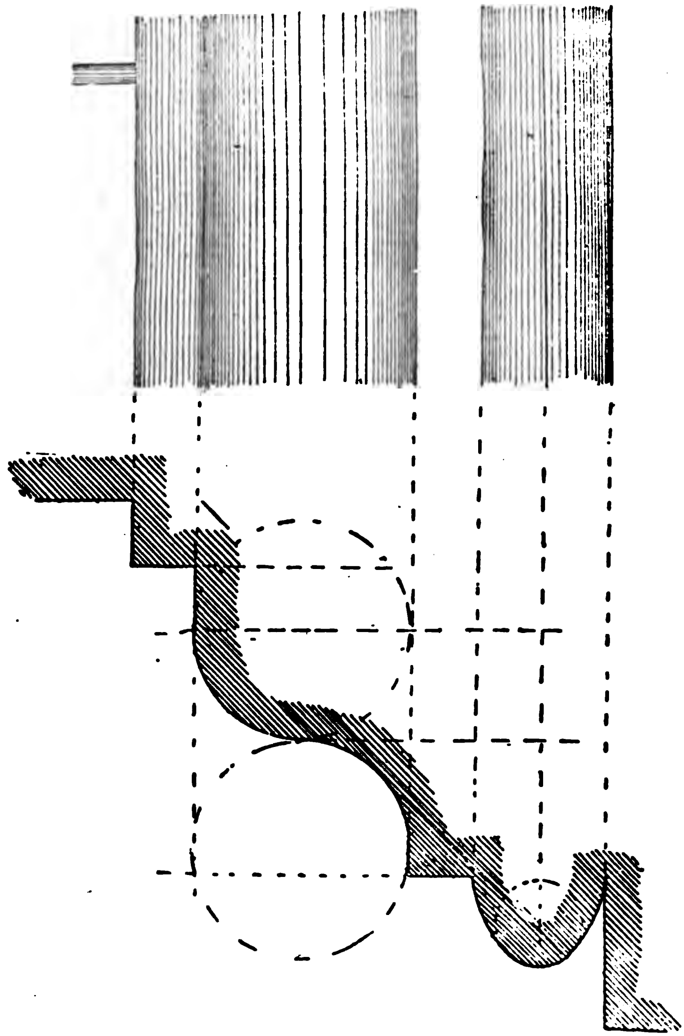


Fig. 64.

arranged on a plan beyond the simple forms of small buildings, and when they assume the form of structures to which the term archi-

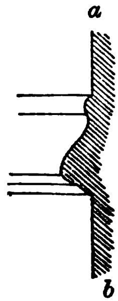


Fig. 65.

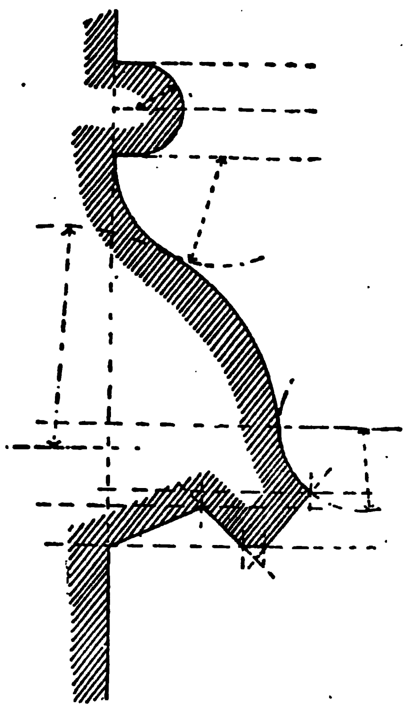


Fig. 66.

tectural is applied, we find that the form or the configuration of stones takes a much higher development than is essential where wall construction considered purely as such is the work of the mason. If the term architecture be properly defined, as some define it, to be ornamented building construction, many of the parts of architectural structure being purely ornamental, the stones which are used to give

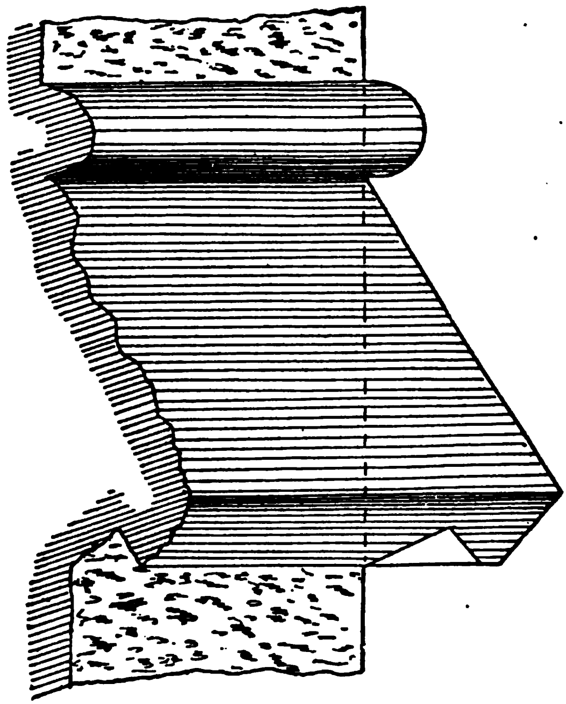


Fig. 67.

those forms must be cut and dressed into forms or shapes in accordance with what is called the *style* of the architecture. The peculiar features of the accepted styles will, if space permit, be discussed in a separate paper, to which the reader interested in the matter is here referred; and in the illustrations which will accompany this paper the peculiar forms to be given to stones will be traced. There are, however, certain forms of stones more or less, but all in some respects, ornamental, which are common to all structures having any pretence to architectural design even when of the simplest character and plan. To these what may be called general ornamental forms we now direct the reader's attention.

Lower or "Base Courses" of Walls of Public and Domestic Buildings.

Walls of houses rarely spring from the foundation courses so as to show a direct intersection with the ground surface, as at the wall *a*

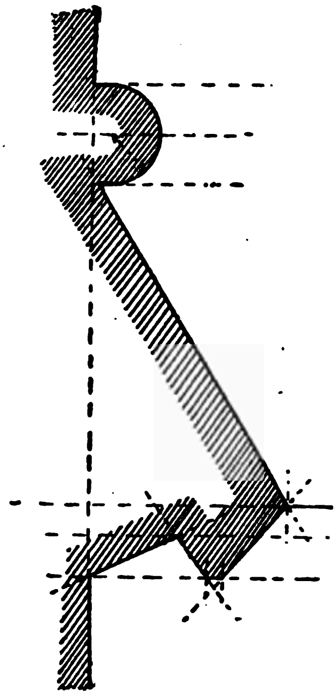


Fig 68.

(fig. 63), springing at once from the ground level *b c*. This is only done in simple or plain buildings, such as stables, out-buildings, workshops and the like. In all dometsic structures, save in the poorest or most economically constructed of cottages, there is a course termed a "base course" intervening between the ground level and the springing or start of the vertical wall. The simplest form of base course adopted is composed of a series of courses of brick or a course or two of stone of height equal to the rise of two or three steps by which entrance is gained to the entrance lobby. This is shown at *e* in fig. 63, *d* being the line of wall, at corner of side and end walls. In this the wall *d* springs directly from the upper part of base *e*, at some little distance from its end, so as to form a "set-off" or return, as is shown. Some of the baldness of this is taken off by having as the last course of the base-course bricks what is called a "splayed"

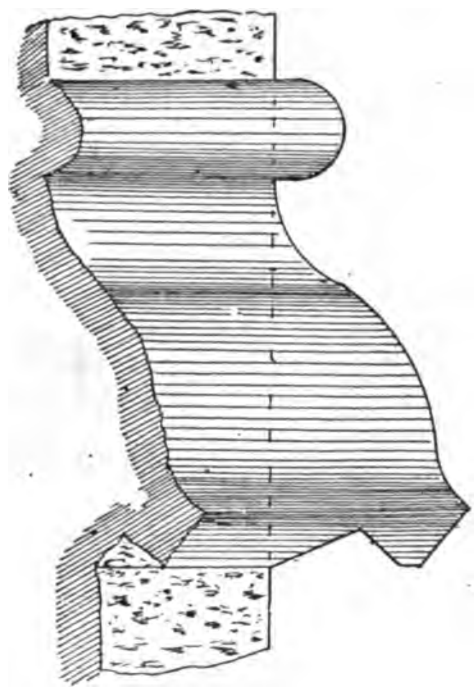


Fig. 69.

course, or if stone be employed the upper course is bevelled or splayed off as shown at *f f*. In more advanced work, this splay is converted into or replaced by some simple "moulding," as at *g g*.

Base Mouldings of Buildings.

Fig. 64 illustrates—one-fourth full size—in section to the left and in part elevation to the right, the "base moulding" for a mansion of ten to twelve rooms. The scale to which fig. 64 is drawn is 3 inches to 1 foot, or one-fourth full size. Fig. 65 is a section of a Gothic base moulding also accepted for a string course: see next paragraph. In fig. 66 we give a section, and in fig. 67 front elevation of a "base moulding" in the more elaborate style of the "Domestic Gothic," and in fig. 68 the section and in fig. 69 the elevation of another form in the same style. The scale to which figs. 66, 67, 68, and 69 are drawn is six inches to the foot, or half size.

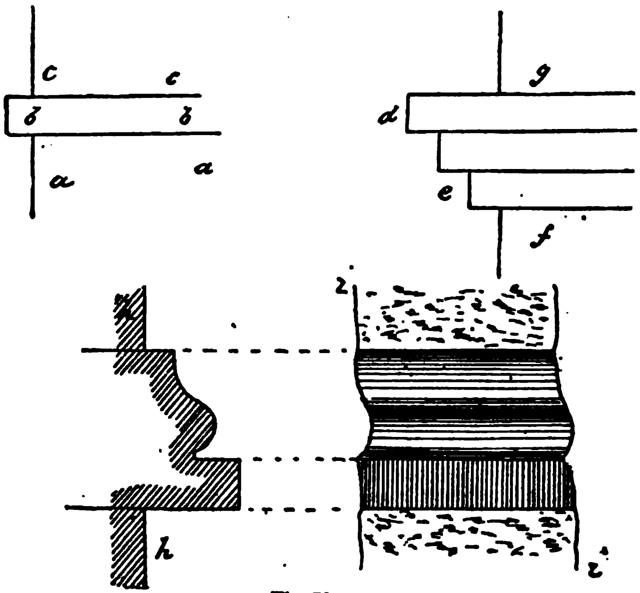


Fig. 70.

"String Courses" in Buildings.

What are called "string courses" are members introduced to break the line or vertical face of wall, and at the level of the different stories of the edifice. Like the "base mouldings," they run along the whole length of wall. It is only in houses finished in a superior style that these two members run round the whole house. In ordinary buildings they are carried along the front wall only, being retained for but a short distance at the end walls—breaking off there. In some cases the "base moulding" is returned and passed along the end walls, but rarely continued round the back wall. The same holds true of "string courses," although, even in cases where the base moulding is carried round the ends, the "string course" is confined to the front wall, having a short return only at the ends. All depends upon the character of the building, according to the pretensions it makes to be a complete and more or less elaborate design, or to the means of the owner. The simplest of all string courses is a mere course of brickwork, such as *b b*, dividing the lower face of wall, *a a*, from the upper, *c c*, fig. 70; or a further advance may be made by adding to the number of courses, as at *d e*, between lower wall *f* and upper *g*. The single course *b b*, as well as the three courses

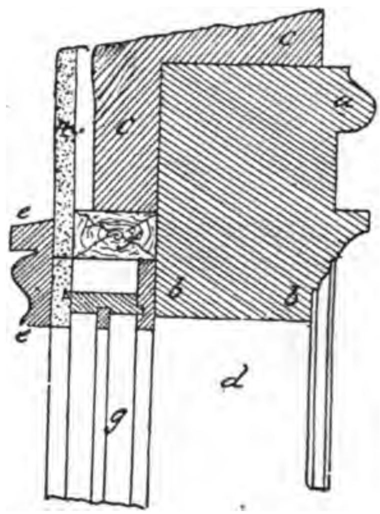


Fig. 71.

stepped off as at *d e*, project from the face of wall. It is this projection which is the feature of the "member," and gives character to this part of the elevation, stonework admitting of being moulded and cut or carved at will; string courses of stone are generally finished with moulded faces, or they may be left plain, as at *b b* in fig. 69. A moulded string-course block is shown at *h h* in section and *i i* in elevation. The mouldings in figs. 66 and 67 might be used slightly modified for those of a string course. Fig. 71 illustrates a "string course," *a*, and a "window head," *b*, in one. Scale 1 inch = 1 foot, or one-twelfth of full size.

Cornices or Cornice Mouldings in Buildings—Cornice Blocks.

Cornice mouldings, as the name implies, are those which finish, terminate, or crown the walls, and are placed at their highest point. They add dignity and completeness to, and afford a pleasing object for the eye to look upon, at the upper part of a wall. Some of the happiest efforts of our architects have been displayed in the treatment and finish of the design for the cornices of a building. Where

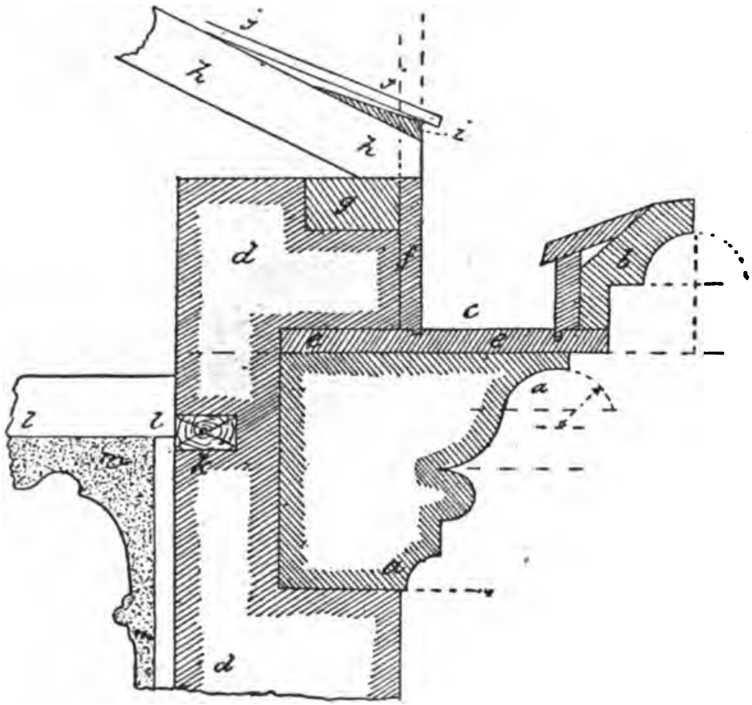


Fig. 72.

the projection is skilfully managed, they give, in conjunction with that of the windows and the doors, the fine play of light and shade produced by the alternation of projecting and recessed parts which distinguishes a well-designed elevation. And this is the characteristic of a well-designed elevation, and distinguishes it from one having little or no projection, which is bald and tame, however lavish and ornate the ornament with which the parts individually are treated.

Fig. 72 illustrates a "cornice block," *a a*, moulded in face, built into the wall *d d*. Part of the design of the "cornice" is in this case formed by the front part *b*, of the "gutter" wood-wor ke *e f*, *h h*

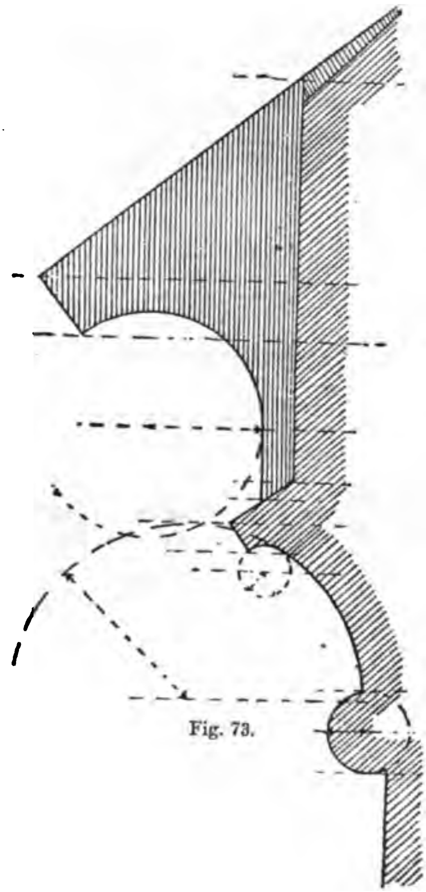


Fig. 73.

being the rafters resting on the "wall plate," *g i* the "tilting piece" to raise up the first of slates, *j j*. The "ceiling joist" in the interior of the wall is at *l l*, *k* the wood-brick, *m m* the "cornice" in the interior of the room—scale same as for fig. 71. Fig. 73 is section and fig. 74 part elevation of the "cornice" of a "bay" window—in the "Domestic Gothic" style—drawn to a scale of six inches to the foot, or half size. Fig. 75 is section, and fig. 76 part elevation, of another cornice—scale same as last two figures.

Chimney Cap and Window Head Mouldings.

Fig. 77 is section of mouldings at the upper part or "cap" of a

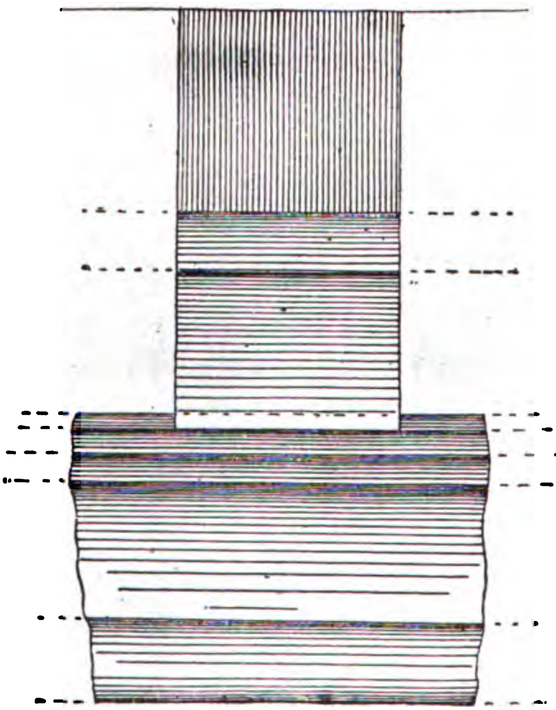


Fig. 74.

chimney in the "Domestic Gothic" style—drawn to a scale of two inches to the foot, or one-sixth full size—of which fig. 78 is half of the elevation, and fig. 79 of the base of same, these two being drawn to a scale of one inch to the foot, or one-twelfth full size. Fig. 80 shows the mouldings for the cap of another chimney—scale two inches to the foot. Fig. 81 is section of window head, and fig. 82 part elevation of the same.

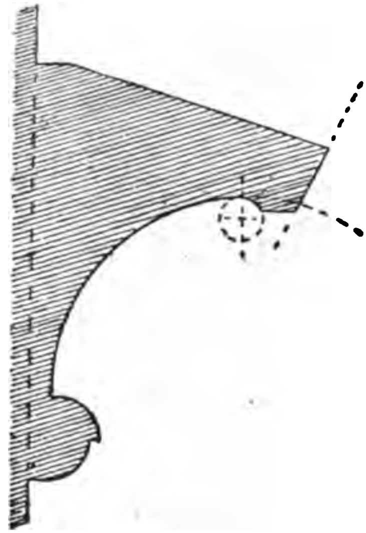


Fig. 75.

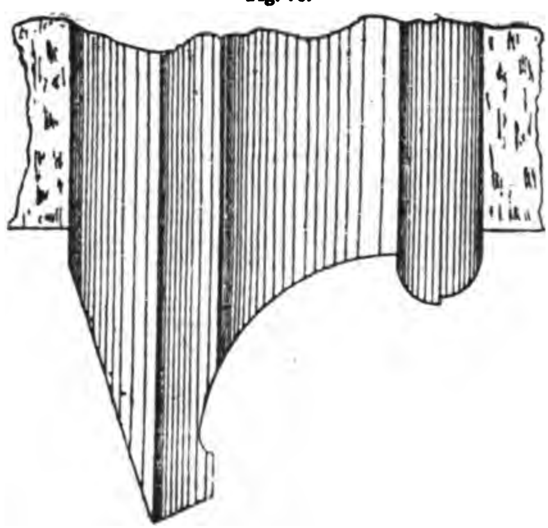


Fig. 76.

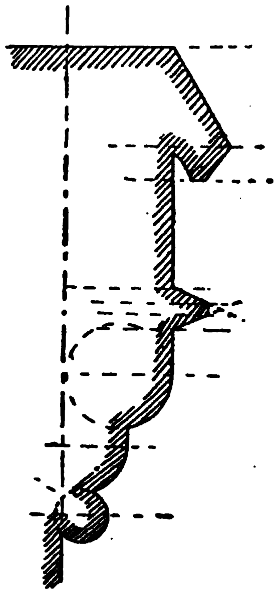


Fig. 77.

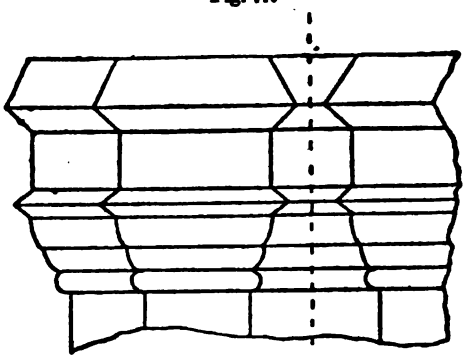


Fig. 78.

Arch Mouldings.

The arches of "Domestic Gothic" work, as the arched heads of doorways, are all more or less moulded in the inside lines; the mouldings run up each side of the door opening, and are continued round the inner concave, or "soffit" of the arch. A section taken through a line, say at right angles to the length of the side of opening, at any point of the arch in a line vertical to the centre from which the curve of the arch is struck or described, will give the "contour" or outline of the mouldings. Thus, fig. 83 represents the outline of mouldings as shown in section of the mouldings of an arched doorway. The drawing shows only one-half of the mouldings on one side

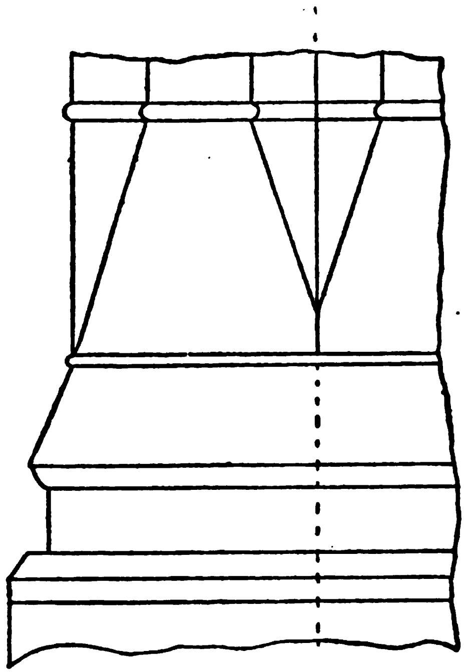


Fig. 79.

of the centre line dotted, the other half being simply a repeat of that shown. The lower part is that which is seen nearest the spectator in looking up to the arch of the doorway overhead; the mouldings gradually widening out from this central point to the sides. In looking at the sides, or jambs, of the arched doorway, the mouldings are seen as shown in the elevation in fig. 84. Figs. 83 and 84 are drawn to a scale of one-half full size. Fig. 84 is section one-fourth full size—three inches to the foot—of another set of mouldings from an arched doorway, fig. 85 being part elevation of the same.

The Stonework of Windows chiefly in the Gothic Style—Mullions—Window Heads, Side or Quoin Dressings, etc.

In many forms of windows, especially in one or other of the varieties of the Gothic as applied to domestic architecture, the window "void" is filled up with moulded astragals, so as to divide the space into two, three, or four equal divisions or "lights," according to the

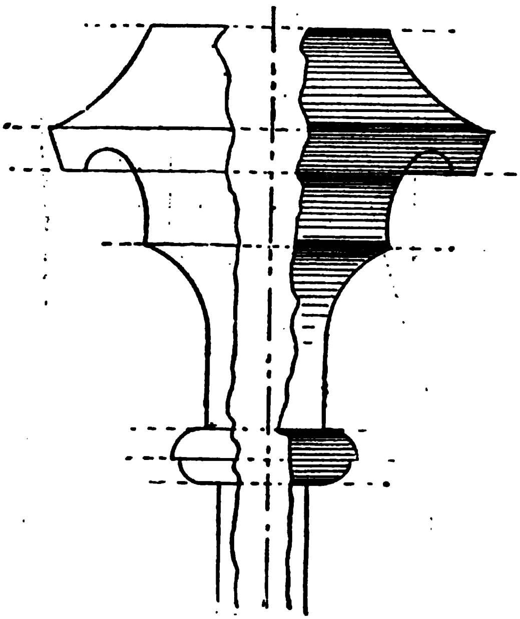


Fig. 80.

width of window opening, each division having its own window framing for glass. In the Gothic styles the window "voids" or openings are provided with stone dressings placed "quoin" fashion in "longs and shorts," as in fig. 26—or shown in fig. 86—which is the lower right-hand corner of a window in "Domestic Gothic" style, divided into four divisions by a central vertical bar, or astragal, *a a*. and a horizontal bar, part of which is shown at *b*, in fig. 1, Plate III. The junction of the four bars is shown in the diagram to the left of *b*, This fig. 1, Plate III., is part elevation of the upper part of window, to the right hand. In fig. 1, Plate III., the window head, or moulded part which runs along the top, and is returned for some distance down each side is shown, fig. 3, Plate III., being a vertical section.

Fig. 2, Plate III., is the drip termination of a window head in the

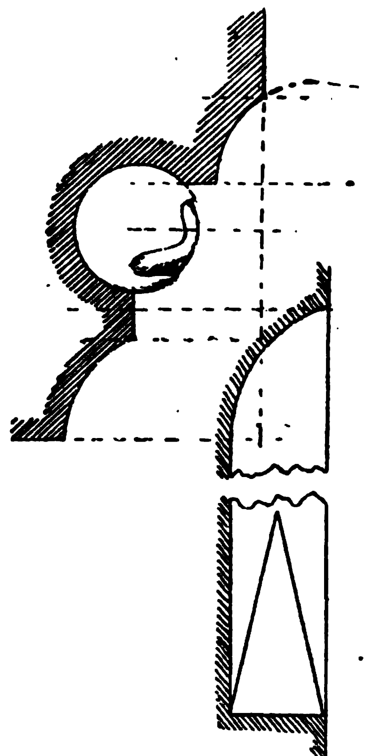


Fig. 81.

"Domestic Gothic" style, a section being given in the upper part of the figure. In fig. 87 we give a drawing showing elevation of junction of horizontal and vertical bars—to an enlarged scale—fig. 88 showing junction of upper end of vertical bar with the centre of the window head, part of which is in elevation on fig. 1, Plate III.

Fig. 89 shows the upper left-hand corner of window-head, corresponding to point *a* in fig. 1, Plate I., and the lower right-hand corner; fig. 88 is the central part of junction of the four bars; fig. 90 right- and left-hand lower and upper corners. Those diagrams to enlarged scale show how the parts are formed.

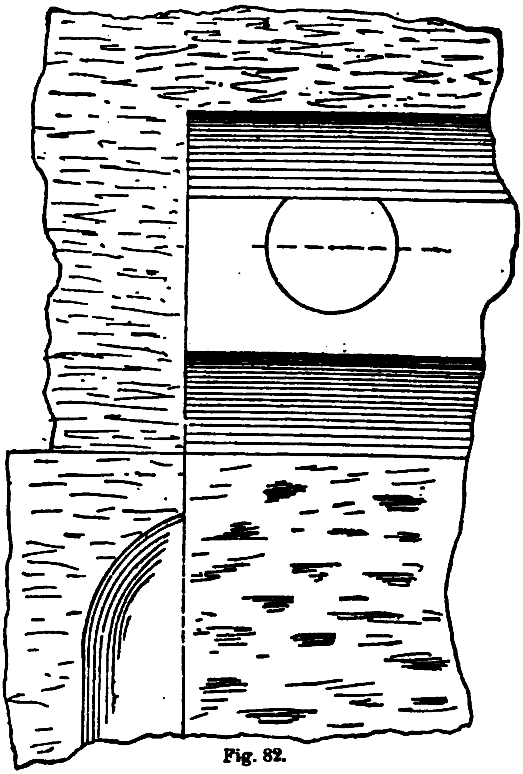


Fig. 82.

Various Forms of Stone Mullions for Windows in Gothic Style.

Figs. 90 to 97 inclusive illustrate various forms of stone window astragals or bars for dividing the void into several compartments, and separately glazed. Examples of various forms of windows, in different styles will be found in the series of supplements embracing the Styles and Types of Domestic Architecture, and those illustrating

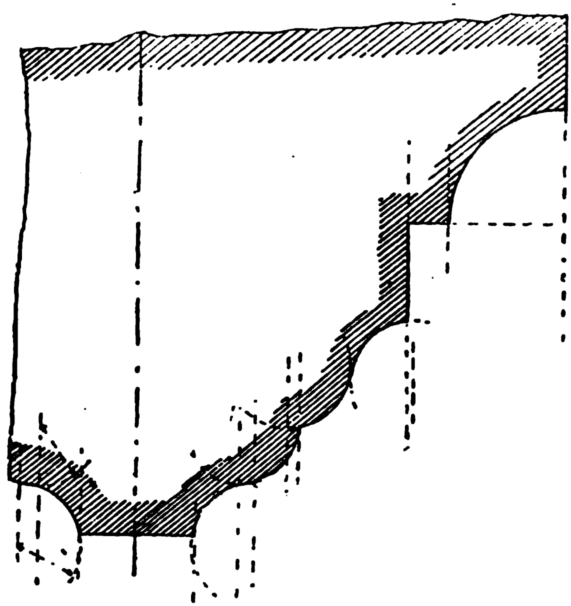


Fig. 83.

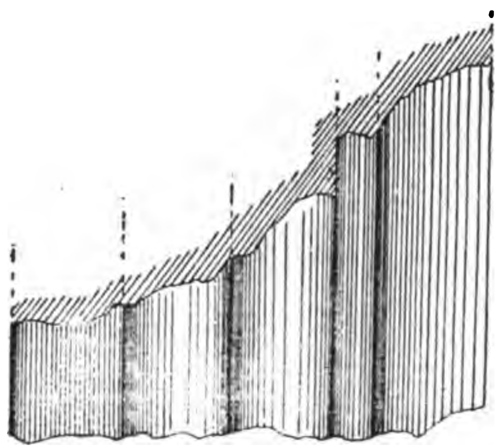


Fig. 84.

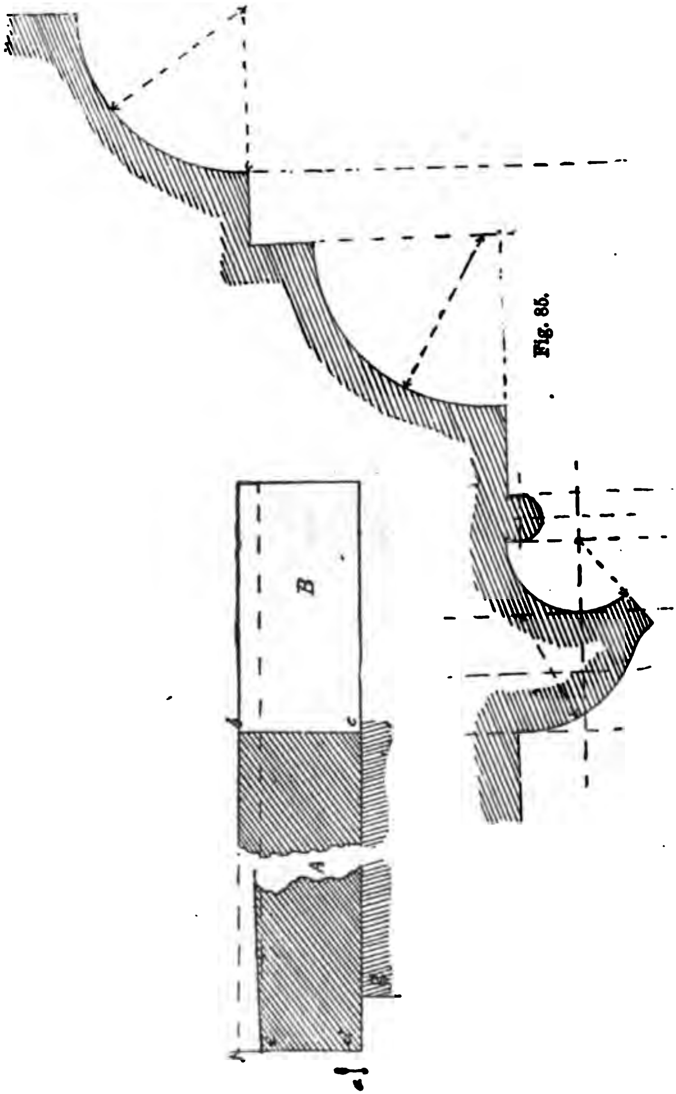


Fig. 85.

the different Styles of Architecture. Fig. 91 is elevation of upper part of a window, showing junction of the dividing astragal with side and top window dressings; fig. 92 being one of the corners—right-hand—at bottom of window, and upper at left-hand corner.

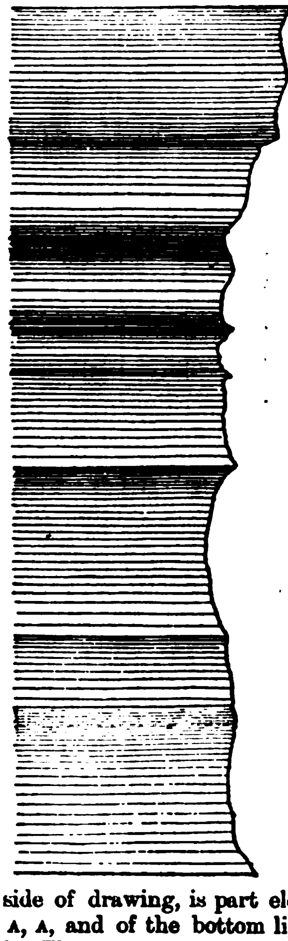


Fig. 93, to left-hand side of drawing, is part elevation showing part of the two top lights A, A, and of the bottom lights, B, B, into which the window is divided. The corners are finished as at *b*, the junction at top of vertical bar as at *e*, that of horizontal bar as at *c*, and tho junction of the two bars at *d*. The drawing to the right is a vertical section, with accented letters indicating parts corresponding in elevation. Fig. 94 shows the corner at A, the junction of the two bars in centre at B, and C the top (and bottom) of vertical bar; in another style of window divided into four lights, as in fig. 93. Fig. 95 illustrates another style of dressing stone astragals for fan-light windows,

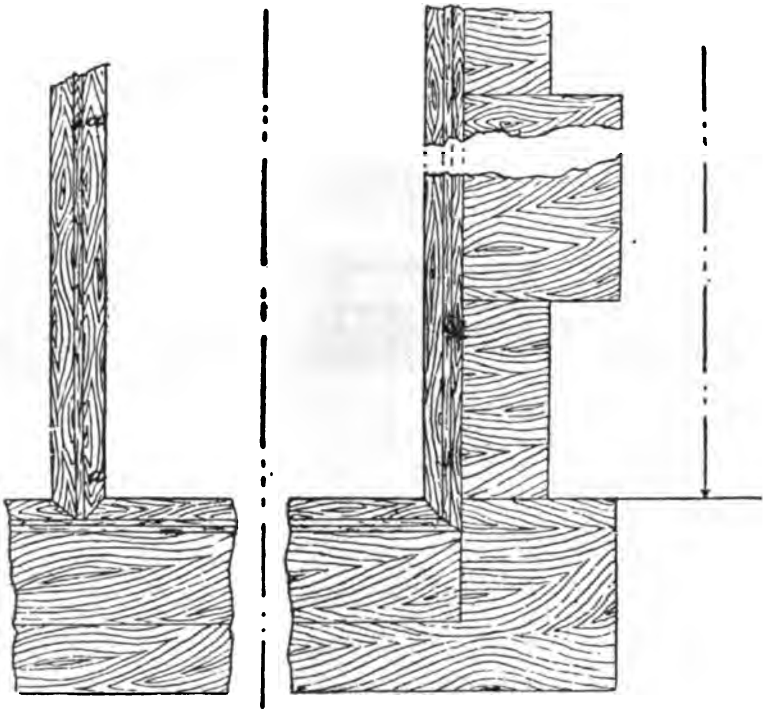


Fig. 87.

A being the junction of horizontal and vertical bars—B junction of vertical bar at top—bottom corresponding, only reversed in position. Fig. 96 gives at C the upper right-hand, and at D the lower left-hand corner. Fig. 97 illustrates another style, in which B corresponds to part of window A in fig. 95, B to part A ditto; and in fig. 98 we give upper right-hand and lower left-hand junctions of side, top, and bottom dressings.

Gables and Gable Stone Dressings.

Gables are in certain styles of domestic architecture finished off with stone dressings; figs. 99 to 104 inclusive illustrate various

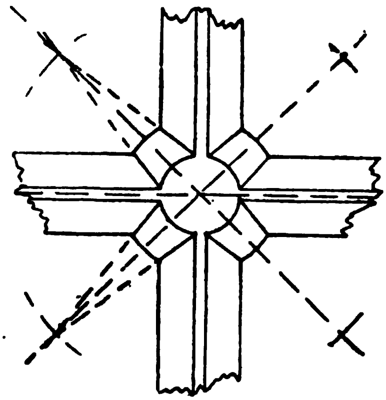


Fig. 98.

modes of forming and arranging these. In fig. 99 the drawing to the left hand is side view of gable course, that to the right front view at the point where the gable starts from the wall. The stones

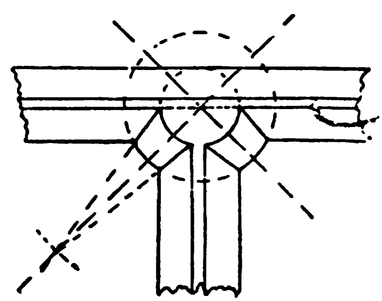


Fig. 99.

at *a′* gradually go in till they approach and reach the centre, where they are finished, meeting those of the other sloping side of gable in some such fashion as is shown in left-hand sketch in fig. 101. In fig. 5, Plate I., *a c* is elevation a foot of gable slope, *a d* side view of the gable. In fig. 99 the cornice *a* is surmounted by an ornamental vase. In fig. 100 A′ is the front elevation at foot of gable, A side ditto. In fig. 101, the sketch to the left shows elevation at lower point of the sloping side of gable; the sketch to the right, side view. Fig. 102 gives views in another style; fig. 103 front and side elevation of another style, views corresponding to those in fig. 99. Fig. 104 shows apex crowned with a "finial." Fig. 4, Plate I., shows another form of finial for a gable in the "Domestic Gothic" style, of which fig. 7 on same Plate is the springing point and cornice block at wall.

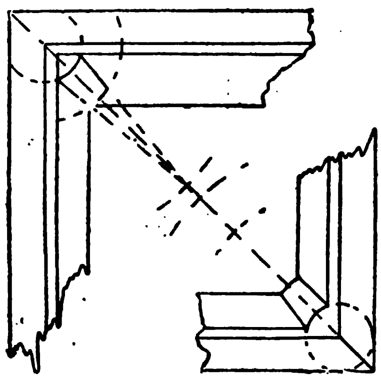


Fig. 90.

Stone Cutting.—General Remarks.

In the illustrations which have been given in the text in the various paragraphs of the present volume, and in the plates which are given under its heading, to illustrate various classes of work which are undertaken by the stone mason, the young reader will have noticed the multiplicity and variety of the forms which the stones are made to assume in order to fulfil their functions in the structure of which they form a part. The material as it leaves the quarry is, for the most part, in the condition either of more or less shapeless blocks—that is, of indefinite forms, or at the best in blocks somewhat or more regularly defined in form, chiefly rectangular, but in all cases with surfaces rough or undressed. It is only in special cases, in certain classes of important work, in which when finished by the mason for putting *in situ* or in their final place the surfaces of the stone are cut in vertical and horizontal planes, or even cylindrical, all of which surfaces are easily worked up by the

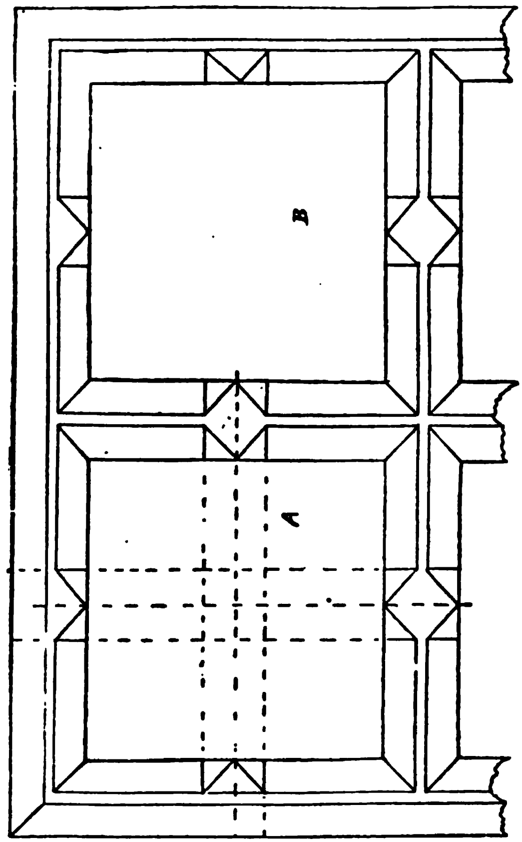


Fig. 91.

mason; also those which are spherical, spiral, winding, or conical. It is only in such cases that the stones are brought at the quarry into such a condition as to form and surface as to facilitate in great measure the succeeding work of the mason, who gives them their final shape and surface. Those blocks partially worked at the quarry having certain surfaces are said to be provided with surfaces of preparation—that is, in a condition so far prepared for the more highly finished and ultimate work of the stone mason. But with these exceptions, and in the case of very large blocks of great weight and with plane surfaces, which are almost wholly cut into form and so surface-tooled or dressed that the stone mason at the work has very little labour to bestow upon them before they are put in their final place in the structure,—all the varied forms which the young reader sees in various buildings around him, and many of which are illustrated in this volume, have to be given to the blocks which he receives from the quarry rough and undressed by the stone mason. From him, therefore, is demanded not merely manipulative skill in using his tools, in giving to the stone upon which he is at work the

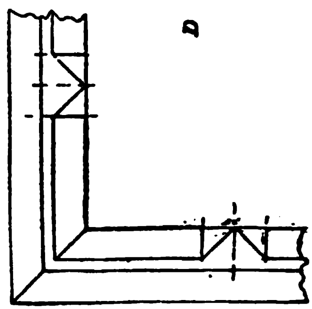


Fig. 92.

required surface and the proper shape or form, but a knowledge of the method by which the "lines" are formed straight or right or curved, which when placed in proper relation to each other give to the stone the precise form which will enable it to be fitted into its place in the building, and this with the utmost accuracy, but to have that form which in relation to the other stones gives through the medium of the whole of them that shape or contour to the building or part of the building as a whole to which a distinctive name is given—as an arch, a vault, a dome, or a groin. If the young reader will stand under a groined vault he will perceive the different shapes the stones assume, and how regularly and accurately they fall into their places, leaving no vacant spaces to be filled up in a makeshift way. And if he will further consider that this groined vault in its dimensions and form must have existed originally in the mind of the mason who designed and constructed it, must have been only what is called a scheme or contemplated structure, and that as a consequence he must have had some method by which he could give to his scheme its due proportions, and by which he could decide not only upon the number of the stones which he would require to give to the structure its completed form, but also know the necessary shape or form the stone was to have in order that it could be fitted

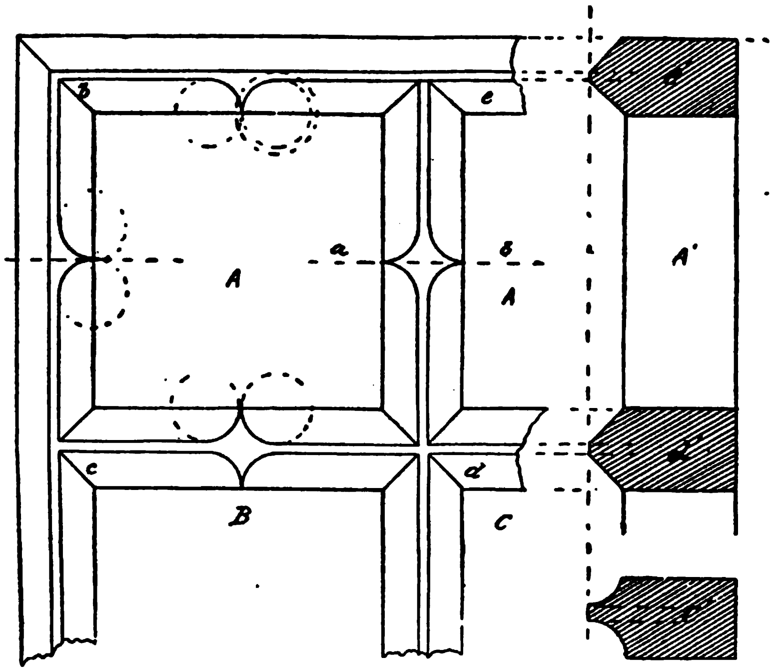


Fig. 93.

with precision and accuracy. In other words, the stone mason in such a work would obviously require to have a knowledge of a plan or method of defining the forms, or of what is technically called setting out the lines of his work. And if the young reader will think over it, he will perceive that this operation will be of a somewhat complicated and diverse character, keeping in mind the various shapes which buildings assume. The problems to be solved by the

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mason are not, however, so numerous or so complicated as the young reader might at first view of the subject be inclined to conclude; inasmuch as all the forms of structures, endless as they appear to be, are reducible to certain elementary or primary forms—such as the prism, the pyramid, the cylinder, the cone, the sphere. Those bodies known as the geometrical solids have their surfaces made up of lines either straight or curved; and it is the relation of these to

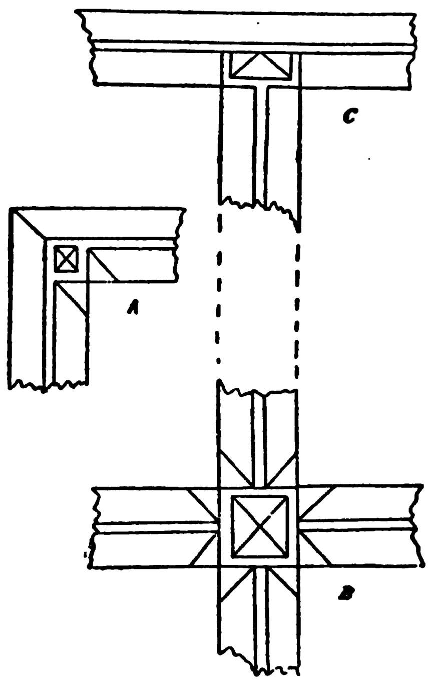


Fig. 94.

one another which constitute the forms of the bodies and give rise to methods of delineating them on flat surfaces, such as a floor—technically termed a drawing floor, a board, or a sheet of paper—and which methods are comprised under the general term of "Projections." What this is in its general principles, and in many of its details as applied to the practical work of the machinist, the stone mason, and the carpenter, will be found in the companion volume entitled "The Building and Machine Draughtsman." The projections made showing subjects in plan, elevation and section, and the lines set out by which the forms of bodies can be given, are known generally as working drawings, the special parts being known as details, the problems upon which the operations are based in pro-

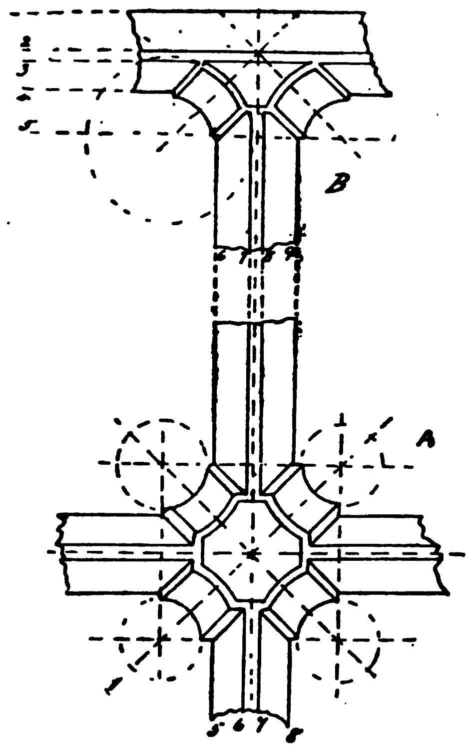


Fig. 95.

ducing the drawings being classed chiefly under the heads of the sections and intersections of solids and the development of surfaces, the principles of all of which are explained in the volume above referred to. The branch of technical science in which these various problems are applied to the practical finding of the dimensions and forms of stones used in buildings of various kinds is designated the science or the art of stone cutting. This term has, however, a less extended and in a scientific sense a lower meaning, inasmuch as it refers also to the purely manual labour involved in the use of cutting tools by which the surfaces of stones are prepared and parts cut away so as to give the form desired. Stone cutting, therefore, divides itself into two branches of work—first the higher, in which by the application of the more advanced problems of practical geometry the forms themselves of the stones are ascertained and projected in full size or in lesser scale drawings, and which enables "rules" and

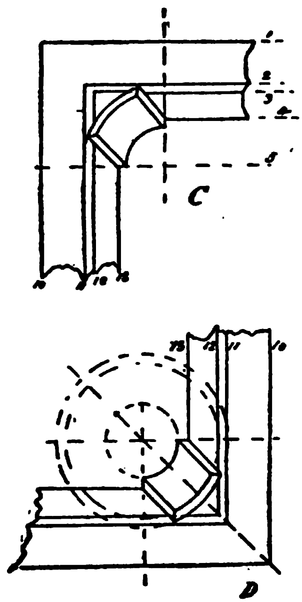


Fig. 96.

"templates" to be made which serve as guides to the mason when he uses the tools by which in the second and lower branch of the art of stone cutting the definite slopes required are cut out of or are given to the rough blocks viewed from the quarry. We have called these two branches of the art of stone cutting the higher and the lower; and this division is justified by the facts of practice, inasmuch as a workman may have such a ready skill in handling and applying his tools that he may give to a block of stone a form or shape which is pointed out to him or given to him as a model or guide, and which is made up of certain lines placed in relation to each other,

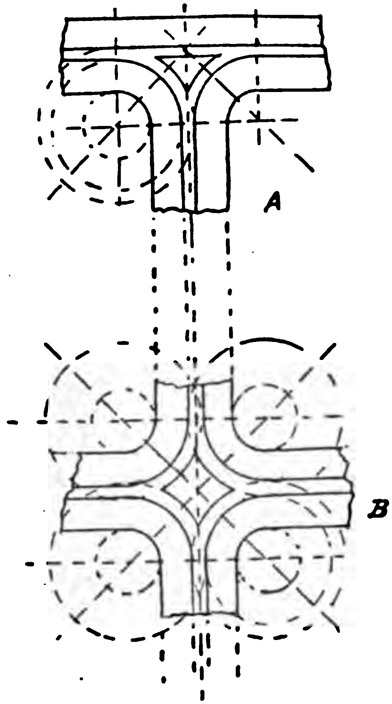


Fig. 97.

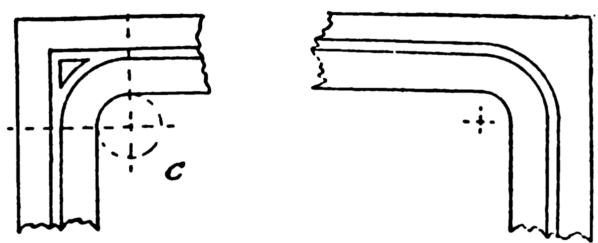


Fig. 98.

and while doing this cutting skilfully, quickly, and in a workmanlike manner, may yet be in absolute ignorance of how these lines are

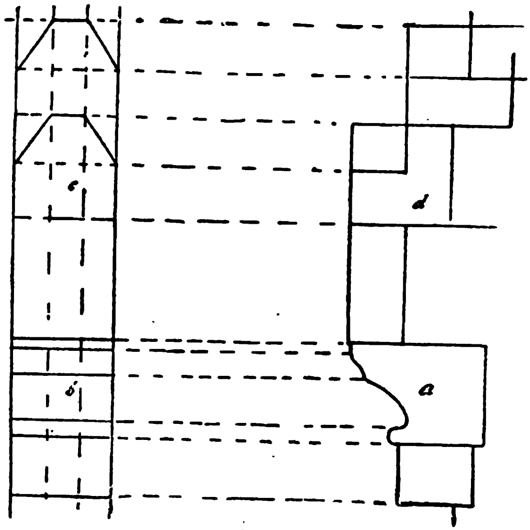


Fig. 99.

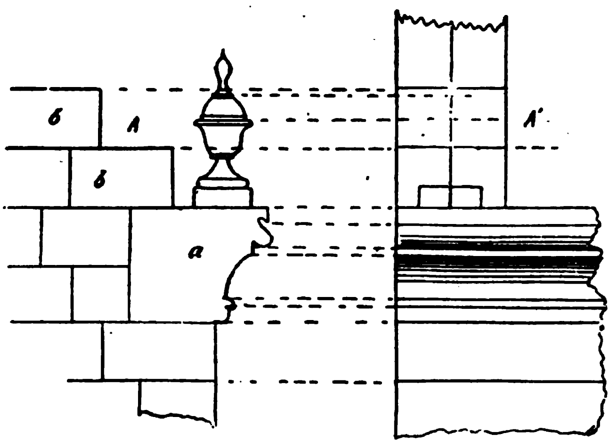


Fig. 100.

obtained, the principles of the science or even the name of the science or that branch of it upon which the methods of obtaining the lines were based. And this just as a worker in metal will construct an iron bridge who is in complete ignorance of why certain

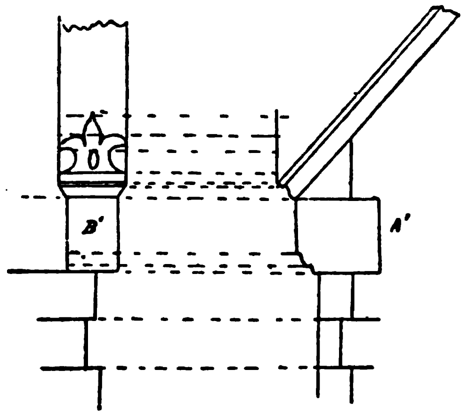


Fig. 101.

parts were given certain forms or sections, and are placed in certain positions, and how it is that so great a strength can be obtained from so little material. The mason is alone entitled to the name

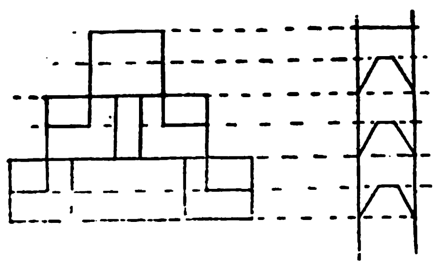


Fig. 102.

of stone cutter who not only knows how to cut—that is, to tool and dress the stone into shape or form—but knows how to give it that form by laying down certain lines, and knows why those are the lines which are to be employed. From what has been said, the young reader will be able to understand how complicated—certainly how wide—a subject the art or science of stone cutting is; a large treatise might indeed be prepared without exhausting its details. We are obviously precluded, therefore, from going into anything like even a brief statement of the details of the art, and this if for no other reason than the lack of space in our pages. While naming this, it is only right further to state that a fairly full exposition of the principles, and in a few instances practical exemplification of the application of those principles upon which the working drawings of

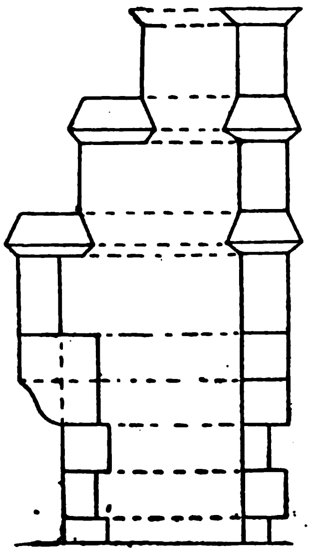


Fig. 103.

Fig. 104.

the mason are made, has been already given in the volume entitled "The Building and Machine Draughtsman," which should be studied in connection with the companion volume entitled "The Geometrical Draughtsman." The methods by which drawings are made of those purely ornamental parts of stonework the formation of which in the actual stone constitutes the work of that other department of stone cutting, to which as a special branch the distinctive name of stone carving or sculpture is given, will be found in the volume entitled "The Ornamental Draughtsman." By the careful study of these three volumes, and by a further extension of this study through the medium of special volumes giving exhaustive treatment of the subjects, the young reader should be able to apply the principles of all the leading problems to the practice of stone cutting, applying the term in its highest sense as possessing and applying not merely the manipulative scale in handling the tools and appliances in giving shape and form to the stones employed, but a knowledge of the principles and problems by which those forms are obtainable.

The simplest form which a stone block assumes is that in which the upper and lower surfaces take the geometrical form known as a square, in which all the sides are equal, or a parallelogram—*i.e.*, a rectangle, in which the sides are of greater length than the ends. These upper and lower surfaces form what are known as the "beds" of the stone—that is, the lower surface upon which the stone rests on the stone in the "course" below, and the upper surface forming in turn the bed upon which the lower surface of the stone in the next or succeeding upper course rests. As the upper courses in a wall or building are all "dead level," so that the vertical face of the wall formed by the imposition of courses of stones one upon another must be vertical or purely "plumb," it follows that the upper and lower surfaces of the square or rectangular stone must be perfectly parallel to each other, and the surface of each "bed" or plane be level throughout. But the block as it comes from quarry may not—as a rule does not—possess those necessary features; they must therefore be given to it by the stone cutter. Laying the block of stone firmly, so that its surfaces can be easily got at, the mason makes with his mallet and chisel a narrow riband-like cutting or channel, termed a "draught," say at one end, as *w v*, fig. 105, of the upper surface of the block. This forms a margin, so to call it, free at the outer end of the stone; but at the inner side, next the body of the stone, it has a wall, so to call it, or edge, of a height equal to the depth to which the "draught" has been made. To borrow a term from the sister art of Joinery, the mason has formed a "rebate" at one end of the stone, as at *a′ a′*, fig. 87. The breadth of this may be some three-fourths of an inch or so, according to the notion of the mason. It is obvious that the bed or face of this draught must be in one plane from end to end; it must not bulge up in the centre, or at any part of its length, so that when a straight-edge is placed upon it, it will "ride" or wobble; neither must it be hollow, showing a vacant space below the straight-edge; but when the straight-edge is placed no the surface of the draught it must rub equally over the whole length, so that if the edge of the straight-edge were rubbed over with red lead, the red-lead mark would be seen over the whole extent of the draught surface. The mason has thus got one plane or flat level surface. At the opposite end of the stone, as *x y*, he now cuts a second and similar draught, working it to a true plane surface. Between the two draughts the surface of the

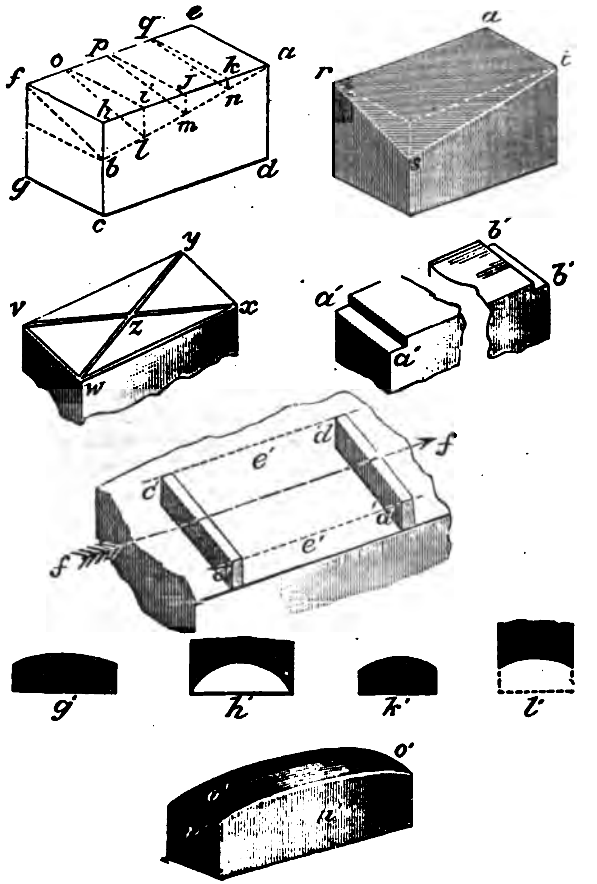


Fig. 105.

stone lies rough and uneven, just as it comes from the quarry. By cutting away this rough part he would obviously join the two end draughts and the surface or plane of the whole would obviously depend for its condition of level in relation to the general block upon the circumstance that the depth of the two end draughts (or rebates) was precisely the same. But if this was different, and the left-hand end draught was half an inch deep from the general surface line of stone, which we presume to have been set firmly, so as to be on the whole fairly level, while the right-hand was only one-fourth of an inch deep—and if these, the two draughts surfaces were joined by cutting away the rough stone between them, forming this into a plane surface—this surface would not be a level one, but would slope from the right hand to the left, being deepest at this point. But in order to work the block of stone to a true surface, it is necessary that those two draughts shall be what is technically called "out of

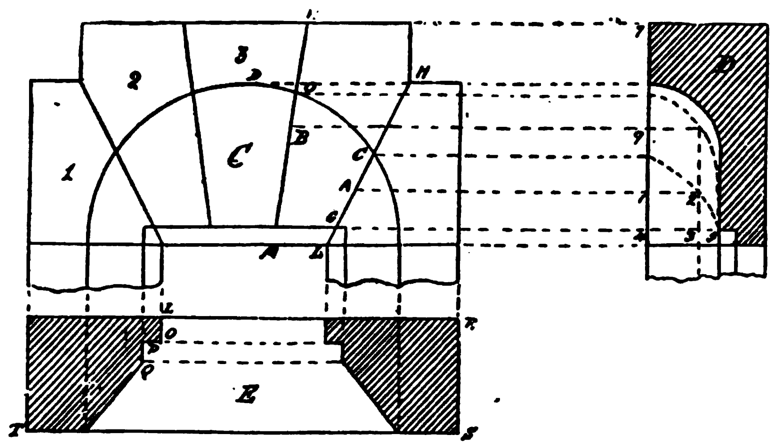


Fig. 106.

winding." This practically means that the surfaces of the two draughts shall be coincident on the same level plane. This is ascertained as follows. Two parallel-faced straight-edges, as *c' c'*, *d' d'*, fig. 105, are taken of precisely the same width or breadth; one of these is laid on edge in each of the draughts, and when so placed the workman looks in the direction at right angles to the length of the straight-edges, or of the ends of the stones, as in direction of arrow *f' f'*, fig. 105; and if the upper edge of the straight-edge nearest his eye coincides with the same line of surface as the edge of straight-edge farthest off, then the surfaces (or floors, as they might be called) of the two draughts are on the same plane or on the same level. If the draught, as *d' d'*, farthest off were below the level of the nearest one, then the eye would show the upper edge of the farthest-off straight-edge as below the surface of edge of the straight-edge nearest to the eye; if the converse, then the line of nearest straight-edge would strike, as it were, part of the side of farthest-off straight-edge. Draughts are then made along the sides, as *v y*, *w x*, of the block on the same level as the end draughts,

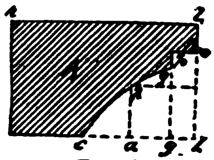


Fig. 107.

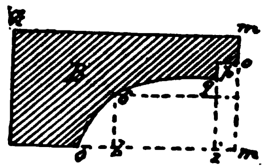


Fig. 108.

and when made they are tested in the above-named manner to see that they are "out of winding." Four draughts will thus be made, inclosing the central part of block in its rough condition, the protuberances of which are cut or chipped or tooled off over the whole surface, including the draughts-surfaces. In a small stone the two end draughts will be sufficient. If the shape of the stone is exactly

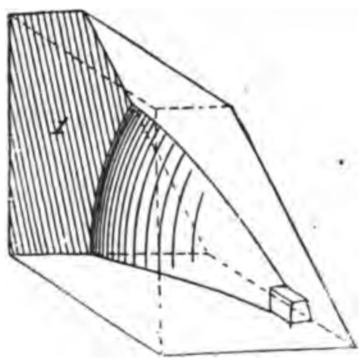


Fig. 109.

a rectangle, then in cutting the draughts, end and side ones, the square must be appied to make the sides and ends of the rectangular block at right angles to each other, the lines bounding the block having been previously marked off on the upper surface of the stone. If the shape of face of stone be angular at any part, this angular line will be marked off accurately by the block square, or by a template cut in the desired angle or form.

One face being accurately obtained with a true level plane, and of the outline desired, the other faces of the block are formed and worked in the same way; and, assuming it to be a prism, the sides and ends must be square or at right angles to each other and to the upper and lower beds. In forming the face of a large stone to a true plane or flat surface, the following is a method adopted. Two draughts are cut, as above described, along at one end, as *v w*, and one side, *w x*, fig. 105, of the block; those, assuming the form of the face or bed to be a parallelogram, must be at right angles to each other, this being set out by the square. Joining the two outer ends of these two draughts, a third draught, as *w y*, is cut in face

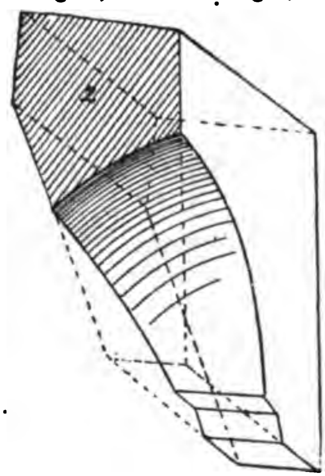


Fig. 110.

of stone, forming a diagonal to the parallelogram, and the face of the stone into two triangles, the base of each of which is equal to the length of side, *w x*, and the perpendicular equal to length of end, *y x*, of block. Next cut a second diagonal, as *v x*, intersecting the first in a point which is the centre of the block, and forming its surface into four triangles, the apices of which meet in this central point, but if the rough or protuberant parts of the stone represented by these triangles be cut or tooled away, so that every part of the surface is coincident with the surfaces of the two draughts—end and side—first cut, the surface will thus be a true plane, and its formation depends upon the fact that all these three sides of a triangle lie in the same plane. To prevent the edges of the stone chipping off when only one end and one side draught is cut, it is better to cut an outside draught all round the stone in the first

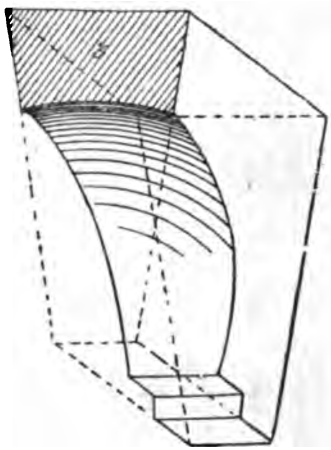


Fig. 111.

instance. When a stone has one surface or, say, its upper face not

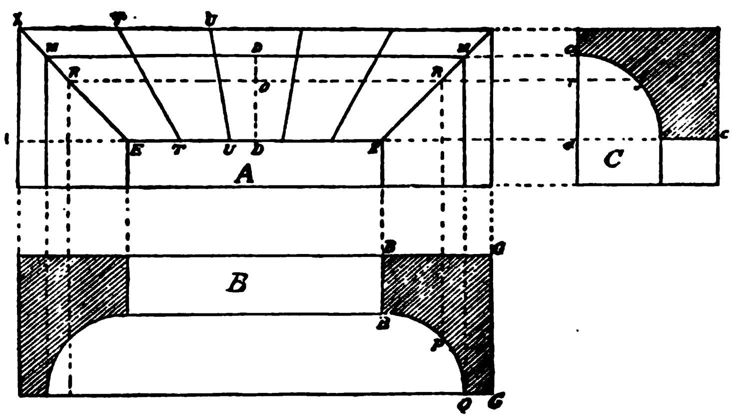


Fig. 112.

parallel to its lower face or bed, but placed at an angle, so that it slopes from the one corner or farthest end of one side to a point a certain height from the base at the nearest corner, and slopes also from this point to the corner at the outer termination of the nearest end line, the surface thus formed is said to be a "winding surface." In this, as here described, it will be perceived that the slope is a double one: it slopes from the corner *a*, fig. 105, to point *b* in side view, *a b c d*, of block, and from corner *e* to point *b* and from corner *f* to point *b* in end view, *f b c g*. The points *a*, *e*, and *f*, are of equal height, this being equal to the thickness or depth of block. The height of point *b* is equal to the amount of "winding," and after the

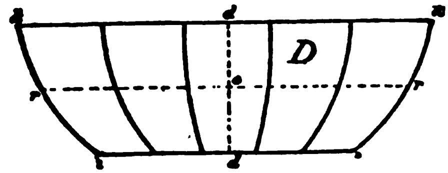


Fig. 113.

block is worked to a true surface by draughts, as already explained, and all the sides tooled and worked square to each other, the height of winding point *b* is set off from *a* to *b*, and *b f*, *b a*, drawn as shown. The side *h a* is next to be subdivided into any convenient number of parts, as at *i j k*, and from these points lines as *i o*, *j p*, *k q*, are drawn parallel to *f h* or *e a*, and other lines, as *o i*, *p m*, *q n*, drawn parallel to *f b*; then *o i*, *p m*, *q n*, are the draught lines which, when the parts between are cut down to, will give the "winding surface" *r s t u*. In same figure is shown a stone cut to a spherical surface,

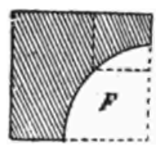


Fig. 114.

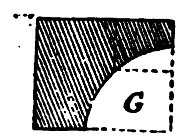


Fig. 115.

of which *h'*, *l'*, are the curved rules or templates used in giving the desired shape. From these illustrations the young reader will see how the surfaces of stones are cut, the manner of finding the forms will be explained, as already stated, in the problems described in the volume entitled "The Building and Machine Draughtsman." The principal part of what may be called the higher class of masonry lies in the construction of arches, vaults, etc., etc.; and as affording practically suggestive illustrations bearing on the subject, we give here various diagrams showing the forms of stones and the lines by which they are obtained for different kinds of arches, niches, etc. For these we are indebted to an able Continental work on the art of stone cutting.

In figs. 106 to 108, we give diagrams illustrating a semicircular

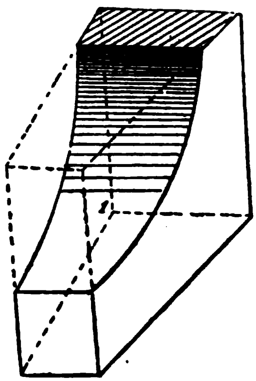


Fig. 116.

archway or door made in a wall. Given the elevation C, fig. 106, and the plan E, we construct the section D, by drawing from the points K, H, D, O, C, B, A, G, I, M, L, lines parallel to the base, and by taking 3 6 parallel to 4 7, so that 3 5 is the quarter of 5 4. We

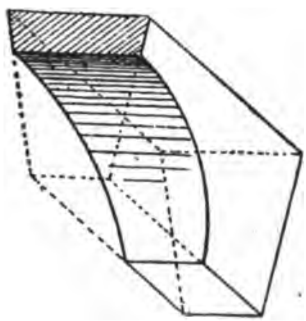


Fig. 117.

might take 3 5 in any other connection with 4 5, but, in whatever way it is taken, we must fix upon one, and the latter seems suitable for finding the splaying in an almost imperceptible manner by supposing besides G A the half of G C, and B O the quarter of I O. From these hypotheses we construct the faces of joint A, fig. 107, and B, fig. 108, by taking K S for the widths, and L H and M K for the lengths,

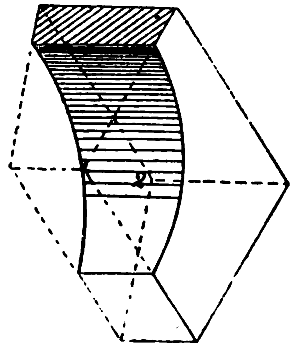


Fig. 118.

l g equal to L G, *g c* to G C, and *g a* equal to G A—that is to say, the

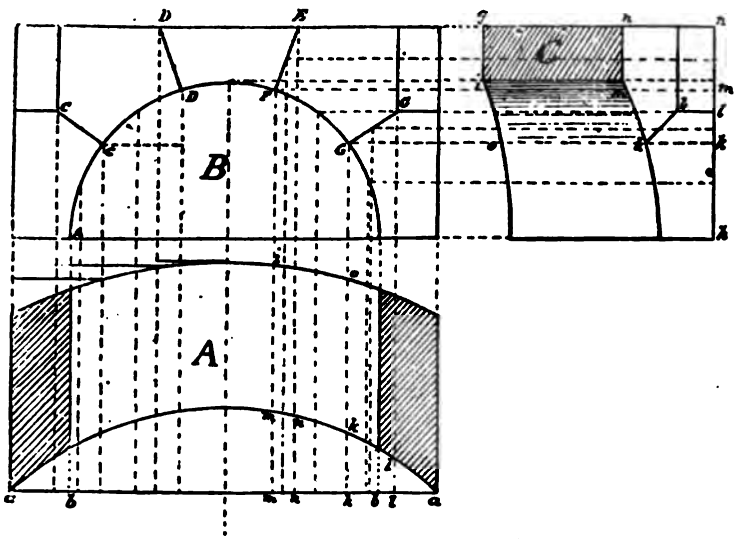


Fig. 119.

half of *g c* or of G C. From the point *a* we raise the perpendicular *a* 2 equal to 1 2, and those, *g q*, *g p*, *l o*, *l l*, will be made, equal to the distances of the points Q, P, O, L, to the line T T of the plan. Next draw the horizontal *p o*, and the point 2 will be the third point through which should pass the curve *q* 2 *c*. Draw the joint B, fig. 108, in the same way, by observing that *o b* is the quarter of *o i*, and

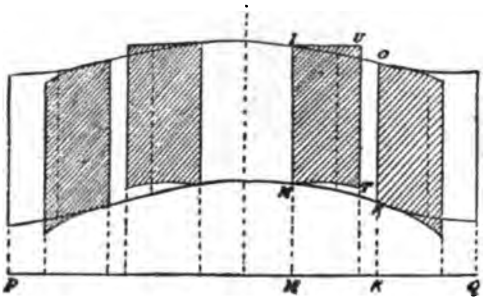


Fig. 120.

the perpendicular *b* 6 will be equal to 9 6 of the section. As to the rest, it is the same as for block A; and figs. 109 to 111 show the arch-stones or voussoirs projected.

In figs. 112 to 118 inclusive we give drawings of a door, with

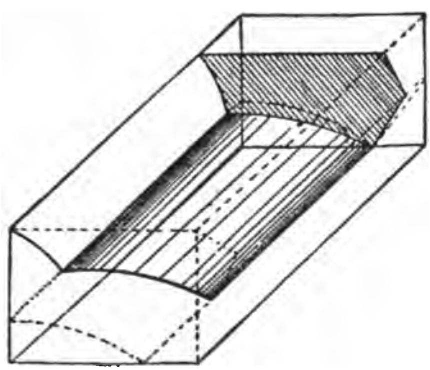


Fig. 121.

detailed views of the stones forming the splayed jambs of the door. The elevation in A, fig. 112, gives as radius of the quarter of circle *a f c* of the section C in same figure, the line D O D, equal to *a r a*; *c c* should be equal to B B, and the total width to *c c* equal to G G. As to the development D, fig. 113, of the intrados of arch-stones, it is clear that the lines *i i*, *r r*, *h h*, should be equal to those E E, R R, M M, of the elevation; the height *d o d* of the development is equal to the

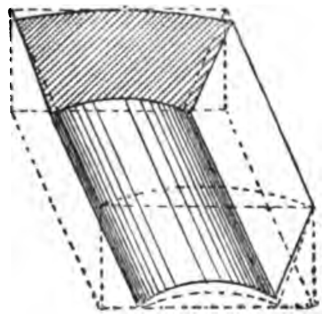


Fig. 122.

arc, *c f a*, of the section. The line P R, which gives the position of *r o r*, being raised through the middle of the arc B P Q, it follows that the line *o r* should be equal to the line O R. To have a third point

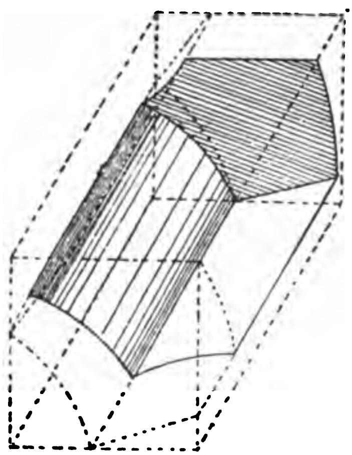


Fig. 123.

of each curved side of the intrados of the arch-stones we divide the line *r o r* into five equal parts. The joints U U, T T, E X, are larger in proportion as they are more inclined. G G is the width of all, E is the joint E X, F the joint T T, and G the joint U U. To draw the joint E we make *c c* equal to the radius *a c* of the section; *r f* equal to the line R F, *c x* equal to E X, *c m* to E M, and *c r* to E R; through the points *c*, *f*, *m*, we pass a curve, which will be that which the joint should have. Next draw the joints F, G, in the same manner. Much stone is saved by hollowing the arches only after having given them

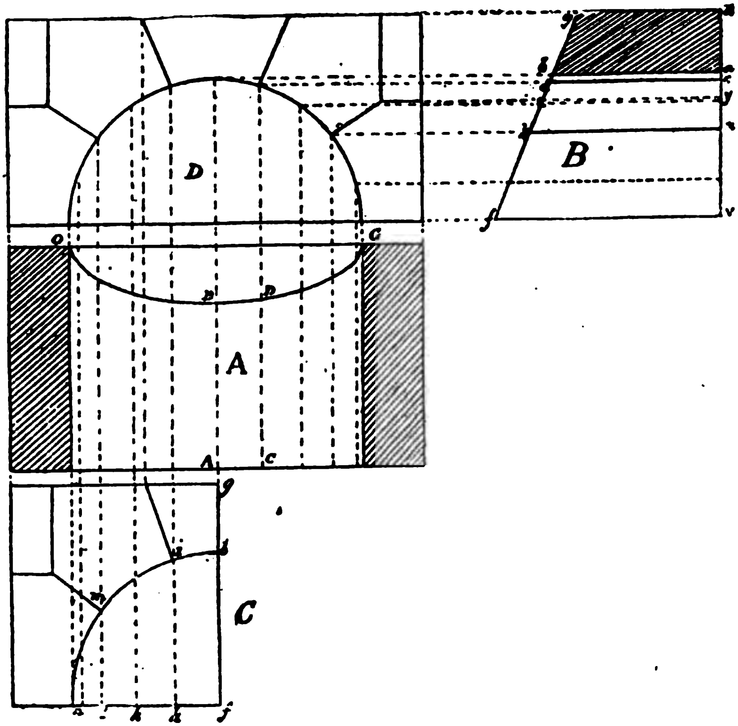


Fig. 124.

a first dressing, according to which the head blocks would be those of the elevation—viz., E T T X, U U T T, etc.; otherwise we should require, for the first on the left, stones of the height of V X, and of a width equal to V T, and so on. In every case we apply the joints to the arch-stones already prepared by the first dressing, according to which we should make the hollow. Figs. 116, 117, and 118 are projections of the stones.

In figs. 119 to 123 inclusive we give the drawings of a semicircular-headed door in a curved or circular wall, in which the plans of the piers are parallel to the radii of the wall, as in fig. 120. The diameter *b b*, and the width *a b*, of the piers having been determined, we make the elevation B, fig. 119, as if the wall were a straight plan. Through

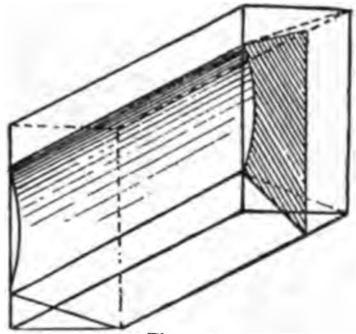


Fig. 125.

the ends C C, D D, F F, G G, of the joints, and through the middle of the arch stones, we lead perpendiculars to *a a* in the plan A, fig. 119, and to *h n* in the section C. On the parallels to *h n g* we make the parts *h h*, *h o*, *l l*, *m m*, *m i*, *n n*, *n g*, equal to the distances of the

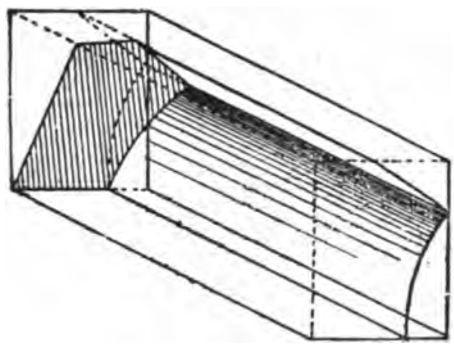


Fig. 126.

points *h*, *o*, *l*, *m*, *i*, *n*, 10, to the line *a a*; the other points of the section will be found by the same method. The lines *h l*, *m n*, of the joints of the section C are not quite straight; we have their curve by leading from the points 8 and 4 of the elevation perpendiculars to *a a* and to *h n*, and by making on the latter parts equal to those which correspond with them in the plan. For the development of the arch-stone, and in order to find the joints, having made P Q equal to five times A C, upon the perpendiculars to P Q we will make, as

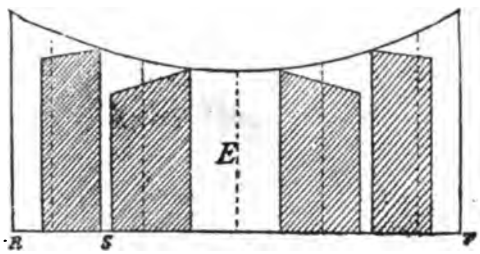


Fig. 127.

we see for M M K K, M I, K O, parts equal to *m m*, *k k*, *m i*, *k o*, of the plan A, fig. 121, which will give the means of drawing the two curves between which the lines of the arch-stones are comprised. We know

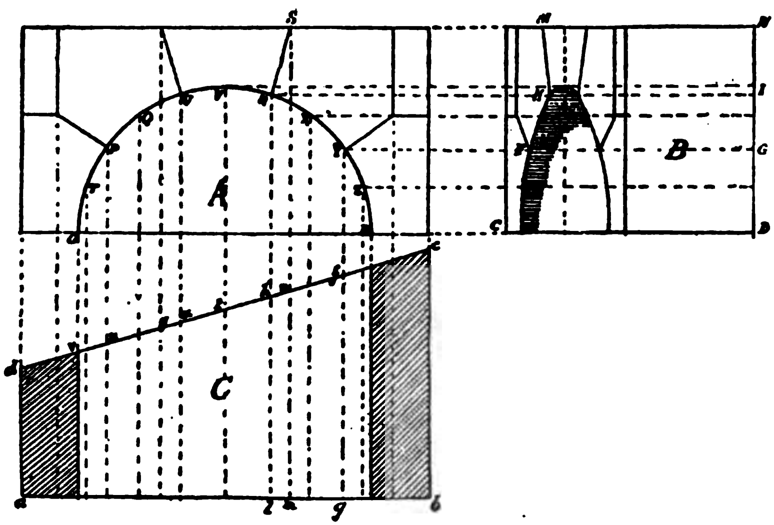


Fig. 128.

that the widths of the joints are C C, D D, F F, G G. M T is a curved line, of which *m n* is the section, and the drawing of whose curves we are about to explain. The length of the stones for the arch-stones will be taken upon the section C, fig. 119, equal to *h o*, *i i*, *n g*. We take them also upon the point A, equal to the difference of the distance from the nearest and farthest point of each projected arch-stone to the line *a a*. The arch-stones will be first made as for a straight opening; the joints, the stones, and the courses, placed upon the plans will determine the lines according to which we should

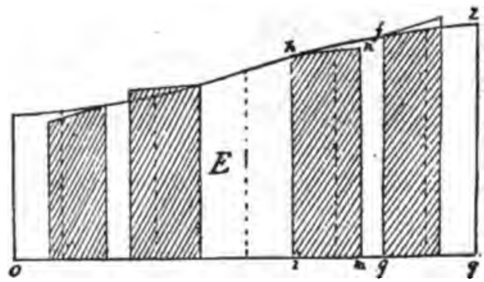


Fig. 129.

desire to build at each end. The key-stones being convex and concave portions of a cylinder, we draw them by taking their height upon the elevation, and their width on the plan. We require three widths for each panel: thus, for the crown we take the projections of the lines D D, E F, fig. 119. Care must be taken that the thickness of the wall, in proportion to the radius of the curve and to that of

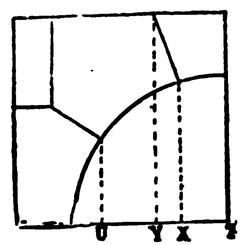


Fig. 130.

the door, is such that the crown may not project beyond the piers The piers, which should be as large within as without, would be less solid than if their sides were directed to the centre of the circular building. We might, however, remedy this by placing beside the piers, stones, the second perpendicular joint of which would be directed to the centre of the tower; but this precaution is not necessary when the opening of the door is very small in proportion to the radius of the building. Fig. 122 is projection of key-stone D D, E F,

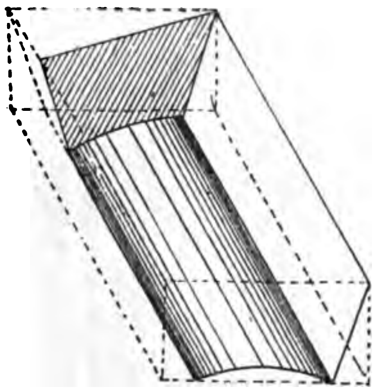


Fig. 131.

in fig. 119; fig. 123 of stone D D, *e e*, and fig. 121 of lowest stone, *a a* in fig. 119.

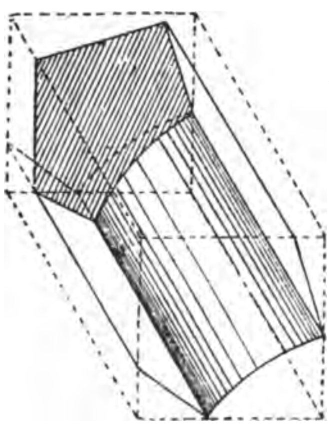


Fig. 132.

In figs. 124 to 127 inclusive we give elevation, plan, section, and details of a semicircular arch in a wall, with a sloping front or surface, as at *f g* in fig. 124. In this the width of opening is less at the upper than at the lower part, as shown in section, as at B, in fig. 124, at *b a*. From this section the plan, as in A, same figure, is drawn, with the curve A B D G, which is the projection of the curve of the opening in wall in front of the sloping side, and in which plan, A A, we have the lines A B, C D, corresponding to lines *a b*, *c d*, in B, the section.

The same section serves to find the curve and the head-panels of the side of the slope by making on elevation C, fig. 124, the lines *f b*, *h i*, *l m*, equal to *f b*, *f g*, *f d*, *f h* of the section B; *f b* is equal to the radius of the semicircle of the elevation D, fig. 124, the inclined front being higher, but of the same width as the straight front.

For the arch stones we take the half of *r s* upon the elevation D, which we will carry ten times, or *r s*, which we will carry five times

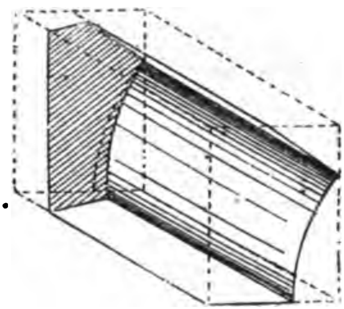


Fig. 188.

from R to T, upon the plan A, fig. 124. The length of each side of the stones will be taken between the curve O B D G and the straight line 10 11; the sides 4 5, 6 7, of the joints will be made equal to *x g*, *y z* of the section. The lines 7 13, 5 14 are straight, because they are the intersections of two straight plans. The lengths of the stones for the arch-stones will be *v f*, *u h*, *c d*, lengths of the largest angles of the arch-stones. Make them at first as for a straight door; then apply to them the joints, according to the sides on which draw the lines which will mark what is to be cut off. We might also, as we see on the second arch-stone, make the angles 8 9, 8 9, etc., equal to the corresponding distances *m h*, *y z*, *c d*, *x g* of the section B, fig. 124. We can verify the heads by the squares taken upon the plan C. Fig. 125 is projection of keystone in D, fig. 124; fig. 126 projection of lower or pier stone in same figure.

Fig. 127 is the projection of fig. 124, corresponding to fig. 120 of fig. 119, *ante*.

In figs. 128 to 133 inclusive we give drawings of an opening with semicircular arch made in a wall, the front of which is on the skew, and the plan of it is a trapezium *a b c d*, as shown at C in fig. 128.

To draw the section B lead through the points of division O T P Q U V R X Y Z B of the arch curve of the elevation A, fig. 128, perpendiculars and parallels to its base, which we prolong to the line N D

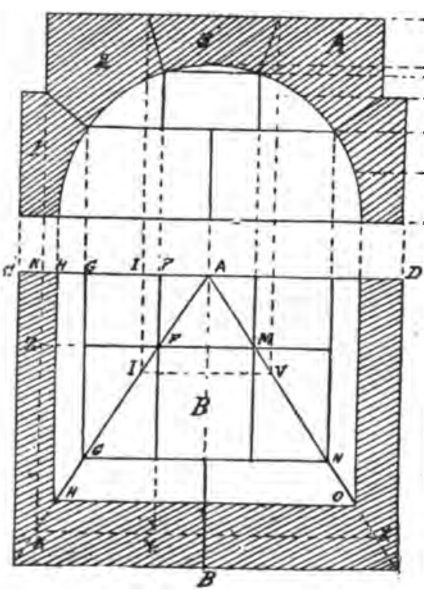


Fig. 134.

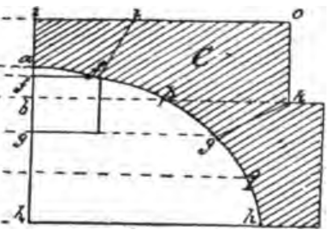


Fig. 135.

of the section B, and to the line *a b* of the plan C; then make on the parallels distances like D O, G F, I H, N M, etc., equal to the parts *b c*, *g f*, *i h*, *m n*, etc. The line *o q* of the plan E, fig. 129, is equal to five times O P of the elevation. The perpendculars to *o q*, such as *i h*, *m n*, *g f*, are equal to the marked lines of the same letters on the plan C, fig. 128. The line *y f h* 13, which terminates the stone, is curved; but all the sides of the joints are straight lines. The width of the joints is given on the elevation: thus, *i m* of the plan E, fig. 129, is equal to R S of the elevation, fig. 128. To have the heads and the curves of the oblique front, we make on the plan D, fig. 130, T X, T Y, T U, T V, equal to the lines *t x*, *t y*, *t u*, *t v*, in the plan C, fig. 128; from the points T, X, Y, U, V, we raise upon T V perpendiculars equal to the lines which correspond to them in the elevation A, fig. 128. The length of the stone for an arch-stone will be equal to the

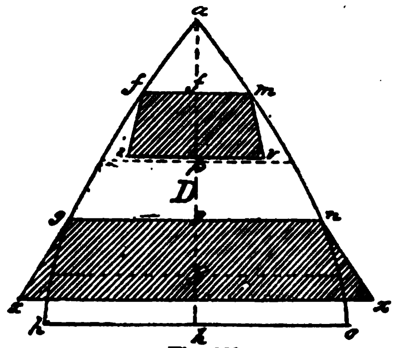


Fig. 136.

largest angle of this arch-stone; *u* 4, *x* 5, *n m* are the lengths of the stones for the three first arch-stones to the left. Having cut these stones as for a straight door, we apply to it the joints, according to which we will draw the inclined part which should be taken away. Fig. 131 is projection of centre or keystone in A, fig. 128; fig. 132

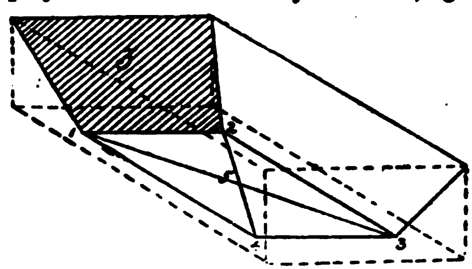


Fig. 137.

projection of second voussoir or arch-stone next keystone, and fig. 133 projection of lowest or pier arch-stone.

In figs. 134 to 139 we give drawings of another arch, in which A, fig. 134, is the front elevation, B half only of the plan and half only of the section; this arch is termed a cloister-arch on the Continent.

We draw the curve *afgh* from the section C, fig. 135, by making *ff*, *gg*, *hh* equal to F F, G G, H H of the plan B; the lines *ii*, *kk*, which correspond to the height of the joints, are equal to I I, K K of

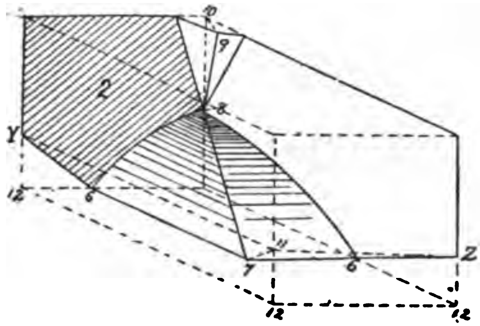


Fig. 188.

the plan B, fig. 134. Plan D, in fig. 136, shows the intrados or inner curve of the arch, and the joints of the side of the surbased arch;

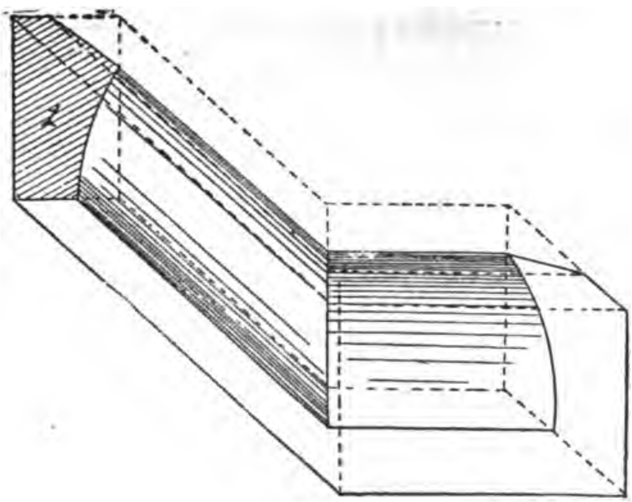


Fig. 189.

ah is equal to the development of the arc *afpgqh*, divided into five parts, not exactly of the same size, but to the points *f*, *p*, *g*, *q*. The lines F M, G N, H O, of the plan B, fig. 134, are carried upon the plan D, fig. 136, marked with the same letters, which gives the means of describing the curves *afgh*, *amno*. *fi* and *gk* are the widths and the joints; I V, X X are the largest sides of it; *fi* and *gx* are the straight lines, because each side of the arch may be regarded as an inclined door. The crown is a kind of truncated pyramid, which will have below F M for the width, and twice F F for length; above, it will have I for width and twice I I for length. The lines 1 2, 2 3, 3 4, 4 1 are straight. In diagram fig. 137, point 5, in the middle, is the joining of the four sides of the arch-stone, or the bottom of the hollowed part, the depth of which is given by *fa* of the section C, fig. 135.

We have supposed the most difficult case—namely, that the arch-stones belong to two contiguous sides of arches. In this supposition the second arch-stone has for length K K, and for width Z F. Upon a stone cut with these dimensions the panel of the joint 2 is cut from the section A, fig. 134, on its width, and on the length the panel *ifgho* from the section C, fig. 135; we then draw parallels, according to which we must cut away the stone and make the hollow for the arch. The arc 7 8, fig. 136, is the meeting of the curved part of each side. We cut away above the small pyramid, of which 9 10 is the diagonal of the base, and below all the space comprised between *z*, 11, *y*, 12, 12, 12, 6, 7, 6. The first arch-stone is made by the same method. We have supposed bases which may be regarded as compounds of two plans, longer on one side than another, in order to show by this example how to proceed in similar cases.

Having in the preceding paragraphs described and illustrated the various methods used in the "setting of stones" so as to form the various structures demanded from the mason, of which the "wall" forms an elementary part; and having also illustrated the different ways in which stones are cut into special forms to suit the different structures, which give more or less of what is termed an architectural character to the structure or building, we now proceed to take up the departments of practical work in which the mason takes a part, and much of which is useful as well to the bricklayer.

Wide Range of Subjects required to be known by the Master Mason.

The art of masonry, theoretical and practical, demands, on the part of those who follow it as a business, the knowledge of a wide range of subjects. All of these require more or less careful study, as well as a no less careful practice, before the student or apprentice can assume the position and fulfil the duties of what is well known as those of the "master mason." Of these we name Geometry first, as its problems and forms must be familiar to him, so that they can be adopted and modified to meet the varied and ever-varying forms which the stones the mason uses have to occupy in different parts of the structure. He must know how to calculate the weights and measures to which his materials are subjected, and to give his materials the form and position calculated best to resist them. He must have a thorough knowledge of Projection, so that he may be competent to put on paper the designs which are the result of his careful study, and that the drawings—or projections—may convey to the workman a clear conception of what the designer intends to be constructed. The student or apprentice in the art must also have a fair acquaintance with the science of Geology in so far that he may be intimate with the characteristics and the constructive or industrial value of the stones which are to be used in his buildings. And as with stones, so with the "soils" on which the building rests,—with these he should have a practical acquaintance, so that, while having economically prepared foundations for his buildings, they will also possess the essential characteristic of permanent stability. A fair knowledge of Chemistry will also be necessary for the student desirous to occupy the position of one who has a right to the name of a "master" in his art. For with this knowledge he will be able to know the properties and trace the action of the limes, mortars and cements which he uses to give solidity to his structures, binding together with a hard, solid, and durable material, the special and separate stones of which his building is to be constructed. The apprentice and student, while knowing these things, must, of course, know practically the handicraft work of stone setting. And so much more valuable and useful will he be if he adds to his other capabilities a knowledge of the work of the Bricklayer. In the setting of the stones the mason uses, he has a valuable means of placing them in relation to each other so that the coherence in the mass otherwise obtained by the use of mortars and cements shall be aided by this artificial binding or binding of them together. With the details of the art of Stone-cutting—that is, of shaping stones—the apprentice must become acquainted. By this art of cutting or shaping after he has designed and set out or drawn the peculiar forms he requires for his buildings, he can for himself—or direct others to do for him—cut out, from the otherwise shapeless blocks of stone received from a stone quarry, the sometimes complicated and frequently beautiful forms which the stones in the finished structure ultimately display. To aid him in producing the beautiful in form and outline, the apprentice and student in masonry should study forms and objects in external nature, and be able by a knowledge of ornamental drawing and decorative design to apply those forms to the various parts of structures in which beauty of form is desirable; and therefore to the solid materials themselves, necessitating a knowledge of modelling and carving.

But, varied and extensive as are the subjects or departments of theoretical and practical knowledge of which in briefest fashion we have thus drawn up the list, that list, long as it is, has still to be added to. For, in addition to a mastery over all that it embraces, the "master mason" must be able to draw up agreements, contracts, specifications of work to be done, to calculate the materials for the bills of quantities, this necessitating an acquaintance with the cost of labour and the prices of materials. Such and so varied and so important are the subjects which the working mason must know if he aspires to and wishes to be able to fill, with credit to himself and profit to his employers and clients, the position of a master of his art. Valuable as a work would be which would take up and discuss *exhaustively* all the subjects we have classified, it is obvious that space would be required so extensive that it could not be obtained in a work otherwise than very voluminous, and therefore beyond the reach of the majority of those having a practical interest in the art. Equally obvious, on slight consideration even of the case as it thus stands, is the fact that the limit must be put at some point, the line must be drawn somewhere, and that of necessity within very narrow limits, so far at least as a book of the present character is concerned. On a serious consideration, therefore, of the necessities of the case, we have decided where that point and that line should have due place; and these have been decided by the practical requirements—requirements of which a pretty wide, varied and extensive experience of the every-day work of those engaged in the constructive arts of building has enabled us to form a practical knowledge. Aiming at—and as we trust we shall be capable of—giving to our pages a thoroughly practical cast or character, we shall open up the various departments of the art still to be treated of by taking up the subject of Foundations; premising first that many of the subjects named above will be found treated of in manuals under special heads in the present series, such as those entitled "The Architectural and Geometrical Draughtsman," "The Ornamental Draughtsman," "The Ornamental Worker in Wood, Stone, and Metal," "The Carpenter," "The Domestic House Planner and Designer," "The Sanitary Architect and Engineer," and "The Road Maker."

Foundations of Walls and Structures.—The Site of the Building.

First, then, one of the most important duties of the "Stone Setter" is the choice of the site of and the extent of the foundations of the house or other structure he may be called upon to erect. It is clearly impossible to overestimate the importance of having good foundations; without them the structure cannot be considered safe, and unless they be well laid they cannot be looked upon as being likely to be durable. Stability and soundness are therefore essential characteristics in all foundations; but there is another still to be noticed, and that is that they be so constructed in the case of buildings in which human beings are to live, as in the case of domestic structures—or animals to be housed, as in the case of stables and farm buildings—that they shall not only in themselves be free from damp, but that they will not be the means of communicating to the walls resting upon them the damp from the soil on which they rest We have thus three essentials to be secured in the foundations of certain classes of structures, and, indeed, we may say, in all classes of buildings, inasmuch as damp is everywhere a destructive agent, which will, if allowed to act, in process of time render the work weak and defective. So that we may deduce the rule that good foundations must possess the three characteristics of stability, soundness of construction, and dryness or freedom from damp. The last characteristic, freedom from damp, may appear to the youthful student to be somewhat inapplicable to, or rather unnecessary in, such classes of work as the retaining walls of river banks, reservoirs, and canal work, etc., etc. A very slight study of the character of such work will show that while of necessity the foundations may be wholly or partially surrounded with water, it is essential that that water should be looked upon as wholly external to the work; for it is evident that if the water be allowed to reach the interior of the structure, it will of necessity weaken the cohesion of the parts, and in time destroy the stability of the foundations and the work.

Different Classes of Foundations.—Rock.

As the nature of the soil varies in different localities, it is obvious that the work of foundations must vary in order to meet the different requirements. Extended experience through a long course of years has enabled the different kinds of foundation work to be classified. This classification we shall proceed to consider in detail.

The best foundation for any structure of masonry, brickwork or concrete to rest upon is rock; but of this there are various kinds, some of which are very deceptive as regards their real strength, presenting the appearance of soundness, yet being actually weak and treacherous. Of this kind may be named the shaly rocks, which laminate easily—that is, split up into plates, and when exposed to the weather rapidly disintegrate and crumble away, and soon get into a soft muddy state. The sooner, therefore, the foundations are covered with building, or, better still, with concrete—on which the foundation courses are to rest—the better for the larger rocks, if by such name they can be so called. The longer this kind are exposed to the weather, the more treacherous and unsafe they become. And even in cases where the rock is hard and sound, it may be, to a certain extent, an unsafe one from the way in which the strata lie. If, when rock is exposed by taking away the surface soil in order to form the foundation trenches, it is found to be of an uneven character, it should be levelled as accurately as possible; and if this be too expensive, the area of the site should be scarfed over or benched out in step-like fashion so as to secure level places for the foundation courses to rest upon. Another precaution in rocky soils is to see that the rock is of sufficient depth to bear the weight of the structure to be built upon it; for rock is sometimes found to be like a mere shell, covering what may be very unsafe material below, and this shell may "give" at certain points, causing unequal settlement in the walls above. Where the proper level cannot be obtained by cutting or scarping out the rock, the best course to be adopted is to bring up the area of the level by filling up the depressions with concrete, or with the stones which may be taken from the raised parts.

In "scarping out," the level may necessitate some parts to be very much deeper than others; in these parts the laying of concrete to bring up the level to a fair average throughout is to be recommended, as, if not done, the settlement at the deepest part will be the worst. Many are too apt to conclude that if a rocky substratum be met with it is sure to furnish a safe foundation; whereas in some parts it may be the very opposite. In fact, care is required to be exercised, even in what are thought to be the safest soils for sites of buildings, so that the most important part of a building—its foundation—be safely constructed.

Gravel.

Next to good sound rock, the best substratum for a site is compact gravel lying on a deep bed of sand. Although compact, the gravel should be open enough to admit of drainage of the upper surface to the sandy subsoil below. But on this point of drainage of the soil of the site we shall have yet more to say, inasmuch as it exercises a most important influence, almost always overlooked in practice, upon the stability of the superstructure. Compact gravelly soil of the above character should be as little disturbed as possible; and where any weak or unsound parts are suspected their existence or otherwise should be a matter of certainty by "tamping" with an iron rod; and if they do exist, the weak parts should be dug out, and the spaces filled up with concrete. To secure a good foundation bed the trench in soils of this kind should not be of less depth than three feet, and the bottom made level throughout.

Clay.

Compact, retentive clay gives a good firm foundation bed, although if the whole area of the site be not thorougly drained it is sure to be an unhealthy site for a house. Clay, indeed, though giving a good bed, is the least desirable of soils on which to build; but where there is no choice left in the matter the best must be made of it by thoroughly draining the area. The clay should be as little exposed as possible to atmospheric influences, and to secure safety in this point the trenches as soon as soon as opened should be filled up with concrete to the level on which the foundation courses are to rest. The trenches should not have a less depth than thirty inches, although as shallow trenches as twelve and eighteen inches are all that is sometimes thought necessary in soils of this nature.

A Firm Sandy Soil

affords a capital bed for a foundation, so far as its capability to resist the weight or purely vertical pressure of the walls is concerned. But the danger in soils of this kind is that the sand will have a tendency to "give," or move aside laterally—that is, to slip away from under the foundation courses. To prevent this danger arising, the best way is to dig a deep trench all round the area of the site, and to fill this up to the level either with masonry or brickwork walls set in hydraulic cement, or with concrete, of which that made with Portland cement is the best. Another expedient, in shifting, yielding soils of this kind, is to have a wooden platform or base on which the foundation is to rest, the great object aimed at being to distribute the weight of the superstructure over as great a surface and as uniformly as possible; concrete gives great facilities to the builder in forming safe foundations on unsafe or uncertain soils.

Light, Boggy Soils,

or soils of a loose, muddy or boggy or peaty nature, which are continually shifting, or liable to shift in position, are those which give the most anxiety to the builder. In dealing with such yielding soils the constructor should always bear in mind this important axiom, that the danger does not rest so much in the fact that they do yield, but that they yield unequally.

Hence, the point to be aimed at is so to distribute the weight of the superstructure that the soil shall yield uniformly over its whole area. Mere settlement is nothing as compared with unequal settlement: if a building is so carefully constructed that its weight shall be uniformly spread over the area, it will not matter much if it does settle a little, so long as it settles equally. This is the object aimed at in all the methods now to be described. Although sandy soils are, as shown above, apt to form poor foundation beds, from their tendency to "give away" laterally, still, from its power to resist vertical pressure, sand is frequently used, and its use in this

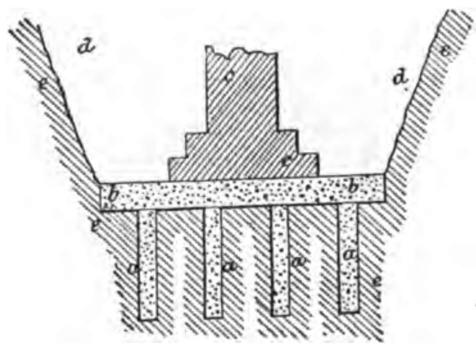


Fig. 140.

way is becoming more general the more widely a knowledge of it is spread. To form what may be called "sand piles," on which the foundation courses are supported, a layer of beton or concrete is placed between the top of the sand piles and the under surface of lower course of foundation, as illustrated in fig. 140, in which *a*, *a*, are the sand piles, *b b* the layer of concrete or beton, and *c*, *c*, the foundation courses; *d d* being the foundation trench cut in the soil, *e e*. The "piles," *a*, *a*, so called, are formed by first digging them out or driving in a wood pile at the spots desired; these being withdrawn, the sand is immediately filled into the holes thus made in the soil; and this is done as quickly as possible where the soil is very yielding, so as to ensure the full diameter of the hole made by the wood piles being filled with the sand. This should be put in slightly damp, and then well rammed, so that the particles will consolidate as much as possible. In place of having sand piles a layer of sand is frequently used in shifting soils of a muddy character, as at *a a* in fig. 141, this being covered with a thick layer of concrete or beton, *b b*, on which the foundation courses, *c*, *c*, are built. Sand piles or sand layers used as thus illustrated have some advantages which wood piles do not possess: these latter exert, or are calculated to resist, a vertical pressure only; but sand, while it possesses this also in a marked degree, has also, from its yielding properties, a tendency to resist a lateral pressure; this, therefore, relieves the sides of the foundation trenches from a side or lateral pressure to some extent, which is an advantage the value of which the practical man will at once perceive. Sand, however, cannot be used in those ways now illustrated in soils which are of a very

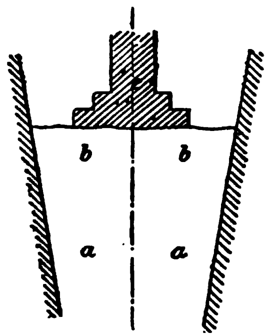


Fig. 141.

mobile or shifting nature. When soils of this kind are met with other expedients have to be resorted to; and these we shall explain and illustrate.

Artificial or Made Soils.

Amongst the soils which are to be classed as bad—and the soils of sites range from gravel as the best down to close retentive "bird-limy clay" as the worst—are what are termed made soils, to be met with on those unlucky (for the inhabitants of the houses afterwards built upon them) plots on which is stuck up a board, "Rubbish may be shot here." Rubbish in the worst sense it is, and the "shooting" one would be inclined to reserve for those who permit its lodgment with the view of forming the site or foundation of houses with it; for assuredly in one sense they commit murder.

It is difficult to overestimate the sanitary evils arising from sites of made soils of this character. Some which have been examined by competent authorities have been found to consist of not merely soil, broken bricks, lime, etc.—which are in one sense not bad—but also of vegetable matter, and, what is far worse, animal refuse of all kinds, both of which, vegetable and animal, are liable to decay. Now, this decay gives rise to several classes of evils: first, the decay allows the subsidence of the soil, or rather compels it to subside at the points at which the decaying matter rested; so that the danger of unequal settlements in the foundation of the house comes into play, causing the walls to settle unequally, and causing ceilings to crack and all the other evils too well known to householders. Secondly, and what is worse, during the period in which the vegetable substances and animal refuse are decaying they meet and send up through the soil foul gaseous emanations, the only outlet in too many cases for which is through the apartments of the house, and the presence of which is indicated by smells, the origin of which not being known, or in the majority of cases not even suspected, are set down in that category known as "most puzzling," or "most mysterious." Again, when once completely decayed, if the soil above does not settle down, holes and cavities are formed in which water or moisture collects, and this again sends forth emanations—none the better for being mixed with the last remains of the decayed substances—which have their only outlet or escape, as before, through the house, and also cause the soil to become damp, and through this the foundations and walls. And thus the evils go on. But, further still, the rubbish is "shot" upon surfaces of the natural soil which have been in no way prepared to receive it, "shot down" upon hills and hollows with a supreme indifference to after results, and "shot down" often upon heaps of filth and garbage of all kinds which have been accumulating for a long time upon plots of waste and neglected land.

Drainage of Sites.

Drainage, so far as regards house construction, is to be considered under two classes; the first being concerned with the drainage of the site or soil upon which the house is to be built; and the second with the arrangements by which what is called the sewage, or liquid refuse of the house, is conveyed to the point of outlet.

We are quite aware that this division of the general subject of drainage is one rather unusual, inasmuch as the drainage of the site, or rather the soil of the site, is considered a point of no importance; indeed, it would more accurately represent the state of the case to say that till only very recently it was almost entirely ignored. We shall see, however, that it is far from being unimportant; on the contrary, that, as regards the maintenance of the health of the inhabitants of the house through keeping the walls dry, it is of the highest importance.

The object of the drains laid down for carrying off the water from the soil of the site is of course the very opposite of that where drains are laid down to carry away the sewage water. For site drainage the drains must be permeable—that is, they must be so constructed that the water from the surrounding soil can have free access to their interior, and be laid so that as soon as the water reaches their interior, it shall be led off as quickly as possible to the outfall. The water should, therefore, flow as quickly to the interior of the drains, and from this as fast as possible. They must, therefore,

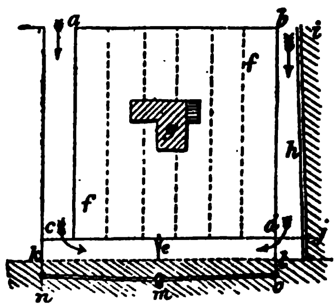


Fig. 142.

be channels formed on the outside of the drains, through which the water can reach the outrun quickly; in other words, the joints between the tubes must be left full and open. We illustrate in a succeeding sentence different methods of forming drains for sites. In fig. 142 we show in a general way the method of laying out the drains of a site, which is represented by the square outline *a b c d*; in the centre of the enclosed area *f f* is the house *g*: we suppose that the trend or slope of the land is in the direction of the arrow, which is the best slope that can be chosen for the site, inasmuch as it favours the natural tendency of the water to drain itself from the land. The first thing to do is to cut a trench along the upper side *a b*, and another parallel to it, as *c d*, joining these by side trenches *a c*, *b d*. These trenches receive drain-pipes (see illustration of these, next to follow) —all leading to the larger drain *e e*, which carries off the water to the outfall; or the drain in *c d* may be enlarged at the points *c* or *d*, should the outfall lie towards either of these points, as shown by the double lines. These drains are catch-water ones, and are designed to arrest the water, which may be flowing in from all sides towards the area inclosed (*a b c d*), and to prevent it from soaking the soil therein. Many would feel satisfied with this, as being sufficient to keep the area dry; but since this may be of considerable superficies, and may therefore present a large surface of land on which the rain falls, and which would or might accumulate below, and not be taken off by the lower catch-drain, *c d*, it will be the safest plan to cross-drain—or "gridiron-drain," as the arrangement is sometimes termed—the inclosed area by smaller drains, as *f*, *f*, these being connected with and leading the water into the lower drain, *c d*. The largest-diametered drain will be *e*, shown in cross section at *m*, which leads off the water to the outfall collected by all the drains; the next largest would be the cross catch-drain *c d*, or *m n*, *m o* in section, and the next the side catch-drain, *c a*, *d b*, these being of equal diameters; while the smallest would be the cross-drains *f f*. A cross-section, as *c d*, is shown at *m*, on *n o*, being the surface line of ground *m o*, *o n*, corresponding to *c e*, *e d*. A longitudinal section is at *i j h*, this corresponding to *b d*, *h* being ground level.

Drains for Foundation Sites of Houses.

The drains may be made in several ways. A "stone-filled" drain is shown at fig. 143 in diagram A, in which the bottom or lower part of the trench *a* is filled up with stones, round generally in shape; *b* the soil or earth covering these, the whole being covered in with the turf which was cut off in forming the trench. Fig. 143, diagram B, shows another form of stone-filled drain, *a*, *a*, being flat stones, which are not so apt to become "silted up" with the fine particles of soil, and which being capable of being placed in a more regular way than round stones, will more readily give a number of longitudinal channels running in the direction of the length of the drain. These flat stones are covered in with a layer of round ones as at points *b*, *b*; above these is placed a piece of turf—in some instances a flat stone, *c*; and above this the soil or earth, the whole being covered by the turf. The best form of drain, however, is that known as the "tubular" or "pipe" drain, this being a tube of fired earthenware. These are generally made with facets at the ends, and are placed in the bottom of the trench, as at *a*, fig. 143, diagram C, this being made perfectly level and uniform throughout its whole length, so that the tubes when laid down will form a continuous and unbroken line. Above the tubes stones are put, then flat-edged stones, *b*: if flat stones are used they may be placed in two layers, *b* and *c*, diagram B, at right angles to each other; above these the soil *c* is filled in and the whole turf covered. As the line or continuity of the tubes is apt to be broken by the unequal settlement of the bottom of the trench, the plan is adopted of providing each length of tube with a socket at one end, into which the square or free end of the tube is inserted, or a "collar" or ring is made which slips over the joint of the two tubes, and thus keeps them connected: this latter plan is often adopted. In using drain-tubes for cross-drains, as at *ff* in fig. 142, the mistake—having its origin in mistaken views of economy—is too often made of having them with too small a bore; this is apt to become quickly silted up, thus effectually doing away with the efficiency of the drain. The minimum diameter we would recommend is 2 in. for the catch-drains, as *a b*, 3 to 5 in. Some will think these too large and costly; at all events we should

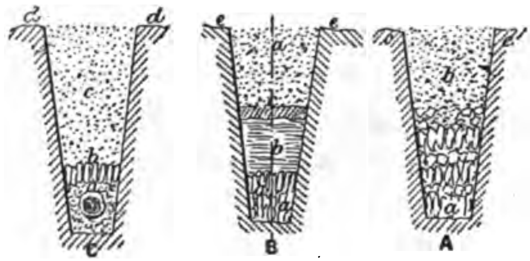


Fig. 143.

not make the minimum less than 2 and 2½ in. respectively. The depth of the trench in which the tubes or stones rest is a matter much disputed, some maintaining that shallow drains are better than deep; it is right, however, to state that the weight of authority and experience is in favour of deep drains, and especially in heavy soils; although one at first sight would think that the opposite would be the rule—namely, the lighter the soils the deeper the drain. The depth is, however, taken as uniform in all soils; and this is recommended to be five feet, but not less than four feet. Of course the deeper the drain or the trench the more costly the work; hence, we believe, the reason why shallow-set drains are so much used. The distance between the drains varies according to the soils: the lighter the soils the farther apart may the drains be. In light porous soil the distance apart of 4 to 5-feet-deep drains may be 40 to 50 feet, in medium soils from 30 to 40, and in close clayey soils from 15 to 22 feet. It is worth knowing that deep-set drains are much less apt to be silted up with fine soil than shallow-set ones; for in the latter, being nearer the surface and within the region in which worms, grubs, etc., work, the fine particles they make are washed in by the rains; but deep-set drains are beyond the disturbed soil, and also beyond the easy reach of the rain-washings.

Great care is necessary in forming the bottom of the drain trench; for a rise in the line of flow, for example, will interrupt the flow of the descending water. As to the fall or rate of inclination, it is better to err in excess than in deficiency of this. As regards the cost of draining house sites, did space permit we could give full details applicable to a wide variety of cases, but we must content ourselves by merely giving the following general statements. For draining an acre in extent on which there is one house built, the rent or rate for twenty years—which period will pay the whole outlay—will be as follows: in "heavy" soils, 28*s.*; "medium" soils, 24*s.* 6*d.*; "light" soils, 20*s.* For one acre—having on it four semi-detached villas built in a row—"heavy" soils, 6*s.* per house, or 24*s.* the acre; "medium" soils, 20*s.* (or 5*s.* per house); "light" soils, 17*s.* (or 4*s.* 3*d.* per house). For one acre having on it twelve semi-detached villa cottages in a row, "heavy" soils, 30*s.* (or 2*s.* 6*d.* per house); "medium" soils, 26*s.* the acre (or 2*s.* 2*d.* per house); "light" soils, 20*s.* (or 1*s.* 8*d.* per house). For half an acre having two detached villas built upon it, for "heavy" soils, 17*s.* (or 8*s.* 6*d.* per house); "medium" soils, 12*s.* 6*d.* (or 6*s.* 3*d.* per house); "light" soils, 11*s.* 4*d.* (or 5*s.* 8*d.* per house). These, of course, must be taken as approximate estimates.

The cost of excavation forms an important element in all drainage work. From the figures of drains we have given (fig. 143) it will be seen that the trenches are wider at top than at bottom; in estimating the solid contents the "mean width" must be ascertained as an element in the calculation. This is obtained by halving the sum of the width at top and bottom; thus, a trench 24 inches wide at top and 6 at bottom would give a "mean width" of 15 inches ($24 + 6 = 30 \div 2 = 15$). To ascertain the solid contents of a trench or ditch, multiply the length by the depth, and the quotient by the mean width = cubic yards. This rule is, of course, applicable to trenches for foundations of equal width, this being taken as the last multiplier.

The cost of digging a cubic yard, if the depth of cutting does not exceed 6 feet, and the soil be so firm as not to require shoring up with timber, may be taken as—In common soils, 7*d.*; in gravel or stiff clay, 8*d.* If the soil has to be carted away from site, the cost of carting must be added to the above, as under: Filling into cart, carting and shooting—not exceeding 1 mile, 2*s.* 6*d.*; for every additional mile, 1*s*. If the site should be situated near London or any large town, it is more than probable that "the shoot" will have to be paid for, in which case the amount must be added. In estimating for the removal of soil—estimates for foundation trenches—it must be remembered that a portion of the soil will be required to "fill in and ram" round the foundation walls, and this filling in and ramming may be estimated at 6*d.* per cubic yard.

Further Remarks on Damp Walls.

While on the subject of the prevention of damp in foundations, and while treating of it also as bearing upon the healthy condition of Domestic Buildings, it will be as well here to give on the latter subject some further remarks. And we would first draw attention to the condition in which the soil is too often left by some neglectful builders or their workmen, which is immediately under the flooring timbers of the apartments of the ground-floors of houses. The soil or surface of the soil in such parts is often left in such a state that it is sure in time to create a nuisance, the space sometimes being nearly filled up with foreign matter. Of course we need scarcely say that we quite condemn the system of placing the flooring boards or the flags—in the case of lobbies, kitchens, sculleries or wash-houses—immediately upon the soil. In all cases a cavity or space should be left below the flooring materials, of whatever kind these may be. This should be of considerable depth, and in the case of flagging, the best plan is to support it upon brick bearing or sleeper walls; and in cases where bricks or paving tiles are used, these should rest or be bedded on a thick (at least twelve inches) layer of dry ashes or highly burnt clinkers. We confess, however, to feeling that for the surface of floors of all apartments in a house where people live or work much in, good well-seasoned boards, laid on joists resting on sleeper walls, and clear above the soil as just stated, are the best.

In the case of the superior apartments of the house, let the utmost care be taken to secure a dry under surface below the floor. By far the most effective way in which to secure dry floors to these rooms is to have them *cellared* under. These cellars, so formed, will also be exceedingly useful for many household purposes, such as the storing away of provisions, keeping of beer, wine, etc., etc. Where the making of these under-floor apartments is objected to, as it often is—although with what reason we fail to see, as we consider a cellar to be as essential as any other room on the score of the convenience it affords, to say nothing of the part it plays in keeping the house dry—let a greater amount of care be observed to see that the soil underneath the ground-floor rooms is in a healthy condition. Few have any conception as to the state in which the soil is often left below a dining-room or a breakfast-room floor. No wonder that smells are complained of as "coming up through the boards, for which we cannot account, you know." If the boards were taken up in such cases, the smells and something else would easily be accounted for. The way in which the spaces under the floors are often left by the workmen is highly culpable. Wood shavings, oily rags, pieces of wood and "other things besides," are left to rot and fester below, and send up through the chinks of the floor all manner of smells marvellously foul.

The soil below all ground floors should be taken out for some depth (the deeper the better), and the excavation filled up with dry materials as non-absorbent as can possibly be got, such as cinders, smithy or furnace clinkers (the more vitrified the better), pieces of broken gas retorts (earthenware ones we mean, of course), or the slag from iron works. And even when this is done, in no case should the flooring joists be placed in contact with the soil or with those materials, but a space between them in all cases left. Where the best—we were about to say the most perfect—method of furnishing the surface of the soil below ground floors is desired, the whole surface should be covered with a layer of Portland cement concrete. This, which is now largely being introduced for paving and flooring surfaces, is almost wholly impervious to damp, is non-absorbent, and so hard as to be completely vermin proof. If, in addition to the soil beneath the floors being laid with this concrete, it was passed under the foundations, or rather, if they were built upon a layer of it, and this was extended for some few inches beyond the walls, we could scarcely conceive of a house being damp.

Special Constructive Features of Foundation Work.

In noticing the class of sandy soils we drew attention to the use of sand in securing a stable foundation either in what may be called the "pile" system, as illustrated in fig. 140, or in mass, as in fig. 141. We now come to the consideration of foundation in soils so treacherous or so unstable as to necessitate the use of timber piles; thereafter glancing at those formed in water, such as the foundations of piers of bridges, and finally, those of structures used in marine works, river banks, etc., etc. In the formation of foundations by means of piles a good deal of judgment must be exercised, not only in their manner of disposition, but in the way in which they are driven and finished off. As a general rule piles are used in cases where there is an upper structure or layer of compressible or yielding soil, which overlies a firm soil more or less non-compressible; the object aimed at being to reach the lower and firm structure by the piles—these affording a means of transmitting the weight and pressure of the superstructure through the compressible to the non-compressible soil. There are exceptions to this rule, as in the case of muddy or marshy soils, which have a tendency to yield in all directions, lateral as well as vertical, and of the manner of treating which we shall presently give an example, proceeding now to finish our remarks on the use of piles generally in foundation work.

Piles have a maximum length, beyond which they cannot be safely driven without sagging or binding laterally. This length may be taken, as a rule, at twenty times their diameter. There is also a minimum distance between the piles in the bed, which, if drained, renders the driving difficult; the distance at which they can be driven with the greatest ease is two-and-a-half feet from centre to centre. The piles before being driven are stripped—that is, the bark clearly

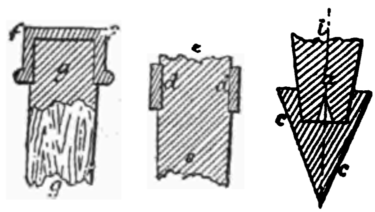


Fig. 144.

and completely taken off; they are then pointed and shod, or provided with an iron cover at the pointed or sharpened end; this is usually of cast iron, solid up to a certain point, and hollow for the remainder of its depth; a wrought-iron spike with sharp point, as *a*, is cast into the centre of this; the sharp end of the spike, as at fig. 144, runs into the wood of the lower end, *b*, of the pile, and secures the "shoe," *c c*, to the pile. In place of cast-, wrought-iron plate may be used as a shoe, this being hammered round the pointed end of the pile, and secured to it by spikes well driven into the wood. In such cases the piles are provided with a wrought-iron ring, *d d*, to prevent them from splitting under the blows of the ram of the pile-driver, these rings being passed over the head, which is reduced in diameter in order to form a shoulder or collar, as at *e e*. Where piles, as in harbour and sea-wall and quay work, are left at intervals standing up for some height above the level of the quay surface or roadway, they are finished off with cast-iron caps, as at *f*, these being merely slipped lightly, and without a collar, or with a collar or shoulder, as at *g*, formed at the head of pile.

Great care is required to be taken in the first starting or driving of a pile; if the blows be too heavy and too frequently repeated, it may be found that the pile will yield laterally or perhaps break, not entering the soil below at all. Sometimes it will be found that successive, rather quick, light blows will overcome the difficulty of starting. When once fairly started, the pile will be found to descend steadily; the ramming or blows should be continued till the pile reaches a part of the soil into which it will not penetrate farther. Damage is very frequently done to piles by attempting to drive them too deep after they show signs of having entered a firm subsoil. When all the piles are driven, they are sawn off to a level as uniform as possible—some ingenious mechanical contrivances have of late been introduced to saw the heads of piles under water—so that

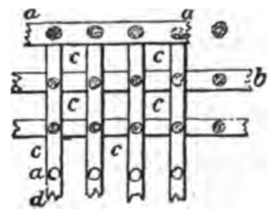


Fig. 145.

they may be fitted to receive the grillage and timber work upon which the foundation of the building is to rest. The number of piles to be driven into a given space depends upon circumstances; in some cases, as closely as they can be driven is the rule, in others the distances between them may be greater. A safe rule is to allow such a number as will support a pressure of about half a ton to the square inch of platform work bearing the foundation. When piles are driven very closely, spreading over a whole surface, the better way is to begin driving at the centre of the space to be piled, working gradually outwards; this will prevent the inner piles from springing up, which they are apt to do if driven too closely. The safe or minimum distance between the piles we have already stated to be two and a half feet from centre to centre.

When the heads of the piles are all sawn off to a uniform level, the outside rows on all sides are provided with "capping pieces," one of which is shown at *a a*, fig. 145. The capping pieces rest upon and are secured to the heads of the piles by nails or spikes of wood or iron. Parallel to the capping piece, *a a*, the pieces of timber are placed, as *b*, *b*, so as to be over the heads of the interior rows of piles; these timbers are termed "string pieces," and are either notched at the ends to the "capping piece," *a a*, which runs at right angles to the cross capping piece, *a a*, or dovetailed to the same and

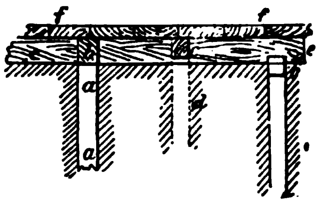


Fig. 146.

secured at right angles to the capping pieces, *a*, *a*, *a*, *a*, and string pieces, *b*, *b*; a third set of timbers are placed there also, lying over the heads of the interior rows of piles. These are called "cross pieces," and are joined to the string pieces, *b*, *b*, by what carpenters call a half-lap joint, so that the top or upper surfaces of the cross

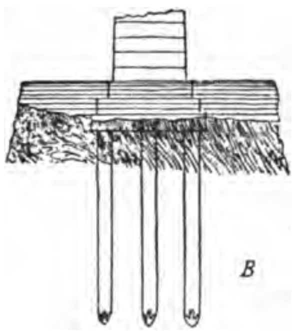


Fig. 147.

pieces and string pieces are joined with each other, presenting thus a level or uniform surface. At this stage of the construction, the timber work presents in plan the appearance of a number of squares, as *c*, *c*, *c*, formed by the intersection of the string pieces, *b b*, and cross pieces, *a a*, the whole shown in section at the diagram in fig. 146. In this figure *d* is a pile, *e e* a "capping piece" corresponding to *a a* in fig. 145, *c* a "string piece," to *b b* in fig. 145. Arranged thus it is termed a "grillage," and generally this is covered by a flooring of

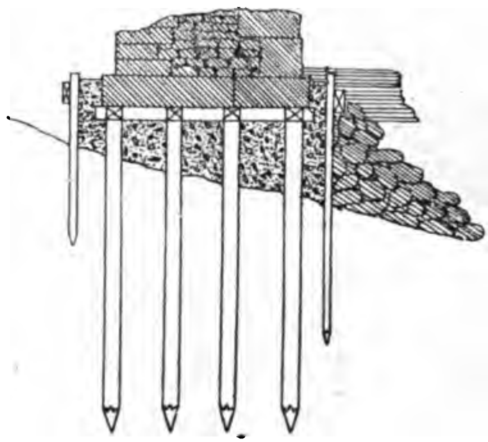


Fig. 148.

planking, *f f*, fig. 146, termed a platform, upon which the foundation of the superstructure is built, the two together forming the arrange-

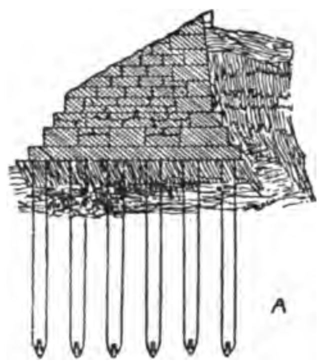


Fig. 149.

ment known as a "grillage and platform." Figs. 147, 148 and 149 illustrate methods of forming foundation work with the use of piles; these two first being connected with foundation in water. To enable the first courses of the walling or pier to be laid in water, as in figs. 147, 148, a space is enclosed by a species of framework, the sides of which are so contracted as to be watertight. The water is then pumped out from the space, and free working ground is provided for the proper setting of the foundation course of the wall or pier. This building contrivance is termed a "cofferdam," and will be afterwards described.

In the construction of cofferdams, and in other classes of work with foundations in or near water, "sheet piling" is used; this is illustrated in fig. 150. It is often used in front of embankments or sea walls or quays. In fig. 150 *a a* is one of the outside row of piles, driven quite close to one another and secured together at top

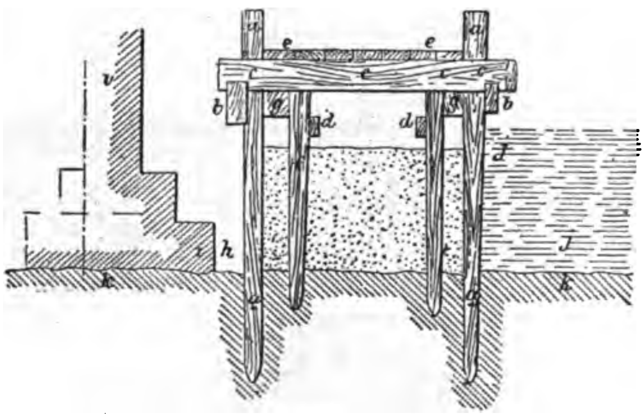


Fig. 150.

by the "string pieces" *b b*, or "wales," as they are sometimes called, *c c* the cross pieces connecting the outer row of piles, *a a*, with the inner row, *d d*, and also supporting the planking or platform, *e e*, upon which the men work, and materials are placed for working with; *f f* are inner rows of piles, shorter than *a a* and *d d*, and having "wales," *g g*, as shown; *j j*, outside water, *k k*, soil at bottom of water. From the interior space, *h h*, the water is pumped out, leaving the work space in which to erect the wall or foundations of wall, *i i*. In figs. 153, 154, and 155, we give other illustrations of cofferdams, fig. 154, showing cross section to the left, and interior elevation in the right.

In soils which are constantly shifting it was formerly a matter of the greatest difficulty to form a foundation, no matter how long and numerous the piles were. The difficulty has been overcome in modern and recent work by the use of screw piles, the invention of Mr. Mitchell. These, as illustrated in fig. 151, are provided at their lower extremity with one or two turns of an iron screw; and the pile is screwed into the soil by appropriate mechanical arrangements to any depth re-

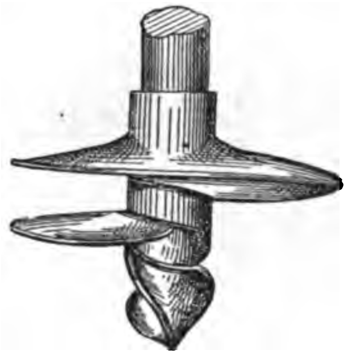


Fig. 151.

quired. The hold or grip which such piles take is very powerful, and a number of them afford a thoroughly secure foundation, no matter how shifting and mobile the soil may be. They are chiefly used for marine work, formation of piers, and the like. The form

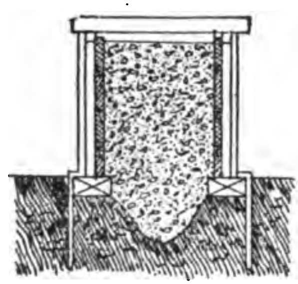


Fig. 152.

and the pitch of the screw varies, of course, according to circumstances; in some instances the "thread" takes only one turn or complete revolution. Figs. 152, 153, 154 and 155 are illustrations of sheet piling work; in fig. 154, *A* is cross section, on line A B in B, *B* showing the outside of the sheet piling on the right side of *A*. Where the soil of the site is of a marshy nature, or a shifting bog or peaty soil, the difficulties in the way of making a good foundation are frequently very great. Generally the plan adopted is to drive over the whole surface of the intended site a series of short piles as thickly or closely together as they can be conveniently driven.

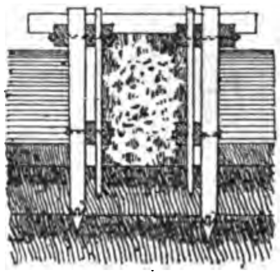


Fig. 153.

These piles should not be longer than ten or twelve feet, and are sawn off level at top, to receive a "grillage and platform." Before commencing to build the foundation proper, the platform is submitted to as heavy a pressure as can be put upon it; the object in this particular class of soils being to consolidate them as much as

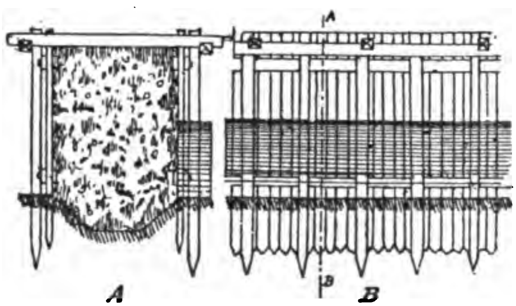


Fig. 154.

possible—this being previously, to a large extent, secured by the closely driven piles which press the soil together and prepare it for the reception of the grillage and platform. The timber platform, however, is, in some cases, dispensed with, and with great advantage in yielding soils; for in the event of any unequal settlement of the piles, the grillage and platform will partake of this, and the latter will therefore have a slope more or less inclined in one direction or another. Now, this will be certain to give rise to some dangerous effect; for, as there is naturally no good hold or "key" between the masonry or brickwork of the foundation and the surface of the

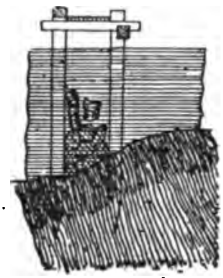


Fig. 155.

platform upon which it rests, this foundation will have a tendency to slide off the platform. Now, by dispensing with the platform (*f f*, fig. 146, *ante*) and retaining the "grillage" only, a series of squares as, A, C, fig. 156, will be obtained, in the interior of which layers of well-puddled clay, concrete, or stonework may be filled

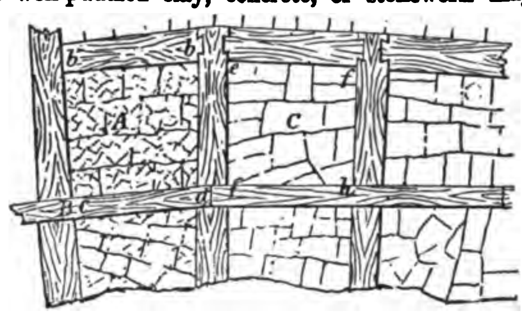


Fig. 156.

in; these having, of course, a good hold or key of the woodwork, and also binding well with the stone or brickwork of the foundation proper.

If clay is puddled in, as at A, it should be rammed in layers, each not exceeding one foot in thickness; and three at least, but four if the soil be very bad, will be better if these layers should be put in to come level with the grillage surface. The heavier the clay is rammed the better; the object already named being kept steadily in view —namely, the consolidation of the soil as completely as it can be effected. If concrete be used, and it be a lime concrete, it is essential that the lime be a good hydraulic one; but the best concrete will be that formed of Portland cement. Some recommend this to be well rammed in layers, but we are inclined to recommend that the first layer—of a foot in thickness only—be rammed, the other layers being simply thrown in. If rubble work be used to fill in the squares of the grillage, it is essential that it should rest upon a layer of puddled clay, or of concrete, at least a foot in thickness.

For soils not quite of such a yielding character as the last, a combination of piles, rubble work, and a modification of a grillage may be used, as in the figure; the outside piles, as *b*, *b*, fig. 157, and sheet planking being useful in preventing any lateral yielding or sliding away of the soil from under the foundation. Where the

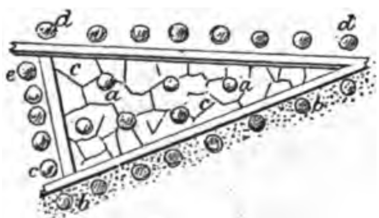


Fig. 157.

lateral pressure arises from that of soil behind a wall which forms the superstructure, the difficulties attendant upon the formation of a sound foundation are often great and exceedingly perplexing to the constructor, necessitating the erection of costly works, such as horizontal buttresses connected together by horizontal arches. If the subsoil or lower strata be firm and more compressible, and situated at no great distance beneath the upper strata of mobile and shifting soil, it will tend much to the security of the wall above if the loose soil be removed so that the piles may have loose rubble work packed in between them from the level at which the firm soil is up to that of the movable soil. One part of the upper soil may be removed, and firm earth or good clay be well rammed or puddled in, the object aimed at being the prevention of the piles spreading out at top, and to give them as much lateral stiffness as possible. Where these precautions cannot from the nature of the soil be adopted, and the formation of horizontal buttresses and arches already alluded to is necessary, a row of piles outside the bed must be driven in, and the buttresses built between the piles and the bed. In fig. 158 we illustrate in a rough sketch diagram the plan of

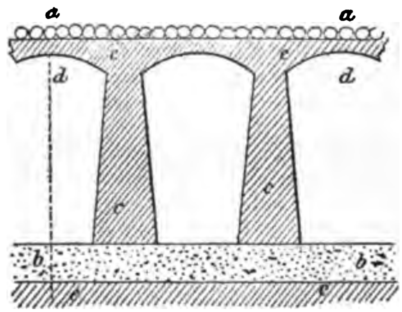


Fig. 158.

arrangement here indicated, and in fig. 159 in vertical section. In the plan, fig. 158, *a a* represents the outside row of sheeting piles, *b b*

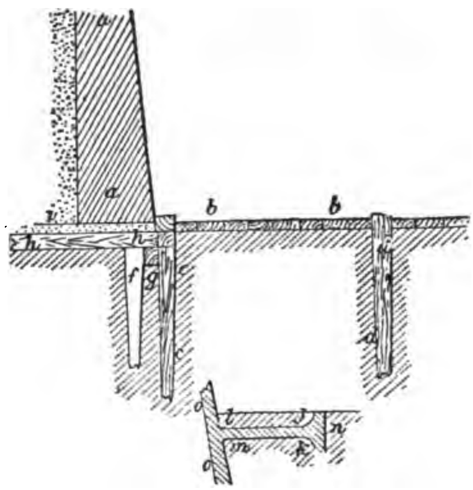


Fig. 159.

the base of wall resting upon the platform and grillage (partly shown in section, fig. 159), *c c* the horizontal buttress—that is, lying flat upon the ground—butting at the outer end against the outer row of piles, *a a*, and at their inner joined to the wall (as at *j k* in section, fig. 159). In place of these being finished off square at their outer ends, they will be stronger by having small vertical returns or offsets on their lower sides, and on their upper sides these returns being joined to the flat body of the buttress by small arches or curved parts, the like being done at their inner end where they join the face of the wall. Another excellent plan to obviate the dangers arising from lateral pressure against a wall from the weight of the soil behind it, is to provide iron rods or ties secured to timber buttresses; this method is illustrated in fig. 160, which shows that adopted at the repair of the Old Burgh

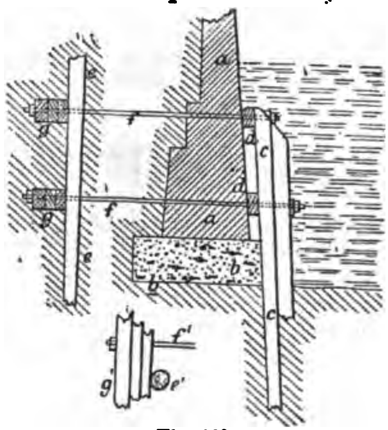


Fig. 160.

Quay, in Dublin, under the superintendence of Mr. T. J. Mann, C.E. —*a a* being part of the quay harbour wall, on a concrete foundation, *b b*, first sheet piling *c c*, and fenders, *d, d*, or longitudinal bars. Wrought-iron rods, *f, f*, are connected with back piling, *e e*, and longitudinal beams, *g g*. Lateral or back pressure exerted against a wall by the soil at the back of a wall, *a*, fig. 161, supported on a grillage and platform, *b b*, and piles, *c, c*, may be prevented by having the grillage and platform repeated at the back, as shown at *h h*, stones filling in the spaces between the piles, and thus obviating their tendency to give or bend sideways, being packed as at *d d*.

Cofferdams.

Where cofferdams are employed in deep water—where, for example, it exceeds twelve feet—additional precautions will have to be taken to prevent the inner row of sheeting piles, *a a*, fig. 161, from being forced inwards by the pressure of the puddling, *b b*, and this from being forced up at the bottom, *c c*, by the pressure of the water, and

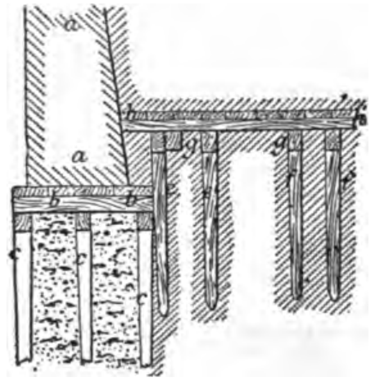


Fig. 161.

thus getting into and filling up the space in the interior. The diagram shows one method of shoring up the interior piles, *a a*, by extra "wales," or "string pieces," *d d*, notched into an upright beam,

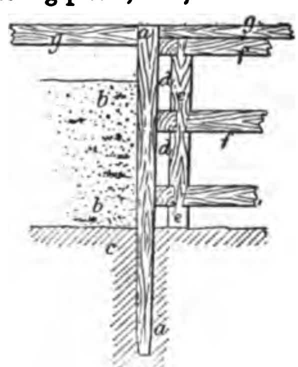


Fig. 162.

e e; this having horizontal timbers, *f*, *f*, *f*, notched into it, and butting at their opposite ends into a beam similar to *e e*; at the other side of the cofferdam, *g g*, is the main cross piece.

Where the bottom is rocky the cofferdam cannot be made in the way already illustrated, but a special modification of the system must be used; in this the main uprights or supports and square timbers, *a a*, fig. 163, the lower ends of which are inserted into holes, are "tamped" or bored in the rock at the proper intervals. Notched to these are two or more rows of "string pieces" or horizontal beams, *b b* in plan, between which space is left for driving in the sheeting piles, *c c* in plan, iron rods, as *i i*, being secured by nuts to the string pieces passing from side to side of the cofferdam.

Beton, a species of lime concrete, is used on the Continent to a large extent—some of the works executed in it being of great magnitude—in the formation of foundations under water. Fig. 163*a*

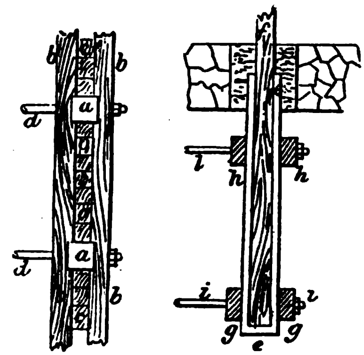


Fig. 163.

Fig. 163a.

illustrates one method of using this material with the aid of a cofferdam. The space on which the foundation, *a a*, is to be built, is enclosed by a row of sheeting piles, *b b*, driven close together, these being secured at top by the string piece *e*; the space within the piles is then pumped dry, and the soil removed, say to the level of *f f*, and in this a bed of beton is placed; before it sets, the inner row of sheeting piles, *c c*, are driven into the beton, and these are secured by the string piece, *e*; the cross piece, *d d*, is then added.

The young mason student will understand, from what we have said in a preceding paragraph generally on the use of sheet piling in the construction of cofferdams, that the cofferdam encloses a space, the sides of the space being formed of sheet piling as in fig. 150. This is placed at one side of the space, and a corresponding row of sheet piling at the opposite side, the space between them, when pumped out, affording room for the building of the foundation courses, *h i*, of the wall or pier. Where the water is not deep and the surface generally calm and placid, the lighter kinds of sheet piling may be used, as in fig. 154; or a double row of piles may be employed, well puddled and provided with string pieces.

In very important works, where the difficulties in the way of working with a cofferdam cannot be easily overcome, the method adopted in practice is to use a "caisson." This in fact is a large case or box made of heavy timber-work securely fixed together, but so arranged that the sides and ends can be disconnected from the bottom when the caisson is in its place. The caisson is constructed on land, and then floated to and firmly anchored over the intended site of the foundation. If the soil or bottom on which the caisson is to rest be of an uneven character, it is levelled as much as possible by workmen descending in the diving-bell; and if it be of a soft yielding nature, piles are driven over the whole surface of site, in the manner already described. The site being prepared for the reception of the caisson, the foundation courses are commenced on the bottom and continued till the weight is such that the caisson sinks and grounds upon the site prepared for its reception. In case the preparation is faulty, it is well to have means by which the caisson can be raised to admit of the necessary work at the site being done: this is secured by having a small trap-door by which water can be admitted and kept out at will; by filling the caisson with water, it will sink, and by pumping this out—first closing the trap-door—it will rise. By this contrivance the caisson can be sunk and raised, etc., till the proper level adjustment of the site has been secured. When this is effected, the building of the foundation courses in the interior may be begun till the caisson is grounded; the sides and ends are then removed, and the foundation is left with the bottom of the caisson which thus acts as a platform.

In the formation of sea walls in harbour work, and in the construction of moles, jetties and breakwaters, and for the casing of river banks, concrete blocks are now largely used.

Great facilities in the formation of foundations in deep water, as in the case of bridge or railway viaduct piers, quay or embankment walls, have been of late years afforded by the use of cast and wrought iron cylinders. These are sunk on the intended site, and the interior filled up either with concrete, beton, or with rubble masonry. By having a number of cylinders and bolting them together, foundations in a great depth of water can be formed, at a cost and in a space of time very much less than could be done under the old system.

When foundations in water are finished, it is advisable—and in rapidly running rivers or streams, or in tidal rivers where the currents are strong, it is essential—to protect them from the action of the water. This is usually done by throwing in stones loosely in front of the foundation, in the direction opposed to the stream. In a tidal river, both sides, lower and upper, will have to be protected to meet the currents of ebbing and flowing tides. To insure these protecting stones from themselves being washed away, it is sometimes necessary to drive piles between the stones, and in cases of more than usual difficulty to have a platform with sheeting piles at the outside. In some cases a timber-framed "starling" is employed, as shown in fig. 164.

Fig. 164.

Walls.—Inclosing and Retaining Walls.

Walls are of various kinds. When they are used to inclose a space, as that of a park, garden, or factory yard, or the like, they are termed "inclosing walls," and have only their own weight to support, being subjected, as a rule, to no vertical pressure, or to but little if any cross or lateral strain. When they are so subjected, in addition to their own weight, and are also subjected to cross strains, as those of beams carrying weights, they come under the category of house or factory walls, etc., etc. When they have to sustain a vertical pressure or strain, and are subjected to no cross strain, they fulfil an office almost identical with that of piers or columns. Walls are also subjected to cross strains as well, as in the use of supporting beams or lintels crossing an opening or void; or they may be subjected to an upward pressure, as in the case of walls covering areas in which there may be water forcing itself upwards; inverted arches in such cases are often used between the walls. Walls are also built to transfer the pressure to which they are directly subjected to lateral supporting points, as in the case of arches.

The thickness of walls is not uniform in the case of high walls, this being reduced, as the height increases either by using offsets, as at *a b*, fig. 165, or by giving the wall a slope, technically termed a "batter," as at *f*; this may be on one side only, as there shown, or on both sides, as at *g h*; in like manner the offsets may be on one side only, as at *a b*, or two sides, as *d e*. Where the wall is of uniform thickness the proportion of the thickness to the height should be one-sixteenth of the height. A brick-and-half wall, when used as an inclosing wall, should not exceed twenty feet in height;

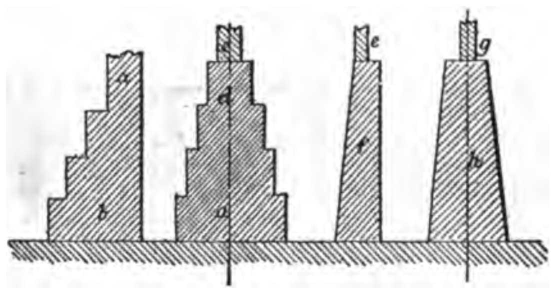


Fig. 165.

a brick-thick wall should not be higher than twelve feet—ten feet would be safer. A rubble-stone wall of uniform thickness should not be less than eighteen inches thick. Where a batter is given to stone walls it should not exceed one of base to six of vertical; the thickness of the wall at top should not be less than eight inches. Where inclosing walls are of great length they will be greatly strengthened by building at intervals of fourteen or fifteen feet buttresses or projecting spurs; if of brick, these may be two-and-a-half-brick thick on face, and may project a half or three-fourths of a brick from general face of wall, the height of this being from ten to twelve feet.

Retaining Walls.

The most difficult class of walls to build securely are those known as "retaining walls," behind which is a mass of earth, often cut up by internal springs of water, which add immensely to the difficulties to be overcome. We have already in preceding paragraphs illustrated one or two forms of walls of this class, in which the foundations have been made by means of piles, and have described the precautions to be taken in certain cases. To enter fully into the details of this important class of work would take up a much greater space than we have at command; treatises have, indeed, been written on the subject, so that we are compelled to give such remarks only as will enable the reader, by the help of what we have already said, to judge what is required to be done in the ordinary

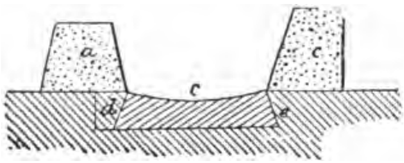


Fig. 166.

circumstances. Retaining walls have a tendency to fail in three ways: first, by slipping along the base of the foundation horizontally; secondly, by sliding along one of the horizontal joints, or, thirdly, by turning as upon a hinge, as it were, upon the outer edge of a horizontal joint. These may all act separately, or act conjointly; or any two of them may be in operation at the same time. In fig. 159 (*ante*) we have illustrated one method of preventing the wall from

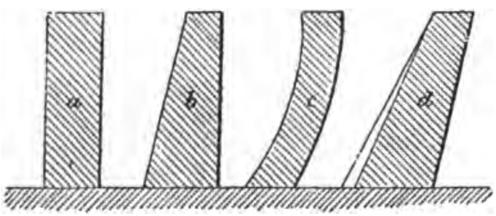


Fig. 167.

sliding along by having in front a row of sheeting piles, between which and the base of wall are placed horizontal arches. Where the nature of the ground admits of it, an earth embankment, as *a*, fig. 166, may be raised in front of the base of the wall *c*, an inverted arch, *c d e*, being placed between the two, and this may form a roadway, being levelled up with stones; or the wall *b* may be used to support rising ground at the side of a public road, for example.

The sections of retaining walls proposed and introduced into practice have been pretty numerous. In fig. 167 four forms are shown: the vertical, *a*, of equal thickness throughout its height; *b*, with a batter or slope at its outer face, and vertical at the back; *c*, with curved concave face and convex back; and the leaning wall, as at *d*. This latter form is the most economical in construction; the batter at the backs hould be one of base to six of vertical. Retaining walls, as *c*, *c*, fig. 168, are much strengthened by building "counter-

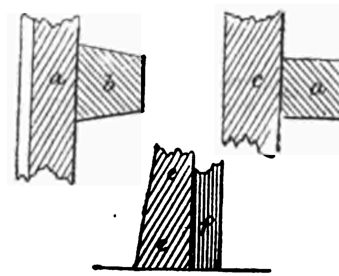


Fig. 168.

feits," or "buttresses," or projecting piers, as *d*, at the back; the best form for these is illustrated as at *b*, fig. 168, not rectangular, as at *a*. The wall may be relieved of a considerable portion of the pressure of the earth at the back by the use of relieving arches, as shown at *a a*, *b b*, *c c* (section), in fig. 169. These remarks apply to walls, whether constructed of stone or brick, having reference only to

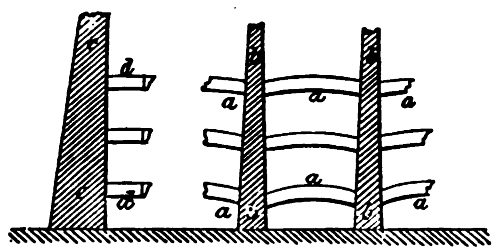


Fig. 169.

their form and the uses for which they are constructed; the way in which their bulk or body—that is, their constituent parts—are put together depends upon the materials used in their construction.

The various methods of setting stone, so as to secure proper bond, will be found described in the earlier paragraphs of the present section. The method of setting walls in brick will be found in the accompanying work on Bricklaying.

Mechanical Appliances used by the Mason in the Construction of Buildings. —The lifting and moving from place to place of Heavy Stones.

In the erection of large buildings constructed of stone very complicated and expensive timber scaffoldings are required. Formerly, even in the building of comparatively small houses, such constructions were required; but of late years much of this expensive scaffold work has been dispensed with, and much simpler arrangements adopted. By a judicious use of the walls and the interior timber-work of a house as they are built and laid down, together with a series of wide boarded or timber gangways, with buttresses nailed across to form steps or footholds, the materials are easily carried up to the workmen, who stand on platforms supported by simple methods. Thus the whole work is carried on inside, and little or none of the

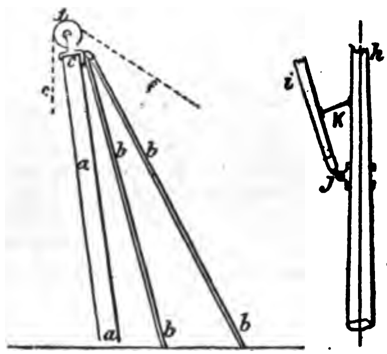


Fig. 170.

"forests of timber scaffolding," which in times gone by formed part of every house erection, are now met with, excepting in the cases of heavy works, such as those of railways or the like. By the introduction of steam-engines and of timber "guys," as in fig. 170, the lifting of heavy stones and building materials is now greatly facilitated, and the work is not only much more quickly and economically, but safely done. In heavy work, by the introduction of "gantries" (fig. 171)—that is, heavy horizontal timbers supported on vertical uprights, properly framed and braced—the whole working area of a building can be commanded, these being carried up to any height desired. On these horizontal timbers rails are laid down, and platforms, with lifting gear, traverse these, and hoist up stones, etc., to any desired height. These platforms themselves carry rails, in which the lifting gear can traverse from end to end of the platform, so that any point within the breadth of the outside horizontal timbers is commanded, while the same is secured at any point within the end timbers, or the length of the inclosed space. Where the works are extensive, steam-engines work the lifting gear, the platforms carrying the engines, which not only work the lifting gear, but also the apparatus by which the platform is made to travel along the gantries, or the engine and lifting gear to traverse across the space. By these and other contrivances the work of

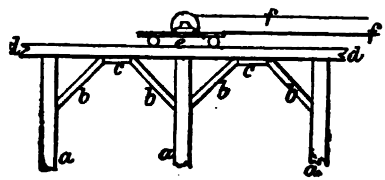


Fig. 171.

carrying on extensive stone erections is very much more simple, quick, and economical than under the old system of large and expensive scaffolding. Fig. 172 illustrates a simple form of hand-worked gear and traversing platform. In fig. 170 the lifting gear is formed by two spars, *a a*, joined at *c* to an iron head or socket, carrying a pulley *d*, over which is passed the lifting rope or chain, *e e*, this being carried down to the ground level, and connected with the winding barrel of an ordinary "crab" or "winch," worked by

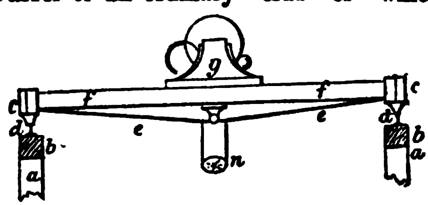


Fig 172.

hand or by a steam crab. The spars *a a* are made to slope forwards, and are kept in place by braces *b*, *b*, behind, firmly attached at their lower end. The lower ends of the spars *a a* are sometimes jointed to iron sockets fixed in the ground. To the right of the same diagram part of another method of lifting is shown in rough sketch: a vertical spar *h* is secured at top and bottom, but so that it can revolve, as it were, on its axis. A "jib" or spar *i j* is jointed to *h* at *j*, the outer or upper end being capable of being lowered or raised by a rope or chain *k*, and it carries at its upper end a pulley, round which is passed the lifting chain, wound and unwound by a crab. A wide sweep can be taken by the jib *i j*, and the stone which it lifts or carries can be transported from one part of the building to another by swivelling round the central vertical spar or upright *h*. A modification of this appliance is shown in fig. 173, the central bar *a* being capable of turning round on a pivot at foot fixed in a stone block as in diagram; *d d* is a horizontal jib, stayed by braces *e*, *e*, *e*, and a small "trolly" or carriage *h*, carrying pulleys, can be moved along the jib *d d*, and these lift, by the pulley *j*, the stone as required. In fig. 172 a form of lifting gear is illustrated, *a a* being uprights running along

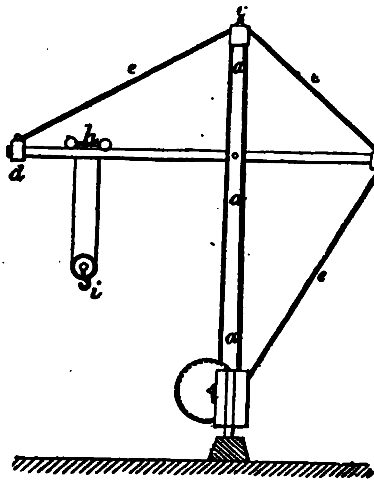


Fig. 173.

the sides of the working space, and carrying horizontal balks, braced as at *b b*, fig. 171, on which rails are laid; on these wheels, *d*, *d*, connected with the cross beam *c c*, run, and the cross beams *f f* carry a platform on which the hand-worked crab or windlass *g* is carried. This works also, by appropriate gearing, the platform along the rails, and likewise moves the windlass itself from end to end of the platform, as *f f*, as desired. The beam *d d* is strengthened by tie rods *e e*, connected to the iron socket *c c* at ends of beam *d d*, and these also carry the wheels running on the rails fixed to the balks *b b*. In some cases a portable steam-engine, with lifting and traversing gear, is carried by the platform on the beams *d d*; but as the weight of this has to be moved along with the platform, a new arrangement has been introduced, in which the steam-engine is fixed on some convenient part, on a level with the gantry, as in fig. 171, and the power of the engine is transferred to a small "trolly," or carriage *e*, by chains *f f*, the trolly carrying the lifting pulleys and chains. Where heavy stones cannot be slung by chains or ropes passing under them, as in cases where they are to be at once deposited in place—in which case the chains, etc., would interfere with the other stones already in position—it is necessary to have some method by which the lifting power can be applied to the upper and face surface of the stone. This is usually effected by the use of what is known as, and called, a "lewis," illustrated in fig. 174. A dovetail-shaped aperture is first cut in the centre of the upper face; into this the "lewis" is inserted. This is made up of three pieces of iron, the upper end of all of which is finished with an eye, through which a strong bolt can be passed. The two outside pieces, *a* and *b*, are made with their inner faces flat or vertical, and their outside faces angular, the slope or angle being

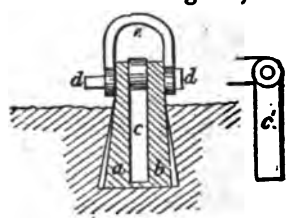


Fig. 174.

made to correspond with that of the sides of the dovetailed hole on the face of the stone. These two pieces *a* and *b* are first inserted, their angular sides coming in contact with those of the hole in the stone; the centre piece *c* is next inserted between the two side pieces *a* and *b*; the bolt *d* is passed through the eyes of all the pieces, *a*, *b* and *c*, and also through the eyes of the ends of the linked hook *e e*, and then secured by a "split key"; the hook of the lifting chain is passed through the hook *e*.

The Materials used by the Mason—Stones, Limes, Mortar, Cements.—The General Characteristics of Stones in regard to their Strength, Durability, and General Fitness for Building Purposes.

Although the material used by the mason is distinguished by one specific and definite term, stone, this generic name includes a great number of distinct stones, each having its own marked peculiarities. These are chemical and mechanical, and vary much in character; as do also the soils or the strata of the globe's crust or outer surface vary in position. Hence, to a knowledge of chemistry as connected with the constituents of stone, and to a knowledge of their physical or mechanical characteristics, the mason should add an acquaintance with at least the first and leading principles of geology. It may appear at first sight to some of our readers that chemistry would not yield the practical mason much help in his selection of a stone for building purposes. But a closer consideration of the subject will show that this is a mistaken notion, and that, on the contrary, much valuable help can be given to the mason by the analytical chemist. Chemists of high eminence have paid great attention to the subject of building-stones, with practical results to the mason of much value, by directing attention to points which had puzzled many, and by formulating certain other points, which have gone far to guide the practical man in his choice of stones for different classes of buildings, and in the application of methods either to prevent or arrest decay in them when selected. In the art of masonry stones for building are those which are, by the labour of man, cut from the mountain or valley side, or dug out—quarried—from the bowels of the earth from a greater or less depth, the mineral masses from which the stones are cut being termed rocks. Rocks are purely mineral, being an aggregation of particles of mineral material, to which the name of earth is given. Stones thus defined are either simple or compound: that is, composed or made up of one kind or class of "earth," they are called simple—as, for example, limestone, which is composed throughout of one kind of earth only; when the stone is composed of more than one kind of earth it is termed compound. The earths of which stones are composed are four in number—namely, silex, alumina, lime, and magnesia. Of these elementary constituents, when silex is the predominant part the stones are termed silicious, or flinty—silex being the earth of flints; sometimes they are termed sandy stones. Silex or silicia is present in nearly all stones, and is a predominating element in gravel, sand, quartz, and flint, which last, however, may be looked upon as pure silex. If the percentage of silex is high in stones they are very desirable for building purposes; but their extreme hardness makes them so very difficult to be worked or tooled, that they are not often used even when they can be had. The earth known as pure clay is alumina, and stones in which the element predominates are termed aluminous; but as silex is more or less present in them, the term argillaceous stones is more frequently employed. The third element of stones or rocks is lime, best known by the name and in the state of quicklime. In chalk it largely predominates; in marble, and in the stones to which the generic term limestone is given, forming a most important class of building limestones. When lime is a predominating element in stones they are classified by the name last given, although the term calcareous is perhaps as frequently employed to designate the class. The fourth element or earth found in rocks and stones is magnesia, which is one of the elements found in several stones, markedly in one of the classes of limestones or calcareous stones known as the magnesian limestones, one of our most valuable building stones.

We have stated that stones are either simple or compound—that is, composed of more than one "earth," the particles of which are kept together in one of two ways, so as to form the solid mass. If the particles of different earths are held together by a cementing material substance, mixed throughout the mass, such as silicia or alumina or clay, the stone is said to be cemented. It will easily be understood that a silicious cementing substance will give to the particles of "earth" composing the stone a closer and more lasting building material than when the cementing substance is argillaceous or clayey; and by consequence a much harder and more durable stone, less subject to the deterioration caused by atmospheric influences. When a compound stone is made up of a mass of earths of different kinds, the state in which they are found seems to have been the original form in which they were brought together; they constitute a mere aggregation of the constituent earths, and are therefore termed agglomerated, sometimes aggregated stones. Stones of this class are termed "granular" when the minerals making up the stone form, as it were, cubes, in which the dimensions are the same every way. Agglomerated or aggregated stones are termed "laminated"—popularly "slaty"—when they are found in masses of which the thickness is much less than the length and breadth, and are found lying flat on the broader surface. What is called the "grain of the stone" is an important element in deciding its value for building purposes. When the grain is fine and uniform, with deep colour, and a texture very compact, the strongest stones are the result; and when stones are similar in the qualities and respects named, the heaviest of the specimens is the strongest. The admixture of foreign substances, such as iron, deteriorates a stone for building purposes; and so also, as is scarcely necessary to be named, are all defects taking away from the homogeneous solidity of the stone—such as hollow places and cracks, or fissures.

A little consideration of the circumstances under which stones are used for building purposes will show the student that certain qualities or attributes are essential where stones of the best quality are desired. The first of these is that the stone shall be strong enough to resist the pressures or strains to which it is subjected. Those are, first, the pressure of "compression," or that of mere weight, which, resting or bearing upon the surface, has a tendency to crush it. Stones are, as a rule, chiefly called upon to resist this compressile strain or pressure. The second strain, which the stone should be strong enough to resist permanently, is that of cross or transverse strain. This is brought into play when a piece or block is stretched across an opening, and supported only at both of its ends, leaving the greater portion of its length unsupported over the void or open space. The cross or transverse strain put upon the stone in this position—the piece being termed a "lintel"—is created generally by the superimposed weight of materials built over and resting upon the block, although the mere weight of the block itself acts as a transverse or cross strain. Stones are not often subjected to a directly acting tensile or pulling-asunder strain (see the companion volume entitled "The Student's Introduction to Mechanics"), although a body under a cross strain, which spans an opening as a beam or a lintel, has its lower fibres or grains subjected to a tensile strain.

The next essential quality which is demanded from a good stone is that it shall be hard enough to resist blows and the wear and tear of rubbing action, such as the steps of a stone staircase are subjected to.

The third and last quality which a good building-stone should possess is a capability to resist what are called the atmospheric influences, such as damp, wet, frost, and the action of the oxygen of the air on the chemical constituents present in the stone, so as not to exfoliate, and get disintegrated or crumble away. This last quality of resistance to atmospheric influences is a very important one, and has given rise to many elaborate investigations and experiments by chemists as to the different points connected with it; and has brought out many methods by which stones can be treated so as to prevent decay, or to avert it when once began. We have said that the most valuable stones are those which possess the greatest weight or specific gravity, have a deep or dark colour, are of close texture, and are uniformly fine in the grain. Generally these qualities accompany each other, and the more fully they are met with in a stone the more valuable is it for strength and hardness. From an elaborate series of investigations into the properties and characteristics of stones it was found that their strength varied in the proportion of the area of their bearing surface or base on which they stood or lay. And of the forms which the base or the block assumed, it was found that the circular form gave the highest strength; and, as a consequence, the next strongest were the polygons, having the greatest number of sides—the greater the number the more nearly approaching a circle, which, properly defined, is a polygon with an indefinite number of sides (see the companion volume in this series entitled "The Geometrical Draughtsman" on problems connected with the circle). It follows that the weakest form which a stone can have is that in which the resting base or bearing surface is rectangular or square. In stone a column cylindrical, that is, with a circular section, is stronger than a column square in section. In blocks of stone, of the same amount of cubical bulk, the strongest in the experiments made were those in which the height or depth was equal to the diameter of the base or bearing surface. As regards their powers to resist a compressile or crushing force or pressure, it was found that in the stones submitted to trial a crushing or disintegrating effect began to be exercised when the weight was a little over 50 per cent., or one half, of that which was required to absolutely break up the stone, or crush it into fragments. A very wide "margin of safety" should, in all cases, be allowed, and authorities recommend that this should be such that the stones in a structure should not be called upon to bear weights or sustain pressures per cubical inch more than one-fourth or one-fifth of that which a trial shows to be sufficient to crush the stone. The order or rate of value, as regards strength and hardness, may be taken in the descending scale, from the highest to the lowest in value, as follows: stones basaltic in character rank the highest; next granite and granitic stones; the third in value being the limestones; while the fourth or lowest in value are the sandstones. As in most other cases, strength and hardness are purely relative, not absolute terms. Thus, a stone may be considered hard when compared with, or in relation to, another stone; yet it may be soft when compared with a third stone. Generally, masons define a stone as hard which, to be cut up into slabs, will require the use of a hard-tempered grit saw; it is said, *per contra*, to be soft if it can be sawn up into blocks by the aid of a common saw, not peculiarly well tempered.

Certain Practical Points to be Attended to in the Choice of Stones for Building Purposes.

In some cases the choice of stones within the reach of the mason is exceedingly limited, unless the building is sufficiently large and important to justify the transport from a greater or less distance of a quality of stone which is likely to prove the most valuable. But although a good building-stone may be within the easy choice of the stone mason, he has to take into consideration certain points bearing upon the uses to which the stone is to be put; to bear in mind also the influence of the stone itself upon the methods by which it has to be tooled or worked up into shape or form. Thus, a stone may be very hard, and so far more valuable than another quality of a softer kind. But the hard stone will be more difficult to work or tool, and therefore be more costly; while such a stone, if this consideration of greater cost could be overlooked, as in first-class work it ought to be, would not obviously be equally valuable in all cases where it might be used. As, for example, such very hard stones are apt to become smooth and polished, and therefore "slippery"; to use them in the case of a staircase would thus be wrong, as they would give steps dangerous to tread upon. Thus a stone which, when finished on the surface, such as a sandstone or a limestone of a certain quality, would on its somewhat rough surface give the "grip" to the foot which is necessary to safety, would, although less valuable *per se* than the hard stone, be more valuable for the particular purpose. Then, again, being hard, stones are sometimes very brittle, preventing them from being worked nicely off, with clear, well-defined sharp arrises, and which if worked are very liable to be chipped or broken off. But strength is not all which is required in a building stone; other points have to be considered. Thus we have stated that basalt gives us one of our hardest and strongest stones; but for a domestic structure basalt would be quite unfitted, inasmuch as it is, like some other stones, very hygrometric, or has a great capacity for taking up moisture, and is liable to be affected by unfavourable changes in the atmospheric conditions. Of this class whinstone, although a hard and strong stone, is another unsuitable for domestic buildings; so also are the aluminous or argillaceous stones generally. If such stones are employed by the builder a dry house need never be hoped for; the walls in the interior will always be more or less damp, while in rainy damp weather, and in thaw after severe frosts, the occupier need not be surprised at seeing the moisture fairly running down the walls in the interior of the house. Stones possessing the requisites of hardness and strength may often be found along the margin of tidal rivers or sea shores; and on shingly shores stones can be had in abundance. This might tempt the builder to employ them, just as he is sometimes tempted to use sea-sand in the making of his mortar. But in both cases, if the temptation be yielded to, it will be at the cost of having almost perpetually damp walls; and this in consequence of the salt which the stones have imbibed by long exposure to the sea water, giving and taking with every change of weather, the salt deliquescing more or less in every change of weather. Such walls would become, in fact, fairly good hygrometers, or hydrometers, giving evidence of the degree of damp or moisture in the air. Other points have to be considered in the choice of a building-stone, such as the point connected with the relation of heat in the interior of a building in this generally cold climate of ours; and also the contrary effect—namely, the keeping of the air in interiors cool in the sometimes very hot weather of summer. These points are secured by choosing stones which are bad conductors of heat, such as those of a dry and porous and not of a very close texture.

Colour is also a point which for buildings of a superior class of the domestic kind, and for public buildings in towns, should be attended to. On this point the architect will be the best judge. There are some stones which possess uniformity of colour in a high degree, and uniformity is deemed most important by many; but yet the colour is sad, dull, and depressing to look at. The dazzling white stone so familiar in many of the public buildings to the visitor to Paris, and which looks so bright and cheerful under the sunny skies there so often met with, is not a colour affected by our architects generally; and possibly this is done with judgment, as the glaring white does not, perhaps, harmonise with our duller and too often clouded skies.

The light yellow or grey of such a stone as that known as freestone, so largely used in the fine buildings of the capital of Scotland, is perhaps the most favourite hue where stone of this class and of fine quality is obtainable. The red sandstone, at one time rarely used for superior buildings of a more or less public character, is now becoming a favourite stone with some architects for employment in such structures as are designed in the Queen Anne style. Why red sandstone should be disliked by many on account of its colour only, when brick of the same colour is admired, one has a difficulty to see. While avoiding a patched mosaic-like look, still some fine effects in building may be secured by the use of different-coloured stones in the same building; just as white stone dressings are employed at doors and windows in houses built with red stock bricks, or as blue and white bricks are used, as in string courses, window head, and in scheme and other arches, where the body of the house is built with red brick. In these and on other points the builder in his choice of stones must always bear in mind that consistent with other purposes strength and durability must not be neglected. As a rule, the fine uniformly grained, close, compact textured stones stand better the atmospheric influences, tending always more or less effectively to determinate them in a climate such as ours, than stones of a coarse grain, or of loose open texture. In the choice of a building-stone the young artificer should be thoroughly impressed with the importance of attending to the physical, or as some call it the mechanical, character of the stones. A stone which through its hardness or density presents a smooth, clear, hard surface, is obviously one which will resist entrance of moisture to its interior parts much more effectively than stones which are of a light, less dense, mechanical structure. Such stones present on their surfaces a series of pores or openings, which, however minute they may be, act as channels or leaders to the pores inside, thus conveying moisture to the interior, and giving admission to damp or smoke-laden air; which atmospheric influences are those which are most potent in deteriorating the strength and the hardness of a stone, which under more favourable atmospheric influences would form building stones of no despicable value. Stones of a crystalline, mechanical, or physical character may always, therefore, be looked upon as being the most valuable for building purposes—possessing the requisites of hardness, strength, and durability. Limestones, for example, cannot in any sense compete with the true granite in hardness, strength, and durability; but one class of limestone—marble, which is a carbonate of lime—may be said to vie with the granite in point of durability; and this simply because its mechanical or physical structure, so to call it, is crystalline. The builders of the old world, who lived in times "hoary grey with eld," such as those of Egypt, as well as did the Romans and the Greeks, knew well the value which a crystalline character gives to building-stones. And those marvellous structures which the Egyptian builder raised on the banks of the Nile, which after thousands of years have come down to us absolutely untouched by the finger of time, and are likely to go down to the times of countless generations yet unborn, were built with the enduring, time-defying granite, the type and symbol of endurance, and of all crystalline stones the best. We now come to glance at the characteristics of the

Different Classes of Building Stones.—The Granites.

Those come under the class of silicious stones, and, as above alluded to, are the highest in quality and therefore the most valuable class of building-stones, as is even popularly understood; for when it is stated that a structure or part of a structure is built with granite, the idea of enduring stability is at once associated with it. A goodly number of stones go under the name of granite, as there is a close general resemblance between stones of the class generally so termed. The constituents of a true granite are, quartz, feldspar and mica, and those existing in the condition known as granular or crystalline.

Of these constituents the quartz is that which gives the greatest value to the granite in respect to its capability to resist atmospheric influences. The quartz is transparent or semi-transparent, like the glass used in many articles, having a white or milky hue; if present in the form of what are known as rock crystals, those are pure silica. But the quartz is generally formed having different hues or colours, or shades of colour, and those predominating give rise to the various names by which the different crystals are known, as rose-coloured and the like. The value of this constituent of quartz in giving the weather-resisting qualities of granite may be judged from the fact that pure silica, in the form of rock crystals, is quite indifferent to the action of even the most powerful chemical reagent (there being but one exception to this—namely, hydrochloric or muriatic acid); hence the general solidity and lasting character of granite, even under bad atmospheric influences. Feldspar, the second of the three constituents of granite, is in colour whitish or of a reddish hue; it has an appearance more opaque, less clear than the particles of quartz; it is made up of silica, alumina, and potash. In some cases feldspar is associated with lime, which also enters into its composition in common with the other substances named. Mica, a substance the name of which indicates that it can be split up into thin plates of shining, glistening character, so familiar to many, is a compound substance composed of silica and alumina, associated with magnesia, lime, and soda, the predominating element giving varieties of mica, such as magnesia mica, the alumina being to a certain extent replaced by magnesia, and potash mica, in which potash is the third element with the silica and alumina. Talc, another clear transparent and incombustible substance, is a magnesian mica, having a large proportion of magnesia in its composition. The quality of granite depends upon the way in which its three constituents, as named above, are aggregated. As might be supposed from what has been said, the granite is of the hardest when quartz predominates—which it sometimes does to such an extent that it is scarcely possible to work the stone from its extreme hardness and brittleness. Of the other constituents, feldspar and mica, both are liable under atmospheric influences to decay; and of the two feldspar is most liable to decomposition, so that when in excess the value of the stone is lowered. When the mica present in a stone decomposes, it gives a granite known as soft. Other foreign elements are present in granites, but they are all deteriorating in their influence; these are schorls, a mineral of a whitish-green colour, found markedly in the sulphates of iron. These, when present under atmospheric influences, greatly deteriorate the value of the granite. When schorl predominates, or is in comparatively large quantity, the granite becomes too brittle to work. The colour of true granite is generally grey through various shades or depths of tone of this colour, but it is often of a reddish hue, the depth of tone of which is owing to the percentage of feldspar present in the stone. The stone known as "Syenite" (from the ancient Egyptian locality of Syene, the border town or land between Egypt and Nubia) is often classed as a granite, but it is not a true granite, the mica being absent, its place being taken by hornblende. It is, however, a beautiful building material, and was extensively used by the ancient Egyptians in the production of their finest works—obelisks and the like. The colour is generally grey, but is often in hue of a reddish tint. Other stones of this class are used or met with: the hornblende becoming visible by wetting or moistening the piece, it assuming a greenish tint. The stone known as "gneiss"—pronounced nice—differs from granite more in the way its constituents are aggregated than from any difference in their constituents. The three stones, granite, syenite, and gneiss, take the first rank as building materials for hardness and durability. Granite possesses the characteristic of being workable, or being capable of being tooled in any direction; this arising from the fact that its particles are generally homogeneous, thus presenting a uniformity of texture throughout the block, so that while being quarried and quarry dressed, it may be split up in any direction with equal facility. This characteristic syenite shares with granite. Gneiss, on the contrary, has more the character of a laminated stone, the aggregation of particles being, so to say, in layers, somewhat like slate; thus affording facilities for breaking it up by the wedge in quarrying, or by the chisel in after tooling, in the direction of the layers rather than in a direction opposite to, or different from these. Porphyry is by some classed as granite; at all events there is a porphyritic granite. To any rock which has distinctly marked crystals mixed up with, or imbedded in, a matrix or field of feldspar, the name porphyry is now given. The red porphyry of Egypt was largely used in ancient times for the purposes of the sculptor. The porphyritic granites of Cornwall are well known, and some fine works of art have been produced in one or other of the qualities found in that part of England. The ordinary granites are met with largely in the same part; they are said to be inferior to the Scotch Aberdeen granite; but this opinion has probably arisen from the behaviour of blocks used in certain public works, which have been quarried from parts where the stone had not been subjected to careful inspection. Where the choice is judicious the behaviour of the Cornwall granite is all that is anticipated—such as, for example, the enormous blocks used in facing the Thames Embankment. The

Cornwall granite quarries yield blocks of larger size than can well be worked in the quarries where the still more celebrated Aberdeen granites are obtained. The Devonshire granites occupy about the same position of practical value as the Cornish; like these, they can be quarried in large blocks. Both of those classes of granites partake more of the porphyritic character than the Aberdeen granites. Of the English granites, that quality found in Cumberland, quarried at Shap Fell, near the summit level of the long railway decline which stretches down towards and near to Lancaster, is decidedly porphyritic in character; so much so that the evidences of porphyry are but too marked in the red patches visible on the surface. There is a light as well as a dark variety; yet this granite is now largely used, especially in the Metropolis.

Granite is also found in Ireland, chiefly in counties Wicklow and Clare; it is also met with in counties Down, Tyrone, and Galway. The Wicklow granite is chiefly used, the kind quarried at Ballyknocken being the best. But the most celebrated and the most widely known, if not the best in quality, of all the granites used in this kingdom are the Aberdeen and Peterhead granites, the latter being a red granite. The Aberdeen granite is fine and firm in texture, its particles being very uniformly aggregated, while the tone or tint is rich and warm; a distinction between this granite and the granites of Cornwall is that in the Aberdeen the hornblende is present, frequently taking the place of mica. In choosing a granite special regard should be had to the character of the constituents, and the way in which they are aggregated. The more equal and uniform the mixture, the finer the texture, the better the quality; when there is a greater percentage of one of the constituents the quality is in proportion lower in value. When the predominating constituent is feldspar the quality is the lowest in value, as this is more liable to decay than the mica. The mean weight of granite per cubic foot is 166·25 lb., the specific gravity 2·66, water being unity. Although one should not calculate that it was so, judging from the hard, close texture of the stone, still granite readily absorbs water, having a comparatively high degree of porosity. The percentage—mean—of water which granite contains may be taken as 0·8; or a cubic yard holds three and a half gallons, to which a third more may be added by long exposure to wet.

There are other stones classed, at least named, by many as granites—such, for example, as the stones found near the town of Leicester, which are of the crystalline class, of much the same character as syenite, having hornblende as a marked constituent. This is the case with the variety known as the Mountsorrel, of which there are two kinds—the red and the grey. The Leicestershire granites are, however, more used for paving and for the making of road metal, their value for these purposes arising from a peculiar toughness which they possess, in consequence of the peculiar way in which the crystalline constituents are aggregated. The stone known as "serpentine," and so valued from the beautifully variegated colours it displays, and from the ease with which it may be worked, belongs to, or is classed with, the granitic rocks. It is a "hydrated silicate of magnesia," and is capable, like granite, of taking on a high polish; and although from this circumstance it is hard, yet it is soft enough to be easily worked, and to be even capable of being turned in a lathe. From its constitution it is, however, liable to be deteriorated by atmospheric influences; hence it is used chiefly for interior work.

The Sandstones.

This class of stone belongs to what are termed by geologists the sedimentary formations. In other words, they are composed of the particles of the rocks of the primary formation—that is, of the granitic or crystalline rocks—which rocks have suffered, from one cause or another, decomposition, and thus created a large supply of what may be called rock. This, under the influence of water, is carried to certain localities, and allowed to become quiescent. In this state of rest the solid particles fall to the bottom, depositing as sediment layers of rocky particles, which on the water drying up become concreted into a solid mass, and in process of time become a rock or stone. The character of this will obviously depend upon the kind of rocks which by their decomposition gave the supply of small particles. According as this basis is silicious or calcareous, the kind or class of sedimentary rock or stone thus formed belongs to one of two classes, these classes being the sandstones and the limestones. It is with the sandstones we have in this paragraph to concern ourselves. Sandstones have for their base the quartz constituents of the granitic or crystalline rocks. But it is obvious that those particles, before they can be concreted or aggregated into a firm rock or stone, must be held or kept in the mass by some cementing substance. The cementing substances in the sandstones are either of a silicious or calcareous, or of an aluminous or argillaceous character. And it is further obvious that the solidity, the hardness and completeness of the sandstone will depend largely upon the kind and quality of the cementing particles. Hence, a sandstone of which the cementing substance is silicious in character is of higher value than a sandstone in which quartz particles constitute the basis, and which are held together by a cementing substance aluminous or argillaceous in character. Sandstone, even of the best quality, is much more liable to deteriorate through atmospheric influences than the granitic rocks, but being of considerable strength, if well chosen and durable, and moreover being easily worked or tooled, it is therefore largely used. The sandstones are divided into two classes, the red and the grey or yellowish-grey. The latter is generally termed "freestone"—a term which, however, is applicable, and is practically applied, to all stones of which the physical or mechanical character admits their its being easily tooled or worked by the mason.

The finest of all the sandstones are almost always designated by this name of "freestone"; *par excellence* is the grey sandstone known as "Craigleith," that being the name of the locality near Edinburgh at which this quality is quarried. As we have already stated, the whole of the New Town of Edinburgh, and practically all the villas now forming the fine suburbs of the same town, are built with this freestone. Quarries giving good qualities of the same freestone are at Hailles and Humble, also near Edinburgh. This celebrated sandstone contains as much as 98 per cent. of silica, and the cementing substance which binds its particles together is silicious, hence its high value. It weighs 146 lb. to the cubic foot; its water-absorbent qualities are represented by four parts to the cubic foot, while its strength to resist compression or a crushing force is equal to 5800 lb. to the square inch.

"Freestone" is of fine grain, and of light yellowish colour, which, however, darkens by exposure to smoke. Sandstones, of much coarser grain than the freestone, which renders them unfit for finer-class work, are still, from their strength and comparative durability, and from being obtainable in good-sized blocks, used largely for ordinary work. Such are those quarried in the north of Scotland, near the towns of Arbroath and Dundee. Some special sandstones, markedly those of Arbroath, are largely used as paving stones and pavement. The sandstones of Yorkshire have long been celebrated for their high qualities, the class known as "Bramley Fall Stone" having a great reputation. That particular quarry is now exhausted and closed, but it is well represented by numerous other quarries in Yorkshire. England, generally speaking, affords large supplies of good sandstones, the counties of Yorkshire—just named—and of Lancashire and Derbyshire being perhaps those best supplied. The sandstone quarried at Darley Dale, near Matlock, in Derbyshire, served to build a large number of the Manchester structures. The Yorkshire sandstones especially, being obtainable in large blocks, are used for heavy work, such as foundations for large and powerful steam-engines. As a rule, sandstone should always be used in ashlar work, never for rubble, as it is a stone which has comparatively little affinity for mortar, and the efficiency of rubble depends mainly upon the strong adhesion between the surface of the irregular stones and the mortar.

There are some stones of the sedimentary class which partake of the characteristics of the two divisions, the sandstones and the limestones, such as the red stone, popularly termed a "red sandstone," quarried at Mansfield, near Nottingham. This has for its base fine silicious grains, held together by a cementing substance of magnesian calcareous character. It is held in high estimation as a building-stone; it weighs 146½ lb. to the cubic foot, and the same bulk is capable of absorbing from four to five parts of water. It is durable in good clear air, but deteriorates in smoky atmospheres. The stone known as Kentish ragstone, which gives its name to the peculiar kind of masonry for walls illustrated in an early paragraph in the present work, is a sandstone found on the greensand of Kent; it is a hard and durable stone, but is expensive to tool in the flattish blocks used in the style. The sandstones of the geological formation known as the Wealden are used for buildings, but they are not satisfactory, as they are very deficient in good cementing substances; carbonate of iron is found in them, but in place of acting as a cementing medium it is a deteriorating element.

The Limestones.

These, constituting the second of the two classes of sedimentary rocks or stones, form in their many varieties the most useful class of building-stones to the British mason,—useful for nearly all classes of ordinary work, and ornamental for the higher and more public structures in which ornamental work is more or less required.

Limestones of a good quality possess to a fairly good extent all the requisites of strength, to resist compressing forces or pressures; hardness, to give durability, yet are soft enough to be tooled or worked with comparative ease, and can be made to take on if not a positively polished yet a smooth surface, to which may be added the valuable attribute of pleasing colour. Limestones are generally composed of carbonate of lime in combination with metallic oxides and various foreign substances. They are rarely found in their pure state, and if so are in colour almost purely white, known as white marble, which is pure carbonate of lime. They vary very much in character, from this white marble to a magnesian limestone, some varieties of which constitute valuable building stones. The carbonate of magnesia is in amount not far off from being equal to the carbonate of lime, which, as stated above, is the general characteristic constituent of the limestones. These are classed popularly as common or ordinary limestones, and the marbles. The marbles, as above hinted at, are composed of lime, a portion of water, and carbonic acid. The marbles are supposed to have been thus formed under the action of very high temperatures, and inclosed within confined spaces, so that escape of the carbonic acid was, if not wholly, to a large extent, prevented. This formation under pressure gives a great density to marbles, which weigh as high as 170 lb. to the cubic foot. Generally speaking, the marbles are employed only for decorative and expensive work. As a rule, masons, without any special reference to the chemical character of a limestone, class all as marbles which are capable of taking on a high polish; and here they are following, perhaps in many instances unknowingly, the correct term—for originally with the Greeks the name was given to any stone which could be made smooth or polished on its surface, the name being derived from a Greek word signifying something polished or shining. A number of building stones thus classed as marbles are really amongst the compact limestones, but they do not stand so high as marbles obtained from the granular limestones. It is the presence of these metallic oxides—in one sense deteriorating elements—which in a true marble, that is, consisting of pure carbonate of lime, give the beautiful tints or colours which are so pleasing to many in those varieties. These go by various names, given from some fancied resemblance which the patches of colour have to certain forms, such as the Florence Stone, or Ruin Marble (from the notion that the patches form miniature pictures of ruined buildings), and the "Bird's Eye" marble. A specimen of marble greatly admired by the ancient handicraftsmen was "verd antique"; it gives its name to one of our variegated marbles of a green shade. The marble displaying sections of shells cemented together by a calcareous substance is known amongst our variegated marbles as "Lumachiela." Another is termed the "conglomerate," the "Neccia," made up of a number of angularly-shaped pieces, and the "pudding stone," made up of round pebbles—in both a calcareous substance forming the cementing material. We have already classed "Serpentine" as a granite stone, but others include it in the marbles, being a silicate of magnesia. The purest of all the marbles is the Carrara, found in Italy, and used only for statuary work of the highest class; but in our country, the counties of Devonshire and Derbyshire yield marbles which are truly valuable for the decorative work of the mason. For a pure white stone we have the "Alabaster," found abundantly in England, of good quality; the finest quality, yielding the largest blocks, being obtained, however, from Montarcent, in Italy. Alabaster is by some considered to be but a superior kind of gypsum or sulphate of lime; others class it as a stalagmite carbonate of lime. It is easily worked, and when cut into plates or slabs it is so transparent that it may be, as it has sometimes been, used as window lights in place of glass.

Coming now to the ordinary building limestones, we find them in practice divided into three classes—the magnesian limestone, the oolitic limestone, and the common limestone. Of these, the first named gives us the most valuable of our building limestones. Let us first glance at the group of oolitic limetones, the varieties of which make up the largest portion of limestones used for building, exceeding in number the stones yielded by the magnesian class. Of all the stones of this class the "Portland Stone"—from the Isle of Portland —takes the highest rank, as at once the heaviest, the hardest, and most durable, and that which is least absorbent of moisture. It is composed of 95 per cent. of carbonate of lime, with a trifle over 1 per cent. of carbonate of magnesia and silica, the crystalline particles, and the cementing material which binds the particles together, being also of carbonate of lime. Portland stone weighs from 135 to 148 lb. to the cubic foot, absorbs nearly seven parts of water to the same bulk, and has a resistance to crushing or compressile forces equal to 3,279 lb. to the square inch. It is this stone which has been used more extensively in London than any other kind, and when carefully selected and tested has proved itself by far the best building-stone for resisting the atmospheric influences. The best bed in the Portland Island quarries is known as the "Whitbed," a vein or stratum of 9 feet 6 inches in thickness. It lies below the bed called the "Roachbed," which lies at a depth of 25 feet below the surface; this Roachbed stone is much inferior for external upper work, being disfigured with cavities and shelly portions, but as it is hard and durable it is employed largely for foundation and concealed work, or for external work when look or appearance is not much cared for. Eight feet below the "Whitbed" lies the "Basebed," but frequently corrupted into "Bestbed"—a confusion of terms which often leads to disappointment, inasmuch as it is selected as the best "Portland," whereas it is certainly inferior to the Whitbed stone. Portland stone requires to be selected with great care, as the same bed will give stones of decidedly differing value, the mere position in relation to the Island causing a change in the character of the stone —the beds on the west side of the Island giving stones of a quality superior to those taken from beds on the east side. Nor is the appearance of the stone blocks altogether a safe rule to go by in choosing a Portland stone, as a block which looks coarse will absorb little moisture, resisting atmospheric influences well; while a block which has a much finer appearance will, says a high authority, "suck in water like a sponge, and soon decay."

Next in value of the oolitic limestones to the Portland is the "Bath stone," largely used also. Like the Portland stone, Bath stone is easily tooled or worked, and has a good colour, but which in both classes is but too speedily lost when subjected to smoky atmospheres. The weight of Bath stone per cubic foot is 123 lb.; it absorbs 8½ parts of water to the same bulk, and possesses a resisting strength to crushing or compressible forces of 2000 lb. to the square inch. These facts show its inferiority to Portland stone; but then it is cheap, and cheapness nowadays is sometimes more thought of than other points worthy of greater consideration. So numerous are the different classes or kinds of oolitic limestones that it is impossible, in the limited space at our disposal, to name them even. We can but just refer to the Caen, a foreign stone obtained from quarries at a place so called in Normandy, France. This stone was much used in London at one time, and this perhaps chiefly from its adaptability to ornamental or decorative parts of buildings, as its texture is fine and uniform, and colour good, and it is tooled or worked with great ease, cutting when first quarried like soap or cheese, but hardening or indurating after exposure to the atmosphere. But from its lack of durability being particularly susceptible to the smoky air of large towns like London, it is now comparatively seldom used. Yet, like other stones, much depends upon the choice of Caen stone; examples of its use are to be met with in this country—as, for instance, in Canterbury Cathedral—where its ordinary qualities have proved quite equal to other stones of a different class. It is a comparatively light stone, weighing 120 lb. to the cubic foot; it is less absorbent of water, and resists a greater compressible force than Bath stone. Of other oolitic limestones we have only space to refer to the product of the quarries at the foot of the Mendip Hills, in Somersetshire, known as the "Doultry stone." This is a little inferior to Portland stone, which it resembles in composition, and in weight and hardness; it is more like Bath stone in appearance, although superior to it. Another stone of the oolitic class is that which has been largely used for ecclesiastical buildings in Oxford, and is known by the name of "Headington stone." Experience of its use is not favourable to its claims for durability. A stone of the same class and neighbourhood, known as the Melton or Chipping Norton stone, from being quarried at this place, has of late years been largely employed for church buildings, etc., and is said to be more durable than the old Headington stone. The stone known as "Kitting" has a good reputation; it is marked for its distinct granular appearance, the grains appearing like the roe of a fish, which is the distinguishing character of oolitic stones, and which has indeed given the name to the class generally. The oolitic limestone known as the "Ancaster stone," quarried near Grantham, in Lincolnshire, has been and is largely used in the county. The Rutlandshire oolitic stones, known as the "Caslerton" and the "Clipsham," have a fair reputation as building-stones of a good class. The oolitic stone, quarried near Salisbury, differs from the other oolitic limestones, as it contains 10 per cent. of silica, this being present in the form of nuclei, made up of the particles of silica, and round which nuclei are deposits of carbonate of lime, which is also the binding or cementing material. Of this stone Salisbury Cathedral is built, and we believe it is now to be used for the constructive work at Westminster Abbey restoration.

The Magnesian Limestones.

These stones are known also by the name of Dolomite, although this term is not always strictly applicable, a pure dolomite being a mineral, which has a peculiar texture, partly granular, partly crystalline, composed of fifty-four parts of carbonate of lime and fifty-six parts of carbonate of magnesia. The magnesian limestones are found in the geological formation just above the carboniferous, and under the new and second stone formations. They are generally of a light brown colour, and are composed of valuable properties of carbonate of lime and carbonate of magnesia, the best qualities possessing equal proportions of those two substances, and having an "even, uniform texture of pearly lustre." The magnesian limestones are of greater density than the oolitic, and the best quality are four times as strong in resisting compressible forces as the Portland stone. Their *locale* is in the north-eastern, and in the central districts of England; but the supplies are principally obtained from the counties of York and Nottingham. The magnesian class of stones, valuable as they are, have suffered in reputation by the result of the choice made of a stone of this class for the New Houses of Parliament. This stone, after the most careful examination, a committee of experts specially appointed, having before them the different classes of building-stones open for selection in the kingdom, at last decided upon (obtained from the quarries at Bolsover, in Derbyshire); and this chiefly from the evidence which certain old buildings erected with the same stone gave of its rare qualities of endurance. Unfortunately, large portions of the magnificent building gave speedily evidence enough, and of a startling character moreover, that some mistake had been made in the selection—a mistake so grave that many feared that not many years would elapse before a large portion of the stone of the whole structure of the Houses of Parliament would have crumbled away. Although their fears have fortunately not been realised, the lesson which the case afforded was a valuable one, and one which every young stone mason should seriously consider. And the lesson, briefly stated, is this. That the greatest care should be taken —as much as that exercised in the selection itself of the particular kind of stone for any proposed building—in seeing that the work at the quarry is properly done, and that no stones are delivered for actual use unless they are quite up to the standard sample; for we may safely predicate that any one quarry will display stones of different quality at different parts of it. And this is what is actually found in practice, a very great difference being observable on careful examination between the stones taken out of one part and those dug out of another part of the same quarry; and this, moreover, at points by no means distant from each other. Even when chemical analysis, with all its strictness of examination, shows that two blocks or classes of blocks are precisely the same in chemical constituents, a difference of a marked kind will be found in practice, as regards the physical or mechanical behaviour of the stone when placed *in situ*. Another lesson by the way for the young stone mason to pay heed to is this. That he must, in his examination and study of building-stones, in addition to their chemical constitution, always bear in mind their physical or mechanical characteristics. All this points to the importance of the duty which really devolves upon the builder—namely, that he must have a practical acquaintance with the quarry from which he selects his stones, and that every care should be taken in the supervision of the quarry work, so that no stones be sent from it which are not up to the sample quality. Many excellent stones have a bad reputation clinging to them, and this solely from a forgetfulness on the part of practical men of the important scientific and practical fact that the *conditions under which a material is placed and is used* have an important influence for good or for evil, according as their conditions are favourable or otherwise. And which of the two exist, every practical man should know, and, if not knowing, should acquire. What we have given in the various sections of this volume should help him in this important work. There is no doubt that if these precautions now glanced at had been taken, in many cases disappointment and loss in the use of certain building-stones would have been avoided. Thus, in the case of magnesian limestone it is not true, as many have said, pointing to the unfortunate results of the choice in the case of the New Houses of Parliament as examples of this—it is not true that magnesian limestones do not or cannot give good qualities of building-stone. The very opposite of this is the truth: there are many kinds of this stone of excellent quality to be met with. Before the unfortunate experience of the New Houses of Parliament, magnesian limestones held a high place in the estimation of the practical builder. Indeed, Sir Christopher Wren gave it as his opinion that it was little inferior to Portland stone in point of durability; and not a few important buildings of modern times prove its value in this regard. An important point which should be observed is what is called the "weathering" of stones after they are quarried. In his great work at St. Paul's, London, Sir Christopher Wren allowed the stones he proposed to use to be exposed to the weather for the long period of three years, carefully rejecting all blocks which showed the least signs of a tendency to exfoliate, crumble, or decay. In these days of ours, when we do in a day what our slow-going ancestors would have expended months over, this careful "weathering" could not, we fear, be exercised. But this test of "weathering" should at all events be exercised in all important works—namely, exposing trial-blocks to the atmospheric influences a length of time sufficient to allow the natural moisture existing in the stone when taken from the quarry bed, technically called "quarry water," to evaporate or dry up. This hardens the blocks, and lessens the tendency which many stones possess to split or face asunder in parts; this tendency, it is scarcely necessary to state, being greatest in frosty weather. All kinds of artificial drying, other than the natural one by exposure, are to be avoided. Another point to be observed, and one of importance, is that the stones used in building should be placed in the courses of the wall so as to lie in what is called their "quarry bed"—that is, in the same direction in relation to their grain and bulk in which they lay in the bed from which they were taken. The reason for this is too obvious to require explanation, as this position, being the natural or original one, is the strongest.

Miscellaneous Stones.

The argillaceous or aluminous class of stones is made up of what are known popularly as slaty or slate stones, although the principal variety of this class is used for the formation of the covering for roofs called slates. Still there are several varieties which are useful in the lower classes of stone walls, such as rubble work. But, as just stated, slate roof covering is the principal use to which the argillaceous stones are put. Slate, like other building-stones, varies much in character. The best variety should be easily split up into thin plates, which when sound and good should give out when struck a clear bell-like or metallic sound. The best slate should be able to resist the absorption of water, and should feel to the touch hard and rough; if it feels smooth, silky, or greasy it may be reckoned to be soft, and one which will readily absorb water. The colour also is an indication of quality. The best are of light blue or whitish-blue; those which are of a dark blue are not good. Silica is the element which gives durability and hardness to slate; when first quarried the stone selected should be the hardest. Weight is a deceptive characteristic in the case of slate stones, unlike the case of other stones we have named, for weight in a slate is generally due to the presence of iron, either as an oxide or in the form of pyrites, and both of those are very deteriorating elements, the pyrites rapidly decaying, and the oxide becoming oxidised on the slate being exposed to atmospheric influences. To the miscellaneous classes of stone some we have already described, such as the marbles, serpentine, Kentish rag, Mansfield, etc., belong. To these named we now add the following, which will complete the class. "Basalt," which belongs to the silicious division of building-stones, possesses great hardness and strength to resist crushing forces, notwithstanding which it is not so durable as other specimens of the same class. It is composed of hornblende and felspar, with a pretty large percentage of iron. It is this which imparts to basalt the disagreeable property of exuding moisture in damp, wet weather—"sweating," to use the not very elegant technical phrase. This peculiarity extinguishes another of the miscellaneous stones known as "trap," perhaps more popularly as "greenstone," and this from the greenish tint which the surface shows. Composed of hornblende and felspar like basalt, like basalt also it contains a varying proportion of iron. When this is not present in too high a percentage, trap makes for common work a good sound and durable wall in rubble work, for which class of masonry it is only suitable, from the fact that practically it is never found in blocks sufficiently large for coursed masonry, as generally the blocks quarried are small in size. The last of the miscellaneous class of stones we notice in this section is the "greywacke," which is made of fragments of a number of minerals varying in character, all of which are held together by a cement of an argillaceous quality. Greywacke is also found in the form of slate. Both of those stones give good material for rubble walls, the greywacke slate being often used for coping stones, and for paving of courts, yards, or the like.

The Deterioration and the Preservation of Stone.

The observant reader will have noticed that throughout the section last presented to his notice, in every description of a building stone reference is invariably made to its relative durability, and that this is always influenced to a greater or less extent by agencies which are classed under a general term—namely, "atmospheric influences." There is no exception to this law or condition under which building-stones exist, from the granite, the type or symbol of durability, down to the softest sandstone, which can almost be crushed between the fingers; all are under those atmospheric influences, the tendency of which invariably is to deteriorate the good qualities of the stones, and to soften them. The intelligent reader may here remind us that the atmosphere has not always this softening influence upon stones, inasmuch as we have named in our preceding notes that in the case of the Caen or Normandy stone, when first quarried it is so soft that it may be cut like soap or cheese; but on exposure to the atmosphere it indurates into a hard-surfaced stone. But even in this case—and the soft, beautifully white stone of which so many buildings in Paris are constructed, is an example of the same class, soft when quarried, hard after exposure to the air—the law or condition we have named is still in force; for, once hardened into what we may call its original normal condition when the stones are *in situ*, from that time the deteriorating power of the atmospheric influences begins to operate. In some cases the Caen stone withstands them very effectively; in others, of which London offers one or two notable examples, the deterioration is, if comparatively slow, all too complete. The law or condition we have named, that the atmospheric influences tend to deteriorate building-stones, may practically be said to have no exceptions. These atmospheric influences, as even the youngest students know, comprise, as popularly expressed, rain, snow, moisture or damp, frost and air, or the ordinary atmosphere; these being obviously resolvable into two elements, air and water. Of these two, water is so powerful an agent in destroying or lessening the valuable qualities of stone which give it its powers of durability, that it may be said to be the chief, if not the only one, to be considered and provided for. For although air, with its varied and deteriorating constituents, may be said to act destructively upon stone, it only does so most quickly and effectively when it acts in conjunction with water or damp, which latter is only water in a less determined form. In considering the deteriorating effects of the atmospheric influences upon building-stones, the student must bear in mind the two characteristics of stones, namely, their chemical constitution and the physical or mechanical features. In many cases—it may be with safety said in all—the true character of a stone is dependent upon, or, to express it more definitely, is really displayed by, not the nature of its constituents considered chemically, but by the way in which those constituents are disposed in relation to one another. In other words, the character of the stone is dependent upon the way in which its particles or molecules are disposed—that is, its physical or mechanical condition. This point or question of *condition* is one which is highly important in the consideration of all points relating to materials of whatever kind, but is one, nevertheless, which is but too frequently overlooked; in some cases wilfully ignored by those who have to do with physical, or mechanical questions. Thus, of two stones which display not the slightest difference in their chemical characteristics, careful analysis pronouncing them to be precisely similar, one is found, notwithstanding, to possess the qualities of a hard, strong, and durable stone, characteristics of the other being wholly different from these. The difference is defined by the *condition* in which the same chemical constituents are placed in relation to one another. A very marked and singular example of this is met with in the case of chalk and marble. Both are composed of the same chemical constituent, carbonate of lime; yet in the one we have a substance which is a synonym for softness—as "soft as chalk," as the popular expression has it; in the other a stone which along with granite is the synonym for enduring hardness. Numerous examples could be cited from the science of chemistry in evidence of the importance of condition, as well as from the sister sciences of physics and mechanics. But, however interesting, suggestive and conclusive such evidence would be, space prevents us from citing them; so that we must content ourselves by simply pointing out in general the essential importance to the student stone mason, of in all cases considering the element of *condition* in building-stones. Impressed with this importance, he will be more likely to succeed in acquiring not only a knowledge of the different classes of building-stones, but of the best methods of selecting and of using them.

Bearing in mind, then, the condition of stones, it will be noticed by the student that in stones considered as rocks *in situ*—that is, in the natural position before being quarried—in every case the masses are not continuous, but are divided, so to say, by seams or fissures, some of them so narrow that a sharp-edged knife cannot easily be inserted in the spaces, others so wide that the hand and arm may be easily inserted. Those fissures or seams are of varying depth; but in all cases water in greater or less quantity finds in them a lodging space. Descending to a more minute inquiry, and taking for examination a block from the quarry, and which has been selected for building purposes on account of its complete and perfect external condition—that is, free from visible cracks, seams, or fissures—it will be found that the stone cannot be called absolutely a solid mass, but that it is what we call porous. This quality of porosity, or openness of texture, is noticed with a facility greater or less according to the class or kind of the stone examined; but in all stones these pores exist. Into these, as into the larger fissures of rocks *in situ*, water can and does find its way in greater or less quantity, according to varying circumstances. We have said that water is the most potent deteriorating influence to which stones are subjected; so potent that it may be said to be the only influence of a deteriorating kind. In no way is the power of this agent shown more in destroying the integrity of rocks and stones than when water is under the influence of low temperatures, or of frost. One has indeed great difficulty in precisely comprehending how what is apparently such a trivial thing as a small quantity of water can, when frozen into ice, exert such a terribly expansive or disruptive force as examination shows it does exercise.

But the effect of frost upon building-stones *in situ*, etc., is not the only cause of the deterioration of these stones. Water itself, not under the influence of frost—that is, in its normal condition in summer and other weather, when the temperature is high or comparatively so—exercises, either in the form of actual visible water, or in the form in which it is usually present in stones, that is, moisture or decided damp, a very deteriorating action upon stones, partly externally, causing them to exfoliate, partly internally by passing into the stone to a greater or less distance from the surface by and through the pores of which we have already spoken as present in stones, causing disintegration and ultimate crumbling away. Students of chemistry and of physics are well aware of the solvent powers of water in action, disintegrating—popularly termed washing away—and mixing with them, to use another popular term, and thus holding in solution the constituents of stone. But this dissolving power of water is largely dependent upon the air which the water takes up and holds in solution. The invariable constituent gases of air, the nitrogen and oxygen, with small and varying qualities of carbonic acid gas, are taken up and dissolved by water, each separately or by itself, the air in water differing very much from that of its ordinary or normal condition in the atmosphere surrounding us. We all know the destructive power of air on various bodies and substances, as in the rusting of iron, or the decay of timber—a power known as oxidising; and this because the deteriorating agent is the oxygen present in the air. Now, when we know that in consequence of water dissolving, so to say, the gases present in ordinary air, the percentage of oxygen is increased more than 50 per cent. or one-half, while the carbonic acid gas is also largely increased, we can readily comprehend how it is that the oxidising or destructive influence of water on materials is greatly increased. The process of oxidation is only effective in deteriorating materials when there is a combination of moisture or wet air and carbonic acid gas; and under usual or normal conditions of the atmosphere its action on stones, although very powerful, is slow, requiring in some cases a long term of years before its influence is very much decided in doing much injury to them. But in our large towns there are other elements in the atmosphere, arising from the smoke and the gaseous products of various branches of industrial work, all of which bring about a deteriorating influence on stone of a very much more decided character. The smoke of large towns, especially of manufacturing or trade industries, adds to the ordinary constituents of the air certain corrosive acid agents, which are known to have a very powerful action upon stone, deteriorating some classes, such as Caen or Normandy stone, so rapidly that their employment is altogether excluded from wise and careful practice. In manufacturing towns where certain chemical trades are carried on, especially those known as alkali making, large volumes of hydrochloric or muriatic acid are sent into the atmosphere. Since the passing of the Alkali Act, the acid forms created by the different processes have under its provisions to be so purified that the final product passed into the atmosphere is very much purer than formerly. Still enough is added to it to make its action quite bad enough. But, further, in large towns the combustion of such vast quantities of coal, which contains on the average, say, one-fourteenth part of sulphur, produces large volumes of sulphuric acid, which is the real bane of building-stones. And, unfortunately, no method of preventing the action of this agent upon stones has yet been discovered.

Taking into account, then, the facts we have detailed under this head, and the circumstances in which building-stones are placed in relation to the deteriorating agents we have named, the question remains, what is to be done in the way of disarming those agencies of their destructive or deteriorating power, or *per contra* dealing with or treating the building-stones themselves so that they will be able to resist the action of those agents, however powerful they may be? Reducing the matter to a single point, we perceive that practically water is the destructive agent with which we have to contend in endeavouring to preserve stone from the destructive effects of what are generally termed "atmospheric influences." What would appear to be the truly effective way of putting a stop to the wasting away of building-stone, and a way as simple in character as it would be effective, is stopping up the pores of the stone so that water and moisture cannot gain access to the stone either in the interior or on the surface. And this plan would be effective; but, simple as it is in statement, it is not so easily carried out in practice, especially when we have to deal with building-stones *in situ*, that is, actually in place in the wall, etc., etc. To discover a method of treating stone so that it would be able to resist the deteriorating effects of the agents we have named a great number of methods have been tried.

The failure of many of the stones of the New Houses of Parliament, to which we have already alluded, was the main inciting cause of a number of methods having been brought forward to meet the case, a Royal Commission having been appointed to inquire into the subject generally. But of all the methods proposed to the Commission none of them were found in practice to meet the case effectually. Many of the plans suggested were mere nostrums; others were really the result of careful study and experiment; but it may be said that all failed as practical remedies, really effective, yet easy of application and economical in use. All the methods suggested may be divided into two classes: the permanent, or those which will continue to be effective for a considerable number of years; and secondly, the temporary, which will remain effective for some time, though not so long as the permanent class. All the methods claiming to be permanent must be mineral in character, inasmuch as they are *per se* inorganic; and of all the minerals silica, as we have seen, is the least liable to changes by atmospheric influences. Silica, either used alone or with a variety of combinations, such as lime, barytes, etc., has been used with considerable success, of which silicate or water glass—which is a soluble flint—may be cited as an example; the silicate is applied as an alkaline silicate, that of potash being the alkali used. When applied to carbonaceous limestones which are damp or moist under the ordinary atmospheric influences, the silicate of potash, with the moisture, forms a soluble *carbonate* of potash; this exudes from the stone, and settles on the surface of the stone, from which it is washed away at intervals as it appears, when ultimately the exudation or efflorescence ceases, and within the pores of the stone a hard durable silica of carbonate and a silicate of lime is formed, which prevents decay. The great objection to this system is that the stone surfaces to which the silicate is applied must be dry, and be kept protected from rain till the hard silicates are formed; it has also this objection, that it imparts a somewhat disagreeable colour to the stone surface externally. This may be taken as a typical or representative example of the permanent methods which are too numerous to be named here. We have only space to allude further to Ransome's system, which is based upon his patented method of making artificial stone. In the first place, Mr. Ransome applies to the stone a wash of silicate of soda, then a second wash of a solution of chloride of calcium; the first result of this double application is the formation of chloride of sodium or common salt, which as it exudes to the surface is washed off; thereafter the second result is the formation of an insoluble silicate of lime, which hardens with and remains in the pores of the stone. Those methods we have classed as temporary are numerous; they all proceed upon the principle of "painting," or applying with a brush or other means, organic substances, such as oils, beeswax, tars, and certain gums and resins. All these substances have this disadvantage, that of being so liable to be oxidised, or have their peculiar property destroyed or weakened, so that the residuum cracks or peels off. It is the oxidation of the oil present in ordinary paints which in time makes them as preservations useless; so that they have to be continually renewed at shorter or longer periods, according to the quality of the paint. What is called "indestructible paint" has been patented, which has for its basis petroleum spirit, combined with certain gums and resins. This has been applied to the preservation of the Obelisk on the Thames Embankment, and so far as an eight or nine years' trial can show, with success. Paraffin dissolved under the action of heat, and mixed with a little creosote, has been applied in America, where the system has been patented by Dr. Doremus, with, however, varying success. Of all the temporary methods, that of the application of linseed oil seems to be the best, as it is assuredly the cheapest and the most easily applied. The writer of these lines has reason to think very highly of it. For brickwork it is especially applicable where an uniform quality of bricks has been used, and which, by reason of their porosity, pass moisture to the interior. In all cases he recommends the *boiled* linseed oil—to be mixed with clean dry—all the better if heated, to secure thorough dryness—sharp river sand; or the boiled linseed oil may be first painted or rather well brushed into the stone, and the sand sprinkled or dusted all over the oiled surface, to which it will adhere. The writer, however, prefers the sand to be mixed with the boiled linseed-oil before applying it. This mixture was applied in the case of a lighthouse which had been built with stone so porous that in times of storm the spray was actually forced into and through the pores, positively flooding the interior with water. A great variety of methods had been tried, but with general failure as the result; and serious thoughts were entertained of rebuilding the structure, so utterly unfitted was it for the shelter of the men, when this application was suggested by an old sailor, which met with a success as marked as the failure of the other methods employed. It may not be generally known that it was at the suggestion of Mr. Mallet, the father of the well-known engineer and scientist of that name, that boiled linseed-oil was applied to the colossal statue of Nelson on Nelson's column, Dublin. This statue was of Portland stone, and this application was thoroughly successful, the stone after a long course of years giving no indication of decay, although, as every one knows, the climate of Dublin is very damp, and the factories numerous enough to create a large amount of smoke, as well as that created from domestic fireplaces and other furnaces. Generally, stone deterioration commences first, and is worst in its effects, at delicate and projecting parts, such as the mouldings or corners, etc. A good deal of decay can be prevented by designing the work so that the water will be freely shed from the surfaces, and not allowed to settle even for a short time on the stone. Where decay in such parts has begun it may be arrested by giving them a thin covering of mastic or of Portland cement concrete made of fine clear river sand as the basis.

Limes.—Mortars.—Lime Burning.—Caustic Lime.

We have now to inquire into the subject of limestones only from the point of view of their use in the making of mortars. We have already drawn attention to their use and value as building materials or stones. A limestone technically defined is a stone or rock, of which the principal element or constituent is carbonate of lime. Some—as, for example, the mountain limestones, otherwise known as carboniferous limestones—are nearly pure carbonate of lime. In the limestones used as mortars there is a difference in constitution, as in the limestone, for example, so well known as the Lias, which is found in a large district extending from Lynn Regis in Dorsetshire to the north-east of the county of York, and which yields the best lime for hydraulic mortars, or those which harden or set under water, and which are not washed out by the action of this element, as is the case with ordinary mortars, as we shall presently see under present section. The chief seats of the Lias formation lie in the counties of Dorset, Warwick, and Leicester. The Lias limestones differ from the carboniferous, which, as already stated, are nearly pure carbonate of lime, in having the carbonate mixed with silica and alumina, varying in amount from one-tenth as a minimum to one-fifth as a maximum.

The limestones are only available for the purposes of mortar making after having undergone the process of calcining, popularly and technically known as "burning." The limestones are quarried or broken up into irregular-shaped and comparatively small, easily handled blocks, and burned in what is called a lime-kiln along with coal as fuel, although gas or gaseous fuel is now being proposed as a substitute for the better known fuel. Exposed to the red heat of the kiln, the limestones undergo a change of condition, the carbonate of lime being calcined, and the carbonic acid gas passing away, the result being that the limestone is in a condition now combined and known as "caustic lime," which is white in colour, soft, and easily broken up or crushed.

The Slaking of Caustic Lime.—Formation of Hydrate of Lime.

To make this "caustic limestone," or "shell limestone," a name by which it is practically and widely known, available for the making of mortar, the lumps are what is called "slaked." The slaking consists in sprinkling or throwing water over a heap of the calcined or burnt stones. There is immediately set up a violent reaction, in which the lumps break up with a hissing sound, heat being at the same time created, and this to such a high degree of temperature that it has been employed for more than one industrial process, the final result of the slaking being the reduction of the lumps into a fine impalpable powder of an almost pure white, with a slight creamy shade, dependent upon the quality and kind of the lime. This powder is called technically a "hydrate of lime." In the combination of lime with water thus effected the atoms or molecules, or equivalents of lime, combine with the equivalents of water in the proportion of three to one nearly. Thus, in the formation of 72 lb. of solid hydrate of lime fifty-six parts of lime are combined with sixteen parts of water, being, as we have said, nearly in the proportion of three to one. The evolution of heat is due to the chemical combination of the water with the lime, and the mechanical equivalent of the heat produced, or the work done by it, is the solidification of the water, or its change from a liquid to a solid hydrate of lime.

Although the "slaking" of lime is but too frequently done with considerable carelessness, the process is one which should be carried out with great care, inasmuch as the goodness of the mortar or plaster made with the "hydrate"—the result of the slaking—depends upon its absolute uniform fineness, and its freedom from all particles of the limestone, which have not come rightly under the influence of the water, and thus become imperfectly slaked. Every care should be taken, therefore, to allow of no particles of caustic or burnt lime remaining unslaked. The workman is often annoyed by having in his plaster parts which "blister" and fall off, leaving awkward blotches on the surface. These abnormal parts are owing to the presence of particles of caustic lime which have not been properly slaked—that is, have not entered into chemical combination with water, in order to be changed into the "hydrate" form. Different limes require different treatment in the process of slaking, these being presently noticed under the head of

Mortar.

Mortar is the thickish pasty substance which is used by the mason to cement or form a strong junction between the stones of a building, so that they will be separated with difficulty when the mortar dries, or "sets," as the technical phrase is. Mortar is composed of hydrate or slaked lime powder mixed with sand, and with water, the proportions varying but slightly, however. According to circumstances or the notions of the mason or bricklayer, from three to two parts of hydrate or slaked lime, and one of sand, with a sufficient proportion of water, form, when well mixed with the sand and the lime, a paste not too thick to be spread over the surface of the stone to which another has to be joined, nor too thin to run easily out of the joints. Experience soon shows the best condition in which the mortar should be for working. The purpose which the sand serves in the mortar is to create a certain number of free surfaces giving an open character to the mortar, and giving what is technically known as a series of keys or points, of which a hold or grip can be obtained, thus giving the mortar a better hold of the stone surfaces. It follows from this that round-shaped sand particles are not so good for this formation of free holding or gripping surfaces or points as sand particles, rough or irregular in form. Sand of this latter kind, so much desired by the mason and bricklayer, is technically termed "sharp," and is generally specified as that to be employed in the making of mortar. A potent cause of dampness in walls is the employment of sand in which salt is present. For wherever salt is present in mortar, whether it has been given to it through the sand or through the water, or through both, the salt will sooner or later deliquesce, and show its presence on the walls by unmistakable dampness; and once in the mortar or the plaster of a wall, it can rarely, if ever, be got rid of. Hence sand taken from the sea shore or the banks of a tidal river should never be used. To use it is as reprehensible a practice as is the taking of stones from the above localities for building purposes, especially for houses of a domestic character.

Mortars, Ordinary and Hydraulic.

When the mortar is spread over the surface of the one stone, that being the stone *in situ*, or in its proper place in the wall, and the stone immediately above it in the course is placed on the mortar, and the upper stone is pressed or hammered down with the wooden mallet, the joint between the two is formed; but the junction is not complete till the mortar hardens or "sets." This "setting" of mortar is not the effect of any one cause singly, but of more than one acting together, producing the one result. The process of "setting" differs in character with different limes, and is modified by certain circumstances. Hence the different treatment of different mortars. Mortars are ranged under two different classes. What may be called ordinary mortar is composed of hydrate of lime, obtained from what are called "rich" or "fat" limes—that is, from pure limestone containing carbonate of lime only. What are called poor or meagre limes—that is, hydrates obtained from burnt limestones, such as those known as the "Lias" already described—contain certain proportions of silica and alumina. Such lime hydrates give what are called "hydraulic mortars," these having the property of hardening or setting under water, which the rich, fat, or ordinary limes do not possess. In ordinary mortar made with the hydrates, a powder of slaked lime of the rich, fat, or pure limestones, the "setting" is in its first stage produced simply by the water passing away by evaporation, small crystals of hydrate of lime being formed as evaporation proceeds. These crystals become indurated or hardened by absorbing from the atmosphere carbonic acid. From this it will be obvious that the lime hydrate crystals will harden more or less quickly just in proportion as they are exposed to the action of the atmosphere. And the evaporation of the water itself from the mortar will, for its rapidity or the reverse, depend also upon the way in which this mortar is placed in relation to the atmosphere. The student will perceive, therefore, that in large work, where the blocks of stone are of great dimensions, or where the walls are very thick, the parts of the mortar situated near their centre may be so occluded or shut up from the action of the atmosphere that evaporation will not proceed at all. In this condition crystals of hydrate of lime will not be formed, or when partially formed will not harden, through lack of the carbonic acid necessary for hardening, the air in which this acid gas is present having no contact with the mortar. It is therefore a fact that in work so heavy that the interior portions of mortar in the wall are practically shut out from the influence of the atmosphere the mortar will remain in, or almost in, its original condition, at least for a long period.

We have said in a former paragraph that "slaking" of caustic lime is a process which requires to be gone through carefully, so that all the particles of caustic lime shall be formed into the hydrate of lime. In the case of rich, fat, or pure lime stones the caustic or burnt stones or lumps may be slaked with a much greater weight or quantity of water than the poor or meagre limes known as "hydraulic." For the rich or pure limes water may be added in such abundance as to reduce the whole to a thick creamy state. And so far from lying in this pulpy condition for a time injuring the "pure plaster" thus formed, it, on the contrary, ripens it, so to say, allowing all the particles of caustic lime to get under the influence of the water used for slaking, and be formed into the hydrate of lime. When the finest quality of plaster is required, as for walls which are to be painted, it is customary to allow the slaked lime to remain for a long period in the thick pulpy state. Indeed, where the slaked lime is to be used for even ordinary wall-plaster work it is the usual practice to allow the thick hydrate to lie for some time in the pit; but in the case of the use of the poor meagre or "hydraulic limes" slaking requires to be somewhat differently gone through with. Water must be given in quantity sufficient only to allow the particles of caustic lime throughout the mass to be changed into a hydrate of lime. The rich, fat, or pure limes combine with water with great energy, the combination being accompanied with the evolution of a higher degree of heat. In the case of the hydraulic or poor limes the combination is much less energetic, and the heat evolved greatly lower in temperature and amount. If too much water is used in the slaking the heat is absorbed or taken up by it, and the process of hydration in proportion hindered. To use the heat evolved by the combination of caustic lime and water, it is customary, in the case of hydraulic or poor limes, to cover the slaked mass designed for the making of mortar with the weight or quantity of sand which is proportioned to the lime, and which will be finally mixed up with it.

While here we see that no harm, but rather good, is done by allowing the slaked lime or thick pulp of rich or pure limes to lie for a time after the pulp is formed, it is, on the contrary, bad practice to allow this to be done in the case of the pulp product of slaked hydraulic or pure limes. The pure limes are *chalk* and *gypsum*, or plaster of Paris, as the latter is usually called. Chalk is a carbonate of lime composed of about five parts of lime and four of carbonic acid gas. When slaked it swells very much, and with three to three and a half parts of sand to one of the slaked chalk forms a mortar, which as a mortar possesses little value, as it will only harden or "set," as the technical expression is, very slowly, and that only in dry situations; where the air or locality is moist it will not harden at all. Gypsum is a sulphate of lime containing 26½ parts of lime, 17 of water, and 37½ of sulphuric acid. Unlike chalk, when mixed or slaked with water it does not swell, but it "sets" very quickly and so completely that it becomes as hard as some classes of stone. As being partly soluble in water, it is only used for work in dry situations, and is chiefly employed in plaster work and internal decorations where mouldings and decorative effects are classed. It is also very useful in fireproof constructions.

We have said that the hardening or setting of ordinary mortar made with rich, fat, or pure limes is dependent upon the drying and the action of the carbonic acid in the atmosphere, and that by consequence, in work in which the mortar is so situated that the atmosphere is largely, and in some cases wholly, prevented from having access to it, it does not set or harden, but remains partially or wholly in the soft pasty condition. In heavy work of this kind it is advisable—we should say that it is imperative—that ordinary mortar be discarded, and hydraulic mortar be substituted for it. This hardens or sets much more quickly than ordinary mortar, and, what is more to the purpose in the present case, it sets with certainty, which we have just seen ordinary mortar does not. Hydraulic mortars are made with poor or meagre limes—such, for example, as that of the Lias formation—that is, those containing some constituent, generally alumina and silica, other than the carbonate of lime. Ordinary lime may be made hydraulic, capable of setting under water and under conditions not favourable to the setting of ordinary mortars, by adding to the ordinary mortar portions of certain materials now to be named.

One of these, which was used from a very early period in the history of the building arts—the Romans employing it most extensively—is a mineral known as "puzzolana," and which was and is still found in the neighbourhood of Mount Vesuvius. This volcanic product is also met with in other volcanic districts. This mineral is technically called a "felspathic tufa," containing silica so changed in its characteristics as to be partially soluble. There is another material found in volcanic districts, notably those of the Rhine valleys, such as that of Bruhl. This material, similar to puzzolana, is known by the name of "trass," and is in high repute, especially by the engineers of Holland, a country rich in experience of hydraulic masonry, in much, if not all of which, trass is used. Ordinary mortar can also be rendered hydraulic by mixing with pure or fat limestones, of which they are made, portions of clays or clayey shales containing silica in such a form that it is soluble. For hydraulic, and indeed for masonry work of a superior kind, what are called "hydraulic cements" are now largely used. Of these a description will be given presently.

Lime, or Mortar Concrete.

The material which goes by this name was up to a recent date used extensively for the formation of heavy foundations. It was composed of mortar mixed with broken stones. In using it, after the materials were well mixed, the quantity required to form the foundation was "tipped" from a height into the foundation trench; this tipping having for its object the thorough consolidation of the mass. This, the old-fashioned concrete, is now largely, in many cases wholly, superseded by the use of Portland cement concrete, made of the cement so known, mixed with certain proportions of sand—for the finest work—or with broken stones, bricks, clunks, or imperishable mineral substances.

Artificial Stone.—Hydraulic Cement Concretes.

"As hard and durable as stone," is a saying which has got so fixed on the list of popular comparative phrases, as to be likely to last for generations yet to come. It is used as indicating that some matter or substance employed in work of some kind is likely to remain sound, even if subjected to hard usage—likely to last for a long time. Although in the popular mind, educated by the phrase we have named, stone has got to be the emblem of the attribute of permanency, which man loves to associate with the works of his hands, its quality in too many instances, as some of us know to our cost, is such that it might well be taken as the emblem of that which, while it gives the promise of durability, gives it only to be broken; so friable, so apt is it to disintegrate and crumble away under the atmospheric influences to which it is exposed.

So marked are the characteristics here named in not a few of the varieties of stone which man has found at his command, and so costly is it to have it out of the quarry, and afterwards to dress and chisel it into form, that for a period, let us say of half a century at the very least, many attempts have been made to substitute for natural stone some combination of materials which are in themselves cheap and easily obtained, and which will give all the characteristics of a hard and a durable stone. Some of these attempts to make what is called artificial stone have been very fairly successful.

In the practical use of any substance or material employed in construction, and when a certain form has to be given to it in order to suit it for occupying certain positions, or to give certain outlines to its mass, the costliest method is that which demands the operation —often slow, tedious, and difficult—of cutting and shaping by tools, either hand-worked or by machine. But when the substance or material used is of such a nature that it can be cast or moulded into form, the operation of finishing for certain purposes is quick, and the expense is trifling compared to that involved by laborious and special tooling or working; this economy being very marked in cases where the form or outline and the fitting up of this is elaborate in design. But facile and economical as this process of casting or moulding is, it is obviously only applicable to the formation of objects or parts of structures which are frequently required of the same design; and the more elaborate this design is the more numerous must be the orders given for these parts, inasmuch as it is only by spreading the first cost of preparing the moulds over a great number of casts or reproductions that such can be made so moderate in price as to be within the reach of most users. But while products such as this are exceedingly valuable for the production of single or separate masses useful in building, and specially so when these are to compete with objects sculptured at a high cost from some of the finer qualities of stone, still, as the process has to be carried out with special appliances, and to go through what may be called a series or succession of operations, it is obviously not applicable to a vastly wide range of practical work which requires to be carried out *in situ*, and which is capable of being done by ordinary workmen with the aid of the usual appliances—those cheaply made, and readily used.

We have said that the cost of forming objects or of preparing them so that they can occupy certain positions in constructive work, is greatly lessened when the materials forming a substitute for natural stone can be cast, or run, or pressed into moulds, so as to give elaborately formed and ornamental objects with as much ease as those which are simple in form and surface. But when the combination of materials forming the artificial stone can, in addition to a capability of being cast in moulds, give through its plasticity a ready facility for being spread out into surfaces, and through its comparative fluidity can be readily run into spaces as desired, we then have a material which can be made useful in a very wide range indeed of practical constructive work. And its utility will be all the greater if the materials forming the substitute for stone are readily enough and cheaply enough obtained, and can be made up as well as used by workmen of no more than the ordinary intelligence met with even amongst the class known as day-labourers.

In concretes made with hydraulic cements, which have the property of quickly setting and hardening, and a capability to resist the action of water, we have such a combination as we have above referred to, and by which, when properly used, excellent artificial stones, so to call them, may be made. Of the hydraulic cements now at the command of the builder, that known as "Portland cement" is by far the most largely employed. In "Portland cement concrete" we have a substitute for natural stone which is really deserving the name—being at once hard and durable, sufficiently hard to resist blows and usage which very few stones, even of the best quality, could resist; durable enough to outlast, in its full integrity, the best of building stones. And as large surfaces as well as bulky blocks can be formed with an almost total absence of joints, a solidity, a capacity of resisting damp, and the passage of water through the mass, is obtained, and in so complete a manner, as to give to the work all the characteristics of a monolith. In the course of his professional experience, the writer of these lines had many opportunities of testing the value of Portland cement concrete in a wide range of work. He applied it largely to ordinary cases, and sometimes to work for which some said it was not, but to which, from the success obtained, it was proved that it was, on the contrary, well adapted. And one valuable peculiarity his practice firmly established—namely, the ease with which it could be worked; and while, of course, skilled labour was all the better to be employed, still, when necessity demanded, as it sometimes did, it was found that the work could be done with almost the rudest and most readily constructed appliances, and that the services of even ordinary day-labourers could be made practically available.

We shall in this section give a few practical hints as to the use of Portland cement concrete as a substitute for stone in the more simple class of building work, such as cottage walls, pavements, and the like, glancing meanwhile at the kinds of hydraulic cements in the formation of the concrete, or, as we may well term it, artificial stone. We have already alluded to the substances used as cements able to resist the action of water by the Roman builder, and in more modern times the Continental engineers. These substances, although having different names, "puzzolano" and "trass," were very much alike, at least in origin—volcanic; still different districts yielded cements having their own characteristics. These substances were for long the only ones described and used as *cements* in constructive work. In this all mortars are classified as "cements" which have the property of hardening and remaining firm under the action of water, which would soften and wash out other kinds of mortar made in the ordinary way with lime and sand, and which also have the property of more or less quickly "setting" hard and firm when exposed to the open air only.

Of all the hydraulic cements now used that known as "Portland" is the best, and stands highest in the estimation of the builder. It was a good many years ago discovered that if the hard calcareous stones or pebbles found at Boulogne in France, and the Isle of Sheppey in this country, and in other places and districts, were first calcined or burnt at a high temperature, and then ground into a fine powder, a cement was produced which in its valuable qualities possessed the properties of the well-known "puzzolano," a mineral substance of volcanic origin largely employed by the Romans. This discovery was made by a Mr. Parker, and hence it was for a long time known as "Parker's cement." What—from its colour resembling Portland stone—is now so widely known as Portland cement, is composed of clay and limestones calcined at a high temperature, and the lumps afterwards ground into powder. A natural mixture of the limestone and the clay is in certain districts found in the form of pebble-like masses, which after being calcined are ground into fine powder as before. "Portland cement," although resembling the ancient Roman puzzolano cement, is nevertheless not only much stronger, hardens more quickly in water, sets more quickly in the open air, but it possesses the additional valuable property of actually improving in strength until a maximum point is reached, while hardening in water or setting in the open air. Thus a sample of pure cement, after being immersed in water for the space of twenty-four hours, increased in strength in the proportion of fifteen to thirteen, or say one-sixth. When the Portland cement is used or mixed with water, and mingled amongst a mass of sand, of broken stone shivers, or of small stones or pebbles, broken bricks, or almost any hard indestructible materials, the mass, when allowed to set, forms what is called *concrete*, and it goes by the name of Portland cement concrete. This being plastic, is easily put into moulds, etc.; and it is used, as we have already said, for a wide variety of useful purposes. As a material, it possesses many claims for the consideration of those who have constructive or building work to do, and this on the ground, not merely of its high constructive value, but of the ready way in which it can be used, even where unskilled labour only can be had. Pavements can be laid, cellar and other floors made, troughs, tanks and cisterns, constructed; old brickwork rough pointed, defective or broken stonework made good by its use; and that, too, by any fairly intelligent day-labourers, if no better service can be had, and with tools and appliances of the simplest and most cheaply constructed character.

From what has been already given, it will have been observed that Portland cement, from its very character, its physical, or, as one may say, mechanical properties, is exceedingly liable to be mixed with debasing or degrading substances; and that, this being so, it will be necessary for those proposing to use it for the making of Portland cement concrete, to be careful to see that it is not adulterated with substances which deteriorate its strength and lessen its constructive value. The extended use which its value justified was at the first greatly hindered by the prejudices raised against the material in consequence of the many failures which arose. But these were not in reality failures of Portland cement concrete, inasmuch as the cement used was not true cement, but a mere compound of materials which, while they gave a body or substance which resembled Portland cement, possessed but few of its properties, and were lacking in the one peculiarity which gives the cement its constructive value.

We have, therefore, been in no way surprised at failures when cements were used with which success was impossible. Where the cement was of good quality we never met with an instance where failure was the result. In all cases this exceeded the expectations of those who had consented to its employment.

In cases where an extensive use of Portland cement concrete is proposed, it will be prudent to have samples tested by an expert on its use, and an analysis made by an accredited analytical chemist; and when this is done, a written contract should be made with the maker to deliver the cement in bulk as per sample. At the same time it is only fair to state that while there are makers only too ready to sell what is said to be, but is not, true Portland cement—and such men of business infest this trade as they infest other trades—there are, it is a pleasant thing to know for the credit of human nature, makers of the cement who would scorn to sell an article of less worth than the best. Such men have a reputation to lose, and have a pride in maintaining its high position. While rigid tests and accurate analyses are valuable when the contract is for large quantities of cement, still one or two simple trials and tests may be sufficient in other cases, where the work to be done is comparatively small in amount, and where the cement is brought from one of the first-class houses above alluded to. Fortunately there are certain simple modes of arriving at a pretty accurate estimate of the value of the cement which are worthy of being known, even if it be that they will not be much practised, as in cases where the character of the maker or seller is trusted as a sufficient guarantee for the value of the cement they make.

A cement which at one time held a high reputation, and was most extensively used by builders, was that known as "Roman" cement. Inferior to Portland cement in strength and in durability, it is now seldom employed, although there is still a certain demand for it amongst the older class of builders, who do not look with much favour on new things, however much superior they may be to the old. "Roman" cement is made by calcining, and afterwards grinding into powder, the nodules or small lumps of calcareous clay found principally in the Isle of Sheppey, near Harwich, and also on the coasts of Kent and Essex. The cement known as "Mulgravia" is made from stones found at Whitby in Yorkshire, and that known as "Medina" from the Isle of Wight. The cement made from the refuse of the blast furnaces in the iron-making districts, and which is known by the name of "slag," is said to be very good, and is being gradually pushed into the market. As the constituents of the "charge" of materials, ore, lime, and fuel put into the blast furnace naturally vary much in character, the same variation or constitution is met with in the slag, which is the final product. And it is this difference in the quality of the "sand" into which, by the patented method of Mr. Wood of Middlesboro', the slag is changed, which constitutes the difficulty with which the makers of slag cement have to contend. There is no doubt of the fact that slag cement is made of very superior quality. All that is required to test its durability is length of time. If it stands the test of time there is a great future for slag sand cement—a thing greatly to be desired, seeing the vast heaps of it which here and there cover large spaces of ground, constituting what in more ways than one is a great, and to iron makers a costly, nuisance.

Portland Cement Concrete as a Building Material for the Construction of Walls of Domestic Buildings, etc., etc.

In describing generally what is known as "Portland cement," we stated that we should give in this section a few notes on the methods of using it in the production of what may be called artificial stone for the construction of walls. One great advantage possessed by the concrete as a building material and a substitute for stone or for brick is, that the materials used as the base or bulk of the concrete are to be met with, and abundantly, almost everywhere, and are, in fact, mere waste and worthless, the getting rid of what in reality is a nuisance—namely, broken bricks, stone shivers from quarries or from masons' yards, smithy clinkers, pieces of stone, slag from iron works, the vitrified masses from glass works, broken pottery, and indeed almost any kind of imperishable substance which may be had in pieces of moderate size, from those like the stones used in the formation of roadways, up to dimensions, say, of four to five inches cube or thereabouts. Sand and very fine gravel, and pounded or crushed brick—these being passed through crushing machines or stone-breakers—are the materials used in conjunction with the cementing material—Portland cement. The "concrete," as it is termed, is made up of "cement" and sand, the proportions of sand to the cement varying from three to one. For pavements and the highest class of works one of cement to three, or at the most four of sand, may be used; although if properly crushed brick be used, a smaller proportion of cement may be employed with equally good results. The whole is well mixed with water in a flat boarding till it is of sufficient consistence to be laid or poured in the place where the concrete is required. For work of this kind (pavements, etc.) this mixture is simply laid on or spread over the surface of a "bottoming" so termed, which is a layer of broken stones like those used in the making of roads, with a depth of four inches, the depth of the cementing materials or "concrete" which is laid on this being about two inches. This layer sets or hardens in from thirty-six to forty-eight hours, and offers, when properly laid down, a surface as hard as stone, without crack or crevice in any part, and quite impervious to wet from above, and proof against the attacks of insects or vermin or damp from below. In the using of this "Portland cement concrete" for the erection of inclosing walls, or of walls of houses, many of which have been of late, and a number more are being built with it, a simple form of mould is used, the width between the sides of which is equal to the thickness of the desired wall. This mould or framework is set up on the site of the wall, and when properly plumbed and fixed the broken stones are put in, forming a layer of greater or less depth, according to the judgment of the workmen or to circumstances, and arranged in as compact a way as possible, so as to secure a certain degree of bond between them, the smaller stones being kept towards the sides, the larger ones thus occupying the centre. The stonework or filling-up, or "packing," as it is generally called, does not come up close to the sides of the mould, but a space is left between it and the sides of the mould. When the "packing" is completed, the cementing material, formed of sand or pounded or crushed brick, etc., and the Portland cement is poured into the mould, just as stone-built walls are "grouted," the material being of the consistency of thin mortar.

This flows between, and fills up the interstices of the stones, and between them and the face of the mould. Then, when the whole is set and the mould taken down, the outer and inner surfaces of the walls are pretty uniformly smooth, and that sufficiently so for ordinary work. In some cases the cementing material is poured into the mould first, and the stones packed in the midst of it, taking care, as already described, to keep the stones a certain distance from the sides of the mould, so that when this is taken down, the outer faces will present a certain thickness of the cementing material, the stone packing occupying the centre of the wall. There are various

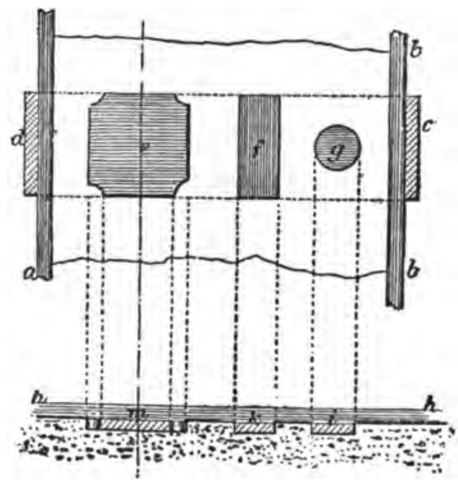


Fig. 175.

methods of forming the moulds, and there is more than one patent for certain ways of arranging the parts to form angles, arches, chimney openings, and the like; but by a little contrivance a good system of moulds may be made of wood at a comparatively small cost. Of course the more buildings one erects from the same set of moulds, the lower will be the cost or charge set against each building for the use of the mould. Where this is the case, concrete-built houses are cheaper than stone or brick-built ones; but it is obvious that if moulds have to be made for one erection only, the whole cost of their construction must be thrown upon one building.

The "concrete," as already stated, is made of Portland cement and sand, or crushed brick, stone, etc., and in proportion varying from three to seven parts of sand, etc., to one of the Portland cement. It is scarcely necessary to say that the higher the proportion of sand and the lesser that of cement, the poorer and less satisfactory is the work. As much of the materials should only be mixed at a time as will be immediately used, as it is so apt to set upon the mixing boards. The materials are best mixed upon a large boarded surface, being first well incorporated in the dry condition, and then the water should be added in quantity sufficient to make the whole of the consistency of thin mortar, so that

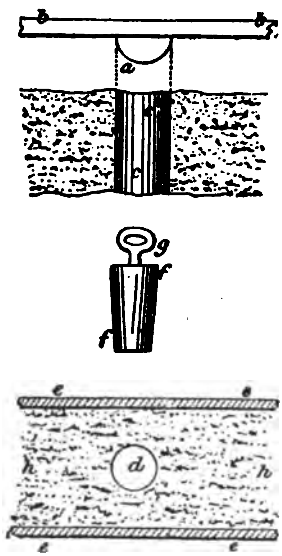


Fig. 176.

it will run easily between the packing pieces. The thinner the concrete the longer time will it take to set, as there is more water to evaporate; hence some prefer to mix the whole rather thicker, putting it into the mould first, and then squeezing the packing stones into it.

This kind of building is easily done, no skilled labour being required, and the method of forming the walls affords unusual facilities for forming window and door openings, ventilating pipes or tubes, so to call them, and chimney flues in the thickness of the walls, and these simply by adapting certain pieces of wood and solid moulds to the framing or outside moulds. By attaching to the inside faces of these flat boards—formed of outlines as desired—panel and other decorative work can be formed on the surface of the walls. This may be illustrated by the simple diagram in fig. 175. Thus, if a simple rectangular panel in intaglio—that is, with its surface below the general level of the wall—be required to be shown on the wall when finished, all that is necessary to be done is to nail in the inside of the mould at the point desired a panel of the proper dimensions, as at *ef*, fig. 175. This is shown in vertical section at *c*, and in plan or horizontal section at *h h*. In the same figure a more ornamental panel is shown at *e*, in vertical sections at *d* and in plan at *m*. These

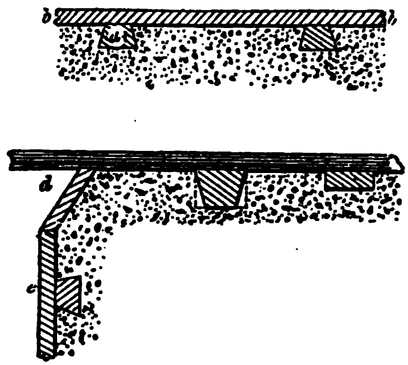


Fig. 177.

panels should be made with a little "draw" or taper upon their sides, to enable the concrete to leave them more easily; and should any adhesion between the wood and the concrete be feared—a thing which may be said never or very rarely to happen in practice—the surface and edges of the panel may be oiled before the concrete is filled in. A round or circular panel is shown at *g*. In the diagram, fig. 176, *a b c* shows how semicircular open drains in plan at *c c* may be made on the surface of concrete floors, *a* being the semicircular batten nailed to a piece of flat board *b*. This is pressed down into the concrete floor surface before it has set and the *b* moulds, or leaves a semicircular depression, as *c* on the surface. In the same diagram, *d* shows how flues or ventilating channels can be made in the interior of walls, by the use of a cylindrical mould as *f f*, having a slight taper on it to enable its being easily drawn out; a handle, as *g*, being attached at the upper and to facilitate this removal. The length of the mould *f f* is equal to the depth of the sides of the mould or box for forming the wall, the sides of which are shown in plan at *e e*. In fig. 177 the method of fixing wood bricks as *a* in the face of concrete walls is shown; the bricks having a taper so as to be of dovetailed form, this preventing them being withdrawn, which they would easily be if the dovetail was the reversed way, or plainsided, as shown by the dotted lines; *d e* in the same diagram shows a method of fixing the uprights of a window or door frame; the reveals, which may be "splayed," as at *d*, or "square" as at *e*, being formed by putting in wood "stops" or "bricks" inside the mould, as shown. In the making of floors of concrete, should it be desired to finish the surface boarded, wood battens as *a* may be inserted in the concrete before it sets, to which the flooring boards *b* are nailed.

As affording material for design in various classes of masonry work, we give, in Plates I. to X. inclusive, a series of drawings, in various styles, of parts of structures, domestic and otherwise. In exercising his knowledge and skill as a draughtsman in designing and drawing, the mason student will find in these plates an abundance of material which he can adapt to a wide variety of work. Plate I. gives detailed drawings of window dressings—finial, gable coping in stone. Plate II. is devoted to designs for drawings, and Plate III. gives drawings of windows in different styles, those being adapted for domestic buildings. So, also, are the drawings in Plates VI. and VII., being drawings of different parts of a house in the Elizabethan style. In Plates IV. and V. we give a number of sketches of windows, etc., used in ecclesiastical buildings. In Plate VIII. we give illustrations in figs. 3, 4, 5 and 6 of methods of constructing scaffolding and lifts for mason work. The illustrations in figs. 1 and 2, Plate VIII., and in Plates IX. and X., refer chiefly to the class of work referred to specially in pp. 123 to 138 inclusive.

END OF THE "STONE MASON."

THE BRICKLAYER.

THE BRICKLAYER OR BRICKSETTER.

Introductory.

It is not necessary to inquire into the relative claims to superior antiquity of the sister arts of building in stone and brick. Unnecessary, in any practical sense; for as regards the history of both, their origin is so shrouded in the mists of time, we have to go back to ages so remote, "hoary gray with eld," that all that is left us is but crude conjectural notions of the vaguest and most uncertain. Examples of construction both in stone and brick are met with in various parts of the globe, the times of which are so remote that the very names of the peoples who built them are almost, in some cases wholly, lost. And of both materials, stone and brick, examples of construction are met with, the work of peoples who flourished so long ago that they formed the very earliest nations, who had become so civilised that they practised various arts, and that in so marked a style of excellence that we moderns have nothing left but to admire and wonder at their work; so far are any examples of ours from approaching the standard they had reached. It is always interesting, and not seldom is it fraught with lessons of practical value, to inquire as closely as may be open to us into the early history of the practical arts, and to trace, if possible, the successive steps by which they have reached the position of practical efficiency, if not of absolute perfection—if this last condition be indeed an attribute of any work to which man puts his hand, and to the designing of which he puts forth the best and highest of his mental powers. Whereas in tracing the origin of arts such as those of building in stone and brick of such remote antiquity, conjecture is only left us; and one conjecture may be taken as of equal value with another, in so far that both at least may be not only possible, but reasonable. In this way, so far as regards the relative claims to antiquity of the arts here referred to, we may hazard the conjecture that of the two brick building was the first to be practised. In the very earliest times, as the poet sings, "wild in the woods the naked savage ran," and the first advance from this wretched condition towards providing himself with shelter would be either hiding himself in the ready-formed caves and holes of the earth, sheltering himself under the shade of recumbent and super-incumbent rocks, or raising rude huts of tree-trunks and of branches. But in regions where wood was absent, and the diversified surface of hill and dale and rocky pass and glen of other countries was represented, as in many parts of the East, by vast plains the soils of which varied from loose and shifting sand to clay or clayey earth of greater or less consistency,—here, where the sun beat fiercely down, and was but rarely obscured by cloud or mist, mere shelter would be a far less important consideration than in the colder and bleaker regions of the West and of the North. Even now, in the sunny lands of the East, the tent gives all the shelter that is needed, and failing that, as in wandering from place to place, where to plant the tent involves labour, which in that lazy land is too often grudged, the "shadow of a great rock" suffices. Man from the earliest times has ever been, as some have defined him to be, a war-loving animal, and whether indulging it from pure love of its exciting dangers, or from a desire to take from his neighbours what he himself does not possess, or possessing, desires to add to, man has from earliest times given almost the first place to war and the arts of war. Mere bodily shelter in those warm climates being but, as we have seen, a purely secondary consideration, what structures at first were built or heaped together would have more for aim shelter and security against predatory foes or warlike neighbours. In those early times, when existed widely

> "The good old plan,
> That those should take who had the power,
> That those should keep who can,"

there would be on the part of those who had taken an endeavour to keep what they had acquired. So that structures such as they were would have for their object not so much merely personal shelter storehouses for "ill gotten gains," which otherwise could not be as defended against those who had the same desire to take what they could.

Brief Glance at Early Brickmaking and Building—Practical Lessons to be derived from it.

In the regions which formed the "first cradle of man" wide plains exist, and in some instances of vast extent, in some parts of which even the shadow of a great rock cannot be obtained. For purposes of defence, then, the most obvious of all means would be the mound and the trench. "Earthworks"—which, in the curious changes which come about in the world's history, form now an important department of the art of war—would then be the prominent feature of construction, either for shelter or defence, of the earliest times in such lands of the East as we have alluded to. Where the soil was sandy, such earthworks, while made with the greatest ease, would, however, be of the least service in the way of defence, nor could any great height be obtained in the sheltering mounds. But where, as in the plains on which the vast hills—for they are literally so—made up of the remains of the once grand and gigantic city of Nineveh presented for so long a period a perfect puzzle to the traveller, alluvial soil of a more or less tenacious character was met with, the mounds and trenches made in the first or earliest efforts at construction would be of a much more effective character as regards strength and size sufficient to resist attack. In the throwing up of mounds and the consequently following digging of trenches with a direct object in view, lumps or masses of soil bound or concreted, so to say, together would often be met with. The value of these lumps or masses, when used in conjunction with smaller pieces or more disintegrated material, in forming a mound, would not remain long unperceived. For men in almost every—except possibly the lowest—state of existence are inventive; some are specially and cleverly constructive animals. The use of such lumps, when carefully assorted, would soon lead to the obtaining of a structure presenting some at least of the characteristics of what we call a wall. Nor, seeing the advantages of having the soil in masses, would it be long before man would perceive that, in place of trusting to chance in obtaining such lumps or masses capable in some fashion of being built so as to form a mass of a certain and a predetermined shape and extent—such chance as his rude spade and mattock would give him in digging the trench for the raising of the mound—it would be a good thing if he could make those masses himself. Very little inventive knowledge would be required at first to show how the tenacious character of the soil could be taken advantage of in forming masses suitable for his purpose, this work being greatly aided by the use of water. In process of time the great constructive advantages of having masses of definite size would be perceived. Further, that a wall—for that would be the ultimate form of the defensive shelter-place—boundary, giving *enclosed* spaces, could be built not only more quickly, but much more strongly, if those masses made, literally and truly *manufactured* by pressing soil together either in its natural condition if moist enough, or by the help of water if too dry, were of small or comparatively small bulk or weight. For in time men would perceive that many small pieces or masses would bind together better than fewer and larger pieces; and hence the first conception of the truly great constructive discovery of the principle of "bond" might be obtained. And it would, as a further step in constructive invention, be next discovered that this binding together or "bond" of the separate masses would be better secured, and a stronger wall would be obtained, if the dimensions of each mass bore a certain proportion to each other, as length to breadth and both to thickness.

At first, in all probability, the successive layers—or "courses," as in modern brickwork they are termed—thus formed of small masses or pieces, would be made to cohere together or pressed into a mass to give stability and permanence, by using the pieces while they were soft and capable of being pressed or squeezed together. We have as little knowledge of how "mortar" was discovered, and its vast advantages in construction began to be availed of, as we have of the origin of the arts of masonry or of brickwork; that it was first used in stone construction is exceedingly probable,—just as it is most likely that what led to the drying of the hand-made or manufactured masses of adhesive soil was the difficulty in carrying them from the places where they were made to those at which they were to be used when in their moist or soft condition. And this characteristic would be still more felt as a disadvantage when handling the pieces in building or constructing the wall or mound. And when dried, and thus more readily transported from place to place, and more easily handled when used in building, the further step of having some medium by which the dried pieces could be kept together, or in close adhesive contact, would follow. Mortar or cement of some kind would thus be introduced into use.

Unburnt or Sun-dried Bricks—Burnt or Artificially Dried and Hardened Bricks.

This drying of the pieces in the East—the cradle of the human race, as it has been called—was effected solely by sun heat. In those hot climates this is not only very powerful, but its continued influence day after day could be so reckoned upon, that it was a comparatively easy matter to obtain the pieces of cohering soil in a condition of dryness so complete that the whole mass throughout was hard and firm. More than that, this climate enabled the pieces to retain their hardness when built up into wall or mound. In western lands, even if the all-too-brief intervals of sunny weather would have given heat enough to have dried the bricks sufficiently to have made them easily carried from one place to another, and handled in the work of building, such is the humidity of their "weeping climates" that they would have been soon softened by the damp and by beating rains, so that the walls would have become masses more or less shapeless and weak, and the pieces reduced to a soft and in some instances a half-slimy condition. Hence the necessity arose to have the pieces of cohering soil hardened by a more perfect system of drying than that of sun-heat could give; and hence in time came the art of burning or vitrifying them under the intense heat created by the special combustion of fuel, either in heaps or in some simple form of enclosing furnace. How and when this art of burning masses of soil arose, history gives us no note of.

Roman Bricks, or rather Tiles—Modern Bricks and Brickwork.

Hitherto we have refrained from giving to the hand-made pieces of cohering soil the name by which they are now known to us—namely, bricks. The Romans, who used this building material most extensively and ably, formed their pieces of such dimensions that the term "tile" is more applicable to them, or gives at least a better idea of their shape, than the term "brick" as we know it. The dimensions of these tiles varied; and in place of being in form a parallelogram, like our bricks—that is, of greater length than breadth—they were square. The squares ranged from seven inches and a-half up to twenty-two inches on the side. They averaged only one and a-half inch in thickness, or about one-half the usual thickness of the bricks we use. To this, as well as to the care with which the tiles were made, the care taken in setting them, and to the good quality of the mortar employed, must be attributed the lasting character of the work done by the Romans, work which has come down to our day in as perfect a condition almost as when first constructed. This thinness of the tiles or bricks, as we may now call them, used by the Romans, that for reasons which will afterwards be more clear, gives such a bond or stability to the structures in which they were employed, has been imitated, or rather has in all probability been handed down directly to them through the long course of ages, by the Flemish brick-builders of the Low Countries and in parts of Northern Germany. This thinness of bricks as compared with ours is indeed a characteristic of the bricks used generally throughout the Continent. The Germans have long been famous for the excellence of their brickwork. It may, indeed, be said that the finest work existing is to be met with in Germany, and it is to that country that our builders should go to study the capabilities of the material for the higher ranges of architectural work. In this country we almost always associate with the employment of brick structures which, however useful, have comparatively little claim to be architectural works of a high class. The only exception to this is afforded by our domestic buildings or houses. And no doubt it is a wide one, embodying some fine examples of what, with good materials and honest work, brick as a building material is capable of.

Brickwork in this Country chiefly confined to Domestic and the Smaller Classes of Structures; rarely applied to the Construction of Large Public Buildings, as on the Continent.

But brick with us is rarely—we may say never, as a rule—thought of as a material for buildings of a large or public character, and which have claims more or less complete to be considered architectural works. It is to the Continent, as we have said, that we must go to see what brick is capable of doing, with artistic treatment and careful building, in embodying the conceptions in ornamental as well as in plain building. The traveller who has visited several of the Continental countries must have had but small power of observation if he has not noticed, and with admiration, not a few examples of large and fine buildings, especially churches. But it is perhaps in Northern Germany, above alluded to, that the finest brick buildings are to be met with. We might, for example, specify the cathedral at Lübeck as a work showing what can be done with brick in the hands of an able architect aided by first-class builders. With us ornamental brickwork is but a thing of yesterday, and its employment even now is decidedly the exception to the general rule, which embraces plain brick-setting only. And even where ornamental brickwork is attempted, its effects are sought to be obtained by colour chiefly, or by surface work, with the use of variously tinted or toned bricks. We have done little or nothing in the way of giving the varieties of form or outline in brick-setting. But on the Continent there are not a few fine examples—as, to wit, the Lübeck cathedral, above alluded to—of what can be done in giving almost every variety of form in architectural decoration by the use of brick alone. Before leaving the retrospective or historical part of the subject, it will be interesting to note that, although we almost always associate with our conception of Grecian architecture, the finest which the world has ever produced, stone as the material in which its beautiful characteristics have been handed down to us, brick was largely used by the Greeks, and used in a superior way, as indeed they used every material they employed in the fine and the constructive arts.

Kinds or Classes and Qualities of Bricks used in this Country.

Before we proceed to explain the peculiarities of practical brick *laying* or *setting*, in the construction of the various works of the builder, we shall consider, as briefly as may be, the kinds or classes of bricks used in this country, and note some of their characteristics and qualities as a building material. It does not come within the scheme or the scope of the present work to describe how bricks are made. Suffice it here to say that the bricklayer will be all the better if he knows something, at least, as to how his bricks are made; and he ought, at all events, to know a good deal as to the qualities of the soils out of which the brickmaker forms his bricks, for this knowledge will be of use to him in deciding the value of the bricks made from the soils of certain localities in which brickmakers have set up their works. The rage for mere cheapness in constructive materials of all kinds—which has extended a desire but too widely that has done more than aught else to deteriorate the quality and to lessen the fame of English work—has not passed-by those engaged in brick-building. Hence it is that not only the poorest of materials have been and are still being largely employed throughout the country, but the making up and the burning of those poor materials have been done in the cheapest and therefore the most ineffective of ways. Thus it has come about that an enormous number of houses and other structures have been erected with bricks of such poor quality that the signs of decay may be said to have shown themselves when the buildings have been but a few years erected. In some instances, indeed, months have barely elapsed before this disgraceful condition of things has been evidenced; and, indeed, it would be quite correct in some instances to say that decay has set in before the bricks were used, so utterly worthless as a sound and lasting building material have they been. There is, beyond a doubt, a vast amount of brick-work done throughout the kingdom in which bricks are used which should never have been permitted to come on the ground—the very look of which, to say nothing of any other and usual test, should have been enough to condemn them as worthless for building. It is only right, however, to state that brickmakers and bricklayers are not wholly responsible for this state of matters. Indeed, if the blame is to be placed in the right quarter, it will be found to rest chiefly with the proprietors of houses and with the class of contractors—often, however, practical bricklayers—so well known in modern times as those who "run up" houses made to sell, not to last. There are many who really build for themselves alone, but who will have their work done at the lowest possible price; so that, if the bricklayer is to do the work at all, he is compelled to buy cheap materials; and the brickmaker, to meet his price, is equally compelled, so to say, to make bricks cheap and utterly worthless, when judged from the right standard of building. We do not here enter into a discussion of the points involved in the morality of the question—not that it is or can be apart from the practical points of it, for man not possessing merely physical properties, but possessing other and higher attributes, his *morals* cannot be got rid of as a working element, even if he would get rid of it—but simply because our space does not admit of our pursuing the subject, practical as it is when viewed from its proper standpoint.

The Use of Cheap Bricks to be Avoided where Good Sound Honest Brickwork is Desired.

But this much we may say, that experience has abundantly proved that in this matter of business, honesty is the best policy, or, as we prefer to put it, the best principle; for it will be found that bricklayers and brickmakers who will not pander to the rage for cheapness as such merely, and who will not do other than the best work and make the best materials possible for them, stand not only the highest in business reputation and in moral character, but find in their experience that this principle or policy pays them, and at an infinitely higher scale, than bad work does. And it is matter of pride that this high-minded and high-acting class is a wide one. If it were not so, our material decadence would long ago have been consummated. Some of our youthful readers may deem such considerations as these to have no practical bearing on the subject of our papers; but as they learn the lessons of life they will, we venture to say, find that they have the closest practical bearing on work as it ought to be done. Work done from high-minded motives will be sure to be good work—must be; work done otherwise may be. And the wise man wanting good work done knows which is best—to trust to chance or "may be," or secure a certainty which must be.

The Soils or Earths Used in and Best Adapted for the Making of Sound Bricks.

We have said that the bricklayer or setter will be all the better if he knows something of the work of the brickmaker—at least, that this may or should extend to his knowledge of the material he uses. A soil of the highest quality is obviously necessary to give the best bricks, and the finest soil is that composed of a pure clay mixed with sand. It must be free from pebbles or hard nodules of stone. Soil largely mixed with vegetable matter, or from which clay is largely absent, cannot yield bricks of the highest quality. Lime in excess is not a desirable constituent in brick soil; neither are metallic substances, known as pyrites: these, when present in too large a proportion, act during the burning process prejudicially, forming a species of flux by which cavities or air-holes in the interior of the brick, and cracks or fissures externally, are formed. When fluxing materials are present in moderate quantities they tend to aid the proper degree of vitrifaction required. And on all good bricks this process is more or less partially produced—that is, a species of glassiness is given to the brick, at least on its surface, which aids greatly its damp or wet resisting powers. This characteristic is obtained in perfection when the clay and sand are present in the soil in the right proportions. Soils are sometimes met with in beds of greater or less extent in which those proportions are naturally present; and these constitute "brick fields" of the highest class.

The Mixing of Soils of Different Qualities in order to make Bricks under Certain Conditions.

The brickmaker has, however, often to mix his soils in order to obtain the desired proportions requisite for bricks of good quality. And the best mixture obtainable can only be found by direct experiment. However good may be the soil or soils used, it is obvious that all extraneous substances must be removed from them before they are taken in hand for brick moulding and burning. This involves extra care in the preparation of the soil, and we need scarcely say that this is not given where "cheapness" must be the chief attribute of the bricks made, whatever other characteristics of a good kind they may by chance possess. To get rid of useless and dangerous extraneous substances, and to fit the soil for good moulding "weathering" and "tempering" must be carefully done. "Hand moulding" requires the exercise of skill and care on the part of the workman; but it is fast being superseded by "machine moulding," which not only turns out a greater number of bricks in the same time than can be done by hand moulding, but gives to them a greater density and compactness, and admits of a wide variety of forms and methods of making. After moulding comes the "burning."

The Burning of Bricks—Good and Carefully-conducted Burning essential to the Making of Sound Bricks—Modes of Burning employed.

This demands the greatest care and knowledge. Nor less carefully must the "cooling" of the bricks when burned be looked to, as much of their quality depends upon the way in which this is done. But, however carefully all the previous processes are done, and however good the materials, the "burning" does not give bricks of uniform quality. This will be obvious on slight consideration. Bricks are burned either in specially constructed "kilns"—themselves built of bricks—or in what are called "clamps," which internally are simply structures or masses built up of the moulded and unburned bricks, mixed with which is the fuel which carries on and completes the burning. Now, from the way in which the bricks—partially air-dried before burning—are placed in the "kilns" or built up in the "clamps," and from the way in which, in both cases, the heat is applied to the bricks, unequal burning is the necessary or compelled result. To heat equally all the bricks is the aim of, but never is absolutely secured by, the brickmaker. There are therefore, in each lot burned, different qualities of bricks, and those qualities are defined by the position which they have had in the kiln or the clamp. The best, as may easily be supposed, are those taken from the central part of the mass, where the heat has been most uniformly applied.

Names by which Bricks burned in Certain Ways are Known or Designated.

These are known by different names in different localities—such as "body bricks," "hard bricks," or "cherry bricks," from their fine, bright red colour. Those bricks taken from the sides and top of the mass are the poorest quality, and, known by various names, such as "soft bricks," "pale bricks," or perhaps more generally as "common bricks," are useful only for the inner courses, being unfitted for outside work exposed to the weather influences, or subjected to heavy pressures, as in superior brickwork. Of kiln-dried bricks, those at the top, or arch bricks as they are generally termed, although hard and possessing a more or less completely vitrified surface, rendering them so far capable of resisting the weather, are generally so brittle that they are unfitted to resist pressure; and mortar does not take kindly to their surfaces.

Bricks Classed according to their Colour.—The Classes or Kinds, with the Characteristics of Soundness.

The above are the general designations of bricks, but there are many special names particularising different varieties according to quality and colour, which attributes are derivable not merely from the materials of which they are made, but from the manner in which and the care with which they are manufactured, dried and burned. As regards colour, there may be said to be three great divisions—red, yellow, and blue. It need scarcely be said that the red comprises the great majority of the bricks used in construction; so much so that this colour is, in the popular mind, always associated with the material, and finds expression in the phrase "as red as a brick," as if bricks of other colours were not to be met with. The colour of bricks goes, as may easily be supposed, through all varieties of tones and tints, this being so largely dependent upon the materials of which they are composed and on the way in which they are made, And the tone or tint in great, if not always in absolute measure. indicates with considerable precision the building qualities or value of the bricks. Thus the best of red *bricks* are generally of a bright colour—what is known instinctively to be a bright, pure, clean, clear colour. The best bricks of this kind give out, when struck with the trowel, a clear sound, in great measure metallic, just as if the trowel were striking some material like itself. The surface gives at once the idea that it will well resist the weather influences of rain and damp. Bad or inferior red bricks have, as a rule, what are at once known to be the opposite of the qualities above named, so far as regards colour, it being dull, or what may be called a muddy colour; while, as regards their physical character, they are more or less soft, and do not give when struck with the trowel the clear ringing sound which is given out by the best bricks. There are, as regards colour, of course, exceptions to this,—good sound bricks, capable of giving strong work and of resisting wet or damp, are met with which have not a bright clear red. The above remarks apply, but with considerable modification, to the yellow and the blue bricks, which do not, as a rule, exhibit such a variety of shades as the red. This is perhaps more applicable to the blue than to the yellow, which often gets so light as to be almost white. The blue bricks, chiefly made in Staffordshire, are generally of a superior quality, being hard, sonorous, and stony.

Names by which the Different Classes or Kinds of Bricks used in Ordinary Work are Known to the Trade.—Their Characteristics.

As regards the special names of the different varieties of bricks, they are very numerous, but may be divided into two great classes: good and sound, or "hard"; and inferior, giving poor work, or "soft" bricks. And between those, as the extremes, there is, as may be supposed, a wide range of quality. What are called Malm or Malm Stock bricks—and frequently only as stock bricks—are of a superior, or constitute the best quality. They are of two subdivisions—the "firsts" and "seconds." The firsts are often termed "cutters," and this probably from the fact that they afford facilities for being cut or rubbed down to assume the shape required in that class—afterwards described and illustrated—of arches known as "gauged" or rubbed. The colour of malm bricks is generally of a fine yellowish tone or tint. The class of malms known as "seconds" includes, as its name indicates, the bricks of a lower quality, which are used for the facing or front walls of buildings. Red "stock" bricks are the best quality of the ordinary bricks used generally throughout the country. Their colour varies, as we have seen—although always the pure or clean, as opposed to the dull colour of inferior bricks of the same sort—in different localities. But the general red colour is derived from the oxide of iron with which the soils of which they are made are largely mixed. The poorest of red bricks are termed "place" bricks—sometimes named as sandel or samel—the former of those two designations probably derived from the soft or sandy crumbling-away qualities which this class of bricks more or less possesses. While stock bricks are used for the best class, place bricks are relegated to inferior positions, generally constituting the back walls. But even there they are out of place, if sound work and that capable of resisting heavy pressures be desiderated. Where cheapness in construction is only looked at, place bricks may be, and indeed are but too often, used. They vary in quality, as all other bricks do, and the cheap builder may, and perhaps often does, select the best qualities of these poor bricks; but as nothing must be lost, work is found somewhere in which, however poor, place bricks are used. Place bricks are what may be called the residuary products of the kilns or clamps, being those left after the "malm," "stock," or best bricks are selected; this will account for their inferior quality. Intermediate between the malm stocks and the red stocks above named is a class of brick known as "grey stocks," made out of good soil, requiring little or no admixture with other soils, and when well made and carefully burned afford a class of brick well adapted to give strong and durable walls. Generally a number of bricks in the kiln or clamp are overburned or partly vitrified—this to such an extent sometimes that partial fusion causes two or more bricks to run together, forming one mass more or less solid throughout. Overburned bricks are known as "burrs" or clinkers. The latter name is probably derived from the quality imparted by vitrifaction, which causes them to give a clinking sound when struck. Or the name may have been taken from the vitrified masses of coal, the product of furnaces in which great heat is sustained, and which are distinguished from the ordinary cinders by the name of "clinkers." The first name, "burrs," may have some reference to the fact that the bricks have been over-*burned*. The term "clinker" brick is also applied to what is otherwise called "Dutch" brick, a species of very hard burnt brick made in Holland.

Bricks made for Special Purposes—Fire Bricks—Paving Bricks.

There are other classes of bricks used for special purposes. Of these the most important and valuable are those known as "fire bricks." They are so called from being used in the lining of furnaces, in which great and long-continued heat exists. They are calculated to resist temperatures of the highest kind, and under which ordinary bricks would be totally destroyed. Fire bricks are made of clays which are exceedingly refractory—that is, capable of resisting great changes in condition, especially of temperature, such as the clays known as the Stourbridge and the Windsor clays. Fire bricks are now made in a very wide range of locality, deposits of clay possessing the necessary qualities having been found to be more numerous than at one time was supposed. What are called "paving bricks," as distinguished from paving tiles, are of the same length and breadth as ordinary bricks, but are thinner, the depth or thickness being usually one and a-half inch.

The Dimensions or Size of Bricks used in Ordinary Building Work.—The "Standard" Size of Brick.

Before proceeding to this part of our subject, we may as well state, with regard to paving bricks, alluded to at the end of last chapter, that they are made of a good quality of soil, and are burned very hard, to give a walking-on or working surface capable of resisting the wear and tear to which they are subjected. Probably the best paving bricks are those made in Staffordshire, the colour of which is generally some tone of blue.

The "standard," or what may be called the "building dimensions" or size of bricks, are—length nine inches, breadth four and a half inches, thickness or depth three inches. The relation to each other of those determinate and always invariable dimensions enables the bricklayer to get in his structures what is technically known as "bond." How this is obtained in brickwork will be explained in future paragraphs. At one period in our history, and that for a long time, bricks were excisable, paying a very heavy duty per thousand to Government. In order to enable the duty to be levied with ease, a determinate size or bulk of brick only could be made; and this bulk was regulated by the dimensions that we have named above. It so happened, therefore, that no bricks could be legally made of dimensions or of form other than the solid parallelopipedon of nine inches long, four and a half broad, and three inches thick. Although it was known that other forms or sections of bricks gave great economy and high value in construction, brickmakers were entirely precluded from any attempts to introduce such improved constructive forms as had been or clearly could be designed. So obstructive to all advance in improved brick construction was the excise law, that a strong agitation in favour of its repeal was at last begun. This was carried on in face of the difficulties which usually environ such agitations with varying features; but at last the influence brought to bear upon the subject was such that the duty was wholly taken off, and the designing and making of brickwork left entirely untrammelled by any external influence. This was some thirty years ago, or thereabouts, and since that period bricks of all sizes and forms have been introduced. It is only right, however, to state that the full freedom possessed by the trade has not been taken advantage of to anything like the extent or in anything like the number of directions which could have been taken. Several exceedingly valuable forms in a constructive point of view have been from time to time introduced, but those have not been availed of to any great extent in practice, while some have been allowed to die out, and are now practically and absolutely unknown. Architects and builders, with advanced and enlightened views as to what brickwork construction might be made, have, in fact, found that it is much easier to get a law repealed than it is to get rid of trade prejudices and trade opposition. For not seldom has it happened that the "trade"—those engaged actually in the work of bricksetting—have passed stringent laws and most distinctive regulations, which practically forbade the men to do work in which improved and in some instances most valuable forms of bricks and modes of construction were used. In this connection a parallel case may with some practical utility, as being most closely connected with the question of technical work and education in this country, be here cited, taken from another branch of building. The use of wrought-iron beams in fireproof and other kinds of buildings was first introduced on the Continent, markedly and perhaps most successfully in Belgium. So valuable were these found by architects to be, that it gave rise to a highly lucrative branch of work in the iron works of the Continent, especially in those of Belgium. Our iron works, with their superior facilities, might have had this trade; but apart from the prejudices of the masters at the first—which must not be overlooked as an element in the matter—when those prejudices disappeared, which they soon did, and they were ready to make the beams for our own architects and builders, they found for a time all progress stopped, simply because the trade, that is, the actual workers, forbade the men to make the sections required. The result practically was that the Belgian iron workers had the monopoly of the trade, and this they have maintained at a point not very far from its original completeness to this day. It is difficult to estimate the actual money loss which this country must have sustained by our practically throwing work into the hands of our rivals and opponents in trade. Facts such as these—for they are not the outcome of opinions merely—could be cited in connection with other branches of our national trade, and have given rise to national losses of the gravest character, which have influenced not only the past, but are likely still to influence the future career of our technical trades.

Brick as a Building Material, compared with Stone—Estimation in which each is held Largely Dependent upon Circumstances of Locality, the Abundance or the Reverse of the Materials.—Stone almost universally used in certain districts of England, and throughout Scotland.

In connection with the value of brick as a building material certain points and considerations are worthy of notice here. And in this connection it is somewhat suggestive, as it is curious, to note that the estimation in which brick or stone is held in any given locality, or the relative value assigned to each, is dependent in large measure upon the simple fact of their relative abundance. Thus, if a district is so well supplied with stoné, and this of good or even only of fair quality, stone is used as a rule as the building material, and brick, if used at all, is used only exceptionally, and often for subordinate purposes, in connection with stone—such as in the building of interior or partition walls; and if used alone, only as a rule for work of no great importance. Now, in districts so situated, it will usually be found that, not content merely with the use of stone with which it happens to be abundantly supplied, many of those who so use it seem to think it incumbent upon them to decry brick as a building material, refusing—as from experience the writer of the present lines knows they so often refuse—to consider the relative merits of the two materials upon a sound practical if not on a scientific basis. The converse of this position of matters may be supposed to exist with equal force. Still some practical experience of districts where brick is used on a much more extensive scale than stone—in fact, its use being the rule, that of stone being the exception—compels us to say that, taking matters on the average, we have not found that those who use brick habitually think little or nothing of stone or greatly decry its use as a building material. There is, for example, no case, at least within our knowledge, in England parallel to that met with in Scotland. In the latter country stone may be said practically to be the only building material used, at once for public and for private structures. And it is difficult for one who has not come in contact with the circumstances connected with daily working life there, and contrasted it with the like circumstances met with in the districts of England with which they are acquainted, to conceive of the low estimate universally taken of brick as a building material. Not merely the dwellers in the houses, but the majority of those who build them, can apparently conceive of no circumstances in which brick could give a dwelling-house, for example, so comfortable to live in and so lasting as one built of stone. One hears on all sides opinions given with the greatest gravity that houses built of brick may do for the warm climate of England, but that for

Scotland, with its weeping climate and its colder air, stone is the only material which will give a warm house and materials impervious to damp. It is forgotten or overlooked that not only are winters, if not normally, exceptionally, and very often, quite as severe in England as in Scotland; while for a weeping and a damp climate we are not aware that any part of our island home is quite free from it, while some districts in England will bear away the palm for rainfall. Still more curious is it, that in Scotland in this connection it is quite overlooked that comfortable, warm and dry houses are, if not as much esteemed, as greatly necessary in England as in Scotland. And we have always been under the impression that a fault found with their English brethren by Scotchmen is that in England material comforts are too much thought of.

Brief Inquiry into the Claims of Brick to be considered an Eminently Sound and Economical Building Material, Superior in many ways to the Ordinary Qualities of Stone.—Decay of Stone.

Apart, however, from local prejudices—which have in daily life a remarkably powerful influence in deciding the most practical of points connected with it—it is from a scientific point of view well worthy of inquiry whether brick is a poorer, and as some say a much poorer, building material than stone. While some materials or substances are practically imperishable (and they are very limited in number), the vast majority of those with which man has to deal, and with which he carries on his daily work, are liable to decay. This indeed may be said to be characteristic of all substances; and although there are exceptions, we do not absolutely know that they really are exceptions, for the element of time is to us only relative, and we cannot tell the limit within which those apparent exceptions to a general rule would cease to be so. Practically, therefore, decay in material substances is the rule; and stone, although we so popularly associate with it ideas of a lasting durability that if we raise a memento of any event in stone we deem it certain that it will be handed down to all time. But while thus popularly thought of, stone practically is a material liable in many instances to a quick decay. This characteristic is, of course, relative, and varies in different kinds and qualities of stone—granite being, for example, a much more lasting stone than sandstone or some qualities of limestone. Much depends upon the influences to which stone is subjected, and of those the atmospheric influences are the most powerful in their deleterious action. In damp climates, and in districts where the air is largely contaminated with smoke and the fumes of furnaces used in certain manufactures, stone of all kinds is liable to decay, and in the majority of instances this is rapid and complete.

Decay of Bricks.—Superiority claimed for Brick in this respect compared with Stone.

Brick—and here we assume that it is at least moderately well made, of a good average quality, just as we assume, in comparative observations between it and stones, that the stones used are of average if not of the best quality—brick is also liable to decay. But if the results of observation of ancient work be worth anything, then this may be fairly challenged for brick, that is less liable to decay than stone.

We hane just stated that the result of experience would seem to show that the notion that stone is less liable to decay than brick might be fairly challenged; for we have instances in all countries where both brick and stone have been used for building, showing that while the structures of stone have decayed and crumbled away more or less, but in some instances so completely as to destroy the original integrity of the structure, those built of brick have remained sound and complete. This is not unknown to, or not denied by, those who have investigated the subject, coming to its study with no preconceived notion in favour of one material, to the exclusion of all points in favour of another, but only impressed with the value of an opinion based upon the actual facts of the case. We have examples of buildings erected by the Romans so long ago as two thousand years and upwards, composed of brick, which remain as sound to-day almost as the year they were built in—while, on the other hand, contemporaneous buildings constructed of stone have crumbled long ago into decay. And the Romans were too practical a people, and too good builders withal—knowing more of construction, and doing a wider range, and an amount of finer examples of it, than we even give them credit for, much as we esteem them in this direction—to warrant us in concluding that in those stone buildings so gone to decay they used stone of poor quality. From what we know of the Romans as a people, and specially as builders, we may safely assume that they in those very instances used stones of the best quality they could obtain. If, indeed, we do not know for certain, we have every reason to conclude, that in some instances at least, if the locality itself in which a stone building was to be erected did not yield stone of good quality, they transported it from another locality which gave it.

Brick and Stone as Building Materials, considered from an Æsthetic Point of View.—Their Relative "Beauty."

We are not considering here the relative claims of stone and brick as materials giving beauty to, as best pleasing the eye, or as giving claims for the buildings in which they are individually employed to be considered the most valuable, as being the most costly. There seems, no doubt, to be an almost universal consensus of opinion that for public buildings of any importance stone is the only material which should be used. Even in localities where brick is the material universally used for dwelling-houses and the like, if a church or town-hall or museum is to be constructed, no one ever dreams of using other material than stone. It would appear as if the use of brick would be a desecration of the purpose for which the public building was to be erected. We have, however, shown that there is good reason for supposing that in some countries, specially and markedly our own, this arises from an ignorance of what can be done with brick as a material for giving ornamental or decorative effects; and in public buildings these attributes are always aimed at. Although we have unfortunately but too many examples amongst us of public buildings built in a costly way of stone in which their architects have not quite succeeded in obtaining those valuable qualities. We have seen also, from the allusion we made in the early paragraphs to the fact, that public buildings have in some Continental countries been built with brick wholly, which, in point of ornamental and decorative effect, will bear comparison with structures of the like kind built of stone.

Claims of Brick to be considered as the Best Material for the Building of Domestic Structures or Houses.

But looking upon the two materials simply from the point of view of their lasting qualities or durability, a close examination of structures as they actually exist amongst us will, we think, very clearly prove that brick has at least equal claims to be considered a durable building material as stone. We are inclined to go further and maintain that the more closely the examination into the two kinds of structures, those of stone and those of brick, is gone into, the more clearly will it be shown that brick is the more valuable of the two. This, at all events, when they are examined in connection with domestic structures, or our dwelling-houses, the term they are better and more widely known by. In this class of buildings we have primarily to consider the purpose which they are designed to serve, and secondarily the condition under which, in this island home of ours, they exist; and how these conditions affect the primary purpose for which our dwelling-houses are erected. The first essential in our houses, then, is that they shall minister to the comfort and the health of their inhabitants; if health, indeed, be secured by them, in so far as any external circumstance in man's life can secure health, it may be concluded that comfort will be secured. Although to some of our readers it may appear a somewhat strange statement to make, durability and strength in a dwelling-house are considerations purely secondary to health. A house must be built of very bad materials, and those put together in as careless and defective a manner, if it does not outlast the life of the occupant who may have built it, or if it be not strong enough to support the weight of his goods and chattels, or resist the fury of the winds which may blow around the walls, or the pressure of the snow which may settle upon its roof. Not but what in these days of cheap—or as it is in some districts called "jerry"—construction, houses are built, not a few of which, if they, from being built in rows, did not receive a support and strength, would, if left alone—possessing individually but little strength—stand a good chance of giving way. Instances, in truth, are not wanting to prove that building in some localities is but a name, so little of a reality that the structures cannot support even the weight of their own materials.

Brick claimed to be a better "Damp" or Wet-resisting Material than the Ordinary Classes of Stone used in the Building of Domestic Structures or Houses.

Now, in this climate of ours, if it be asked what is the attribute or quality in a domestic building or dwelling-house which secures that health to its inhabitants which we have seen, and all know, to be its primary purpose, we find the reply readily enough—freedom from damp. We do not require here to enter into any disquisition upon the importance of this point; the reader will find it fully discussed in the work in this series entitled "The Sanitary Builder." Now, it is in securing this freedom, or let us say this comparative freedom, from damp, that we claim a high, if not the highest, place for brick as a material to be used in the erection of our dwelling-houses, in which this is a prime necessity. And in making this claim we base it upon the facts of observation. To secure this one would require two fields: a locality or a district in which stone was the material chiefly or wholly used for dwelling-house construction; and another in which the use of brick was the like rule. We have such localities in Scotland and in England. And in referring to those, the writer of these lines has to note that he does not draw his conclusions on the point now under notice from the evidence of those resident relatively in those localities,—he happens to have had personal experience of the building characteristics of both. Taking, then, the average of the materials used in those two localities, the stone on the one hand and the brick on the other, the result of a very wide and, as the writer hopes, a very honest and fair examination of houses built with the two materials, is the conclusion that there are a much greater number of houses built of stone damp than of houses built of brick. Of course, it scarcely requires to be said that, to make this conclusion of any value, strict regard must have been paid to the similarity of the local, or, as we should rather say, the ground or site peculiarities of the several houses examined and compared. This regard was strictly paid in the cases alluded to.

Another Point in favour of Bricks as a Damp or Wet-resisting Material.

Nor need this conclusion be wondered at, however much many accustomed to stone building only may be disposed to doubt its accuracy, if we closely examine the physical characteristics of stone and brick. We here assume that those materials, so examined, if not of the best or highest quality in each, are in each case of fair or of average good quality. We think that an examination, given free from prejudice on either side, would show, almost at the first glance, that a well-made brick has at all events the look of a material more fully impervious to damp or moisture than stone. In lack of a wide and a carefully conducted set of experiments, we cannot lay before our readers any authoritative statement as to the relative powers of stone and brick to absorb or take in water or moisture. But even if we admit that the average quality of bricks take in more water in a given time and for a given bulk than the average quality of stone—which, however, we do not admit—we can, on the other hand, claim for brick this quality of utility, considered as a material for the construction of dwelling-houses—that it gets rid of such water or moisture as it may take up much more quickly than stone does. Many stones, if they once get thoroughly well wetted, scarcely ever get dry thoroughly; while those well acquainted with brick as a building material for houses have had abundant opportunities to see that such moisture as it may have taken up is got rid of, not only effectually, but quickly.

The Durability of Brick as a Building Material.—Practical Considerations connected with this Feature.

A word or two on the points of durability and strength. As regards the first of those qualities we have given some evidence; abundance of it is to be met with amongst us now. While a good brick of average quality is less impervious to moisture, or takes up a less amount of it in proportion to its bulk, than the stones usually employed in building, also of an average quality, brick seems less liable to be prejudicially influenced by the atmosphere than stone.

Granting that the bricks have not in the first instance been soft, as also that the stones when set up have been sound, we think a close examination of old buildings in both materials will show that a greater number of houses built of brick have remained in good sound condition than those built of stone. The brick builders of olden times, and even those who flourished but two, or say three generations ago, used good brick only. Their principle was, beyond all doubt, to give the best work possible, and to use the best materials within their reach. This says much for the integrity of workmen of former times, just as the fact that it is lost sight of by so many nowadays says but little for those of modern times. The same honesty in work characterised the builders in stone. So that each gave to their work the highest characteristics they could command, and thus it may safely be predicated that in each case the best brick and the best stone was used, and the best work given in using them. Of course, in such comparative observations it is essential that the circumstances in which the houses are placed should be alike, or as nearly alike as possible. It would not be an accurate comparison between a brick house and stone-built one, in so far as their respective ability to resist the deteriorating influence of the atmosphere was concerned, if a brick house built in a rural and therefore a comparatively, if not quite, pure air were compared with a stone house built in a town in which the air was largely impregnated with smoke and the gaseous emanations from various furnaces used in manufactures. The observance of this rule, we may note in passing, is of great importance in all technical experiments, no matter in what branch of work, where comparisons are to be made between two processes in two materials; and the neglect of it, common-sense as the rule is, is the reason why so many so-called comparative observations have been and are still practically valueless. Now, in such observations as we have made in connection with the point here under consideration, and from what we know of the examinations of others, we have noticed, almost as an invariable rule, that the brick-built houses had the bricks almost untouched by those atmospheric influences of the locality, while the stone-built structures presented surfaces more or less, and in some cases very greatly, injured. Brick may, and in certain atmospheres does, get greatly discoloured, being even more blackened than stone; but save this, no other deteriorating influence is observable. But in stone the surfaces become exfoliated, and in some instances blocks have even largely crumbled away, while as regards damp it was always in a worse condition than the brick. Many stones used in the present day seem to have so little capacity to resist the deteriorating influences of certain atmospheres, such as those prevalent to too great an extent—for it is largely preventable—in our manufacturing districts, that decay often begins to set in before the buildings in which they are used are many years old. Some stones, indeed, are so liable to attack that decay begins to set in almost as soon as erected. A very fair index indeed of the relative value of brick and stone, in point of durability, is to be met with in this—namely, that all the compositions brought out of recent years, and the methods of treatment for preventing the decay of building materials, and enabling them to resist atmospheric influences, have been designed almost exclusively for application to stone. One rarely hears of their intended application to brickwork. It may be said by some that this arises chiefly from the circumstance that, as stone is the more expensive, and much nobler, in popular estimation at least, of the two materials, it is only in the case of stone that the expense of such preserving compositions, etc., and the trouble of applying them, is gone to and incurred. But this is not the true position of the case: it simply arises from the fact that brick is found *per se* to resist the chemical action—for it is this, almost entirely—of the gases of impure or smoky atmospheres much better—in many cases completely—than stone. Costly enough houses are built of brick to justify their owners in going to the expense—and the expense in such cases would, as a rule, be cheerfully incurred—of applying compositions to prevent or to arrest decay, if decay had set in. But they are not so applied; and for the distinct and special reason that brick to a large, if not to a complete degree, possesses an immunity from atmospheric attack not enjoyed, in at least anything like an equal measure, and by many qualities not possessed at all, or if so, to a very slight extent, by stone.

The Strength of Bricks as a Building Material.

As regards the strength of bricks compared with stone, we have not data to assist us in making a proper comparison. While numerous experiments have been made from time to time to test the strength of various building stones, it might almost be said with perfect truth that none have been made to ascertain the strength of different varieties of bricks—that is, considered as individual masses. And to make such comparative observations of any value practically, it would be necessary to experiment upon blocks of stone, of different kinds and qualities, of the same dimensions as the standard dimensions of bricks. Such experiments, so far as we know, have not been made; those made relating to stones have been instituted to compare one quality and kind of stone with another, but not with bricks. But so far as regards the strength of bricks in mass—that is, when put together in building—we have a wide enough range of experience open to us to enable us to decide that brick is capable of giving a structure as strong as a like structure built of stone, and at a much cheaper rate. For while the very number of the individual pieces in a brick building gives of structural necessity a strong building, by virtue of the "bond" secured, the pieces being of determinate size, are ready at once to be handled and put in place; whereas the stone, in important structures, where great resisting strength is demanded, have to be cut into the various shapes, chiselled or trimmed to secure bond, and are costly, in so far as their handling, so to call it, demands special and often costly appliances and machinery. The railways of the kingdom give numerous examples of brickwork which are evidence enough that it is capable of resisting almost any pressure to which built structures are liable.

The Advantages of Brick as a Building Material, claimed for it in Preceding Paragraphs, only Obtainable where the Materials are Good and Sound—Cheap or "Jerry" Work inadmissible.

In claiming, then, for brick such high qualities as a building material, it is of course to be understood that we refer to bricks honestly made and to brickwork honestly constructed. The bricks used to an enormous extent in the cheap and "jerry" built structures of modern times do not come within the scope of our observations; nor have such structures come within the range of our comparisons between brick and stone buildings. Those qualities or kinds of bricks made specially to suit the desire for cheap buildings are not, in truth, deserving of the name. Of these one may say, without much fear of being contradicted, that had the brickmakers of the day been capable of making such low-quality bricks as are now daily made, the bricklayers would not have used them—they would have been absolutely unsaleable. We venture to say that in none of the brick houses built about the period and during the reigns of the first Georges; or of an earlier period, as that of Queen Anne, will there be found bricks of poor quality, or bricks carelessly set and bonded. There has been of recent years a craze or rage which has led to a wide-spread revival of the architectural characteristics of what is called the "Queen Anne style." It would have been more to the purpose, and would certainly have indicated the rise of a higher morale, had there been as earnest an endeavour to imitate, in some degree at least, the honest use of good-quality bricks, and the as honest mode of applying them in construction, which characterised the practice of the bricklayers of Queen Anne's reign, and was observable also, as above stated, in the later reigns of the early Georges —up, say, to the end of the reign of the third George. At those periods the art of brickwork occupied a very high position in this country; and to have a due estimate of what it is capable of in giving good construction we must go back to those reigns. And it is chiefly those brick-built houses then constructed that, lasting almost in perfect condition to this day, afford us the examples by which we can compare brick as a durable material with the stones used in stone-built structures. Nor were the bricklayers of those early periods in our national history noted solely for giving good sound and honest work. They did admirable service also in showing to what an extent the material of brick was capable of giving ornamental and decorative, or in other words architectural, effect. With the introduction of so much material of the lowest possible quality, as we have seen, resultant upon the desire for cheapness of construction so widely spread now amongst us, all the higher uses of brick seem to have died out. There are, however, it is pleasing to be able to say, those who seem determined to revive the old custom of giving honestly done work with good materials. And with this revival, it is to be hoped, will come about the re-introduction of old, and also the devising of new methods of using brick, so as to give fine architectural effects.

Constituents of Bricks.—Their Influence upon their Colours.

As a practically useful conclusion to the foregoing paragraphs, we here append a few notes in connection with sundry points already treated of, or alluded more or less fully to. The first not only shows the constituents of certain bricks—and however various the localities in which they are made, they all, as a rule, present something like the same constitution—but some points also bearing upon colour, and the effect of certain ingredients and modes of burning upon this. The note is from the pen of an able Continental scientific authority, and is taken from *Dingler's Polytechnic Journal.*

"A brick manufactured in the neighbourhood of Stralsund exhibited on its surface a dark-red colour, while the interior was yellowish-white. The outer coating, of about 5 mm. thickness, and the inner portions, were examined with the following results :—

	Outer coating.	Inner portion.
Silica	63·71	71·25
Alumina	9·81	8·60
Oxide of iron	5·16	5·92
Lime	8·72	9·24
Magnesia	2·20	1·89
Sulphuric acid	8·49	0·61
Manganese	traces	traces
Chlorine	"	"
Alkalies and loss	1·90	2·49
	100·00	100·00

A still more characteristic difference in the composition of the outer and inner part of a brick is shown by the following analysis of a specimen manufactured in Szegedin (Hungary). The exterior was of a dark purple-red colour, which reached to a depth of about 10 mm.; the interior was brimstone-coloured, very porous and light.

	Outer coating.	Inner portion.
Silica	45·73	56·07
Alumina	10·22	14·02
Oxide of iron	4·49	5·49
Lime	12·81	16·53
Magnesia	3·53	4·50
Sulphuric acid	19·58	0·74
Alkalies and loss	2·24	2·66
Water	1·40	0·39
	100·00	100·00

There is hardly any doubt that this large amount of sulphuric acid in the outer portion is derived from the gases of combustion, which, when coals are employed, will often contain considerable quantities of sulphur compounds."

Constituents and Properties of Fire-Bricks.

Professor (now Sir) F. Abel, chemist to the Government at Woolwich Arsenal, has made some valuable investigations into the constituents and properties of fire-bricks in use there. The following statement of these inquiries is given in *Iron*. The remarks are preceded by the following analyses:—

Description of Firebrick.	Silica.	Alumina.	Iron Peroxide.	Alkalies, Loss, etc.
Stourbridge	65·65	26·59	5·71	2·05
"	67·00	25·80	4·90	2·30
"	66·47	26·26	6·33	0·64
"	58·48	35·78	3·02	0·72
"	63·40	31·70	3·00	1·90
Newcastle	59·80	27·30	6·90	6·00
"	63·50	27·60	6·40	2·50
Kilmarnock	59·10	35·76	2·50	2·64
Glenboig	62·50	34·00	2·70	0·80
Dinas	96·20	2·00	0·28	1·70

"Fire-clay derives its valuable properties from the presence in combination of two special constituents—silica and alumina—of which the former predominates, forming, in the majority of instances, about two-thirds of the whole; and its quality is enhanced in proportion to the absence of other constituents, the alkalies especially, which diminish its refractory power. Of these deteriorating elements peroxide of iron is the most detrimental, and indeed may be regarded as the chief cause of the wear and waste under heat of fire-bricks, etc. The district around Stourbridge has hitherto been most noted for the production of fire-clay goods; Newcastle also, and Dinas, with one or two other minor sources, have contributed to the supply. The last-named, Dinas fire-bricks, are considered the best, mainly owing to the small percentage of peroxide of iron—namely, as little as $\frac{3}{10}$ per cent., but partly to the presence of silica in excess, which is about 96 per cent.

"In Cornwall, some new deposits of fire-clay have been found, adjacent to the line of the Redruth and Devoran mineral railway, and with water carriage easily accessible. They are close to the surface, forming two considerable hills, in depth measurable not by feet only, but by tens or hundreds of feet, and can be "got" or "won" without need of mining or pumping operations. The clay is remarkably fine and free-working in its nature, rendering it easy of manipulation and treatment. Its composition is as follows:—

Silica	67·51 per cent.
Alumina	24·97 "
Iron	A trace.
Moisture and combined water	6·08 "
Lime	A slight trace.
Magnesia	0·64 per cent.
Alkalies	0·80 "
	100·00 "

"Fire-bricks made therefrom possess all the characteristics and qualifications for such uses: they have been tested in blast and other smelting furnaces, and found to possess powers of resistance and endurance under great heat in a very remarkable degree. The great freedom from iron probably conduces largely to this result."

The Strength of Various Kinds of Bricks.

We have said that there are on record no comparative experiments made to test the relative values or strengths of bricks and stones of various kinds and qualities. Even as regards bricks we have few experiments recorded showing the relative values of different kinds. The most complete set of recent investigations is probably that made and published by Mr. Harris. The bricks experimented upon were taken from various localities and countries, including the American States, and comprised examples of machine-made as well as hand-made bricks. The relative values, as regards strength, are calculated for dimensions as follows: length, 7 in.; breadth or width, 4½ in.; thickness or depth, 3 in.: the two last dimensions are those usually adopted in practice, but the length is shorter by 2 in. than that of what may be called the "standard" brick, the length of which is 9 in.

The reader will see, when we go into the subject of practical bricklaying, opened up in the paragraphs succeeding this, that the breadth or width of a standard brick being just one-half of the length, greater facilities are offered for securing a good bond between the bricks in a structure, than when the proportion of width to length is different, as in the brick above named, where the breadth is to the length as $4\frac{1}{2}$ to $7\frac{1}{2}$. Taking a London-made brick, the weight of which, at the ordinary dimensions of $9 \times 4\frac{1}{2} \times 3$ in., is 6 lb. 19 oz., the greatest strength is, in pounds, calculated, as above stated, for a brick $7 \times 4\frac{1}{2} \times 3$ in., 6100, least, 4126, and mean, 5064. Taking a Lancashire Oldham brick, the weight of which at the standard size was 8·31 lb., the greatest strength was 1193 lb., least, 898, mean, 982; the absorbing power, after twenty-four hours' immersion in water, was 9·27. A Nottingham brick gave as greatest strength 2142 lb., least, 1090, mean, 1583. A Birmingham brick, machine-made, gave as greatest strength, 3286, least, 724, mean, 2150 lb.; hand-made, 900, 421, 600. A brick of the same locality, a hundred years old—taking us back to the period we have already named as that of the best British brick-building—gave for greatest strength 4250 lb., least, 1160, mean, 1920. A Leeds in Yorkshire brick, machine-made, gave for greatest strength 4133 lb., least, 2616, mean, 3198; a hand-made brick, of the same locality, gave as greatest strength 1233 lb., least, 835, mean, 1038 lb. A Staffordshire blue brick—Tipton—gave as greatest strength 5553 lb., least, 2801, mean, 3975.

The Staffordshire blue brick referred to at end of preceding chapter is also shown in its absorbing power; this being in percentage as low as 0·33, or hardly perceptible; so that it may be taken as an absolutely perfect wet-resisting brick. A Dutch brick showed a greatest strength of 4000 lb., least, 3016, mean, 3580.

The Practice of Bricksetting or Bricklaying in the Formation of Walls.—Different Forms of Bricks used in Construction.

We have in the preceding paragraphs more or less completely gone into the consideration of sundry points of importance connected with brick as a building material, and its characteristics as regards strength, durability, and capability to resist moisture or damp. We now proceed to take up the points connected with the setting of bricks; in other words, the practical construction of the various classes of brick-building.

We have already remarked that since the duty has been taken off bricks a great improvement has been made, not merely, as in some instances, in their manufacture, but in the introduction of new forms adapted to meet the requirements of different classes of work. Under the old system, when "duty" was paid, there was no deviation allowed from the form and the dimensions named in the Act. And although every practical man saw the advantage which would accrue from certain alterations in them, the clauses of the Act were so clearly worded, and they were so rigidly enforced by severe penalties in the case of their being infringed, that few attempts were made to introduce improved forms into practice. Now a very different state of matters exists, the result of the freedom which the trade now has to make bricks of any size or form. We have thus so wide a variety to choose from that for nearly every kind of work there is a peculiar form at hand to meet its requirements. We have hollow bricks of all kinds, segmental bricks for the building of circular work, bricks for quoins for coping, string courses, etc., etc.

The size was, or rather the dimensions of the brick under the Duty Act were, as follows: length, 9 in., breadth, 4½ in., thickness, 2¾ in. These dimensions, with slight variations, either over or under, are still those of the bricks generally used for ordinary work, the habit of making bricks of such dimensions having taken such a hold, both of brick-makers and bricklayers, through the operation of the Duty Act of Parliament, that it has been very difficult to break through it—so much so that even where larger or smaller dimensions would be more convenient for the various requirements of practice, it is found very difficult to get the workman to use them. This, however, is being overcome more and more every day. A great improvement in this ordinary-sized brick has been largely adopted, and this is the placing on the face *a b c d*, or bed of the brick, a recessed or hollow part, as *m m*, fig. 6, Plate I., shown in longitudinal section at *n n*, *o* being the solid part, the brick being here recessed on both faces; the cross section is at *p p*, *q* being the solid part. This admits of the mortar passing into the recessed parts, and thus forming a "key," which gives the bricks a better hold of each other, and thus adds to the strength of the wall built of them. Bricks are also made hollow—that is, having through their length, breadth, or thickness, apertures, either rectangular, circular, or elliptical, as illustrated in same figure, in which, at *x*, a circular hole passes from one end of the brick to another in the direction of its length, as shown at *z*, 1, 1—2, rectangular holes, as *e*, are made. In other cases the holes pass from side to side of the breadth of the brick, these being rectangular, as in the end section at *z*, or at *r*. In other forms the hollows go through the thickness of the brick, and are of various shapes, as circular or rectangular, as at *p r q* in fig. 7, Plate I.

In fig. 6, Plate I., is shown the longitudinal section of the hollow brick, *x*, with one hole passing through its length; the dotted line at *v v* shows its position in face of brick. The recessed bricks, as at *m m*, may have a hollow or void place, as at *m m* 3, 4. There are other methods of giving a key to the mortar, as at *r r*, which shows two angular depressions made in the face of the brick in parallel lines, *s* being the longitudinal and *t t u* the cross section.

In some cases the holes or apertures are oval or elliptical. These hollow bricks are exceedingly useful in adding to the dryness of the walls in which they are used. They are, of course, also much lighter than a solid brick, and as strong; this more especially when the holes or apertures are circular, which gives the strongest, the weakest being the elliptical. These hollow bricks are also very often adopted, and with great advantage, for the formation of what are called "damp-proof courses,"—that is, the course laid just a little above the ground level, the object or aim of which is to prevent the damp from rising upwards to the upper courses from the damp soil. A form of brick especially adapted for this purpose is that known as "Taylor's." This is illustrated in fig. 4, Plate II., at *j j* in cross section; the recessed parts at the sides give a good bond or tie between the hollow bricks, as they stretch across the face of foundation courses. Hollow bricks have also been introduced for the formation of partitions; the diagram in *i i*, fig. 4, Plate II., illustrates the form designed by Roberts; *k l* that by Halstead, and *n o o* by a Scottish maker. These give all good lateral and cross bond, and, being hollow, are light and dry. Other forms of hollow bricks, as at *a b c*, *d e f g* and *h*, have been designed by Roberts to fall in with a systematic method of securing hollows or cavities throughout the whole of the work. The advantages of these, and of others we have illustrated, will be seen more completely after the subject of bond has been fully gone into. Some forms of bricks have been introduced which, being solid when laid together, give cavities as in the illustration *p p*, *q q*, *r*, *s*, fig. 4, Plate II.; *t t*, *u u*, and *v v* illustrate Morris's bricks for building chimney shafts, with cavities for ventilation, etc., and *w x* Bunnett's hollow brick fire-proof system.

Bricks of these hollow forms, illustrated at *j j*, fig. 4, Plate II., or by others, are much better for the formation of damp-proof courses than the plans so long and still so frequently used where a layer of slate or tar or lead is placed round the whole wall a little above the ground level. Another advantage these forms give is that they act as ventilating bricks, allowing the air to pass under the joists, thus preventing the rise of dry rot in these. These hollow bricks, used for this purpose, are placed at certain intervals along the wall just below the line of joisting; but in the case of Taylor's system there is a whole line of hollow bricks round the building, thus securing ventilation of a thorough kind through the under part at *every* point.

Another form, or modification of the old form, of brick is what is called a "bull-nosed" brick. This is one in which the corner or both corners are rounded off, as shown at *s t*, fig. 7, Plate I.; if at one corner only, as at *s*, they are used for the formation of the door-openings of a house, getting rid of the sharp angles which, in the case for example of stables or cow-houses in farm buildings, are apt to inflict injury on animals coming quickly or strongly against

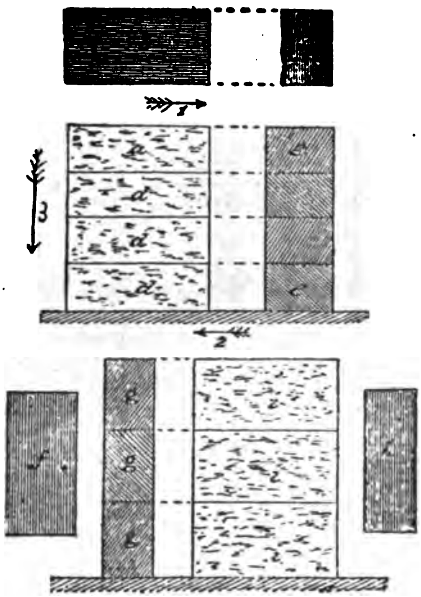


Fig. 1.

them. If rounded at both corners, *t t*, they are useful for pillars supporting slop stones in sculleries, etc., or stone shelves, the rounded corners being placed to the outside. In this form they are useful for coping of walls, or for drips. For other purposes angular or "splayed" bricks, as at *f e*, *l i*, may be used; *f e* is a brick with one angle or corner cut off. Splayed bricks are used in foundation courses a little above the ground level, as at *m*, in which *n* is the line of outside of face of wall. Bricks for coping are made semicircular, as at *t*.

The first three diagrams in fig. 6, Plate I., illustrate the three views and dimensions of a standard size or ordinary brick, *a b c d*: the full length, *a b* = 9 in., breadth, *b d* = 4½ in., *e f g h*, side view, giving depth or thickness, *e f* = 3 in., *i j k l*, and view in cross section giving breadth, *i j*, equal to *a b*, of 4½ in.

Technical Terms used in Bricklaying—"Brick on Bed," etc.

Bricks when set on the flat, or when lying on their broadest surface, are technically said to be "bricks on bed," as at *a b* and *c* in fig. 1, *a* being the side view, *b* the plan or upper surface view, *c* the end view, and *d a d d* elevation of several bricks, *e e* being end view of this. When the bricks are set so as to stand on their edge, they are technically called "bricks on edge," as at *g g* in fig. 1, which is end elevation of several bricks on edge, *h* plan of top of ditto, looking down on *g g* in the direction of the arrow 3; *i i* showing front view of *g g* looking out in the direction of arrow 1 or 2. In the same figure *a d*, *d* is side or front view of bricks "on bed," looking at it (*e e*) in the direction of arrow 1 or 2; *f* plan of *e e*, looking down upon *e* in direction of arrow 3.

The Position or Placing of Bricks in a Wall.—Their Binding together.—"Bond" in Bricklaying.

The setting or placing of bricks in relation to one another, in using a number of them for the erection of a wall, for example, constitutes a very important branch of the constructive arts, and is known as "brick-setting" or "brick-laying." A wall built of bricks, being made up of a series of blocks of regular and unvarying size, must obviously be so constructed that they will not be merely a loose collection—the only tie, so to say, between them, and keeping them together, being the strength or cohesive power of the mortar used to connect them together into a mass; but they must also be so placed that each will in some measure, and this to the maximum extent, give to its neighbour a species of support, and also a connexion. The whole, in short, must be "bound" together, so that the strongest possible wall may be obtained by the way in which they are related to each other. This is technically known as "bond," which has been already described in this series in "The Stone Mason." But the pieces in brickwork are smaller than in a wall of the same dimensions built of stone, in which the pieces or blocks are large; they must, therefore, be much more numerous, and a more intricate kind of bond is demanded. There are, in fact, in brickwork more than one kind of bond. What these are we now proceed to illustrate and explain.

Bricks placed Longitudinally in Walls termed "Stretchers"—Transversely "Headers."—The Relative Positions of "Headers" and "Stretchers" in a Wall give the Two Kinds of Bond, known as "Old English" and "Flemish Horizontal Bond."

A brick having its length greater than its breadth is obviously capable of being placed "on bed" in two ways, with relation to the front or face of the wall, *a a*, fig. 8, Plate I. Thus it may be placed as at *b c d e*, or as at *f g h i*, the dotted line *a a* being

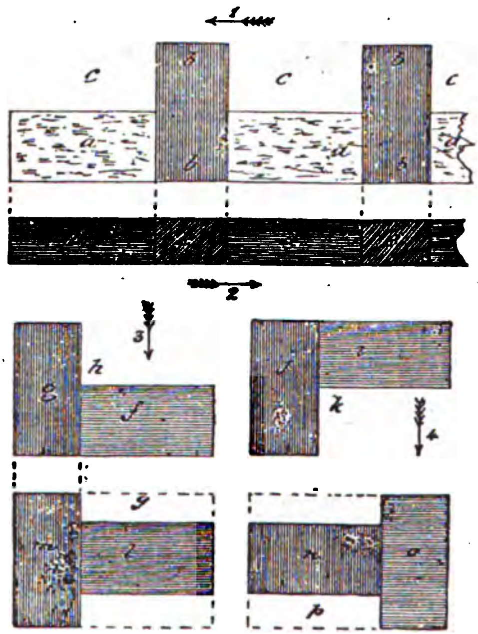


Fig. 2.

supposed to be the front or face, or direction in which the length of the wall runs. When placed as at *a b c d e* the brick assumes a position which is technically termed a "stretcher"; when placed as at *f g h i* a "header." By placing a number of bricks so disposed together, a wall of a certain kind may be constructed, of which we may suppose the plan to be at *a a*, *b b*, in fig. 2, *a a* being all "stretchers" and *b b* all "headers." But as a brick has a breadth just half the distance of its length, if placed as at *e f*, in relation to another, as *d g*, a space, as *h*, is left vacant, the reverse position being as at *i j* and *k*. In the central position, as at *l m*, *n o*, a space on each side of *l* and *n* is left vacant, as at *k*, *n* and *o*, this being equal to one-half of the breadth of a brick, as shown by the dotted line *p q*. Now, by arranging the bricks as in fig. 2, at *a a*, *b b*, a series of spaces, as *c c c*, are left at the back part of the wall, the lower line being supposed to be the front of this. These spaces in width are just half the length, and, therefore, just the full breadth, of a brick; and by placing bricks, and so filling them up, as at *c c c c*, a solid flat surface is obtained, all those, as *c c c c*, being "stretchers." Here we have a species of binding together of the bricks by the way in which they lie "on bed" in relation to one another, and in which they are viewed from the front in "elevation"; the "stretchers," *a a*, alternate with the "headers," *b b*, as at *d d*, the latter being "stretchers" in elevation, corresponding to the "stretchers" *a a* in the plan; *e e* being "headers" in elevation, corresponding to the "headers" *b b* in plan. This arrangement is, in fact, that kind of "bond" known as "Flemish" bond, in which the "headers" and "stretchers" alternate; and the wall in fig. 2 would be what is technically called a "one-brick wall"—that is, a wall having a thickness equal to the length of one brick—or a brick, as *b*, placed as a "header," as at *f g*, *h i*, in fig. 8, Plate I., and *b b* in fig. 2. In place of arranging the bricks as in fig. 2, they may be placed in one row, as in fig. 3, these being all "headers," as *a a*; or they may be placed in two rows of "stretchers," as *b b* in same figure. If the row *a a* be placed above the row *b b*, so as to be in the position as in "elevation" at lower courses *a' a' a'* and *b' b' b'*, fig. 3, the arrangement is that species of bond known as "Old English" or "English bond," in which there is one row entirely made up of "headers," *a' a' a'*, corresponding to *a a* in plan, and another row as entirely made up of "stretchers," as *b' b' b'*, corresponding to *b b* in plan. We shall see presently, however, that although fig. 2 illustrates the chief feature of what is called "Flemish," and fig. 3 that of "Old English" bond, the arrangement of the bricks as there given is deficient in giving a '*true* bond."

Any one row of bricks, as *a a* or *b b*, fig. 3, is known technically as a "course," and is equal in thickness, invariably, to the depth or thickness of a brick—the exception being when the bricks are laid or "set on edge," which, however, is only done in certain kinds of work, as in forming the coping or last course of an open or exposed wall, and in a certain class or kind of hollow brickwork, hereafter to be described; in which case the depth of a course is equal to the breadth of a brick.

Walls built up in a Succession of Layers called "Courses," necessitating "Vertical Bond" as well as Horizontal.

In the arrangements thus so far illustrated in figs. 2 and 3, the "bond" or connection between the various bricks making up a course as lying "horizontally" is obvious enough while lying "on bed," or in "horizontal bond" as it may be termed; the bricks, as *a a*, *d d*, fig. 2, being clearly prevented from moving laterally or sideways, as in the direction of the arrows 1 and 2. by the bricks *b b* or *c c*, although

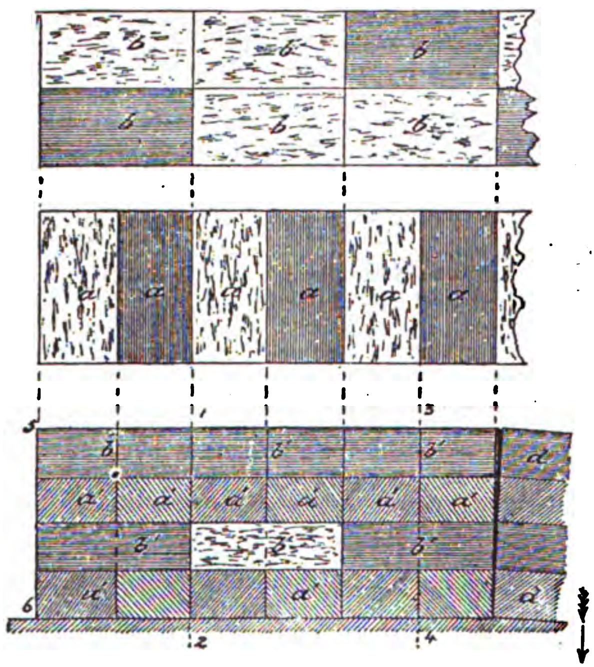


Fig. 3.

there is nothing in the arrangement shown to prevent the bricks *b c c*, from being moved out of place by pressure acting in the direction of the arrows 3 and 4, save the cohesion of the bricks to those as at *a a* or *d d*, by means of the mortar or cement with which in practice they are laid.

But as a wall, in the sense of its height, is made up of a succession of "courses," these also ought and require to be so placed in relation to each other that they will be connected or bound together—that is, there must be "vertical" as well as "horizontal bond." Thus, by placing the courses as shown in fig. 3, it is obvious that this "bond" is not secured, inasmuch as all the joints, 1, 2, 3, 4, run vertically in a line from top to bottom of the wall, and this would be the case however high it was. This, if carried out in practice, would form exceedingly defective walls; for any unequal settlement of the walls might, and would, cause a disrupture vertically at the joint or joints corresponding to or near the points of unequal settlement. One part would be thus torn away from another more or less completely, the joint being wider at the top than at the bottom, as shown in fig. 3, at *d d*; *a' a'*, *b' b'* being supposed to be a succession of "courses" of "stretchers," *b' b'*, and "headers," *a' a'*.

Relation of Bricks one to another in Vertical Bond.—"Breaking Joint."

Now, this evil is prevented from occurring, or its chances of occurring are at least greatly lessened, by so placing the courses in

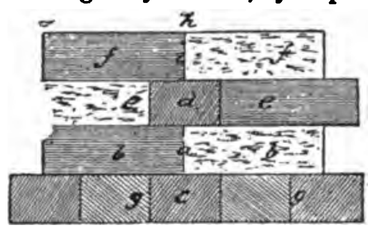


Fig. 4.

relation to each other that the joints shall not run in the same vertical lines as in fig. 3, at lines 1 2, 3 4, but shall "break joint," as the technical expression has it.

This "breaking of joints" is illustrated in fig. 4, and simply means that the joint formed by any two bricks placed together at any part of a "course" shall be covered by the solid part of the brick of the course immediately above and below it. Thus, in fig. 4 the joint *a*, formed by the juxtaposition of the two "stretcher" bricks, *b b*, is covered by the solid part of the "header" bricks, *c* or *d*, in the courses above and below it, while the joints *e e*, *g g*, are covered by the solid parts of the bricks *f f* and *b b*, the joint *h* of bricks *f f* being placed above the central or solid parts of *d*. Another arrangement of "breaking joint" is shown at *h h*, *i i*, in the same figure. We have used the term "covered" to denote how the upper and lower edges of the joints *a* and *i* of the two adjacent bricks *b b* and *f f* are concealed by the solid parts of the bricks above and below them. But the technical term employed is "butting" or "bearing." Thus the joint *a* is said to "butt" or "bear" against the solid part of the bricks above and below it, as the bricks *b b* and *d*. The lower edge of joint *i* "butts" against or bears upon the solid parts of the brick *d*. The young pupil will note that the bricks *b b*, *e e*, and *f f* are "stretchers," while *c d* and *g g* are "headers." The diagram is not designed to show any particular kind of "bond," but simply to illustrate what is an essential feature of every kind or class of bond—namely, the "breaking of the joints"; the joints in all cases being so arranged that they all butt against or bear upon solid parts of other bricks lying below or placed above them.

"Breaking Joint," to secure "Bond," necessitates the Use of Parts of Brick in Courses.—"Closers."—"Closures."

But while "bond" gives the security to the wall required, it throws any arrangement aside by which an even number either of

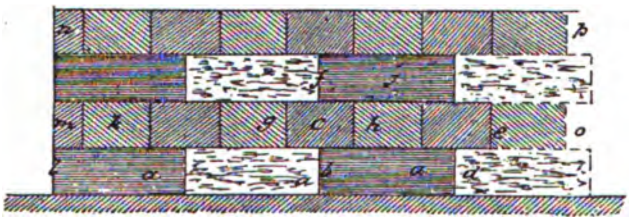


Fig. 5.

"header" bricks or "stretcher" bricks can be used in any one course. Thus, in the arrangements shown in fig. 3—"Old English" bond—the end of the wall, as 5 6, is finished vertically off, by either a "stretcher" or a "header," as the case may be. But by introducing the system of "breaking joint," as in fig. 4, this evenness of finish at the ends of a wall cannot any longer be obtained, and voids or breaks are introduced. This is illustrated in fig. 5: beginning with the first course which we make use of—"stretchers" (Old English bond), *a, a, a*—the next course, which is one of "headers," must be so arranged that the joint *b* of the two "stretchers" in the first course shall be covered by the solid parts of the "header," as *c* in the second course, the centre of this covering the joint *b*. Carrying on this course of "headers," we find it finishes with a break or void, *d*, caused by one-half of the header at the end projecting, as at *e*, beyond the end of the "stretcher" below it. Taking the next course—another row of "stretchers"—the joint *f* is placed immediately above the centre or solid part of the "header" *c* below it; the joints *g* and *h* of the two "headers" being covered by the solid parts of the two "stretchers" *i* and *j* above. The first course of "headers" is finished by the header *k*, but this is too short—so to say—for its end to come up flush with the end *l* of the "stretcher" *a* below it. Another void or break or empty space is left, therefore, at *m*. But by starting the two courses (first and third) of "stretchers" as shown, the "header" *k* in these condcourse has to be so placed that it leaves a void, or a break, *m*, at the left-hand side of the wall; thus, at every alternate course these breaks occur alternately to the left-hand and right-hand ends of the walls, as at *m*, *n*, *o*, *p*. These breaks, or voids, must be filled up so as to make a proper solid and vertical finish to the ends of the wall.

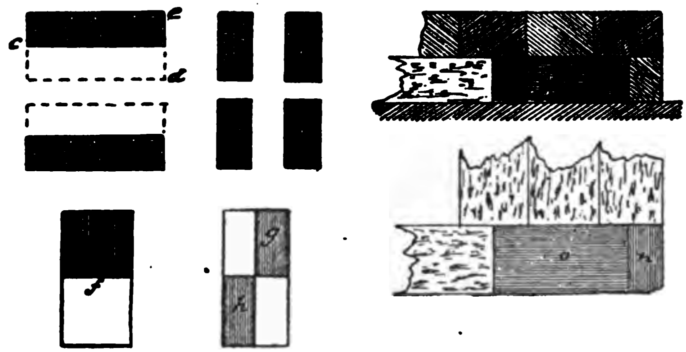


Fig. 6.

Different Kinds of "Closer" or "Closure" Bricks.

It will be observed that in all cases the width of these voids or breaks is equal to half the width of a brick on its face, so that to fill them up half-bricks are used. These are known technically as "closers" or "closures," as closing up or finishing the wall; and are obtained or formed by cutting a brick in two in the direction of its length, as at *a* in fig. 10. Thus one brick gives two closers, as *a* and *b*, as shown by the dotted lines. These "closers" are half-bricks, in the sense of being half in the direction of the length, as *c d*, as well as in the direction of the breadth, as *d e*. But in some cases a "closer" is not required the whole length of the brick, but only half of the length; a half-closer is, therefore, cut in two by the line *f*, thus giving two "quarter-closers," *g* and *h*, or four out of a brick, as at *i*, *j*, *k*, *l*. In the same figure the void, as *o* in fig. 5, is shown filled up with the quarter-closer *m*, as in elevation, and *n* in plan, the "stretcher" *o* corresponding to *d* in fig. 6. It is obvious that by arranging the courses as in fig. 5, so as to throw the voids to the outer extremities of the wall, the arrangement would not be very sightly nor strong. The practice, therefore, is to make the "closer" in a course always, or at least generally, *the last brick but one* in each course. This is shown in fig. 7, in which *a b c d* is the front elevation of the first course of stretchers, the "closer" being placed

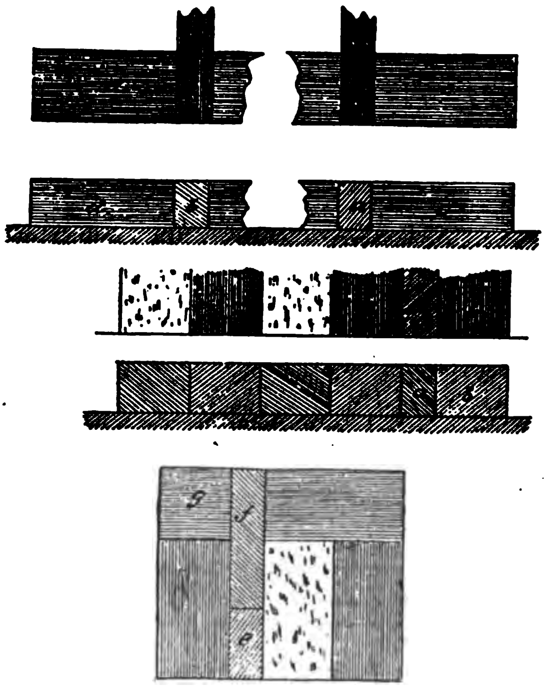


Fig. 7.

next the last stretcher, as at *a* at one and *b* at the other extremity of the wall; *c* and *d* are the last stretchers shown in plane at *c′* and *d′*, *a′* and *b′* corresponding to *a* and *b* in elevation. The second course, or that of "headers," the bond being "Old English," is shown in the lower part of fig. 7; *a* is the "closer" in elevation *a′* in plane, and is placed next to the last "header" *b* and *b′*, nearest the end of wall. In the same figure *e* shows a "quarter-brick" closer and *f* a "half-brick" closer, as used in the second course of a brick-and-a-half-thick wall in English bond. In some cases a three-quarter-brick closer is required, as *g*.

"Bats" in Brickwork.—"Splayed" Bricks.—"King Closers."

If a brick be thus cut across in the direction of its breadth at a line *a b*, fig. 12, one-fourth from the end, the other or three-quarter part is usually called in the technical language of brick-setting a "bat"—although this is often used to denote broken bricks, or rather parts of bricks, whatever the proportion that part bears to the whole brick; only that the bricks in this case are cut in the direction of their breadth, as at *a b*, not in the direction of their length, as *e d*. What is known and called a "king closer," is a brick cut, or which should be cut, of the form shown at *d e* in fig. 8, the crossed part *f f* being cut out, forming a shoulder at *g*; this is shown in side elevation at *d" g" e"*. But as in practice this cutting is not easily executed so as to be accurate, or without running the risk of breaking the brick, the usual practice is to cut the bricks as at *h*, cutting off the crossed part *i*. This forms what is called also a "splayed brick," as at *j*, the angular part *k* being the "splay" or bevel, and from this a "splayed" is sometimes called a "beveleld brick."

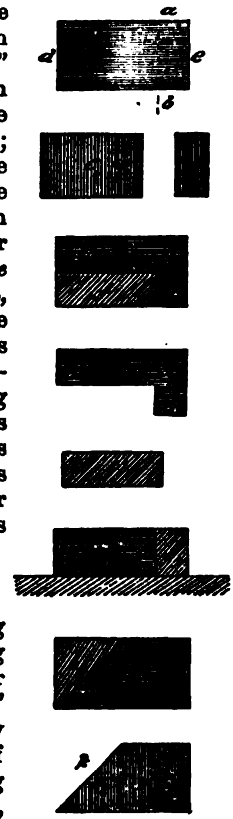


Fig. 8.

"Reveals"—"Jambs" in Brickwork.

The form of closer now illustrated, "king closer," as it is used at the corner of the opening or "void," as it is termed, of a window or door at that part known as the "reveal" and "jamb" (in Scottish building construction technically called a "rybat," clearly a mere corruption of the term "rebate." A window or door opening may have its sides or interior parts, as *a b*, *c d*, at right angles to the wall *e f*, fig. 9, the parts *a b*, *c d*, having no projections. This part *a b* or *c d* is called the "jamb," and sometimes the "cheek" of a door or window opening. When there is a projecting part to this, as at *i j j* in fig. 9, the name "jamb" is applied only to the inner part, as *g h*, the part *i j j* being called the "reveal."

The "reveal" in ordinary work is only made half a brick thick or deep, from *i* to *j*; but in superior work it is much deeper. The door or window frame, as *k*, goes into the part *l m*. In another class of "reveal" work the inner face at the point *h* is "splayed" or bevelled off, as at *n*, and the reveal is then called a "splayed reveal" or "splayed jamb," a "square jamb" or "square reveal," being as at *o p q*. In fig. 9 we give in diagram A the first course of part of a brick wall—one brick thick—showing a square reveal, and in B the second course of same. All the succeeding courses, to whatever height the wall may be carried, are just repetitions of these two first courses. In diagram A, *a* is the offset or reveal, which is square, *b b*

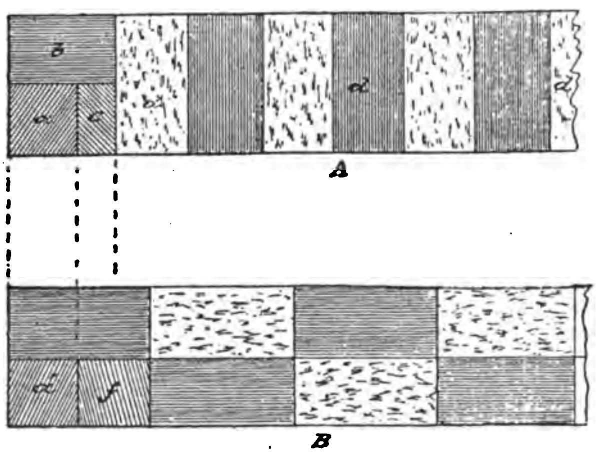


Fig. 9.

is a three-quarter brick, and *c* a "bat"; *d d* the course made up of "headers." In diagram B the course is made up of "stretchers," *a'* being the "square reveal" corresponding to *a*, *f* being a half-brick, put in to form the shoulder of the "reveal." The drawing in fig. 9 shows the reveal, as *a' a*, as a crossed or hatched solid: this should be a dotted space, as in next fig., not shaded. In fig. 10 we give in A first course of a "splayed reveal" for a wall a brick and a half in thickness, in which the reveal is formed by a half-brick, a splayed closer, and a splayed bat. In the second course at foot of drawing the reveal is formed by a half-closer and a splayed or rubbed half-brick. The application of a square reveal to a wall in which recesses are formed in its face at intervals, is shown in fig. 11 at A, in which *a a* is the wall, *c b c* the recess, with reveal at *c*, *e d* the centre line of recess, corresponding to *f g* in B, which is the opposite half of second course, a splayed brick being used at *d′*, and a half-closer at *e′*.

Special Methods of adding to or securing the "Bond" of the "Bricks."—Timber.—Bonding—Chain Bond.—Wood Bricks.

"Bond" in brickwork, in addition to being obtained by one disposition of the bricks in relation to each other, as we have explained generally in the illustration already given and which will be more fully and specially illustrated in giving, as we shall presently do, the various thicknesses of walls, both in solid and in hollow brickwork,

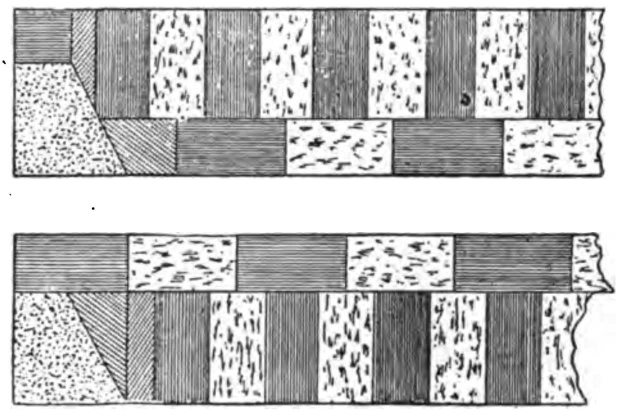


Fig. 10.

is also secured, or at least aided, by the use of what is called "bond timber" and "bond hoop iron." Bonding with timber is simply the placing of narrow battens or pieces of wood of greater or less length on the upper face of the course, and building or covering this in with the upper courses. The wood may either be wholly concealed in the interior of, or by the brickwork; or it may be exposed at one side of the wall; this is generally the interior side, and this is done in order that the wood bond may be made available to nail or secure to the wall the interior fixings of joinery work, such as skirting boards, dados, or the like. If the bond timber is carried round the room, it is called "chain-bonding," and there are usually several tiers, so to call them, of this—such as one tier or chain at a height from the floor sufficiently high to admit of the skirting board being secured to it (this being called the "skirting bond"). If a deep dado be used in place of the shallow skirting board, another chain of bond is placed above, to which the upper part of the dado is secured. Another chain is placed near the ceiling, and is called the "wall or plate bond."

In fig. 12, *a a* shows a chain bonding of timber in front view or in elevation, *a*, as laid or let into the wall *b b*. The surface of *a a* as generally flush or coincident with the surface of the wall as shown at cross section at *c*, *d d* being face of wall.

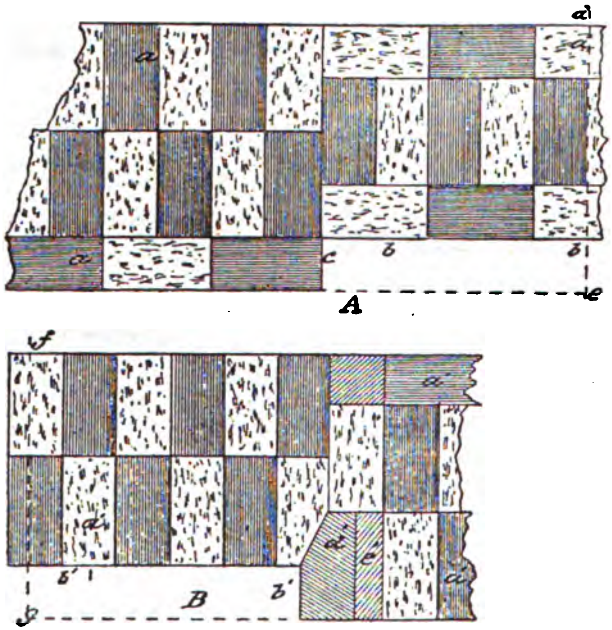


Fig. 11.

To fix or secure the various parts of door and window linings, it is necessary to have pieces of wood built into the walls, in order that these shall bond with the ordinary bricks; they are made of the same dimensions, and are called "wood bricks"; they are usually inserted in the "jambs" or "reveals" of the window or door openings, as at *e*, fig. 12, *f* being front or side view. They do not go through the whole thickness of the wall, but stop short of the exterior surface of it, as at *g*.

"Hoop Iron" Bonding.

Timber being very apt to decay, and thus to produce unequal settlement in the wall into which they may be built, it is now in first-class work discarded in the case of chain bond. Wood bricks still require to be used in order to nail the wood or joinery linings to. But iron in the form of what is known in the trade as "hoop iron" is used in place of wood bond. This iron is in narrow strips, about an inch in breadth, and is generally coated with a painting of tar before it is built into the wall, this being done to secure immunity from rust. The hoop iron is usually laid in the centre of the wall, as at *a a*, fig. 13. In order to insure a still more perfect bond or union between the surface of the hoop iron and the brickwork

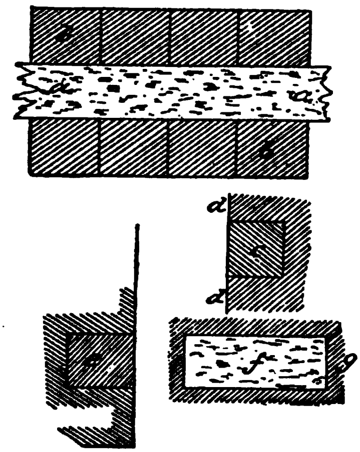


Fig. 12.

and mortar, holes are sometimes punched at intervals along the surface of the iron, as at *b* or *c* fig. 13. These are all punched from the upper or the same side, and the rough protuberances, the result of the operation, as *d*, are left or allowed to remain on the under side. These protuberances serve as keys or holdfasts, taking into the mortar or the joints of the brickwork. A very excellent kind of hoop-iron bond is that known as Tyermann's, and is now largely used. In this, diagonal cuts, as at *e e′*, fig. 13, are made on each side or edge of the hoop iron; and as these are made, they are lifted up or raised a little, as at *f f*; forming catches corresponding to the protuberances *d d*, which take hold of the mortar and bricks, and thus secure a very firm bond.

Formation of Walls of Different Thicknesses—One-Brick Wall—Brick-and-a-Half Wall—Two-Brick Wall, etc., etc.

Having now gone into what may be called the elementary details of brickwork, we are now prepared to give illustrations of "Bond" as practically carried out in the construction of walls executed of different thicknesses and of different classes of bond. Of these we shall take up the "Flemish bond" first, of the principle of which we have given a diagram in fig. 2 *ante.*

Brick walls for exterior work usually range in thickness from one up to three bricks; a one-brick wall being generally known or classed as "nine-inch work"; and this is very extensively adopted for the walls of cottages and inferior houses, although it is in this damp climate of ours too thin for dwelling-houses, unless the bricks are so

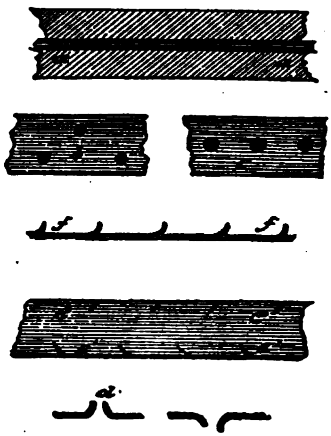


Fig. 18.

disposed as to form a hollow, or cavity, which increases the thickness to "eleven inches," and this without involving the expenditure of additional bricks. Walls of a brick and a half thick are usually termed "fourteen-inch work."

This is the thickness generally adopted in the better class of work. All walls are, as already stated, erected in a series of layers of "bricks on bed," each layer being termed a course. However high the wall, there are only two kinds or classes of courses; these being repeated alternately from bottom to top of wall till it is completed. The lowest course, or that which rests upon the ground, is called the "first course," the next above it the "second course"; and, as just now said, these are repeated alternately throughout the whole height of wall.

Foundation or Lower Courses of Walls.

We have said that the first course rests upon the ground; but this is never the case, except in exceedingly poor work, or in cases where the foundation is exceptionally dry and firm, as in the case of rock, which being "benched out"—that is, cut into terrace-shaped parts in order to secure the proper level—the walls may start at

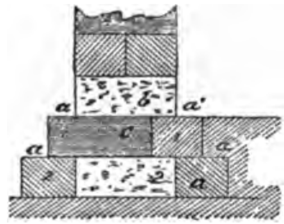


Fig. 14.

once from the rocky surface. But in nine cases out of ten the soil or site upon which a wall is built is of such a nature that special foundations require to be made, upon which the superstructure rests or is built. The lower part of the wall is so formed as to be part of the foundation, and is made much wider or thicker from interior

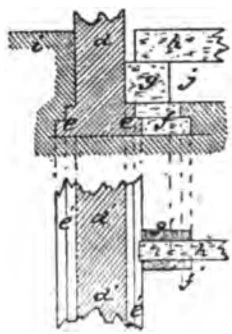


Fig. 15.

to exterior surface, in order to secure a good broad bearing surface, to resist the weight or pressure of the upper wall. This increased width or thickness is obtained by a series of step-like projections, termed "offsets," as shown in the diagram in fig. 14, at *a*, *a*, *a*. These are, of course, of depth equal to a course of brickwork, and generally of such a width as to project a distance equal to half a brick, or sometimes a quarter of a brick. This latter is, however, too narrow, and should not be adopted, the object being to spread out the foundation so as to have as wide a "bearing surface" as possible. (On the extreme value of a good bearing surface for all heavy superstructures to rest upon, some remarks will be found in the volume in this series entitled "The Stone Mason.") Part of the upper wall is shown at *b b*, and the line *c* separating this from the lower part—which is termed the "footing" or "footings" of the wall—indicates the point at which the "damp-proof course" is built in, being a little above the ground level. The joists or flooring beams of the floor—supposing the wall is that of a house—are in inferior work made to rest upon the upper surface of the "offset" or proejcting part nearest the surface of the ground, as at *a′*; but in

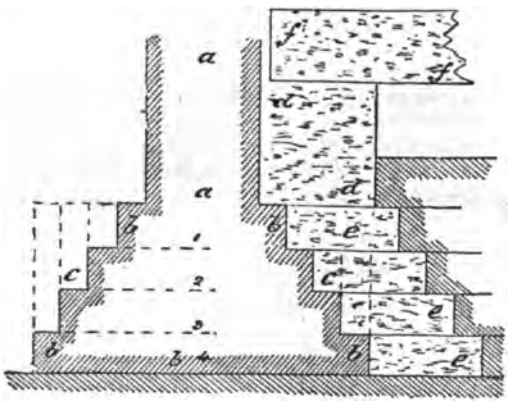


Fig. 16.

superior work it is the custom to rest the timber joists upon small piers of brickwork which are made at intervals along the footings corresponding to the distance between the joists.

Piers or Bearing Walls for Joists at Foundation Courses.

The method of forming those piers or bearing walls for timber joists is illustrated in fig. 15, in which *a a* is supposed to be vertical section of part of the outside wall, with its footings *e* as at *a a* in diagram fig. 14. The footings *e* are carried out at intervals—as at *f* and *f*, in plan—along the length of wall, corresponding to the distance between the timbers to be supported, as in the case of "girders" and "binding joists," or carried along the whole length of walls on the sides at which the joists terminate. Those footings carry the piers, or bearing wall *g*, in plan *g'*, which projects sufficiently far from the wall *d* as to give a good length of bearing—say nine inches to the end of the joist or beam *h*. The upper surface should be some distance above the ground level *i*, so as to throw the boarding floor above the ground—and afford a clear, dry, vacant space, as *j*, below the joists and flooring. Two steps—three or four are better—from ground level *i* to level of floor of lobby of house will give the height

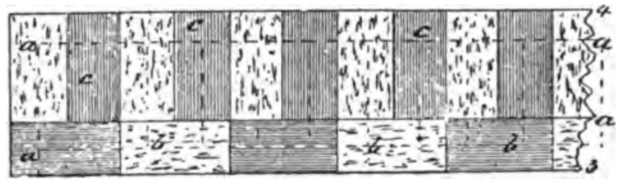


Fig. 17.

desired of floor surface above that of external ground, and thus secure a dry foundation. In fig. 16 we give the section of a thicker wall, *a a*, than in diagram *a a b* in fig. 15, with deeper and wider footings, *b b*, the offsets, as *c c*, being four in number. The lines of bearing wall *d d*, or of piers, are shown at *e e*; *f f* being part of a girder or binding joist.

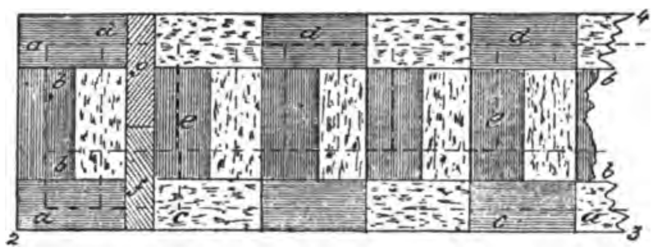


Fig. 18.

"Footings" or Foundation Courses of a Nine-Inch or One-Brick Wall, with different "Offsets" or Courses.

In fig. 17 we give the plan of "footing" for a "nine-inch" wall—that is, one brick length in thickness—which is that of the upper wall borne by, or resting upon, the footing shown in the drawing. The first course of this nine-inch wall is shown by the dotted line *a a*. The "footing" course is made up of a line of "stretchers," *b b b*, with a set of "headers," *c c*, behind—at right angles to them—thus making a course equal to a brick and a half in width. This gives one "offset" only to the footing, as at *a a′* in fig. 15. If there are to be two "offsets" to, that is two courses in the "footing," the course below that in fig. 17 is shown arranged as regards bond in fig. 18, which with a two-course footing giving two offsets and two courses, as 1, 2, in fig. 16, obviously forms the lower course, fig. 17 being the upper course of the footing as a whole. In fig. 18 the dotted outline *a a a a* gives the position of the second or upper course—namely, that in fig. 17—*a a a a*, fig. 18, corresponding to 1 2 3 4, fig. 17—while the outline *b b b b* in fig. 18 shows the position of the first course of upper wall, corresponding to *a a a a* in fig. 17. The course in fig. 18 is equal to a brick and a half in width, and made up of two outside lines of "stretchers," one at front *c c*, the other at back *d d*, with a row of "headers," *e e*, at right angles between them, two half-brick closers, *f* and *g*, being used at the end.

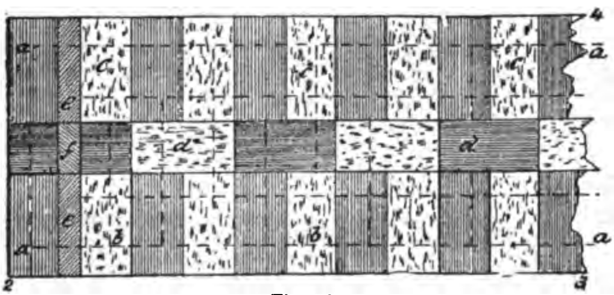


Fig. 19.

In fig. 19 we give the plan of the course where the footing is of three courses, as 1, 2 and 3 in fig. 16 (*ante*). In fig. 19 the dotted outline represents the course 1 2 3 4 given in fig. 18; here the course is equal to two and a half bricks in width or depth from front to back, and is made up of two rows of "headers," one at front, as *b b b*, one at back, as *c c c*, with a row of "stretchers," as *d d d*, between, and running at right angles to them. *e, e*, are two half-brick "closers," with a quarter-brick closer at *f*. In like manner, we may proceed, as in fig. 20, to show a fourth course, where the footing has four offsets and four courses, as at 1 2 3 4, fig. 16. Here again the dotted outline *a a a a* may be supposed to represent the position of the course illustrated in fig. 19, and of which the outline is 1 2 3 4, corresponding to *a a a a*, fig. 20. The course in this figure which forms the lowest or base course of the supposed four-course footing, is made up of three distinct rows, on each of which two "stretchers," as *b b*, alternate with a "header," as *c c*; the front row "stretcher"

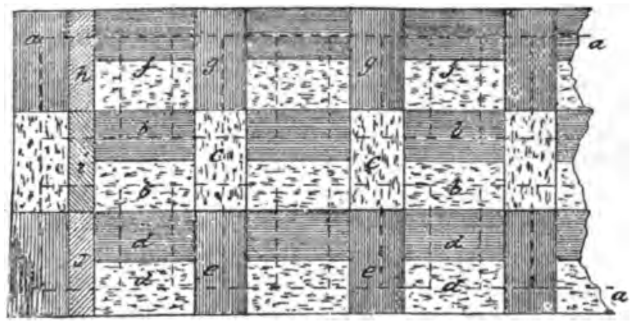


Fig. 20.

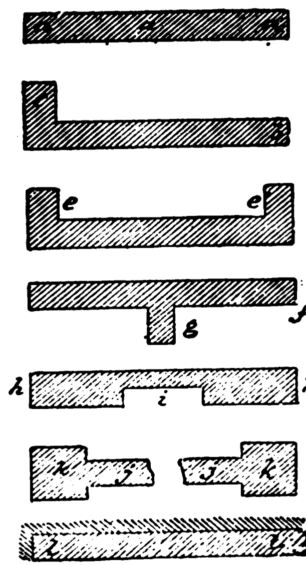


Fig. 21.

being *d d*, the back row *f f*, the "headers" being respectively *e e* and *g g*; *h*, *i* and *j* being half-brick "closers."

Varieties of Walls in Brickwork.

Walls of brickwork may be classed as follows:—*First*, straight-running walls or open walls, finished square or flush at the ends—as, for example, in garden wall *a a*, fig. 21. The *second* kind are walls with "returns"—that is, another wall running at right angles to the front wall. The return may be only at one end, as *c*, of the wall *b* (fig. 21); or with two returns, one at each end, as at *e e*. *Third*, a straight wall, as at *a a*, or one with return, as *c*, or two as at *e e*, having another wall, *g*, projecting at right angles from any part of

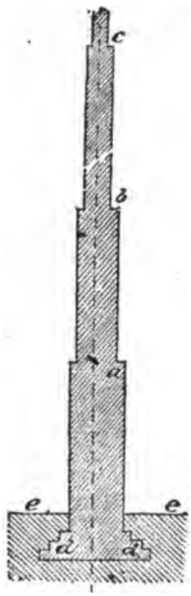


Fig. 22.

the wall *f f*. The wall *g* may be of equal, greater, or less thickness than the main wall *f*. *Fourth*, walls with recesses, either with square or arched heads, made at some point, as *i* in the wall *h h*. *Fifth*, a straight running wall, as a garden wall, terminated with square piers or columns at one or both ends, as *k k* in the wall *j j*. All these walls are open walls, inclosing spaces, as yards, or the interior of a house. To these classes has to be added a *sixth*—namely, walls facing earthwork behind, and known as "retaining walls." Walls may be made flush or even on their surfaces—that is, of equal thickness throughout their whole length; but when they are very high, and consequently very thick at the bottom, "offsets" are made at

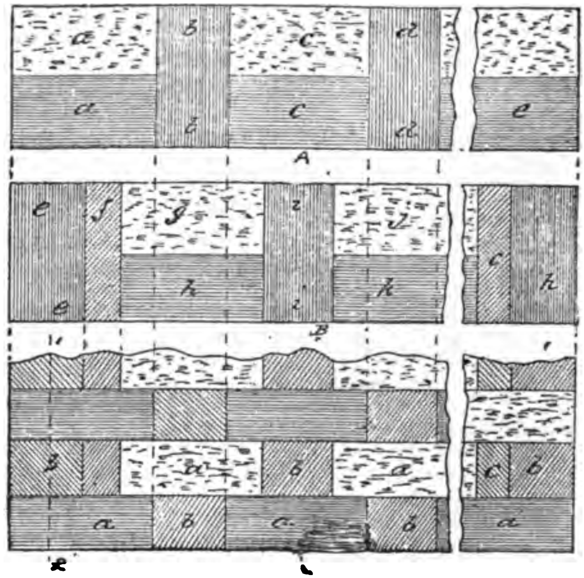


Fig. 23.

certain heights, as at *a b c* fig. 22, gradually reducing the thickness

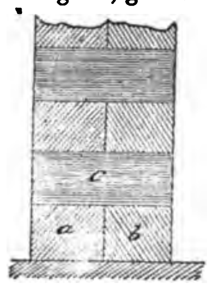


Fig. 24.

as the wall approaches its upper termination. This is illustrated in fig. 22, *d d* being the footings, *e e* ground level or line.

High Walls decrease in Thickness as they go up.

Where the wall of a house is of great height, the thickness of the wall gradually decreases, the inclosing walls of the first floor being thinner than those of the ground floor below; the walls of the second floor being thinner than those of the first, and so on. The thicknesses are reduced by offsets, precisely as shown in fig. 22, at *a b c*;

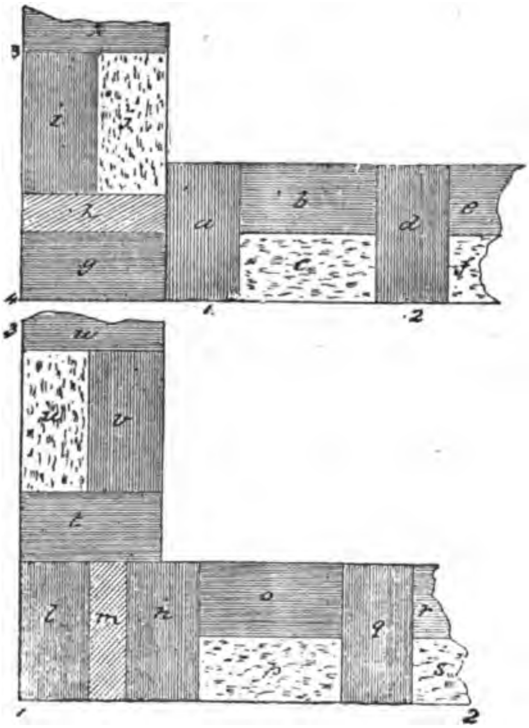


Fig. 25.

with this difference, however—that the offsets are all confined to the inner side of the wall of house. The reason for this is obvious; it being essential that the surface of wall outside, or to the street, should be uniform or all on one plane.

Varieties of Straight or Plain-running Walls.—A Nine-inch or Brick-thick Wall in "Flemish Bond."

The two first courses of a nine-inch wall in "Flemish bond," with square terminations, as at *a a*, in fig. 21, are illustrated in fig. 23. In naming the numbers or the individual bricks of which each course is made up, we begin at the left-hand end of the wall. The other, or right-hand termination, is precisely the same as the left-hand, and is shown in all the diagrams.

First course, A, fig. 23.

Two stretchers *a a*, a header *b*; two stretchers *c c*, a header *d*; and so on alternately along the whole length.

Second course, B, fig. 23.

A header *e*, a half-closer *f*, two stretchers *g h*, a header *i*, two stretchers *j k*, a header, and so on alternately.

The front elevation is shown in C, fig. 23, the "end elevation," in fig. 24, being taken on the line 1 2, in B, fig. 23.

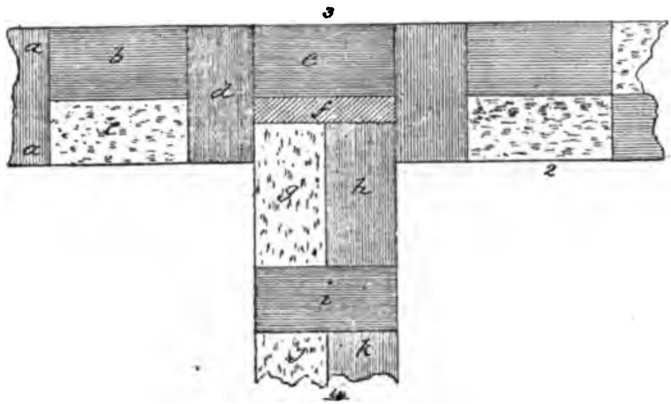


Fig. 26.

The two courses of a nine-inch wall with "return" at end, as *c* in fig. 21, in Flemish bond:—

First course, fig. 25.

Front wall 1 2, a header *a*, two stretchers *b c*, a header *d*, two stretchers *e f*, and so on alternately. Return or end wall 3 4, a stretcher *g*, a half-closer *h*, two stretchers *i j*, a header *g k*, two stretchers, and so on alternately.

Second course fig. 25.

Front wall 1 2, a header *l*, a half-closer *m*, a header *n*, two stretchers *o p*, a header *q*, two stretchers *r s*, and so on alternately. Return wall 1 3, a header *t*, two stretchers *u v*, a header *w*, two stretchers, and so on alternately.

The two courses of a nine-inch wall, Flemish bond, with "return" at the centre, or another wall at right angles, as at *g* in wall *f*, fig. 21, illustrated in figs. 26 and 27:—

First course, fig. 26.

Wall 1 2, right and left of 3 4, a header *a a*, two stretchers *b c*, a header *d*, etc., etc. Wall 3 4, a stretcher *e*, a half-closer *f*, two stretchers *g h*, a header *i*, two stretchers *j k*, etc.

Second course, fig. 27.

Wall 1 2, two stretchers *a b*, and header *c*, alternately, the ends finished as in fig. 25. Wall 3 4, a header *d*, two stretchers *e f*, a header *g*, etc.

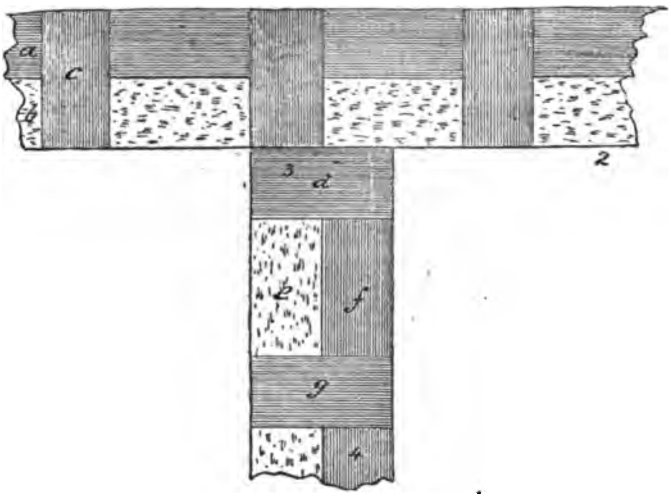


Fig. 27.

A Fourteen-Inch or Brick-and-Half Wall in Flemish Bond.

First course in A, fig. 28.

A header *a* and a bat or half-brick at *b*. Two closers—a half-brick *c*, and a quarter ditto at *d*; a stretcher *e*, and two headers *f* and *g*; a half-brick or bat *h*, and a header *i*; a stretcher *j*, and two headers *k* and *l*; a bat *m* and a header, then a stretcher *j*, two headers *k* and *l*, and so on alternately throughout the course.

Second course in B, fig. 28.

Three stretchers *a b c*, a header *d*, two stretchers *e* and *f*, a header *g*, and two stretchers *h* and *i*, and so on alternately, these bricks are at end and front; at back a stretcher *j*, a bat or half-brick *k*, a second ditto *l*, then a stretcher *m*, and so on.

In fig. 29 we give part front elevation of this wall, in which *a*, *d*, *e*, *h*, and *j* correspond to the parts similarly lettered in plan diagram A, fig. 28. These make up the first course in elevation; the second is made up of bricks *c l f*, corresponding to those similarly lettered in diagram B, fig. 28. In fig. 30 we give end vertical view, looking at fig. 29 in direction of the arrow 1; letters in this correspond to letters in *a* and *b*, fig. 28.

A Nine-Inch or Brick-Thick Wall in "Old English Bond."

First course, A, fig. 31, is made up of a series of stretchers *a a* in two rows, placed side by side and end to end along the length of projected wall.

Second course, B, fig. 31, is made up of a series of headers *b b b*, placed side by side in single row.

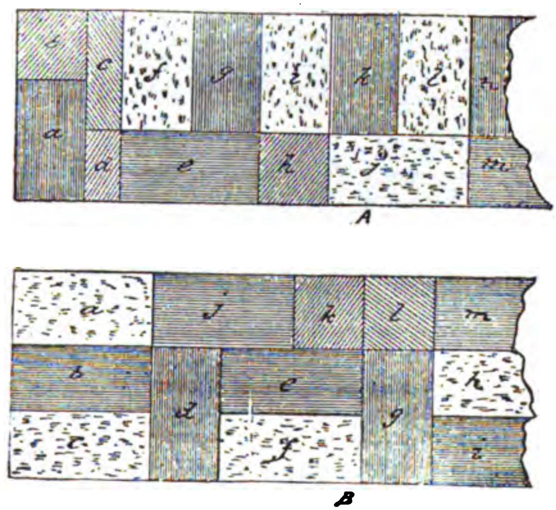


Fig. 28.

Starting from one end with the two rows coincident to form the face of each, as the breadth of a brick is just half its length; if the second course, as B, was placed on the first course in A, the joints as 1 2 of the second course would coincide with the joint as 3 4 of the first course, so that no vertical bond would be obtained. To get rid of this grave objection, a "closer," as *c* in diagram B, is inserted in second course, which breaks the joints of all the courses, as shown in fig. 32, which is front elevation, fig. 33 being an end view.

A Fourteen-Inch or Brick-and-Half Wall in Old English Bond.

First course A in fig. 34.

Starting from the right, are first three stretchers *a b c*, and in front a row of headers *d d d*, and at back a row of stretchers *d d*.

Second course B in fig. 34.

Starting also from the right, we have a header *a* and a bat or half-brick *b*, a half-brick closer *c*, and a quarter-brick ditto *d*; at front a row of stretchers *e e*, and at back of headers *f f*.

In fig. 35 we give front, and in fig. 36 end elevation; the letters correspond to correspondingly lettered bricks in fig. 34.

Projections and Models of the Bonding of Brick Walls of Different Thicknesses, without and with "Returns," highly useful to the Young Bricklayer.

We would recommend the student of brickwork to project for himself the different courses of work in nine-inch Old English bond,

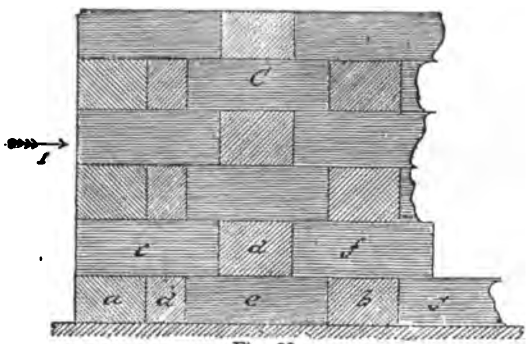


Fig. 29.

and in fourteen-inch Flemish bond, for return at courses as in fig. 25, and of one wall meeting another at right angles, as in fig. 26, and also to project the courses of brick walls up to two and a half bricks in thickness. To aid him in this and in other projections of bond, we would strongly advise him to purchase a set of wooden toy bricks, taking care that they are in due proportion to each other. Or he may very easily make a long strip or feather of wood of the proper width and thickness corresponding to a brick on any scale or size desired, and that being thus determined, he may cut off numerous separate lengths from this, each length corresponding to the length indicated by the scale. By means of these small-scale wood-bricks the student should be able to master a wide variety of combinations in bond, making drawings of each combination as he produces it, the drawings being to some definite scale. Had space permitted we should have given projections of walls up to three bricks in thickness, with returns as in figs. 25 and 26; but the purpose of our paper will be amply served by what we have given in connection

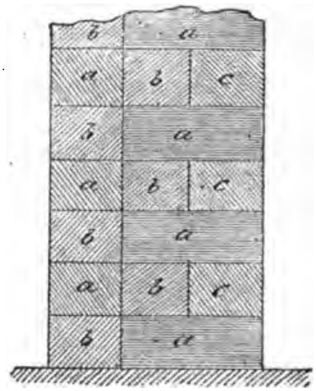


Fig. 30.

with nine-and fourteen-inch walls, which comprise by far the largest part of brickwork executed for ordinary purposes. The illustrations

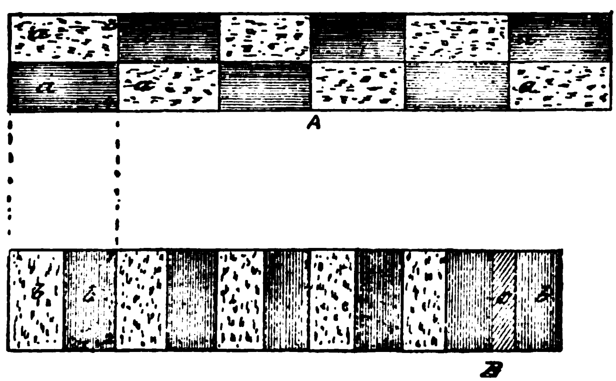


Fig. 31.

we have given together with our remarks on "bond" generally, should give the pupil material enough to enable him to make projections of a wide variety of brickwork, and to become well acquainted with the combinations of which bricks are capable. This he will be greatly aided in if he should use the small-scale bricks we have here recommended. We now proceed to illustrate the various classes of what may be called general brickwork, taking first the department of hollow walls, or brick walls having a cavity in their interior.

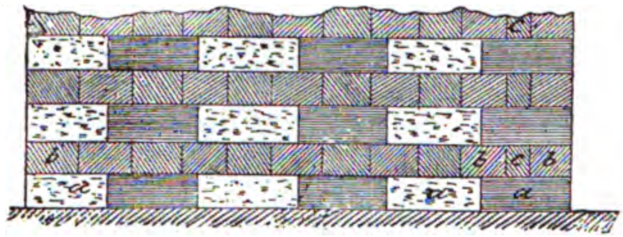


FIG. 82.

Hollow or Cavity Walls.

In the volume entitled "The Sanitary Architect," while treating of foundations, we drew attention to the importance of so constructing them, and the superincumbent walls resting upon them, that they should give as dry a wall as possible; and we there alluded to the system of building walls hollow, or with a space or cavity in

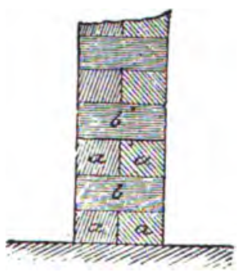


Fig. 83.

their interior as being now much used with this end in view. At first, on examination of the various systems of building walls hollow, now about to be illustrated, it would appear that they would also be economical in construction, inasmuch as they obviously require fewer bricks; but the advantages in this respect which they offer are, to a large extent, done away with, from the increased cost and from the longer time in bonding and setting of the bricks which the systems involve. Nevertheless, they offer such advantages in regard to the securing of dry walls that they are worthy of being universally adopted where these are desiderated—which, properly speaking, should

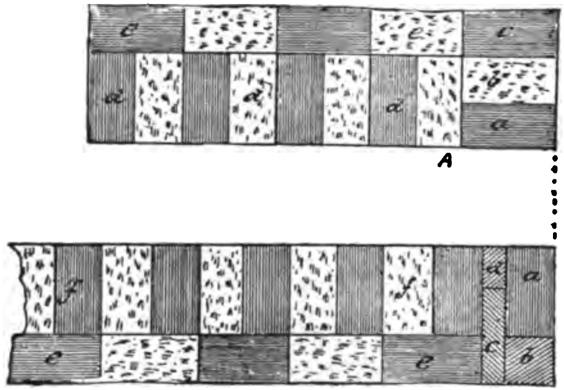


FIG. 34.

be in the case of every building designed to shelter living beings. The invention of hollow walls is not a thing of yesterday, but dates back for a considerable period of time, a Mr. Dearn having, in 1829 or thereabouts, introduced his "nine-inch hollow wall," which we illustrate in plan and section, fig. 1, Plate II. In this the bond used

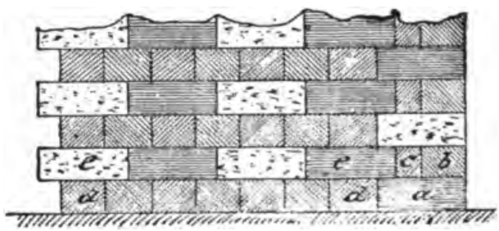


Fig. 35.

is the "Old English"—already described and illustrated—the lower courses, as shown, being first a row of headers and then a row of stretchers, the next course being a row of stretchers laid "on edge," not "on bed," the next above being a row of headers. The arrangement of the two courses is shown in section to the right; the hollow spaces in alternate courses being formed by the rows of stretchers on edge. In Silverlock's system of hollow wall, as illustrated in fig. 2, Plate II., "Flemish bond" is used, the bricks being set on edge, both in the stretchers *a a* and headers *b b*, the header bricks *b b* going "through" from front to back of wall, and thus forming a strong "bond" to the whole system. The diagram in B gives a section of A on the line 1 2, showing how the headers *a a* pass through from front to back of wall. This, although nominally in Flemish bond, is an irregular bond, as shown in the part elevation in diagram B, fig. 2, Plate II., as the courses are deeper than usual, the breadth of the bricks giving the height of the courses in place of the thickness as in ordinary bond.

The method of giving a hollow brick wall eleven inches thick with a two-inch cavity is illustrated in figs. 3 and 4, Plate II., and consists in simply leaving a space *a a*, in fig. 3, Plate II., of two inches

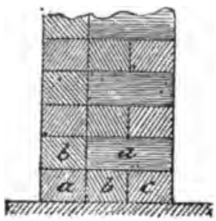


Fig. 86.

between the stretchers *b b b*, advancing the inner faces of these the same distance beyond the ends of the headers—thus forming a series of cavities or hollows two inches wide in the centre of the wall, the same being repeated in the inside of wall, should "firring" or timber battens be nailed or secured in the inside, as shown by the double dotted line, *a a*, fig. 4, Plate II., on which the plastering is laid; or should this not be adopted, and the plaster laid at once upon the inside, the projecting faces *b b* of stretchers, and the indentations between those ends and heads of the headers *c c* form excellent "keys" or bond for the plaster. In fig. 3, Plate II., diagram A shows the first course of the headers, *a a*; B the second course of stretchers, *b b*, with space between them, as *a a*. The dotted lines in each show the courses placed above each. The front face of the stretchers *b b* in B being flush with the end face of headers *a a* in A, as shown in section at *d e*, and a space of two inches being left between the stretchers, the second or inner stretcher, as *c* in A, fig. 4, Plate II., projects beyond the ends of the headers, this forming the spaces as *b b* in A. Sketch to the right. B in same figure, gives an elevation. In fig. 5, Plate II., in diagram A we give the first course, and in B the second course, of another system of hollow wall, in which the thickness is equal to a brick-and-a-half or fourteen-inch wall. Diagram C, fig. 5, Plate III., is part elevation. In this the "headers" *a a*, *b b*, alternate, showing alternately to the front as *a a*, and to the back as *b b*, two stretchers, as *c c*, *d d*, being placed between two headers. In fig. 7, Plate II., we give first and second course of an eighteen-inch hollow wall. Fig. 2, Plate IV., is the first course of another method, showing the return wall at a corner, fig. 3, Plate IV., being the second course of ditto, two bricks thick. The front wall, as *a a*, shows the course in "Old English bond," the return wall, *a b*, in "Flemish bond."

Piers and Chimney Stacks.

In fig. 4, Plate IV., we give at A the first course, and at B the second course, of a pier built hollow, the hollow space in *a b c d* being fourteen inches square, the outside wall being a brick thick. Fig. 5, Plate IV., diagram A, is the elevation of the side *g i*, B of the side *g h* of fig. 4. Fig. 6, same Plate, may also be taken as the first and second courses of a "flue" or chimney stalk—a 9-inch-by-14 one, the thickness of outside wall being one brick. Of these two plans we give part side elevation in A, fig. 7, Plate IV., and in B part end elevation. In fig. 1, Plate V., at A we give plan of first course of a "chimney stalk," or a "hollow pier" of which the length is greater than the breadth. If fig. 1, Plate V., be taken as the plan of a chimney stalk, it gives a flue *a*, 14 inches by 9, and a second flue *b*, 14 inches square; in B, fig. 1, Plate V., we give the second course; in fig. 2, same Plate, in A the elevation of the courses of the side *c d*, fig. 1, Plate V.; and in B, fig. 2, Plate V., elevation of the end *c e*, fig. 1, Plate V.

Pointing.—In finishing off the outside faces of brick walls, the operation of pointing is resorted to; this consists in filling up all the joints with a superior mortar, and in the best class of work with cement. To properly "point" a wall requires great care, and indeed skill, where thorough neatness and finish in the joint are to be secured. Moreover, pointing requires to be conscientiously done, for much of the capability of a wall to resist the action of damp and of driving rains depends upon the way in which the joints are made good. The first operation of "pointing" is to remove all the mortar from the face of the wall which has been pressed out from between the bricks (or stones) in placing them in bed; the mortar is next removed from between the joints, and for some distance inwards, this being done in order to give a "key," bond or hold for the mortar or cement with which the pointing is done. The joints between the bricks (or stones) being thus opened up, the loose dust is next blown or brushed out, and the mortar or cement is inserted carefully into the joint, and pressed well up into the cavity so as to get a good hold. There are more ways than one of finishing off the outside of the joint or of its face. What is called a "rule joint,"—"pointed and finished off with a flat rule joint,"—is done by bringing the mortar or cement a little forward in front of the face of wall, and

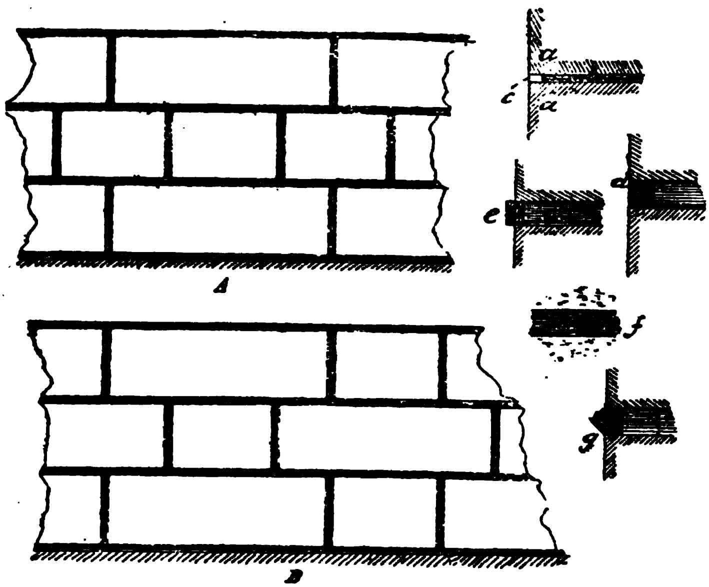


Fig. 37.

finishing its lower and upper edges perfectly square and level by means of a flat straight-edge or rule applied to the joint, as shown in diagrams A and B, fig. 37, which represent pointed work in "Old English" and "Flemish" bond respectively. The diagrams to the right of this figure illustrate "pointing": *a a* shows two adjacent bricks, with the mortar between them represented by a thick line; part of this is picked out in front, as at *c*, and the space filled up, as at *d*, with fine mortar or cement; and when flush with the surface of the wall, as shown, it is called plain pointing, but when filled in with a part projecting, as at *e*, and finished as above described, it is called "rule" pointing, shown in front view at *f*. The diagrams A and B will perhaps enable the student to decide for himself the much disputed point, already alluded to, as to whether the "Flemish" bond, as in B, is so much more beautiful or pleasing to look at than the "Old English" in A. All this is done with the point of a finely pointed trowel. In some classes of brickwork the cement used for pointing is mixed with a proportion of lampblack: this gives the wall a series of horizontal and vertical lines (of the joints) in black, which is by some supposed to impart a higher finish or look to the wall than when the mortar or the cement is left its natural colour. In "rough pointing" the outer face of the joint after being filled up as above described is finished off simply with the point of the trowel, without the application of the rule or the straight-edge. In some cases the face of the joint is wrought to a point or sharp arris or

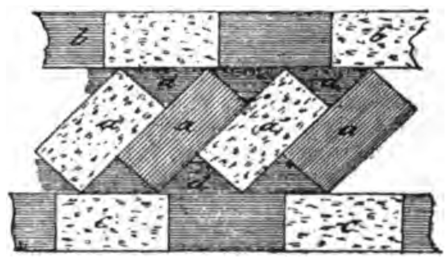


Fig. 38.

edge, as at *g* in fig. 37, this being done to throw off the water from the joint; but such methods as this have not been successful. What is called "flush pointing" is literally facing a wall with a coating of cement, generally Roman cement, to enable the brickwork the better to resist the weather, or to conceal the fact that the wall is of brick, and to induce the belief that it is stone—a "make-believe" or sham which is always a failure, as all shams deserve to be. It is altogether a mistake to suppose that a cemented house front would look better than a brick wall. Brickwork well executed is in itself a beautiful object—infinitely more so, at all events, than a cemented front purporting to be stone, which nobody is deceived by, and which, from the cement used being generally of bad quality and scaling or peeling rapidly and irregularly off, gives a look which is beyond mistake shabby, and tells its own tale. Even if the brickwork be not well pointed or pointed with a rule joint, if it is good—that is, the bricks sound and well laid—it looks better, and this if for no other reason than that it looks what it is, and carries no pretence with it. It is honest-looking work, which cannot be said of cemented work, with which, either from a constructive, an æsthetic, or a moral point of view—the latter when the purpose of cement is to deceive—we have not the slightest sympathy.

Diagonal Bond.

In addition to the classes of bond we have illustrated, there are several others, some practised on the Continent, where brickwork has received its best and widest developments, some in this country. The bond used in certain species of hollow brick or cavity walls may be called an extra or new variety. Although not new, having been long practised, are the bonds known as the "diagonal" and the "herring bond"; the latter, indeed, may be classed amongst the oldest of bonds,—the diagonal being but a variety or sub-class of it. This—the "diagonal"—is illustrated in fig. 38. It is chiefly used for filling in the interior spaces of brick walls or courses, such as those of foundation courses. It is obviously not applicable to walls of inferior thickness or depth from front to back, as there must be room in the interior spaces in each course—that is, between the line of inside and outside bricks—for the diagonal bricks to lie in. The minimum depth from front to back in the thickness of wall is that equal to two bricks long, and the bond invariably used or that adapted to diagonal work is Old English—that is, alternate courses of headers and stretchers. The angle at which the diagonal bricks lie, as *a a a a* in fig. 38, is that of 45°, but if the student will make up some courses in model bricks giving different thickness of walls, he will find that the angle will have to be varied according to circumstances. The illustrations in figs. 38 and 39 are not designed to show further than the arrangement of the diagonal bricks and their relation to the outside course of bricks which form the inclosing space within which the diagonal bricks lie, such as the stretchers *b b*, *c c*. It will be observed that, whatever be the angle at which the diagonal bricks lie in relation to the outside bricks, they will only touch the inside of these inclosing bricks at points, and will form angular spaces, as *d d*, shown in black in the diagram. These spaces will vary in size and outline according as the angle of the bricks varies, and are usually filled up or grouted with mortar or pieces of brick, or left void, thus forming a species of hollow wall. In diagonal work the bricks lie at opposing angles in the alternate courses. Thus, if fig. 38 be taken as the first diagonal course, the angle or inclination being from left to right, the next diagonal course will have the inclination in the opposite direction, as from right to left. By looking through the sheet or page of paper on which fig. 38 is printed, but with the opposite side of the paper nearest the eye, the arrangement here last indicated will be illustrated. In diagonal brickwork, the first course is that of the ordinary brick bond: thus,

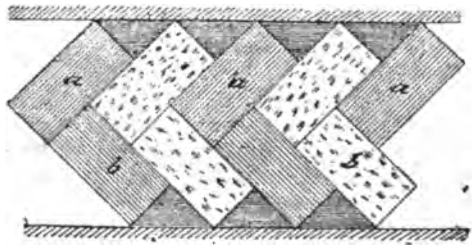


Fig. 39.

if the wall be two bricks (lengths) in thickness, the first course will be two lines of headers placed end to end; in three brickwork, three lines of headers placed in the same way, and in three-and-a-half brickwork three lines of headers end to end. It is in the second and third courses that the diagonal bricks are used, the one course lying

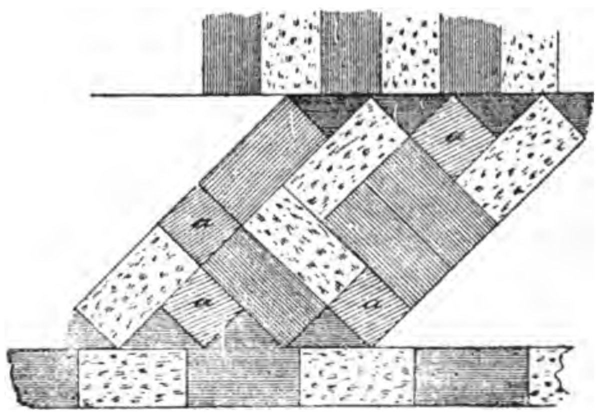


Fig. 40.

at one, the next course at another angle; the fourth course being a repetition of the first as regards the bricks in number, but reversed in position: if a row of stretchers be used along with three rows of headers—that is, if the first course has the stretcher in the front face of wall—in the fourth course these will be placed at the back. Fig. 39 illustrates in diagram fashion a course of two rows of bricks diagonally set. All these changes in position in this class of bricklaying, as in all other classes, is to secure what is the aim of every good bricklayer—as perfect a "bond" as possible.

When two rows of diagonally placed bricks are used in the same course of a wall, the bricks in each row are so arranged that the two rows lie in opposite directions. This class of bond is that known as "herring-bone" bond. The diagram in fig. 39 illustrates the way in which the two rows are placed at opposite angles—*a a*, for example, laying from left to right, *b b* from right to left. The angle, as in diagonal work, varies according to circumstances, and "bats" are in some instances necessary to make the rows complete. The arrangement of the two rows in the figure is symmetrical or regular,

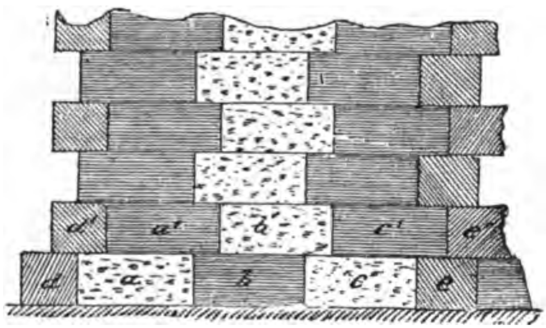


Fig. 41.

but an arrangement of what may be called irregular herring-bone bond is shown in fig. 40: in this bats or half-bricks are used to make up the bond.

There are other varieties of bonds in use in connection with solid or ordinary walls; a very common form is that known as "garden wall bond." This is illustrated in fig. 41, showing that each course is the same as the one above and below it, and each course is made of the same arrangement of bricks—namely, three stretchers, as *a a′*, *b b′*, *c c′*, and one header, as *d d′*, this being carried on throughout the course. Fig. 42 shows two methods of starting and finishing the courses at the ends of the wall. In diagram A the first course is begun with a "header" *a* and a "closer" *b*; the second begins with a "stretcher" *c*, next a "header" *d*; then follows the regular arrangement, three stretchers and a header, and so on. In diagram B the first course begins with the three stretchers *e*, *f*, and *g*, the next being a header. The second course begins with a "closer," *h*, then follow on three stretchers and a header, and so on to the end of the course, the last brick in which is a "closer," as at *h*.

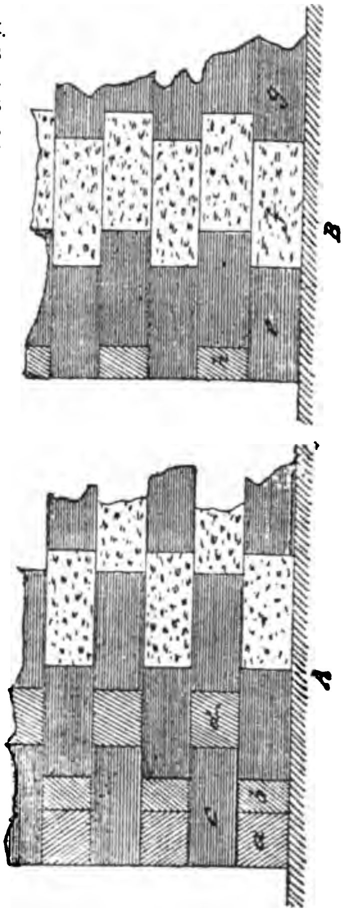


Fig. 42.

So far as the face or the look of a wall built in different kinds of bonds is concerned, one bond may be taken to be as good as another. The general public, at all events, form no conception of what the peculiarity of the bond is—if indeed, as is more than probable is the true state of the case with a vast majority, they have any idea that there is more than one kind of brick-setting. Even as regards the usually adopted bonds, the "Flemish" and the "Old English," it takes some practice to enable students to tell at once whether a wall is built in the one bond or the other; and "experts" only can tell at the first glance whether neither the one nor the other is used, but some other variety. We might, if space permitted, give illustrations of not a few other varieties than those we have given, but our object will be served if to those we add the bond illustrated in fig. 43, in which the wall begun in "Old English" bond in the first two courses, as *a a*, *b b*, has four courses of stretchers, as *c c*, *d d*, *e e*, *ff*, the next two courses being repetitions of the first two, *a a* and *b b*, these followed by four more rows of stretchers, and so on till the desired height is reached. If we suppose the first course in fig. 43 to be a row of headers, and the next five courses all stretchers, as *c c*, etc., we have a species of bond much used by bricklayers in the North.

Brick Arches.

The last department of bricklaying we shall illustrate in ordinary or plain work, before taking up the subject of ornamental brickwork, is "arches." In the volume in this series entitled "The Stone Mason" the reader will find the general subject of arches explained. In

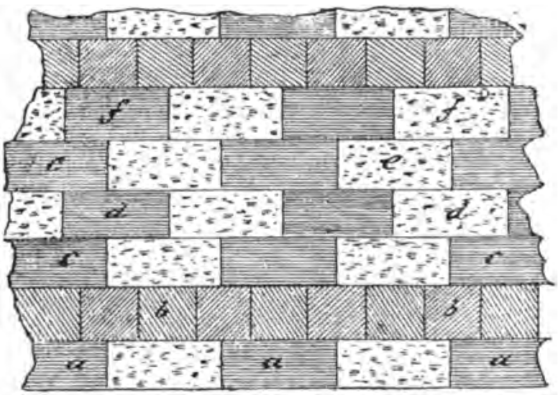


Fig. 43.

mason work the stones of the arches are cut into certain forms dictated by the kind or class of arch; the different stones having each a separate place to fill and a distinct office to perform, and being designated accordingly. In brickwork, as all the pieces are of the

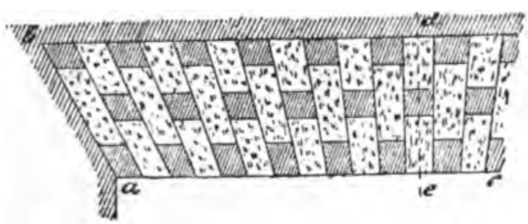


Fig. 44.

same and uniform size, they may be and are used indiscriminately, so far as the individual pieces are concerned, so that there is no distinctive name given to any one piece in the collection used by which to form the arch. It is therefore only the shape or section of the arch, and the way in which the bricks are individually set in relation to that form which gives the distinctive character to the arch and the name by which it is distinguished from some other form. The forms of the arches and the names by which they are known are illustrated in the following figures. In fig. 44 we illustrate what is called a "flat arch," sometimes a "straight" arch, and in fig. 45 a "camber" arch. This has some of the elements of a true arch, as the lower edge or line *b c*, or what may be called the "intrados," has a slight curve; but as the centre of this curve is very distant from the intrados or curve line the bricks are so disposed that they all converge to a series of points nearer the line *b c* than its true centre. This in practice causes all the bricks to be of different shapes. To get those shapes the bricks are cut or rubbed down. The flat or straight arch illustrated in fig. 44 possesses none of the

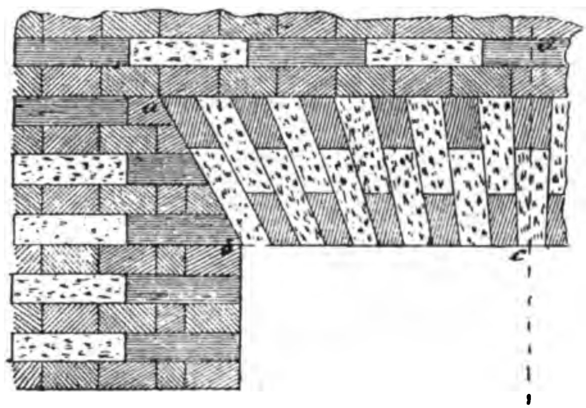


Fig. 45.

features of a true arch—unless, indeed, it may be in the fact that the bricks are so disposed as to make the whole act as wedges, any superincumbent pressure acting upon them tending to force them down to the side or retaining walls of the opening spanned by the flat arch.

The bevel line, as *a b* (fig. 45), which gives this wedge-like arrangement to the arch, is called the "skew-back," being at an obtuse angle to the line *a c*. This so-called brick arch is anything but strong, as may be seen exemplified in the many brick houses in which it has given way. It is only used when cheap work is desired or necessitated. But, defective as it is, it is infinitely superior to another form of "flat" or straight arch known as the "French" arch,—which is altogether a misnomer, as it contains no element whatever of a true arch, and is altogether so vicious and irretrievably bad from a constructive point of view, that it should never be seen in brickwork which has any pretensions whatever to be considered good because honest work. Its use is altogether calculated to mislead, as it gives the proprietor the idea of security or strength which the mere name of an arch conveys, while it possesses none of it. We illustrate (fig. 46) this imported monstrosity in construction—if, indeed, its birthplace was, as is assumed, France—by way of warning off from its employment. In fig. 47 we give the disposition of the bricks in two flat arches of one brick deep, the diagram in A showing the depth as made up of stretchers, the diagram in B the arch with depth made up of two courses of headers.

The "true arches" in brickwork are the "semicircular arch," the simplest and the strongest arch of all, illustrated in fig. 1, Plate VI.

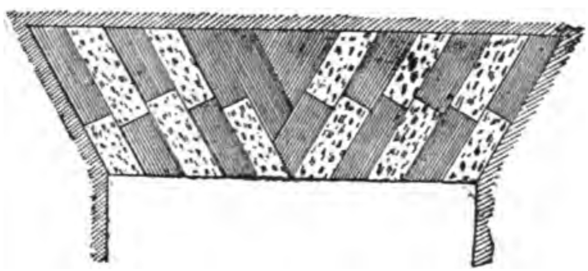


Fig. 46.

the "segmental arch" in fig. 3, same Plate; the "elliptical arch," or rather the semi-elliptical, in fig. 4, and the "Gothic" in fig. 2, Plate VI. Of the segmental, the elliptical, and the Gothic, there are many forms.

When the bricks in a segmental arch, as in fig. 3, Plate VI., converge to the centre of the arc, as the bricks *a a* to the point *b*, the arch is then technically called a "scheme" arch. The brickwork used in arches is termed either "gauged," "cut," or "rough" work, according as the bricks are treated; this treatment having reference to giving them the form more or less nearly approaching that which they assume when the arches are properly set out. Some of the methods of setting out brick arches will be presently given.

What is called a "relieving arch" is a segmental or scheme arch turned over an opening, as that of a door (fig. 6, Plate VI.), *a a* being the arch, *b b* the wood or timber lintel spanning the door or window space, side or jamb of which is at *c*. "Inverted" arches are shown in fig. 5, Plate VI. For the kind of arch known as a "trimmer arch"—being that turned over between the trimmer joists of a floor near the fireplace, and on which the hearthstone rests—see illustrations and descriptions in the volumes entitled "The Stone Mason" and "The Carpenter."

The following diagrams illustrate the methods of striking the lines giving outlines of the bricks used in the foundation of flat, scheme,

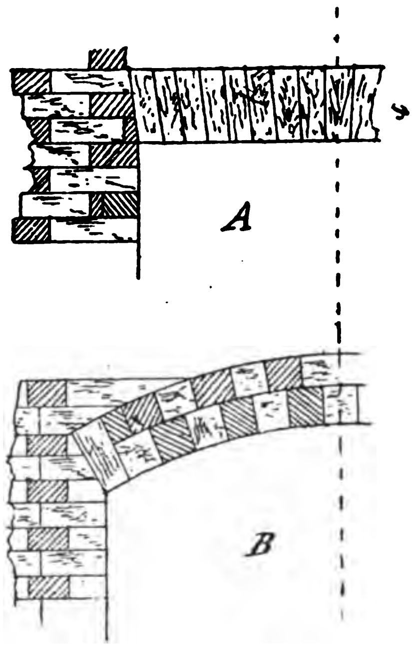


Fig. 47.

and elliptical arches. In fig. 1, Plate VII., we show half of a flat arch of two bricks length in depth from *c* to *d*, this depth being made up of two layers or courses—as first the course *d g h e*, and second *g c f h*, the two being divided by the line *g h*. Each course is made up of a series of "stretchers," as *i i*, *l l*, and two "headers," as *j k*, *m n*, placed alternately. To find the dividing lines, as in the direction *d c*, *i m n*, draw any line, *c f*, representing the "soffit," inner and lower surface, or intrados of the arch, and make *c f* equal to half of the span or width of opening, as a door space or a window void. From *c* to *d* set off the distance equal to two bricks length, or 18 in., and from *d* draw *d e* parallel to *c f*. From point *f* draw, at right angles to *c f*, the line *f o*. Make *o e* equal to 9 in. or the length of a brick. In practice, however, this distance is generally 7½ in. or thereabouts. Through point *c*, the centre of the span or arch opening, draw a line, *a b*, of indefinite length. From point *e* draw through *f* a line, as *c h f p*, which, continued beyond *p* far enough, will cut the centrė line, *a d c*, continued in a point which we call *b*. This point, to save unnecessary length in the diagram, is not actually given in it; but we suppose all the problems we give to be drawn actually on the board by the student in the art of bricklaying. From the point *b* as a centre, with the radius *b e*, describe an arc *e a q*. On this arc the divisions or starting points of the bricks in the arch are set off. Take the distance of *a r* or *r s*, equal to half the thickness of a brick, and set it off from the point *a* to *r* and *s*. From *r* and *s* draw lines converging to the point *b* on centre line *a c b*. These will give the full thickness of the bricks *i'* and *m' n'*, exactly in the centre of the arch. In all brick arches the bricks are set off so that the centre line of arch will pass through the centre of the central bricks, which thus take the place of the keystone of a stone-built arch. With the distance *r s*, or the thickness of a brick; set off on the arc *a e* an equal number of parts to *e*, as *t u v*, *w x q*. From these points draw lines converging to the point *b* on the centre line *a c b*, as *v z*. When completed the lines will be given as in the half of the arch *d c f e*; the other half, to the left of line *a c b*, being put in in a similar way.

It will be observed that, although the bricks, as *i' i*, *l l*, and *m' n'*, *m n* (fig. 1, Plate VII.), are so disposed that they break joint, the joints are horizontal—that is, parallel to the top and bottom lines of the arch, as *d e*, *c f*. But to obtain the full strength of joints, they should lie at right angles to the lines or faces of the bricks. Thus in fig. 2, Plate VII., let *a b*, *c d*, be the lines of two adjacent bricks of an arch, as in fig. 1, Plate VII. The joint *e f* is horizontal, forming an obtuse angle with the line *c d*. The line *g h* gives the proper direction of the joint, it being at right angles to the line *c d* or *b a*, which represent the faces of the bricks. This method of setting out the breaking joints of a flat or scheme arch is shown in fig. 4, Plate VII. Set out the arch, as *a b*, *c d*, so as to get the width of span *b c*, depth of arch *a b*, and the "skew back" *c d*, as explained in connection with fig. 1, same Plate. From point *c* produce *c d* indefinitely, as to *e*; from point *d f* indefinitely at right angles to *d c*, and make *d f* equal to the thickness of a brick, as *r s* in fig. 1,

Plate VII. From point *f* draw to point corresponding to point *b* in centre line *a d c*, fig. 1, Plate VII., the line *f g*, cutting upper line of arch *a d* in the point *h*. From point *h* draw indefinitely a line, as *h i*, at right angles to the line *h g*. Make *h i* equal to *d f*, or the thickness of a brick, and from *i* draw to centre point on line *a b* the line *i j*. From where *i j* cuts *a d*, as *k*, draw a line *k l* at right angles to *i j*; and make *k l*, as before, equal to *d f*, and draw to centre point, as *a b*, the line *l m*. Proceed this way, and a series of lines, as *d f*, *h i*, *k l*, will be produced, to which lines are drawn parallel, giving the points in the arch as *n*, *o*, *p*, *q*, *r*. The lines, as *f d*, *k l*, can be made parallel to their corresponding lines, as *f c*, *l m*, by means of the set-square; but failing this, the geometrical way is shown in fig. 4, Plate VII. Thus, set off on the line *c d e*, produced any convenient distance, as *d e*, from *d* to *e* and *s*; and from *e* and *s* as centres, with radius equal to *s e*, describe arcs cutting in points *t* and *u*. Through *t* and *u* draw a line cutting *c e* in *d*; *t d w* is at right angles to *d c*. The same may be done in the points, as *h*, found, and the lines, as *h g*, being drawn.

To draw the lines of the joints of an "elliptica arch," as in fig. 3, Plate VII.—The curve here shown is not a true ellipse, but merely such an approximation to the true curve as is used very frequently in practice, as being more easily produced. The three centres from which the curve here given is drawn are at *a*, *b*, and *c*. The easiest, and one very commonly used to get the lines of the arch bricks, is here shown—namely, by dividing the intrados of the arch, as *d e*, into the desired number of equal parts corresponding to the thickness of a brick, as *d f*, *f g*, *g h*, etc. From these points lines, as *f l*, *g m*, *k n*, *o p*, are drawn converging to the two centres, as *a* and *b*. The lines at the points between *d* and *i* are drawn to the centre *a*; those between *i* and *e* to the centre *b*. The right-hand side of the drawing gives a clearer view of how the lines are divided,—the first set, between *s* and *r*, stopping at the line *r*, which produced goes to the centre *c*; the second set converging to the lower centre *b*.

This method, however easy it is in practice, does not give a pleasing look to the lines of the arch, as they bear no direct relation to the curve at its different points. This is more noticeable in arches of which the curve is a true elliptical one. The diagram in fig. 5, Plate VII., gives a method of finding the lines of the arch in direct relation to that part of the curve at which the line is drawn. Let *a b* be part of the intrados of the arch, and *c* and *d* the two foci of the curve. Let *e f* and *g* be the divisions in the intrados *a b*, marking off the thicknesses of the bricks. From any point, as *g*, draw lines to the two foci, as *g c*, *g d*, and extend them indefinitely beyond the extrados or outer curve of arch. Then, from point *g* as centre, with any convenient radius, describe an arc joining or cutting the lines *g c*, *g d*, in the points *h*, *i*. The arc *h i* is to be bisected in the point *j*, and from *j* a line drawn to point *g*: the part *g k* of this is one of the joints of the arch. To find the next lowest joint, from point *f*, with any radius, describe the arc *l m*, cutting the lines *m f d*, *l f c*, drawn through *f* to centres *c* and *d*. Bisect *l m* in *n*, and draw *n f*; *f o* is the next joint. The next is found in like manner, by drawing from the point *e* the lines *e c*, *e d*, extended beyond the extrados as before, describing from *e* as centre any arc, as *p q*, dividing it in *r* into two equal parts, and drawing *r e*, *s e* being the joint.

Another and strictly mechanical way of finding the joints, which will have a direct relation to the curve at the various points, is also shown in fig. 5, Plate VII. Take any flat ruler or straight-edge and mark off its edge, the two points *t*, *u*, giving a distance equal to *a v*, which is half of the span or width of the arch. By making the two points, as *t* and *u*, always coincide—first *t* with one of the divisions in the intrados *a c*, marking off the brick thicknesses, as *t v w*; next the point *u* with the centre line *b v x*. A line drawn along the edge of the straight-edge will give the line of joint as *t y*. The next, as *v z*, is obtained in like manner by making *t* and *u* respectively coincide with point *v* and the line *b v x*.

The methods illustrated in figs. 3, 4, and 5, Plate VII., give joints which make the ends of the divisions at the extrados of the arch wider at the ends than at the ends nearest the intrados. This must indeed necessarily happen in all forms of arches in which diverging lines are met with more or less pronounced. Thus, while the end *f e* in fig. 5, Plate VII., is the thickness of a brick, the end *o s* is greater than this. Now, as a brick is uniform in thickness, when two are laid together to suit diverging lines, as *o f*, *o s*, the outer ends must be separated, as shown at *l h m* in fig. 3, Plate V. Thus, let *a b c d*, fig. 3, Plate V., be the edge of a brick—that is, showing its thickness, which is of course the same at the end *a b* as at *c d*. Now, if the shape of the part of the arch between two lines of joints—say, such as *e s*, *f o*, in fig. 5, Plate VII.—be such as shown by the letters *a e c d*, fig. 3, Plate V., then it is obvious that the part to make this shape complete, which is lacking, as we see, in *a b c d*, must be made up by some body or substance indicated by the wedge-shaped dotted part *c b e*. This substance in practice is the mortar or cement. This is further shown in the lower part of the diagram in fig. 3, Plate V., which represents in an exaggerated form part of a brick semicircular arch,—here the parallel-sided bricks being placed at their inner ends, as *i f*, *i k*, quite close to each other, must have their outer ends separated, leaving angular spaces shown by the dotted parts representing the mortar or cement. It is obvious that this defect is more pronounced in a small curved arch than in a large one. Where good cement is used, such as Portland, and which will set as hard as the bricks themselves, good solid construction will nevertheless be secured. It is needless to say that this defect in the setting of brickwork arches inherent in the very nature of them from the unvarying size of the bricks, is a serious evil where bad mortar is used for filling in and making good the joints. With this it is impossible to get anything like a solid arch. As we have already said, bricks are often cut or rubbed so as to assume somewhat of the form indicated by the setting-out of the lines in the methods we have illustrated. Thus, a brick may be cut so as to take the form as at *o* in fig. 3, Plate V., and two placed together as at *p* and *q* would fill in the space of the shape shown—though here there would be a joint shown in outside or fine work. The dotted lines in *o* and *p* show the brick-on-edge view complete.

Ornamental Brickwork.

In preceding paragraphs we have discussed the subject of brick as a building material as contrasted with stone. We have also explained the principles upon which the practice of bricklaying or brick-setting is based, and have illustrated and described the methods in use as applied to walls and other structures, these embracing that important department of what may be called ordinary or plain brickwork. We have now to follow all this up by glancing very briefly at the next department, ornamental brickwork or ornamented brick construction.

This the reader will observe is to be distinguished from architectural effect, or what is popularly and in one sense correctly enough defined as architectural or building design. This may be obtained by the use of brickwork, as it is secured in the employment of stone, simply by the arrangement, plan or design of the building, which will give an elevation or external appearance which will be pleasing to the eye. But while this gives the element of architectural effect, or what we call design, it gives it solely through the medium of the general mass—the surfaces of the material employed being perfectly plain, that is, devoid of what is generally known by the name of ornament. Of this element of ornament, the building, whether of brick or of stone, may be perfectly or absolutely destitute. It is not necessary here to enter into an explanation of what constitutes ornament; what can be said of it will be found in the volumes entitled "The Ornamental Draughtsman," "Form and Colour as applied to Decorative Design,"—and with reference to certain special subjects, such as the work of the cabinet maker, the worker in iron, wood, and stone, in the volumes entitled "The Cabinet Maker" and "The Ornamental Worker in Wood, Metal, and Stone." All that is necessary for our present purposes is to point out that anything added to the otherwise plain surface of a mass or body of material employed in the construction of a building, which gives a certain arrangement of lines straight or curved, or a combination of both, is termed ornament. This added attribute to building material of any kind may either be applied at isolated parts of the structure, at intervals greater or less in amount, or be applied to certain parts in continued line or mass. This effect of ornament may be obtained in various ways: either by giving to an otherwise plain surface in the sense of its profile or section a certain contour, form, shape, or configuration, as instanced in what we call a "moulding"; or it may be spread over the whole surface, as of a block, or the united surfaces of a continued series of blocks, in the form of decoration known as "relief," that is, projecting from the surface, and produced by the art of carving; or it may be produced by purely surface effects, either of arrangement of coloured surfaces or by surfaces specially filled in with designs exhibiting straight and curved lines, or a combination of both, and which are produced by the arts of the ornamental draughtsman or of the painter.

Any one of these effects, or all of them in combination, when applied to a built structure, are in technical work said to constitute construction ornamented. But this effect, which is thus obtained by decorated material, may be, and often is, applied to structures which have no pretension to be so considered, and in reality possess none of the features of what constitutes architectural effect or design; although *per contra*, as we have seen, a structure may possess much of this latter effect, and strike the beholder with a sense not only of fitness for the purpose for which the structure has been built, but of beauty, grandeur, and even of sublimity, without possessing any one of the attributes obtained by the use of what we call ornament or decoration.

From the very nature of the material, or rather from the form in which the material is universally made, differing as it may and does differ in different districts and countries in dimensions, brick is not capable of being dealt with or manipulated and worked in the way stone is. Stones employed in building can all, with greater or less ease, be cut by tools so as to give to blocks of indefinite size and possessed originally of plain sides at right angles or oblique to each other, certain contours or profiles which will give them final forms which are truly ornamental. And stones can be quarried and cut into such bulky masses as to give wide, indeed comparatively large expansive surfaces, upon which designs in relief can be cut or carved. Stone, then, lends itself with, on the whole, wonderful ease and ready adaptibility to the purposes of ornamented or decorated construction. Hence, in all buildings in which ornament—using the term in its ordinary sense—is an attribute or peculiarity to be added to the effects produced by architectural design proper, stone is the material employed. What can be done in treating it ornamentally or decoratively, there are abundant examples of everywhere around us. Whether all these are examples of what is pure in architectural taste is another question, on which the reader may find some remarks of a more or less suggestive character in one or other of the volumes referred to, or in that entitled "The House Planner."

Brick, unlike stone, is not capable of being specially cut so as to give an ornamental form to its section, nor provided with ornament in relief on its larger surfaces: it is too hard and generally too brittle, and of far too small dimensions, to be so treated. Ornamentation or decorative effect, then, in brickwork has to be obtained in a way or ways specially applicable to the peculiarities of the material; and these, from its very nature, are limited both in number and in scope. So far as form, profile or section of bricks is concerned, something can be done so that certain decorative effects may be produced by their use, either singly or in conjunction—generally the latter. But what has been done, at least in this country, has been very limited in character and scope. The chief of the forms used here and on the Continent will be presently illustrated. If we wish to see of what forms individual bricks are capable, and how decorative effect can be obtained by their combined use, we must go to the Continent. It is there that the finest construction in brickwork is to be met with—not merely in the smaller structures of domestic life in town or country, but in the gigantic buildings of a public character, chiefly in churches. But while examples of fine work done in our own day can still be met with, it is to the works of the old bricksetter we must go, to become convinced of the truth that brick is a material as capable of giving high architectural and decorative effects as it is one which gives construction of the strongest and most durable character. Of late years a good many forms of bricks with decorated or ornamental profiles or sections and surfaces have been introduced. As before stated, they are much more frequently met with abroad than with us; still even here their use is spreading. In Plate IV. we give diagrams showing different forms of bricks with ornamental profiles and surfaces. In fig. 1, Plate IV., we illustrate at *a* in section an ornamental brick for the reveal of a window. This is not carried up throughout the whole length of the reveal, but is finished off near top and bottom after the manner of a "stop chamfer." Other forms of ornamental bricks are shown in same plate.

But while decorated or ornamented construction can be obtained in brick, giving effects in projecting parts by one or other of the methods presently to be illustrated, ornamental effect, in this country at least, is generally attempted to be obtained in modern work chiefly by surface decoration. This is obtained by a process which may be called a modification of mosaic or inlaying work; bricks of different colour being let in here and there, in accordance with a prearranged design, so as to form a pattern more or less complicated or simple, and the colour or colours of which contrast with, or stand out, so to say, from the general surface, which is of course built in brick of uniform colour and quality. There is still another decorative or ornamental effect produced in brickwork, and which is produced by a method akin to the perforated work in stone of the Gothic architects and builders or of metal workers and wood carvers. In this, holes or apertures are formed in the general surface of the wall by leaving out bricks here and there, and this in accordance with a general plan or design, which is so arranged that the holes considered as a complete series form a pattern. These three methods comprise the different classes or styles of ornamented or ornamental brickwork, and of these we now propose to give sundry illustrations.

Coloured Bricks.

We begin with what is essentially the simplest method, in so far that its effects can be obtained by the use of the ordinary or common bricks used in all structures—that is, no bricks of distinct form or section require to be specially made for it. Work of this kind naturally divides itself into two subclasses or divisions: first, the employment of ordinary bricks, so that effects more or less decorative or ornamental in character can be obtained in projecting surfaces; second, their employment so as to obtain decorative effect in surface work,—the only thing which requires to be specially done in these ordinary bricks being to give them different colours by the use of different kinds of clay. What the ordinary colours of bricks are, and how obtained, we have in preceding paragraphs explained; suffice it here to repeat that white, black, blue, yellow, and red are the colours met with, and these often in different shades.

We take up first the second of these two subclasses of ornamental brickwork obtained by the use of bricks having the ordinary or usual forms and sections and dimensions—namely, that by which decorative effects are produced by surface treatment or by the method which we have said to be akin to the mosaic or inlaying art, in which the effect is obtained simply by the disposition of bricks which are different in colour from that of the general surface. The simplest arrangement is the "band" or "strip," and of this the simplest form is the single band, as in fig. 1, plate XI. The colour of the bricks, *a, a*, forming this, should be in appropriate or complementary contrast to the bricks, as *b b, b b*, forming the general surface of the wall. Thus, if *b b* be yellow, the band bricks *a a* may be red, blue, or black; or if the general surface be red, the bricks *a a* may be yellow, white, blue, or black. The bands may either be single (as in fig. 1, Plate XI.), or double, each row or course being of a different colour. We have seen an arrangement of five rows, as in fig. 2, Plate XI., which looked very effective; in this *a a* are black bricks, *b b* blue, and *c c* yellow. In fig. 3, Plate XI., we give another of the same kind, in which the bricks marked *a a* and *b b* are black, *c c* and *d d* dark or bright red, and *e e* yellow, the general surface being of reddish or light-red bricks. When we come to illustrate coloured brick arrangements in projecting parts, other examples of the band or strip arrangement will be given.

Coloured bricks in this inlaying system are frequently arranged so as to form patterns showing on the general ground or surface of the wall in various dispositions, which in many cases are very effective, and tend to relieve the uniformity of large surfaces of one colour only, and that but too frequently of a dead, dull character. The combinations of bricks under this system are numerous, as may well be supposed; it may be said, indeed, that practically there is no end to combinations of this kind. In fig. 6, Plate XI., a very simple disposition of black bricks in alternate and corresponding positions gives a symmetrical arrangement which contrasts with the general ground of yellow bricks, *b b*; and it is perhaps more effective if these two broken bands or straps *a a*, as they may be called, are covered or topped by a continuous band of black bricks, *c c*. In this arrangement the upper band, *c c*, should be of a deeper tint than the lower black bricks in the broken band *a a*, as these latter might be dark blue.

Another arrangement of coloured bricks, as in fig. 3, Plate X., gives a series of crosses, the bricks of which are a contrast to the general ground or surface. If the latter be red, the cross bricks, *a a*, may be yellow, or blue, or black; if the ground be yellow, the crosses may be red. This forms another example of what may be called a broken or interrupted band or strip. But by arranging the crosses alternately, as in fig. 4, Plate XI., continuing them along the line decided on, two broken rows may be obtained, the pattern being simply a repeat. Or, in place of having this arranged in lines or bands, the disposition as in fig. 1, Plate X., may be used as a single pattern, repeated at intervals in the surface of the wall according to the taste of the builder. On this as a separate or isolated pattern the bricks may be arranged, as shown, where the third cross is below the two crosses; or it may be reversed; in both cases the cross *a* or *a'*, fig. 3, is placed centrally between *b b* and *b' b'*. The combination of those two diagrams in fig. 3, Plate X., gives the pattern or arrangement illustrated in fig. 1, same Plate. A series of this pattern may be carried along the surface of a wall on the same level, forming a species of broken band; and the pattern may be separated at intervals by the interposition of a single cross, or by two crosses, as in fig. 5, Plate XI.

Fig. 5, Plate XI., shows a modification of the cross in fig. 1, Plate X. This may be used in line—that is, as a broken single band—or by arranging them as in fig. 3, Plate X., it may form two broken bands. Arranged as in diagram A or B in fig. 3, Plate X., the pattern may be used as an isolated one, separated by intervals of the ordinary and general surface of the wall. Or by adopting the arrangement indicated in fig. 1, Plate X., the isolated pattern may be obtained as in fig. 4, Plate XI., and the intervals between this may have at the centre point of each interval a single pattern of the same kind, as at *a a* or *b b*. But in place of having this to run horizontally, it will look better and give greater diversity by placing it vertically—the point *c* being the top, and *d* the lower end of the pattern.

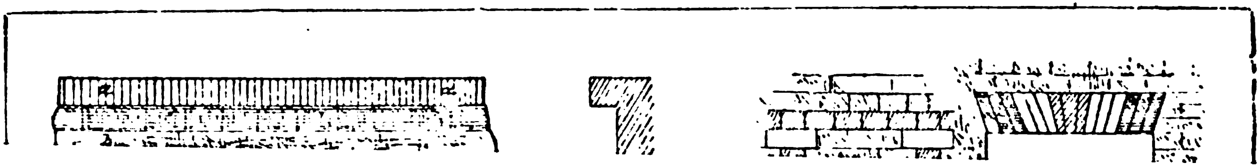
Figs. 1, 2, 3, 5, 6, Plate XI., and figs. 2, 3, 4, Plate I. inclusive, show other arrangements of coloured brickwork in the same class. In fig. 6, Plate XI., the upper courses *a a*, *b b*, and two lower courses corresponding in position, are of black brick, the parts *c d*, *e e*, in blue, and the central parts, as *f g h i j k l m n o p* and *q*, formed by the juxtaposition of the parts of which *c d e* is one of yellow bricks, the general surface being red brick. In fig. 6, Plate V., the bricks marked 1 2 3 4 are red, 5 6 7 8 white, 9 9 blue, 10 10 black; the general surface being yellow.

Figs. 4, 5, 7, Plate X., and fig. 4, Plate XI., are illustrations in the same class adapted for panel work.

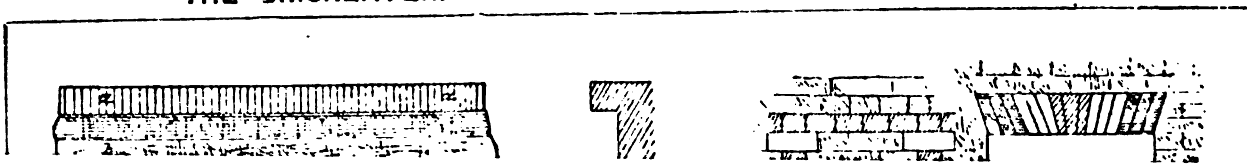
The majority of those styles will be used chiefly for the breaking up of large flat surfaces of brickwork; but how, and in what combination of colours, will depend, of course, upon the builder, and this will show what is called his good or bad taste. In some cases the band arrangements are adopted as string courses, and as forming part of cornices. We now illustrate arrangements of coloured bricks in the case at present under consideration—namely, what we have called a modification of the mosaic or inlaying method of treating materials—in such construction as shown in fig. 3, Plate IV., fig. 6, Plate V., and fig. 1, Plate VII. In projecting work, such as in string courses and the like, considerable effect may be obtained by the use of coloured bricks, and by the simple disposition of ordinary bricks. Of this class of work we give illustrations in figs. 1 and 4. Plate I., and in all the figures in Plate X. Examples of perforated work are given in figs. 1, 2, 3, 6 and 7, Plate X.; in figs. 4, 5 and 6, Plate XI.; and a suggestive hint as to the employment of drain tubes for the same class of work in fig. 8, Plate VI. Examples of combined work in wood, stone and brick are given in figs. 1, 2, 4 and 5, Plate VIII.

THE END.

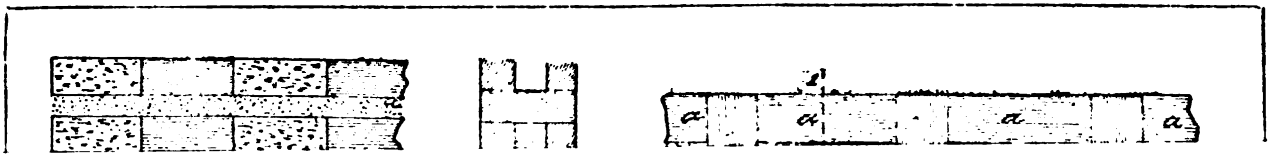
THE BRICKLAYER. *ORNAMENTAL BRICKWORK. DIFFERENT FORMS OF BRICKS.*



THE BRICKLAYER. *ORNAMENTAL BRICKWORK. DIFFERENT FORMS OF BRICKS.*



THE BRICKLAYER.



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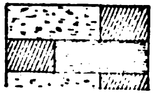
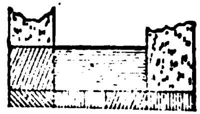




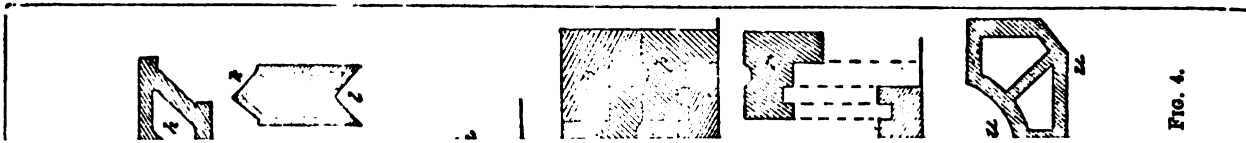
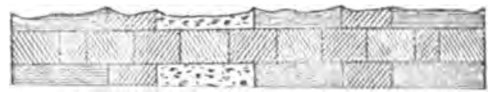
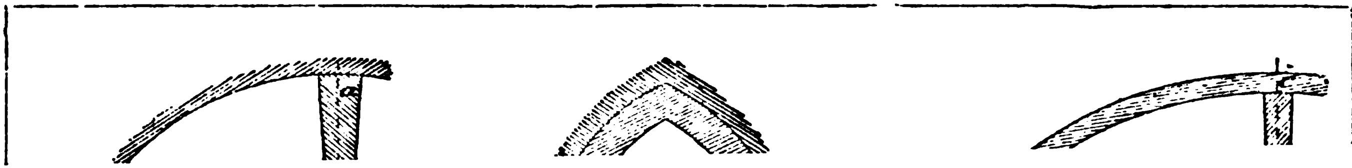


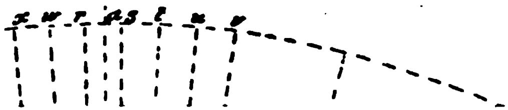
Fig. 4.

e

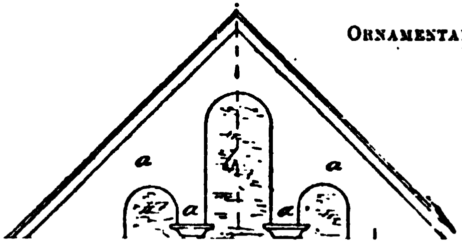


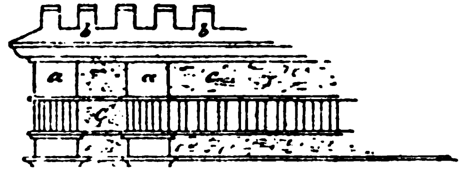


THE SETTING-OUT OF ARCHES.

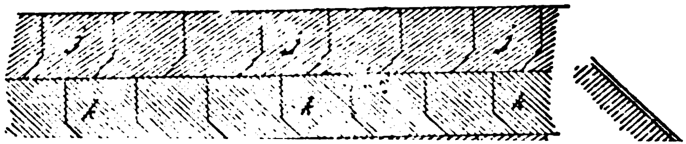


ORNAMENTAL BRICK AND STONE WORK COMBINED.

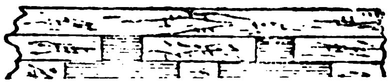


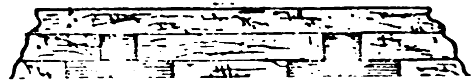


ORNAMENTAL BRICKWORK.

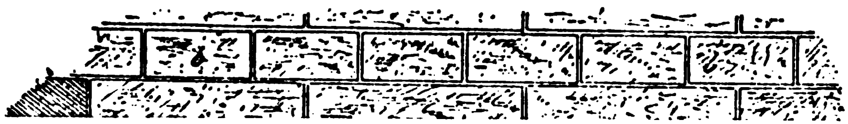


ORNAMENTAL AND PERFORATED BRICKWORK.





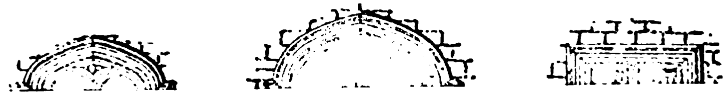
THE BRICKLAYER.



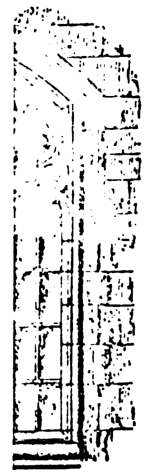
THE STONE MASON.

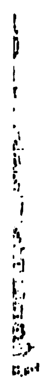
DOORWAYS—STYLE DOMESTIC GOTHIC, FIGS. 1, 2, 3, 4, 5, 6; STYLE ELIZABETHAN, FIGS. 7, 8, 9, 10, 11, 12.

THE STONE MASON.



6. Early

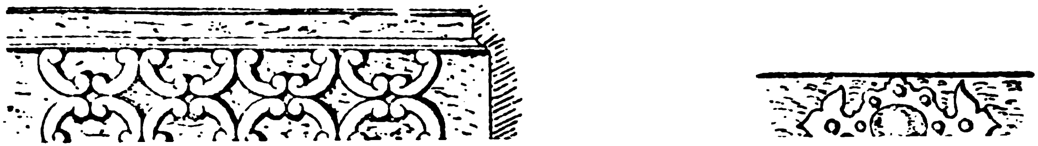




[Plate IV.

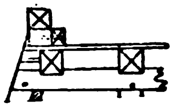
[illegible]

DETAILS FOR DOMESTIC ARCHITECTURE—STYLE "ELIZABETHAN."

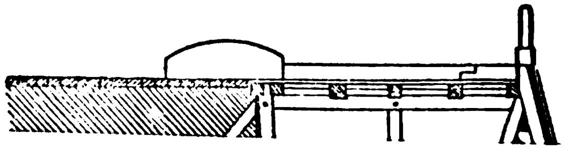


Details Exterior and Interior.—Style Elizabethan.

THE STONE MASON.



·THE STONE MASON."



THE STONE MASON.