away. In another machine, also with revolving table, two moulds receive the charge of clay at once. While these are being filled the two that had just been filled are being subjected to considerable pressure, and the two bricks that had been pressed immediately before are in process of delivery out of the moulds, and on to a flat belt which takes them away. (This machine is also suitable for dry clay.) In yet another, a cylinder revolving under the pug-mill presents to it successively four brick-moulds, each of which, on reaching the lowest point, is made to deposit its brick on an endless band. The annexed drawing represents one of Messrs H. Clayton, Son, & Howlett's single delivery machines for brickmaking with plastic clay. After what has been said little description will be necessary. A is the pair of rollers, B the pug-mill, C the stream of issuing clay, which a little further on is cut across by

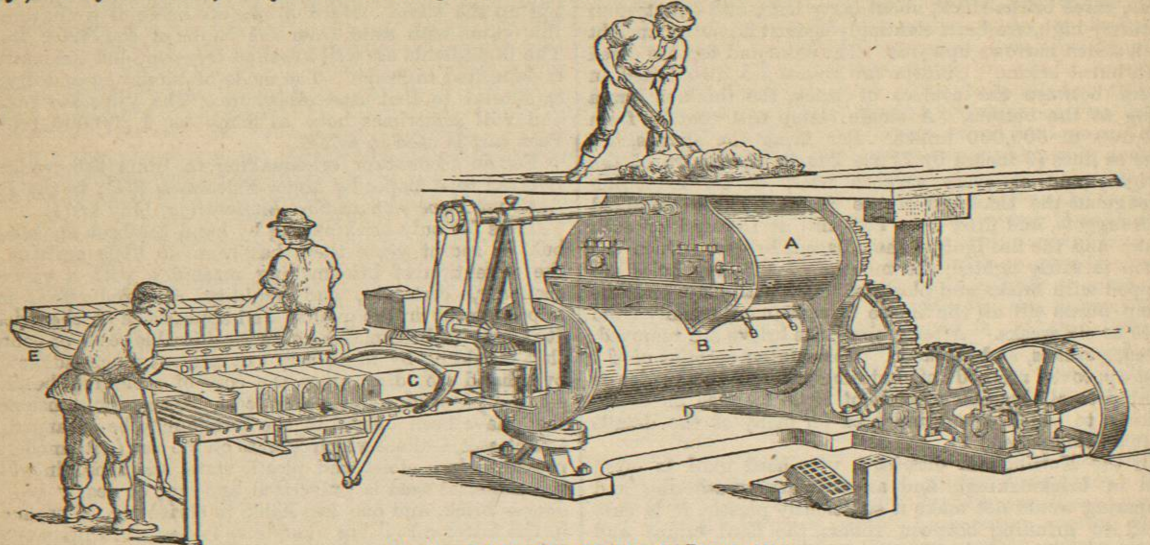


Fig. 2.—Brickmaking Machine for Plastic Clay.

means of the wire frame D. The bricks are then removed to the barrow E. These machines are often constructed for double delivery.

As an example of the second class of machines,—those for working dry, or half-dry, and non-plastic material,—we may take another machine constructed by Messrs Clayton. It affords a good practical solution of the problem of making bricks from coal shale, bind, fire-clay, or the like. The arrangement is shown in figs. 3 and 4. In fig. 3, A

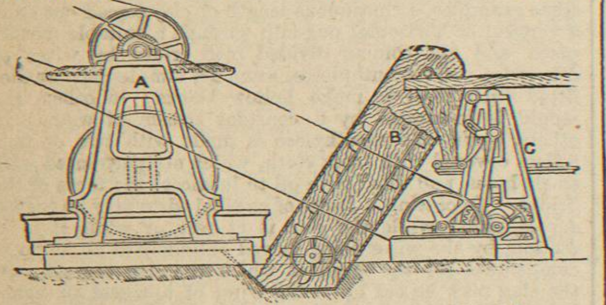


Fig. 3.—Section of Machine for Non-plastic Material.

is a pan roller mill, in which a pan containing the raw material is driven round under rollers; there are perforations in the bottom, through which the ground clay escapes, and is swept by arms into a general receiver, whence a band with buckets conveys it to the hopper of the moulding and pressing machines C, of which fig. 4 gives another view. Here the moulds are contained in a box at B, bolted between the standards. There are two sets of pistons, one above and the other below the brick-moulds, and they simultaneously press the top and the bottom of the brick in the mould. The lower pistons are attached to a cross bar which slides in vertical guides in the standards, and has friction rollers C on the lower extremities, in contact with which work two pressing cams D on the main shaft. The upper pistons E are attached as shown to a cross-head above, which is moved up and down in its guides by connecting rods and two cranks on the main

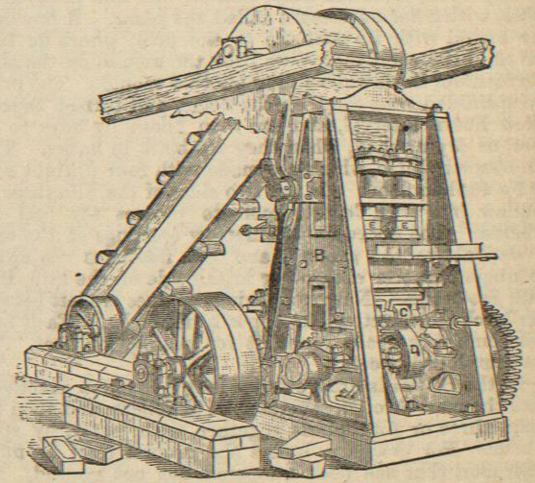


Fig. 4.—Part of Machine shown in section in fig. 3.

shaft. These pistons are hollow, and are heated by steam to prevent the brick-earth adhering to them. The prepared material is supplied to the two moulds by a feed-box which slides to and fro under the feeding hopper of the machine and thus passes alternately under it and over the moulds, conveying sufficient each time to fill the latter. The bricks are delivered from the moulds by the lower pistons, which are forced upwards by the complete revolution of the cams, and the newly-made bricks are forthwith moved forward by the approach of the feed-box with a fresh charge of the material. In another dry-clay machine constructed by Messrs Bradley and Craven of Wakefield, two or three distinct pressures can be given to a brick, and by this means the air is gradually forced out from the interstices, and the brick consolidated to a greater extent than can be effected by a single pressure.

The varieties of brickmaking machinery are too numerous to be separately noticed, however briefly, but the foregoing may suffice to illustrate the general principles involved in their construction. With suitable modifications, perforated or hollow bricks are frequently produced, on which there is a saving in cost of carriage, and also in mortar and labour.

Among the objects at the International Exhibition of 1874 there were several varieties of brick prepared without burning, according to a process devised by Messrs Bodmer. They are made by intimately mixing certain materials of the nature of cements or mortars, and squeezing the mixture into the desired shape by hydraulic pressure in a specially-constructed machine. Sand and selenitic lime are the constituents of one kind of brick; these substances, together with Portland cement, of another; and a very serviceable kind of brick is prepared from blast-furnace slag, which, consisting chiefly of silicates decomposable by lime, is just as suitable for the purpose as the volcanic products, trass and pozzuolano, which have long been employed. The bricks give good results on application of the usual tests.

The old invention of *floating bricks* (known to Pliny) was completely lost till M. Fabroni discovered they could be made from the earth known as fossil meal, which is abundant in Tuscany, and is found near Castel del Piano in the territories of Siena.

For the drying and burning of bricks, the construction of kilns according to Hoffmann's method is a remarkable improvement of late years. These kilns are formed by a series of arched chambers connected by passages to one main chimney flue, each passage or flue having suitable dampers to regulate the heat at any desired point. Small coal, slack, or peat fuel may be used, which is fed in from the top of the kilns through small openings. The waste gases from the burning and cooling chambers are made to pass successively into other chambers and give out their heat before escaping to the chimney, thus completing the drying, and effecting a partial burning, of newly-made bricks before the actual firing of the chambers in which these latter are newly set. Such kilns are no doubt beyond the means of most brickmakers, but it is perhaps a question for consideration whether bricks must necessarily be burnt in immediate proximity to the spot where the clay is obtained.

In an instructive report on the manufacture of bricks, drawn up a few years ago by a committee of the Manchester Society of Architects, the following points were specified as requiring attention, in order to improve the character of the common brick:—(*a*) Greater care in cleaning the clay and in thoroughly tempering it; (*b*) variation in the size of moulds, so as to produce uniform sized bricks from various clays; (*c*) moulding the brick with material of such consistency that it may not become misshapen by the effects of its own gravity; (*d*) greater regularity of surface of the drying-ground; (*e*) protection from extreme variations of temperature and rain in drying; (*f*) less frequent and more careful handling in the process of drying, so as to preserve the edges; (*g*) a means of burning whereby the amount of firing shall be under control. In experiments on the absorption and retention of moisture, it was found that the bricks which parted most readily with their moisture at first were the longest in drying, and *vice versa.*

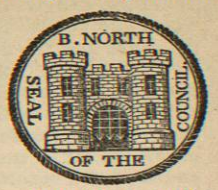
Tiles, being a thinner ware than bricks, have to be made of purer and stronger clay, and require more care in treatment, but the process of manufacture is not essentially different. The numerous varieties of tiles may be roughly arranged in three classes, viz., *paving tiles, roofing tiles* (including the flat plain tiles, the curved pantiles, hip, ridge, and valley tiles), and *drain tiles.* In weathering, the clay is spread in layers of about 2 inches thickness during winter, and each layer is allowed the benefit of at least one night's frost before the succeeding layer is put upon it. Sometimes the weathering is effected by sunshine. The comminuted clay is next placed in pits and allowed to mellow or ripen under water. Then it is passed through the pug-mill, and the tempered product, if necessary, *slung* (that is, cut in thin slices with a piece of wire fixed to two handles, in order to detect any stones), and then passed through the pug-mill again, after which it is generally ready for moulding. To take the case of *pantiles* (hand-moulded), the moulder turns the tile out of the flat mould on to the *washing-off frame,* on the curved surface of which, with very wet hands, he washes it into a curved shape. Then he strikes it with a semi-cylindrical implement called the *splayer,* and conveys it on this to the flat block where he deposits it, with the convex side uppermost, and, removing the splayer, leaves the tile to dry. The tile is afterwards beaten on the *thwacking-frame,* to correct any warping that may have occurred, and trimmed with the *thwacking-knife.* In the kiln, which is constructed with arched furnaces at the base of a conical erection called the dome, the tiles are closely stacked in upright position, on a bottom of vitrified bricks. The fuel used is coal, and the burning continues usually about six days. In making *pipe drain tiles,* the clay is first moulded to the proper length, width, and thickness, then wrapped round a drum; the edges are closed together, and the tile is carefully shaped by the operator's hand, sometimes assisted by a wooden tool. Tiles as well as bricks can be made by machinery; with suitable dies, almost any form of tile may be thus had, which is producible by the advance of a given section of clay parallel to itself. In other machines pressure is exerted on the clay in a mould.

The manufacture of *tesseræ* and *encaustic tiles* has been brought to great perfection in recent times, through the enterprise especially of Mr Minton. It is a revival and extension of a very old art, which originated, probably, with the Greeks. The tesselated pavements of the Romans, of which many specimens are still extant, were formed of small pieces of stone or marble of various colours, bedded one by one in a layer of cement. The principle on which tesseræ are now made, is that dry and finely-powdered clay, compressed between steel dies, is changed into a very compact and hard solid body, a fact first observed by Mr Prosser in 1840. The solid pieces, which are thus produced in a screw-press, are enclosed in earthenware cases or pans, call *saggers,* and fired in a potter's kiln, after which they are ready for use, unless they are required to be glazed, in which case they are dipped in a glazing composition and again fired. The mode of setting the pieces differs essentially from the Roman method. In manufacture of the tiles called *encaustic,* in which various designs are produced by addition of clays of different colour from that of the ground, the clays first undergo sundry washings and purifications. A portion of the kind which is to form the ground first receives an impression, in the plastic state, from a plaster in relief. The bulk of the tile is made up with coarser clay added in a frame, and this is solidified in a screw-press. Then comes the filling in of the design, which the maker does by spreading the coloured clay in a creamy or slip state on the indented surface. After a few days' evaporation, the surface is scraped or planed, and the tile passes successively to the drying house and the oven. The colours desired in encaustic tiles are sometimes those given by the clay in ordinary treatment, sometimes they are obtained by staining with manganese, cobalt, &c. The products of this branch of manufacture are much admired.

The fine ornamental bricks of various shape and colour known as *terra cotta* have of late been much used, especially in the facing of public buildings, and with the happiest effects. (A. B. M.)

BRIDAINE, JACQUES, a celebrated French preacher and home-missionary, was born in 1701 at Chuslan in the department of Gard. Though a rigid Catholic in principle, he gained the good-will of the Protestants of France by the boldness with which he advocated their cause on many occasions, and the personal kindness which he displayed towards many of their number during the persecutions to which they were exposed under the Regent Orléans and Louis XV. He accomplished no fewer than 250 evangelizing journeys through various parts of France, in the course of which he made himself universally popular, being possessed of a powerful though rugged eloquence. He was the author of a collection of *Cantiques Spirituels*, which has been frequently reprinted, and of five volumes of sermons, printed at Avignon in 1825. In the neighbourhood of this town he died in 1767.

BRIDGENORTH, a parliamentary and municipal borough and market town of England, in the county of Shropshire, on both sides of the Severn, 18 miles S.E. by E. of Shrewsbury. The river, which is here crossed by a handsome stone bridge of six arches, separates the upper from the lower town. The former is built on the acclivities and summit of a rock which rises abruptly from the river to the height of 180 feet, and gives the town a very picturesque appearance. The railway passes under by a long tunnel. On the summit is the tower of the old castle, leaning about 17 degrees from the perpendicular; two parish churches, one of which, St Leonard's, was rebuilt in 1862; and a large public reservoir. There are in the town a mechanics' institute, a public library—founded by the Rev. Mr Stackhouse, an infirmary, a jail, a theatre (1824), a market hall (1855), and a considerable number of schools and charities. It has manufactures of carpets, worsted, and tobacco-pipes, and some trade in agricultural produce. It returns one member to parliament. The population of the parliamentary borough amounted in 1871 to 7317; that of the municipal borough to 5876.



Arms of Bridgenorth.

Bridgenorth, or Brigge, is said to have been founded by Ethelfleda, the daughter of Alfred, and it was fortified with a castle and walls by Robert de Belesme, earl of Shrewsbury. On the earl's rebellion the town was besieged and taken by Henry I. in 1102; and in the reign of Henry II. the castle was dismantled. In 1646 the town, being held by a Royal garrison, sustained a remarkable siege by the Parliamentary forces, who at last obtained possession.

BRIDGEPORT, a seaport town in the county of Fairfield, Connecticut, United States, is situated on an arm of Long Island Sound, 58 miles N.E. of New York, in 41° 10′ N. lat. and 73° 11′ W. long. It has several iron-foundries and manufactures fire-arms, metallic cartridges, sewing-machines, carriages, harness, locks, blinds, &c. The coasting trade and the fisheries are both extensive. The bar at the mouth of the harbour, which is formed by the Pequonnock Creek, has 13 feet at high water. Bridgeport is the centre of an extensive system of railways, and steamboats ply between it and New York. The township was separated from Stratford in 1821, and the city, formerly called Newfield, was incorporated in 1836. Population in 1870, 19,835.

BRIDGES

§ 1. *Definitions and General Considerations.*—Bridges are structures designed to carry roads across streams, gullies, or roads. A viaduct may be distinguished from a bridge, inasmuch as the object of the former is to carry a road at a considerable elevation above the surrounding country, by means of structures, similar indeed to bridges, but in which the object of the open spans is to save expense rather than to cross some obstacle which could not be passed by a level road or embankment. The aqueduct is a structure similar to the viaduct, but employed to convey or support water. A culvert may be distinguished from a bridge as an opening, the primary object of which is to let water flow past a road or other obstacle, the object being similar to that of a large drain. A large culvert might be called a small bridge, and a bridge having long approaches with many spans might be called a viaduct. The present article will treat only of Bridges.

Every bridge may be divided into two parts, the *substructure* and the *superstructure*. The substructure of a bridge consists of foundations, abutments, and piers. The end supports of the bridge are the abutments, and the intermediate supports are called piers. Piers and abutments rest on foundations in the ground. A bridge of one span has no piers. The superstructure of a bridge consists of the roadway and the beam, arch, or chain used to carry the roadway from support to support.

The dimensions and design of a bridge depend on the nature of the obstacle to be crossed and on the traffic to which the road over the bridge is subject. The engineer is usually bound to design the cheapest structure which will perform the required duties; he has, therefore, in each case to consider whether a small number of large spans or a large number of small spans will be cheaper. Large spans will be desirable where foundations cannot be easily obtained, or where the height of the structure is great. The engineer has also to determine whether, considering the prices of materials, labour, and transport, one or other form of superstructure is to be preferred. The traffic to be accommodated will determine the width of the bridge and the load which the superstructure must bear. In many cases it will also be the duty of the designer to endeavour to combine beauty with utility. Beauty does not require ornament or expense, but demands, what may be more difficult to supply, correct taste in the designer.

In Great Britain law prescribes the following minimum dimensions for the over and under bridges of railways. (An *over bridge* is one in which the road goes over the railway; an *under bridge* one in which the road goes under the railway.) *Over bridges.*—Width: turnpike road, 35 feet; other public carriage road, 25 feet; private road, 12 feet. Span over two lines (narrow gauge), generally about 26 feet; head room, 14 feet 6 inches above outer rail. *Under bridges.*—Spans: turnpike road, 35 feet; other public carriage road, 25 feet; private road, 12 feet. Head-room: turnpike road, 12 feet at springing of arch, and 16 feet throughout a breadth of 12 feet in the middle; for

public road, 12 feet, 15 feet, and 10 feet in the same places; private road, 14 feet for 9 feet in the middle; for exceptions the Acts must be consulted. In designing a bridge to cross a stream care must be taken to insure that the openings are suitable for the maximum floods.

The *load* which the superstructure of a bridge has to carry in additicn to its own mass may be estimated as follows:—

1. For a *public road;* one hundredweight per square foot will represent the weight of a very dense crowd. This is greater than any load which ordinary carts or vans will bring on the bridge, but of late years traction engines and road rollers have been introduced, and a weight of perhaps 10 tons on each wheel on one line across the bridge ought in future designs to be provided for. The bridge must be strong enough to bear this maximum weight applied at any point, and also to bear all possible distributions of the crowd. A bridge might be fit to carry the crowd uniformly distributed over its surface, and yet fail when the crowd covered one-half of its length or width.

2. For a *railway;* the maximum passing load on each line of rails may be taken as the weight of a train composed exclusively of locomotives. The bridge must be fit to bear this load distributed in all possible ways along the line. For spans above 60 feet on the usual 4 feet $8\frac{1}{2}$ inches gauge this load may generally be taken as equivalent to 1 ton for each foot in length of each line of way, or in engineering language, "one ton per foot run." Where a very heavy class of locomotives is in use $1\frac{1}{4}$ tons per foot run must be provided for. For small spans the distribution of the load as a locomotive passes is such that the above allowance is barely sufficient. For very small spans of 8 or 10 feet the maximum passing load is a little more than the weight on the driving axle of the locomotive, or say 14 tons.

§ 2. *Classification.*—Bridges are classed, according to the design of their superstructure, as *girders*, *arches*, and *suspension bridges*. A beam of wood crossing a stream, a brick arch, and a platform hung to a flexible wire rope are common examples of the three types. The essential distinction between the three types may be said to be, that in all forms of the suspension bridge the supporting structure (*i.e.*, the wire rope in the above example) is *extended* by the stress due to the load; in all forms of the arch the supporting structure (*i.e.*, the ring of bricks in the above example) is *compressed* by the stress due to the load; and in all forms of the beam or girder the material is partly extended and partly compressed by the flexure which it undergoes as it bends under the load,—thus when a beam of wood carrying a load bends, the upper side of the beam is thereby shortened and the fibres compressed, while the lower side of the beam is lengthened and the fibres extended.

Beams or *Girders* may be of various materials,—wrought iron, cast-iron, and wood being chiefly employed.

Arches may be of masonry, or they may be of wrought or cast iron or steel, in which case the compressed sector of a ring is usually a continuous and stiff structure.

Suspension bridges are made of wire ropes or of separate links of wrought iron or steel pinned together so as to form a chain. The metal beam, arch, or suspension bridge may be a continuous structure or an open frame; we shall also find that in some designs the several simple types are combined so as almost to defy classification.

Whatever design be adopted, the strength or efficiency to carry a given load depends on similar considerations. The designer selects that form of superstructure which the principles of statics show to be most desirable; he calculates the maximum stress which the load can produce on each part, and then so distributes his material that the maximum intensity of stress on every part shall be a definite fraction of the ultimate strength of the material. In metal structures, where the above principle can be very perfectly carried out, this fraction varies from one-sixth to one-third, according to the certainty with which the stresses and strength of the materials are known. In stone structures the engineer has greater difficulty in calculating the stresses on each part, and relies more on empirical rules based on long experience.

I. STRENGTH AND OTHER PROPERTIES OF MATERIALS EMPLOYED IN BRIDGES.

§ 3. *Classes of Stress.*—There are three kinds of stress, due to tension, compression, and shearing. Tension tends to cause failure by the extension or lengthening of the part strained; compression tends to cause failure by the crushing of the part strained; and shearing stress tends to cause failure by the sliding of one part of the piece across the other from which it is shorn off.

§ 4. *Tenacity, or Strength to resist Tension.*—When tension is applied to a rod or link of any material so as to be resisted equally by each element of any imaginary section in a plane normal to the direction of the pull, this section, which is called a *cross section*, is said to be subject to a stress of *uniform intensity*. This intensity p is equal to the quotient of the whole pull P divided by the area S of the cross section, or

1. . . . . $p = \frac{P}{S}$.

The ultimate strength of a rod subject to uniform stress is proportional to the section S, and the ultimate strength of the material is measured by the maximum intensity of stress which it can bear, or in other words, by the stress which the unit area of cross section can bear; for example, if the unit of force employed be the weight of a ton, and the unit of area the square inch, the strength of materials will be measured in tons per square inch, or by the number of tons which will just tear asunder a rod one inch square, great care being taken that the load is so hung on the rod as to bear equally on all parts of the cross section.

The following table gives in tons or lbs. per square inch the ultimate strength f_t of some of the materials used in bridges:—

TABLE I.—*Tensile Strength of Materials* $= f_t$.

Name of Material.	Tons per sq. inch.
Wrought Iron Plates	20 to 25
,, ,, Bars and Bolts	25 to 30
,, ,, Wire	30 to 45
Steel Plates	30 to 40
Steel Rivets	41 to 48
Steel Wire	50 to 100
Cast-iron	6 to 8
Red Pine	5·1 to 6·3
Larch	4 to 5·5
Oak	4·5 to 8·5
Teak	6 to 9
	Lbs. per sq. inch.
Brick (specimens of)	250 to 300
Basalt ,,	1000
Sandstone ,,	285
Common Mortar	10 to 50
Hydraulic Mortar	85 to 140
Roman Cement, 12 months old	46
Portland Cement, 7 days old	270
,, ,, 12 months old	350 to 470

The ultimate strength P_1 of a bar with the cross section S to resist a stress uniformly distributed over that section is given in terms of f_t by the expression—

2. . . . . $P_1 = Sf_t$.

Table I. gives some idea of the tensile strength of the materials, but for a full comprehension of the subject special treatises, or the article on the STRENGTH OF MATERIALS.