MILL ENGINEERING

(PART 1)

MILL CONSTRUCTION

SELECTION OF A MILL SITE

1. Introduction.—The immediate reasons for the erection of textile mills may be classed under three heads: (1) capitalists seeking a new location of investment; (2) established mills making extensions; (3) local individuals promoting the erection of a mill. Under the first condition a company or corporation is first formed and the necessary capital invested. A location for the plant is then chosen, in which connection there are many points to be considered, all of which depend on the natural and artificial advantages of the locality. From the mill engineer's point of view, the natural advantages of a location, such as the character of the soil on which the foundation is to rest, the reliability of the water supply, if water-power is to be used, and many other like considerations are the more important, while from the manufacturer's standpoint, the artificial advantages, such as proximity to the market and to the raw-stock supply, and the class of help that can be utilized, are the more important. It is the function of the mill engineer to adapt a site, often chosen without particular regard to engineering considerations, to the needs of the manufacturer.

Under the second and third conditions, the choice of the site for a mill structure is generally more limited, and both the manufacturer and the engineer must adapt themselves to the conditions that are met with, especially when additions are to be made to established plants.

2. Class of Goods to Be Manufactured.—In entering into a discussion of the natural and artificial advantages of various locations, the first consideration should be the class of goods that is to be manufactured. For instance, if the mill is to manufacture cotton yarns or fabrics and a fine quality of goods is to be made, it is advisable to locate the mill in a district where there are other fine-goods mills; that is, in a fine-goods center. For the medium and coarser grades of cotton manufacturing the South is now offering excellent locations, while the fine-goods mills are still largely confined to the North. The same conditions apply to silk mills, which are usually concentrated in some locality that is especially adapted to their needs, owing to its proximity to a supply of labor, or other considerations. If the mill is to engage in the manufacture of woolens or worsteds, the field is larger, since these industries are not so concentrated, but more scattered throughout the country, each mill being erected where the best and most advantageous conditions are found; worsted mills, however, are more concentrated than woolen mills.

3. Help to Be Employed.—One of the main considerations entering into the choice of a locality for the plant is the class of people from which operatives can be obtained. It is preferable to locate the mill where skilled and trained help can be obtained at a minimum expense; but if this is impossible the mill should be located in a district where large numbers of intelligent people can be utilized as operatives even if they are totally untrained. With the aid of a skilful superintendent and overseers, together with a few skilled workmen, this class of help can, in a short time, be trained to meet the requirements of the mill. Formerly the native help was depended on entirely in American mills, but of late years a large number of French-Canadians, Portuguese, etc. have been utilized, so that a well-located mill is often situated in close proximity to a large resident population of foreign help. In the South, many mills are located in the upland, or mountainous, districts and the mountain population is drawn on for the necessary help. In the North and Middle States, the question of a good supply of native help is not so important, because of the large resident colonies of foreign help in all large manufacturing centers.

4. Market and Transportation Facilities.—The proximity to the raw-stock supply is also an item of the utmost importance to the manufacturer, and in the South many mills are advantageously located near, and in some cases actually in, the cotton fields. The Northern and Middle States, which are essentially manufacturing districts, do not offer these advantages, and the mills should be located preferably with reference to large markets and shipping points. This is true of cotton, woolen, worsted, and silk mills, since by this means the raw stock can be more readily and cheaply transported to the mill, while the buyer for the mill is also able to keep in closer touch with the fluctuations of the market, thus enabling the mill to purchase to advantage, and likewise keep in closer communication with the selling houses.

Railroad and other transportation facilities should in all cases be carefully considered, and if possible the mill should be situated in close proximity to two or more railroads or other methods of transportation under separate control, thus securing the advantage of competitive freight rates. It is always an advantage to have the plant situated on the direct, or main, line of a railroad, but in some cases where this is impossible the railroad company, especially in the South or West, can be induced to run a spur, or branch, track to the mill, provided that the amount of traffic will warrant the expense; the railroad companies will not always do this in the Middle or Eastern States, however. Railroad facilities are indispensable and the distance from the market is not so important an element as the freight rates, for it often happens that one location, while more remote from the market than another, offers greater facilities for transportation.

5. Fuel and Mill Supplies.—Another consideration that should enter into the choice of a location is its proximity to the machine shops where the equipments of the mill were purchased, and which also are frequently sources of mill supplies; since if the locations are near, parts of broken machines, supplies, and other materials can be obtained at short notice, thus preventing portions of the mill from lying idle while awaiting repairs. This is an especially important consideration with mills that are not equipped with complete machine shops, including facilities for producing parts of the machinery most liable to become worn or broken.

A mill should be located near large coal fields, if possible, thus insuring a plentiful supply of fuel at low rates; but, as in the case of New England, this is often impossible. In many instances the best location is on tide water, since the rates of transportation of coal by water are much lower than by rail.

6. Water Supply.—If the mill is to be located on a stream and water-power is to be used, several points in regard to the character of the stream should be noted. The abundance of the water supply for a number of successive years should be determined, in order that the maximum and minimum amount of flow can be ascertained. It should be determined whether the minimum supply will be sufficient to operate the mill; in this connection the extent of the watershed, or area drained, should be considered, since some very small streams are never known to run dry, while many larger ones run extremely low during certain portions of the year. The water supply should be as uniform as possible and the river free from freshets as well as from dry periods. A river that is free from ice is also to be preferred to one that is periodically blocked, although the Merrimac River, on which Manchester, New Hampshire, and Lowell and Lawrence, Massachusetts, are situated, and which is the largest manufacturing river in the world, is subject to both ice and freshets. The natural conditions that govern the construction of the dams, canals, sluices, etc. should also be considered before finally deciding on a mill site, as these will enter largely into the cost of construction, unless there is an existing water-right from which water-power can be purchased. As water-power is the most easily developed power and can be had for a very small expense, many small mills are located largely with reference to the water-power facilities.

Care must be taken also to have a suitable water supply for general mill purposes, such as for the boilers, drinking water, dyeing purposes, and in the case of woolen and worsted mills for scouring and finishing. The mill should also be located with regard to the drainage and sanitary conditions and should preferably be situated on a gentle slope.

7. Formerly the climatic conditions were a very important consideration in the location of a mill, because of the greater facility with which some fibers could be manipulated under certain atmospheric conditions; but at present this is of little importance, since the temperature of the mill is easily regulated, and with the improved types of humidifiers now on the market the percentage of moisture in the air is easily governed.

In many cases, especially in newly developed territory, local authorities will remit the taxes of a proposed plant for a term of 5, or sometimes 10, years as an inducement to attract worthy enterprises to their locality. Offers of this kind should always be solicited and accepted, provided that no serious conflict with other advantages is thereby created.

EXCAVATIONS

CHARACTER OF SOIL

8. After the general locality of the mill has been decided on with due regard to the natural and artificial advantages, it is necessary to choose the actual site of the structure. In this connection the character of the soil on which the foundation is to rest should receive the most careful consideration. It is well to have expert engineering advice on this point, since the services of a mill engineer are invaluable in the erection of large and important mill structures. A good mill engineer, especially one who is independent of machine shops, will save the cost of his fees many times over, not only in the reduced cost and increased stability of the structure and its equipment, but also in the reduced cost of operating the mill, by so arranging the equipment that the transit of material and the number of employes necessary are reduced to a minimum.

A perfect foundation is one of the most difficult problems of engineering as well as one of the most important, for on it depends the stability of the whole superstructure. If after completion and the installation of the machinery the structure settles to any great extent, the results are disastrous; even a small settlement, especially if not uniform, will cause great annoyance by throwing the shafting out of line. When this happens the wear and tear on the shafting and hangers is greatly increased, as well as the power required to drive the mill. Besides the annoyance resulting from having the floors out of level, if the foundations are weak or insufficiently supported, all the subsequent stonework and brickwork are likely to crack and greatly spoil the appearance, and lessen the strength, of the structure.

Before building the foundations for the mill the ground must be excavated, either for the basement or for trenches, so as to place the masonry below the frost line; but before the excavation is begun the nature of the soil that is to support the foundation should be determined. If this cannot be determined from existing structures or wells, borings should be made. For this purpose, an auger about 2 inches in diameter and of suitable length is used—similar to an auger for wood boring—and tests made, from 5 to 10 feet apart, over the entire area of the foundation. As the auger brings up samples of the soil, the character of the substrata is determined. When the importance of the proposed structure requires it, trial pits are sometimes dug from 10 to 20 feet apart, especially where a shelving bed of rock or gravel exists at a comparatively short distance below the surface.

It is not always safe to rely on the character of the soil in close proximity to the proposed mill site, since conditions varying from a bog to a solid granite ledge are often found in the space of a few yards. The soil or strata usually met with in building operations may be classed under three divisions—*rock*, *virgin soil*, and *made ground*.

9. Rock, in its original geological formation, is spoken of as bed rock, or solid ledge. It forms the finest foundation for heavy structures, provided that it is of sufficient area for the entire mill to rest on. But it is undesirable to have a portion of the foundation rest on a ledge while another portion rests on a softer material, since the mill will not settle uniformly and the walls will often crack open at the junction of the ledge and softer material. It often happens that the surface of the rock is uneven and requires considerable blasting and concrete work to secure a good foundation, which adds considerably to the cost. The sandstones and limestones are often found in strata, beds, or layers, one on another; if these layers are not separated by clay, and the beds are even, they make good foundations. The strata, or beds, of rock may shelve, or dip, at varying angles, especially in hilly sections. A ledge is not always reliable, and in many cases will be found to be shaly in structure, partly decomposed, or faulty in other respects.

10. Virgin soil is either gravel, clay, loam, sand, or marshy ground in its natural condition.

1. *Gravel*, when compact and united with sharp sand into a firm, unyielding stratum, is known as *hard pan*. It makes the best foundation (except bed rock) and, on account of its being more easily leveled, is much less expensive to build on. Usually a 6- or 8-foot stratum of gravel will support any mill structure although there may be softer material underneath.

2. *Clay* is the most uncertain of soils, owing to its elasticity, due to being mixed with marl, etc.; to its tendency to absorb moisture; and, in many cases, to the position of its bed or strata. In dry seasons it is very firm, while in wet

seasons it is elastic and unreliable. When the layers of clay are inclined, the foundation has a tendency to slide, producing results threatening the stability of the superstructure.

3. *Loam*, or clay mixed with sand and other earthy substances, when compact and of considerable depth, is a good material to build on, provided that the structure is not an extremely lofty or heavy one.

4. *Sand* is formed from the decomposition of the older rocks, either by the effects of the weather, the action of heavy rains, the wearing away by running water, or the spontaneous decomposition of the rocks themselves. The particles are carried to the rivers and either deposited in their beds or borne out to the ocean. The sand usually found in excavations has its origin either as the formations in the beds of ancient rivers that have long ceased to flow, and is therefore called *river sand*, or by the attrition, or grinding, of the rocks themselves during the geological upheavals in past ages. The latter is called *virgin*, or *pit*, *sand*, and has never known the action of water.

5. *Quicksand* is a very fine sand, often mixed with clay or loamy material in such proportion that it will retain water until it is perfectly saturated. But by confining quicksand and keeping it as nearly dry as possible, it may be excavated or built on with little more difficulty than common sand. In many cases, quicksands are mixed with a bluish or leaden-colored silt, or soapstone slime. Often in excavating quicksand, beds of this blue marl are found; when wet it is tough and hard, but when dry, it crumbles to a powder and is utterly unfit for foundations. An attempt to excavate in quicksand without previously getting rid of the water contained therein, is almost as useless as to dig in water itself, for the saturated sand will flow into the excavation as fast as it can be removed.

6. *Marshy soils* are formed by the decay of plants, weeds, and other vegetable matter in sluggish water, which, having no current, allows the plants, etc. to take root in the bed. When these plants die, others take their place each year. These successive beds of decayed matter are formed under

slight pressure and have innumerable cavities between them, as would a heap of decayed hay. Sometimes these deposits reach such a depth that their bottoms have not been reached. Large areas of marshy lands are formed in this way, by the periodical overflowing of rivers, and the rise and fall of the tides along the coast. The terms *swamp* and *bog* are often used and may be considered here as having the same meaning as marshy soil.

During freshets, rivers bring down large quantities of soil held in suspension, which is deposited when the waters subside. This formation is called alluvial, from the Latin word *alluvius*, meaning a washing upon. The term alluvial is often used to designate deposits that are of yearly recurrence, as the Nile and the Mississippi deltas, although the river bottoms of many streams are of this origin. The value of alluvial soil for foundation purposes varies considerably. In many cases, it consists of a clay formation that is hard on top, especially during dry weather, but soft and unreliable underneath. Heavy buildings should not be erected on alluvial ground without a careful investigation of the subsoil by means of borings or trial pits.

11. Made, or **artificial, ground** may consist of various kinds of materials; such as the refuse of cities, earth and other materials removed from cellars and other excavations, the cinders, ashes, etc. from manufactories and furnaces. It should not be built on, if the structure is of importance, until the nature of its subsoil has been investigated, though for minor edifices a suitable foundation may often be obtained on it.

12. From this description of the soil and materials met with in foundation beds the following deductions may be made:

It is generally safe to build on bed rock any structure that may be required, provided that the foundation beds are kept level.

Gravel, even when mixed with small boulders, can be considered perfectly reliable for any ordinary structure, under usual conditions.

Sand will carry very heavy loads, if it is confined; but great precautions must be taken to properly confine it, and also to keep water, especially if running, from it, as the action of water will soon wash it away.

Clay, when compact and dry, will carry large loads, but water should be kept from it, both under and around the structure, the foundations of which might otherwise give way, due to the difficulty of retaining the pasty or semiliquid mass formed.

A thick, hard, or compact stratum, overlying a much softer one, even silt or quicksand, will often carry a considerable load, the hard stratum floating on the soft as a raft floats on the water. It is usually better not to break through this hard stratum, as it serves to spread the base and distribute the pressure over a large area.

The silt, slush, and decayed vegetation contained in the marshy lands, especially in the Southern States, are not fit to build on without piling.

BEARING VALUE OF FOUNDATION SOILS

13. There is some difference of opinion regarding the safe bearing value of foundation soils, due probably to the difficulty of arriving at any experimental results that will have a general application. Conservative engineering practice dictates that the greatest unit pressure on the different foundation soils shall not exceed the values given in Table I.

FOUNDATIONS

FOOTINGS

14. It is important that the area of the footings, or supports, for the foundation wall be increased beyond that of the latter in order to decrease the weight per square foot. By spreading the weight of the structure over a larger area, it is more evenly distributed, and the likelihood of a vertical

TABLE I

SAFE BEARING VALUES OF DIFFERENT FOUNDATION SOILS

Material	Tons per Square Foot
Granite formation	30
Limestone, compact beds	25
Sandstone, compact beds	20
Shale formation, or soft, friable rock	8 to 10
Gravel and sand, compact	6 to 10
Gravel, dried and coarse, packed and confined	6
Gravel and sand, mixed with dry clay	4 to 6
Clay, absolutely dry and in thick beds	4
Clay, moderately dry and in thick beds	3
Clay, soft and semifluid	1 to $1\frac{1}{2}$
Sand, compact, well-cemented, and confined	4
Sand, clean and dry, in natural beds, and confined	2
Earth, solid, dry, and in natural bed	4

settlement, due to the compression of the ground, is greatly diminished. For this reason, the higher and heavier the building is to be, the wider and deeper must be the supports, or footings, for the foundation; and if extremely soft or yielding ground is encountered, piling should be resorted to in order to carry the weight of the building to a more solid base.

15. Footings may be of iron; timber; large, flat, building stones, laid directly on the ground or on a bed of concrete; or they may be of concrete alone, or concrete and stepped-up brickwork. Where piling is used, heavy capping timbers are often placed on the heads of the piles, with either stone or concrete footings; or large footing stones may be laid directly on the piles.

16. Timber Footings.—Timber is often used for footing courses where a large bearing surface can be obtained and is necessary; provided, always, that the timber can be kept from rotting. In some cases the timber is charred on the outside; in others, it is coated with asphalt. If the ground is continually wet, there is little to fear, as timber will not decay when continually saturated with water; but when alternately wet and dry, unprepared timber cannot be depended on.

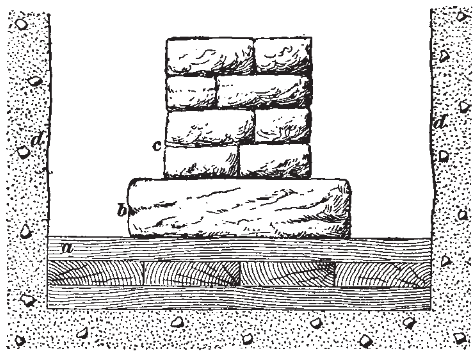


Fig. 1

The best method of placing plank under walls for footings is to use 3″ × 12″ plank cut in short lengths and laid crosswise in the trench. A layer of plank of the same size is then laid lengthwise, and the third layer is placed transversely. As

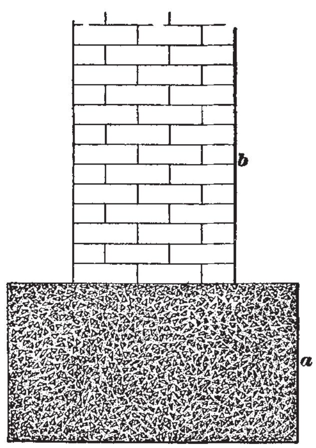


Fig. 2

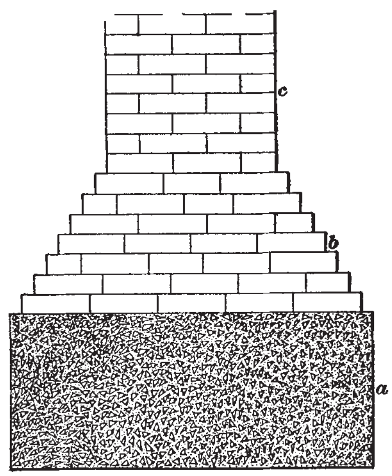


Fig. 3

shown in Fig. 1, *b* is the stone footing resting on the planks ***a*** and carrying the stone foundation wall *c* between the walls *d*, *d* of the trench.

17. Concrete and Stone Footings.—Fig. 2 shows a 20-inch brick foundation wall *b* on a concrete footing *a* 20 inches thick and 3 feet wide.

Figs. 3 and 4 show the concrete base *a* and stepped-up brick footing courses *b*. In Fig. 3, each course of brickwork sets back $1\frac{1}{2}$ inches for each course; in Fig. 4, the courses are set back 3 inches for each two courses. At *c* is shown a 20-inch brick foundation wall resting on the stepped-up brick footing.

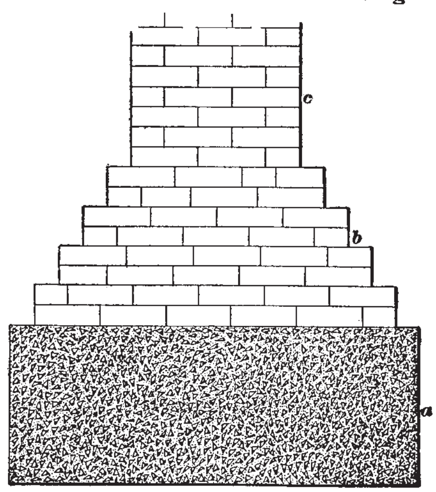


FIG. 4

Fig. 5 illustrates a stone footing composed of three courses *a* of flat stone, each course being 8 inches thick. The top course has a projection of 6 inches on each side of the 20-inch brick foundation wall *b*, while the middle and bottom courses project 3 inches each, making the width of the bottom stone 3 feet 8 inches.

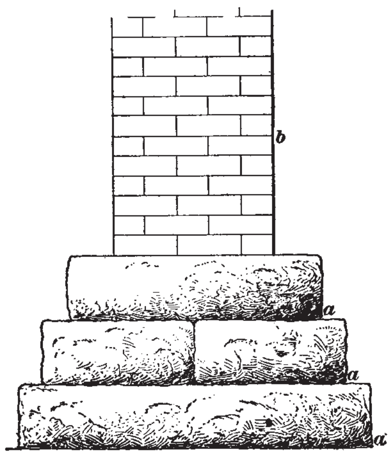


FIG. 5

Fig. 6 shows a stepped stone footing *a*, similar to that shown in Fig. 5, but supporting a 24-inch stone foundation wall *b*. Each base course advances in stages of 3 inches.

Fig. 7 shows a footing consisting of a single course of stone *a*, 8 inches thick and 2 feet 4 inches wide, carrying a stone wall *b* 20 inches thick.

18. As a general rule, concrete, when of sufficient depth and width and properly made and laid, makes the best of footing courses. It should be made of one part good cement, three parts clean, sharp sand, and five parts sharp, broken stone. In very important work, such as the footings of very high buildings, chimneys, etc., a proportion of one part cement, two parts sand, and four parts broken stone is generally used. The New York building laws call for the first proportion.

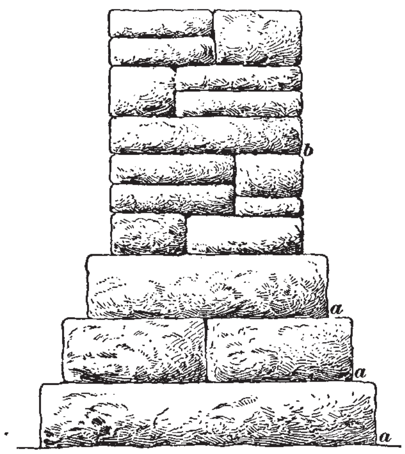


FIG. 6

None of the stone used in making concrete should be larger than will go through a 2-inch ring. In localities where stone cannot readily be obtained, broken brick or terra cotta may be used in the same proportion as stone, taking care to use good hard-burned material. Well-broken foundry slag and scoriæ, steam-boiler ashes from anthracite coal, and clean-washed gravel, mixed in the proportion given, make good concrete, though gravel, being round and smooth stone, does not adhere to the cement as well as broken stone, slag, brick, or scoriæ.

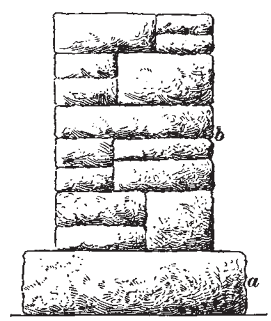


FIG. 7

In preparing concrete, the material should be worked on a platform of boards, with sides about 10 inches high, battened on the back and laid on the ground near the work. The platform is used in order that no loam or clay may contaminate the concrete, the effect of which would be a loss of strength in the concrete, as the clay adheres to the stone and prevents close contact with the cement. The sand and cement should first be thoroughly mixed by being shoveled together while dry, at least twice, so that there will not be an unequal proportion of sand to cement in different parts of the heap. The broken stone, or whatever material is used for the *aggregate* (as the stone, slag, or other coarse material is called), should then be added, the mixture being kept wet all the time and thoroughly shoveled together, so that every portion of the stone or other material may be perfectly coated with the cement. No concrete should be made unless it is to be used at once, because the cement, forming its most essential part, sets or hardens quickly, and if it sets before being placed in the footing trenches, it is valueless.

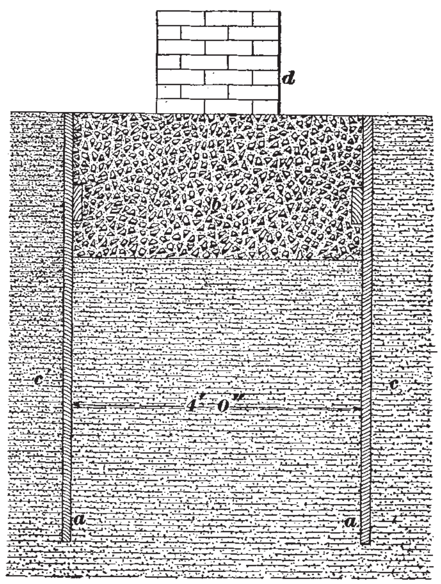


FIG. 8

19. Fig. 8 shows a method of confining quicksand by using sheet piling, between which the concrete is placed. The sheet piling *a* is placed, in this case, 4 feet apart; the concrete *b* is 2 feet thick and extends the full width of the piling; the quicksand, through which the sheet piling is driven, is shown at *c*, and the 20-inch brick foundation wall at *d*.

Fig. 9 gives an example of a footing, composed partly of timber, that was placed near the water-line of a marsh, in New York state, to carry a mill 50 feet by 80 feet and 40 feet high. The soil is a stiff, black muck, and at a depth of about 5 feet, water-soaked sand was found. A concrete bedding *a* 12 inches thick was laid in the trenches; on it 2-inch spruce planks *b* were placed crosswise, and then 8″ × 8″ timber laid parallel with the trench and filled in with concrete. On these were laid the base, or bed, stones *d*, on which was built a 20-inch foundation wall *e*. The trenches on each side of the wall were filled in with sand, rammed down, as shown at *f*. No settlement has occurred, though the mill has been built several years.

20. Stone footing courses should be laid with large, flat stones not less than 8 inches thick. If more than one course is laid, as shown in Figs. 5 and 6, the joints should never come over each other as this would defeat the object of bonding, which is to tie firmly together the parts of the wall. All stone footings should lie on their natural, or quarry, beds, and all the joints and spaces between the stones must be well filled with mortar, which acts as a bedding between the stones and prevents the uneven pressure of one stone on another, which might cause a fracture of the lower one and produce settlement. All footing courses, as indeed all mason work below ground level, should be laid in cement mortar, although in dry, well-drained soil lime-and-cement mortar may be used.

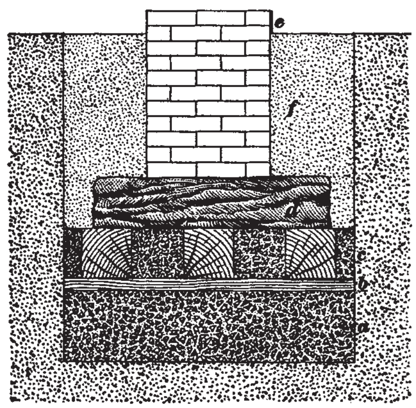


FIG. 9

21. Stepped-up brick footings having concrete bases, as shown in Figs. 3 and 4, are often used. The pyramidal form of stepped-up brickwork carries the load of the superstructure more evenly to the footings and reduces the risk of settlement or fracture; it is used very extensively for piers supporting iron columns. Nothing but good, hard, well-burned bricks should be used, and they should be laid in cement mortar and should break joints; that is, no two joints in successive courses should come directly over each other.

22. Footings on Rock and Gravel.—In placing foundation footings on rock, it is sometimes found that some portions of the footings will rest on the rock, and others, owing to the diversified character of the surface, will rest on clay, sand, or gravel. The settlement of the foundation walls—and as a necessary sequence, that of the whole building—will then be uneven, as the walls resting on the rock will not settle, while those resting on the sand, gravel, or

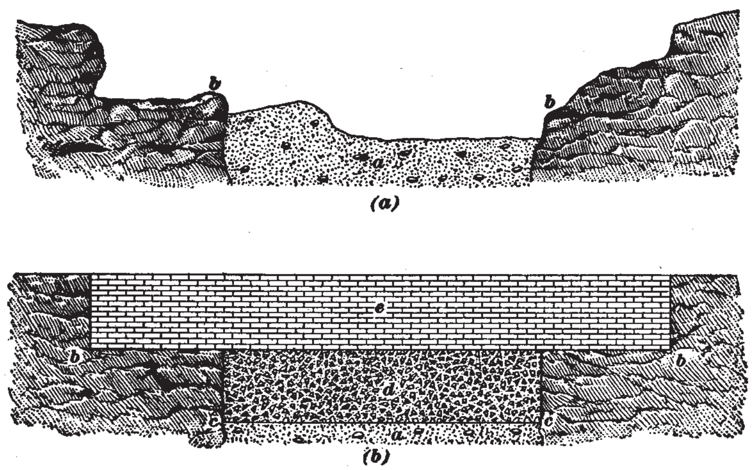


FIG. 10

clay will, by compressing the material on which they are carried.

Fig. 10 shows the method used to obtain equal settlement in this case. At (*a*) is shown the rock and gravel before leveling or excavating, *a* indicating the clay or sand, and *b*, the rock. It is customary to remove the rock to a certain level, as shown in (*b*). The softer soil *a* is then removed and leveled off, as at *c c*, and a bed of concrete about 3 feet thick, as shown at *d*, is then put down; the concrete is brought to the level of the rock and the brick or stone foundation wall *e* is built on it.

23. Footings for Piers.—The brick or stone piers or iron or wooden columns that support the timbers of the first floor should be set on concrete and stone or stepped-brick footings of sufficient area to support, without appreciable settlement, the weight that they will carry. Even more attention should be paid to these footings than to those of the foundation walls, since the piers carry the weight of the whole interior of the structure, including the floors, machinery, stock in process of manufacture, and live load, while the footings for the foundation walls support practically but little more than the actual weight of the mill walls. The piers are also subjected to a greater amount of vibration from the machinery than the foundation walls—an element that is peculiarly liable to produce excessive settlements. Vibration becomes an important factor where a large amount of weaving machinery is to be supported.

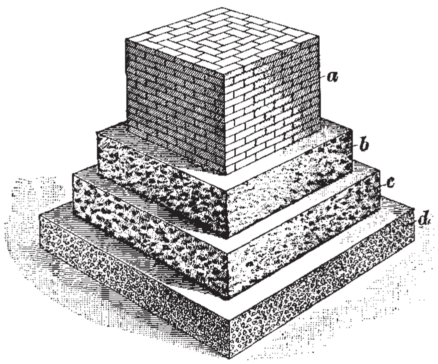


FIG. 11

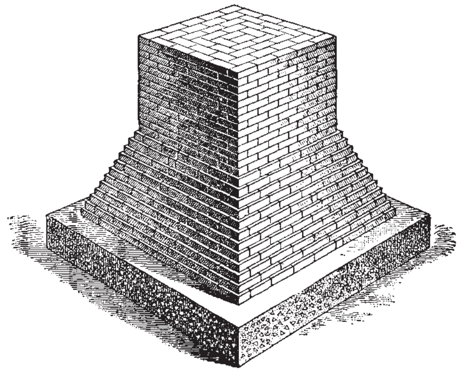


FIG. 12

Fig. 11 shows a brick pier *a* resting on a base stone *b*, which in turn is supported by a bedstone *c* resting on a thick bed of concrete *d* of sufficient area to carry the required load. In many cases only one stone is used between the pier and the concrete. When wooden or iron columns are supported in this manner, an iron plate should be let into the upper surface of the base stone *b* to give a true bearing for the column, as the load that can be safely carried will thereby be greatly increased.

Fig. 12 shows a brick pier resting on stepped brickwork and supported on a concrete base. Sometimes the concrete footing for piers is made to run the entire length of the mill, to insure sufficient bearing surface and thus do away with any settlement and prevent the soil squeezing up between the piers, as it sometimes does when heavy structures are supported on isolated piers.

PILING

24. Piling is an important branch of foundation work that, although not masonry work in itself, is yet, as a supporting structure, considered as pertaining to masonry construction. A *pile* may be considered as a column with a base more or less rigid, according to the nature of the soil into which it is driven. It is held in place by the pressure against its end and sides, just as a stick driven into damp sand will stand upright and support a load, even though it may not have reached firm bottom, the friction of the sand—or the pressure of its particles against the sides of the stick or pile—holding it in place. It is usual to excavate to a point below where the heads of the piles are to be cut off, in order that they may be leveled before the concrete is put in or the foundation begun.

Piles are usually driven by successive blows of a heavy block of wood or iron falling from a height. This block weighs from 1,200 to 2,000 pounds, and is called a *hammer*, *monkey*, or *ram*. It is raised by means of a rope or chain that passes over a pulley fixed on top of an upright frame, and falls between parallel guides directly on the head of the pile placed under it. The chain or rope is wound over a drum, which is driven by a small engine. After the hammer or ram is drawn up to the required height on the frame, it is released, and falls on the head of the pile, forcing it into the ground.

Piles are generally round and from 9 to 18 inches in diameter at the head, and should be straight and clear from bark and projecting limbs; but where piles are exposed to the rise and fall of tides, it is considered best to drive them with the bark on, since they are then not so easily affected by the action of sea-water, and are not likely to be attacked by the *teredo navalis* and other boring sea worms.

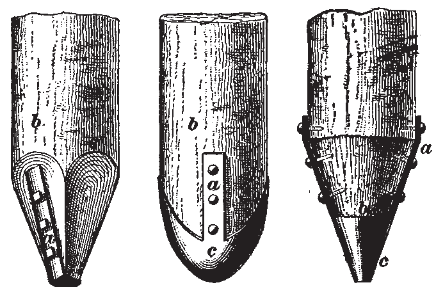
Oak, spruce, hard pine, cypress, and elm are the principal woods used for piling. Oak has the advantage of being hard and tough, and stands hammering well, but cannot be obtained in as large, straight, or long pieces as other woods.

Piles are prepared for driving by cutting or sawing the large end square and bringing the small end to a blunt point with an ax, the length of bevel being about 1½ or 2 feet. In very soft and silty material, however, they can be driven in better line if left blunt. A pointed pile on striking an obstruction, invariably glances off and is thrown out of line; the blunt pile, on the contrary, cuts or breaks through the obstruction.

The large end of the pile should be cut or chamfered for a few inches from the end, so that a wrought-iron ring about 1 inch thick and approximately 3 inches wide will fit over it tightly when struck one or two light taps by the hammer, or ram. Sometimes a ring from 1 to 1½ inches less in diameter than the pile is placed on the top of the pile, and driven into it by light blows; this, however, is not as desirable as the other method, as the ring is apt to split long pieces from the sides of the piles, and usually is not put on until the pile is more or less battered on the end, so that it is carelessly placed and is not concentric with the head of the pile. The rings lessen the tendency of the pile to split or *broom* from the repeated blows of the ram. This splintering of the fibers is known as *brooming*.

25. Shoeing Piles.—Piles driven through soft material have a tendency to split on reaching rock or hard gravel, thus greatly impairing their bearing capacity; to prevent this, their ends are often protected with wrought- or cast-iron shoes.

Fig. 13 illustrates three methods of doing this. At (*a*) is shown a $\frac{1}{2}'' \times 2\frac{1}{2}''$ wrought-iron strap *a* bolted to the pile *b*, forming a shoe that is the same on both sides of the pile. At (*b*) is shown a cast-iron conical shoe fitted over the end of the pile *b*; the head *c* protects the end of the pile and the straps *a* hold the shoe in place. Fig. 13, (*c*) shows one of the best forms of cast-iron shoes. The pile has a blunt end from 4 to 6 inches in diameter, shown at *b*, which the top of the solid conical point of the shoe *c* fits; the straps *a* extend up the sides of the pile, and are bolted or spiked to it, as shown. The straps and bolts hold the shoe in place, while the flat end of the pile receives the effect of the blow.



(*a*) (*b*) (*c*)

FIG. 13

26. Timber Footings on Piles.—For footing courses on pile foundations several methods are practiced. Fig. 14 shows a timber footing course, or capping, laid below the water level to prevent rotting. Heavy timbers *b* are spiked

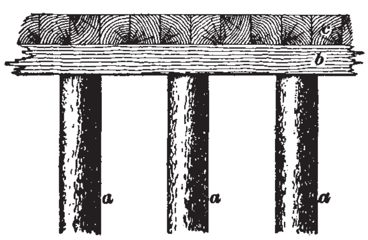


FIG. 14

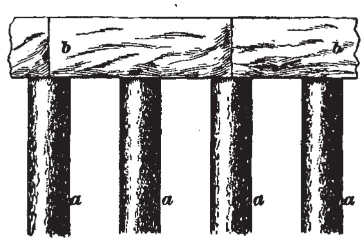


FIG. 15

longitudinally to the tops of the piles *a*, which are cut off at an even height, and the timbers *c* laid transversely on and secured to these. By this method the load is distributed evenly over the tops of the piles.

27. Stone Footings on Piles.—Fig. 15 illustrates footings made of large-sized building stone with level beds, *a* being the piles and *b* the building-stone footings. These stones must in every case rest directly on the piles. Great care must also be taken that one pile comes under each corner of the stone, to keep it from tipping, and that the stone has a full bearing on each pile head. To insure this, the piles must be sawed off perfectly level and all the same height, as no pieces of wood or small bits of stone should be placed under the stones to give them bearing on the piles; wooden chips crush under a load, and pieces of stone are likely to be broken or dislodged, leaving the block in a state of dangerous instability.

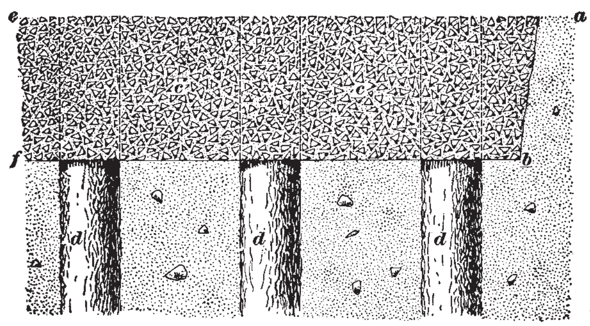


FIG. 16

In many cases concrete filling is used between the piles, as shown in Fig. 16. After the piles are cut off at the water level, which is shown at *a e*, the earth is excavated to *b f*, usually about 2 feet, and the space thus obtained is filled in with the concrete *c*, well rammed around the sides of the piles *d*, and leveled off at the top to carry the foundation walls. This method is best adapted to situations where the soil is constantly wet, as then the piles will not become dry and rot.

In some instances the piles are covered with 3-inch planking laid transversely on top of the concrete and the foundation walls built on this.

FOUNDATION WALLS

28. The **foundation walls** above the footing courses are usually of stone or brick. The method of building brick foundations is the same as for all brick walls; therefore it will not be described here, but will be taken up under Brickwork.

29. Thickness of Walls.—A very good rule for fixing the thickness of stone foundation walls is, that they shall be at least 8 inches thicker than the wall next above them, for a depth of 12 feet below the surface; and for every additional 10 feet or part thereof in depth, they should be increased 4 inches in thickness. Thus, if the first-story walls are 12 inches thick, the stone foundation walls should be 20 inches

TABLE II

THICKNESS OF FOUNDATION WALLS

Height of Mill	Brick Inches	Stone Inches
Two stories . . .	20	24
Three stories . . .	24	28
Four stories . . .	28	32
Five stories . . .	28	32
Six stories	32	36

thick for 12 feet in depth, and 24 inches thick if the depth is greater. The thickness of foundation walls in all large cities is controlled by building laws; where there are no existing laws, Table II will serve as a guide.

30. Stone-Rubble Foundation Walls.—Stone foundation walls below ground, when concealed from outside view, are usually constructed of rough rubble, as shown in Fig. 17, which represents an elevation (*a*) and section (*b*) of a 20-inch rubble stone wall, shown at *a*, 10 feet high, with footing stones *b*, 8 inches thick, and 2 feet 8 inches wide. These walls should be bonded together as shown in Fig. 18, where *a* shows a *bond stone*, or *header*, of the stone foundation wall *b*. All stone walls 24 inches or less in thickness should have a header extending through the wall at least every 3 feet in height and 4 feet in length; if the wall is over 24 inches in

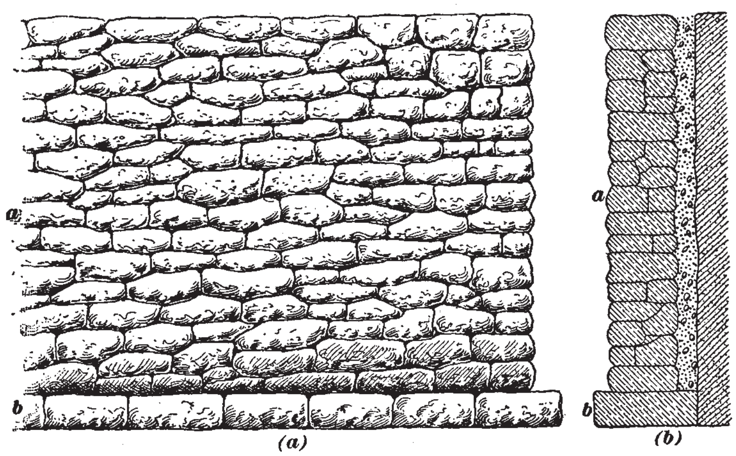


Fig. 17

width, one header should run into the wall at least 2 feet for every 6 superficial feet of wall space. These headers serve to bind the stones of the walls together and keep the foundation from splitting apart crosswise when weight is placed on it. They should not be less than 18 inches in width and 8 inches in thickness, and should be good, flat stones.

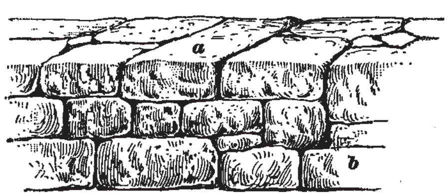


Fig. 18

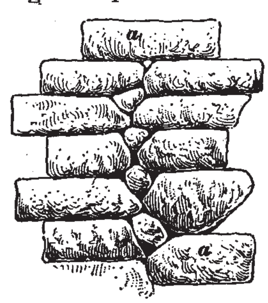


Fig. 19

Fig. 19, at *a*, *a*, shows vertical joints coming one above another through several successive outside courses; this should never be allowed, but the joints should be broken, as shown in Fig. 17. Where a long vertical joint occurs, the weight above may cause the wall to settle more on one side of the joint than on the other and produce serious rupture.

All wall angles should be well tied by long stones laid alternately, as shown at *a*, Fig. 20. By this means the weight on the corners of the wall is more equally distributed and the wall can be kept plumb and true.

Foundation stones should always be laid on their natural, or quarry, beds. The tendency to splitting, or cleavage, in a stone is with the grain or bed; so that when the stone is laid on the original bed, the weight of the material placed above it comes against its grain. No stone should have more face than bed, and one side, at least, should be reasonably flat. When laid, every stone should be well bedded in mortar.

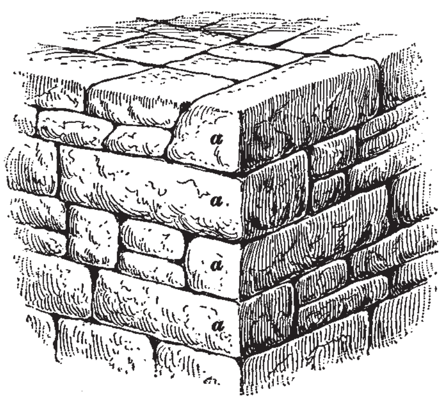


FIG. 20

31. The usual practice with masons in rough walling is, after setting the larger stones, to fill the interstices with spalls or chips of stone, or even pebbles, more or less carefully fitted, and put in dry; then to dash in mortar, trusting that it will work its way into the crevices. It does so to some extent, but the method is not a good one. A good, conscientious workman will place no stone, even the smallest chip, except in a bed of mortar prepared to receive it, rubbing it in well, and settling it with blows of the trowel and hammer; again driving smaller fragments into the mortar, which is squeezed up around it, so that all the stones have a layer of mortar between them.

It is a good plan to *grout* the walls; that is, fill all the joints with mortar made so thin that it will flow into the interstices, or spaces, between the stones.

For good work, the outside of the wall (even when concealed by the bank of the excavation) should be carried up with a good face, as shown in Figs. 17 and 20, and the joints well filled with either cement, or lime-and-cement mortar. If this is properly done, any moisture that runs out from the bank or descends from above, so as to flow down over the outer face of the wall, will drip off instead of running into the joints.

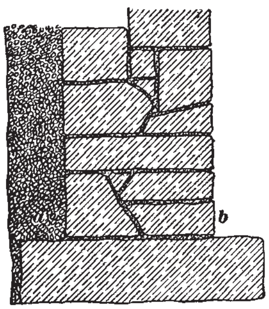


FIG. 21

The space between the outside of the foundation and the bank of the excavation should be filled in with gravel or sand (preferably the former) well packed down. Thus, in Fig. 21, *a* is the filling in the space between the foundation wall and the bank while *b* is the stone wall. This method makes the basement dry and warm, and keeps much of the moisture away from the foundation walls. Before filling the trench on the outside some engineers give the outside of the foundation wall two coats of hot tar to make it impervious to water.

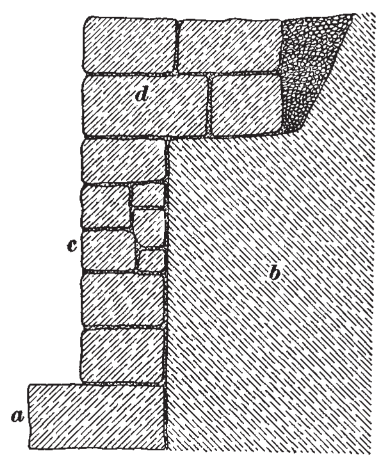


FIG. 22

32. Foundation Walls Partly on Rock.—A very faulty construction that is sometimes met with is that in which a portion of a ledge of rock projects into the foundation wall, so that the foundation is built partly on the rock and partly on the footing course. This is shown in Fig. 22, *a* being the footing course; *b*, the rock projecting into the foundation wall; *c*, the thin wall in front of the rock to bring the foundation to the thickness figured on the plans; and *d*, the wall of the building carried up to its full height and thickness, and resting partly on the thin wall *c*, and partly on the ledge of rock *b*.

In a wall so built, the water will find its way either through the imperceptible seams of the ledge of rock *b*, or over its top into the body of the masonry, keeping it constantly damp. Besides, there is a serious risk that under the heavy weight of the upper wall, the thin wall built against the ledge—but in no way bonded to it—will separate from it and fall away, leaving the superincumbent masonry most insecurely supported; moreover, a foundation wall, built partly on unyielding rock and partly on softer soil, will settle unequally and crack, perhaps injuring the masonry above, and, at least, opening an inlet for moisture. The ledge should be cut away so as to leave ample space for the whole thickness of the foundation walls down to the footings, with sufficient space between the wall and the ledge of rock for packing gravel, as shown at *a*, Fig. 21. This will intercept the water and carry it away from the wall.

MILL-BASEMENT CONSTRUCTION

33. A very good mill construction in cases where it is desired to obtain room for storage of stock or for mill processes in the basement, consists of excavating the cellar so that the basement floor will be about 5 feet below and the first floor about 7 feet above the surface of the ground. This construction admits of windows in the basement walls and makes a basement that can be utilized for the heavier types of machinery or for dyeing or other wet processes and also for those machines that require a solid foundation on account of vibration. The floor should be cemented; sometimes small, crushed stones or rubble are first laid down and the cement laid on top. The small stones or rubble are often filled with grout.

The pillars in the basement may be of wood if there is a good air circulation, and of iron or brick if the cellar is damp; in any case, care should be taken to have a solid foundation, since these pillars or piers support the entire weight of the floors, machinery, etc. that is above.

Fig. 23 shows a mill foundation of this construction; *a* is a thick bed, or footing, of concrete; *b*, a footing course of broad building stones; *c*, a stone foundation wall rising to the surface of the ground, and *d*, the brick wall of the mill; a_1 is a concrete footing for the brick pier c_1 that rests on a footing stone b_1 supported by the concrete footing. The basement floor is laid with a grouted layer of rubble *e* over which a cement floor *f* is laid. Where heavy machinery that

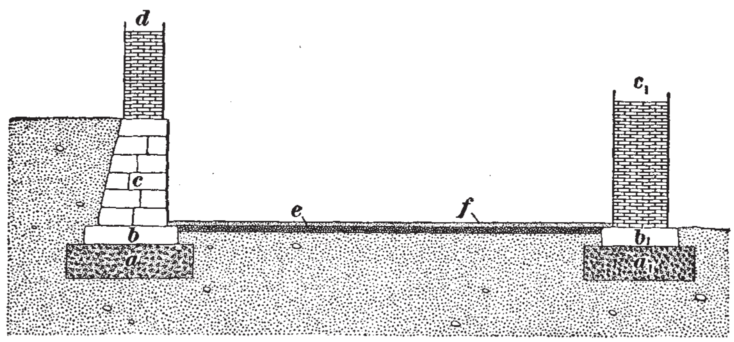


FIG. 23

must be lagged down is to be used in basements, the best practice is to place 8-inch timbers, to which the machinery may be fastened, on a solid foundation, and fill between them with well-rammed stones covered with coal-tar concrete to the level of the top of the timbers. In some cases a board or plank flooring is placed over the whole. It has been found that timbers set too closely confined in cement concrete will rot; therefore, the coal-tar concrete is recommended.

MORTAR

34. All foundation work, whether stone or brick, should be laid in **cement** or **cement-and-lime mortar.** If the soil is wet or damp, cement mortar should be used, but for ordinary purposes cement-and-lime mortar fulfils the requirements. For foundation walls above the ground and for the general wall construction of the mill good lime mortar may be used.

35. Cement Mortar.—Cement mortar, if made of Rosendale or any of the ordinary quick-setting, light cements, should be made in the proportion of three parts sand to one part cement; but if made of the heavy, slow-setting cements called Portland cements, may be made with four parts of sand to one part of cement. When mixing cement mortar, it is advisable that these parts should be actually measured in barrels. (It is a common practice with many builders to have one laborer shovel cement or lime, while three or four others are shoveling sand; this is a very unreliable method of measuring.) After the sand and cement are thrown on the platform, they must be thoroughly mixed by being shoveled together, at least twice, so that the cement may be thoroughly incorporated with the sand. (A little lime may be added in winter to prevent freezing.) Sufficient water is then added to make a stiff paste; the mortar must be immediately conveyed to the work and used, as the cement *sets*, or hardens, very rapidly, and when once hardened cannot be used again.

36. Lime Mortar.—Lime mortar is prepared in much the same way as pure cement mortar. A bed of sand is first made in a mortar box, and the lime is distributed as evenly as possible over it, both the lime and sand being first measured in order that the proportion specified may be obtained. The lime should then be slaked, by pouring on water, and covered with a layer of sand, or, preferably, a tarpaulin, to retain the vapor given off while the lime is being converted into hydrates of lime by action of the water; sand is then added, if necessary, until the mortar contains the proper proportions. The proportion of sand to lime usually specified and called for by the New York and Boston building laws, is three parts of sand to one part of lime. If, however, both the materials are of good quality; that is, if the lime slakes freely, becomes a fine, impalpable powder, resembling flour in texture, and perfectly free from foreign matter, and the sand is clean and sharp—one part of lime to four parts of sand is sufficient, but more sand than this is injurious. It is considered good practice to make lime mortar in large quantities, and then leave it in piles for use as it may be needed, after stirring and tempering.

37. Cement-and-Lime Mortar.—For this mortar, the cement, lime, and sand should be well mixed together, before water is added, as described for cement mortar. Cement-and-lime mortar should be used shortly after it has been mixed, before the cement sets.

BRICKWORK ABOVE THE FOUNDATION

BRICKS AND BRICKMAKING

38. The present American practice is to build the walls of the mill above the foundation of bricks laid in lime mortar, although in certain localities where large amounts of suitable stone may be obtained cheaply mills have been constructed of this material.

Bricks may be said to be artificial stones manufactured from a peculiar clay containing protoxide of iron, in regular and uniform shapes for convenience in laying. Other substances that form part of ordinary clay either do no good or are absolutely harmful; carbonate of lime, in any large quantity, renders the clay absolutely unfit for making brick. Sand or silica should not exist in any excessive quantity, as an excess of sand renders the brick too brittle and destroys cohesion; 25 per cent. of sand is considered a good proportion. The protoxide of iron in the clay causes the red color in the brick after burning, the color varying with the proportion of iron.

39. Hand-Made Brick.—Many of the common bricks, especially in the smaller towns and cities, are made by hand. The clay is thrown into a circular pit, where it is mixed with water and tempered with sand or ashes by means of a tempering wheel attached to a long lever and worked by horsepower. When soft and plastic, it is taken to the molding table and pressed into the molds by hand. The molds are dipped either in water (called *slop molding*) or in sand (called *dry molding*) to prevent the clay from adhering to the mold. The sand-molding process gives cleaner and sharper brick than the slop molding. After the bricks are shaped in the mold, they are laid in the sun or in a drying house for three or four days, after which they are stacked in kilns and *fired*.

40. Machine-made bricks, as their name implies, are made by machinery, the object of which is to facilitate the process of preparing the unburned bricks. There are several systems of preparing machine-made brick, but in general the results obtained by these processes are similar to those obtained by hand.

41. Burning the Brick.—When either the hand- or machine-made processes are used, the bricks, after drying, are built into a large mass, or kiln, containing from 100,000 to 300,000 bricks. *Eyes*, or flues, are left at the bottom as receptacles for fuel. The bricks are laid loosely together in order to allow the heat to pass in and around them. When ready, the fire is started, slowly at first, but afterwards increased to an intense heat; and after burning for a period, determined partly by the fuel used but mainly by experience, the fires are allowed to die out gradually.

The quality of the brick contained in a kiln that has been fired may be divided into four classes: First, the extreme outside brick, which are burnt so little that they are almost worthless. Second, a layer inside the above, in which the brick are underburnt and soft; these are called *pale*, or *salmon*, *brick*, and are unfit for foundation or face work, but are used for filling in between stud partitions, and sometimes between harder brick in the inside of walls, although their use for this purpose is not recommended. Third, a layer consisting of brick well-burned, hard, well shaped, and of a good red color; this brick is good for any purpose. Fourth, the brick in the inner layer and those just above the flues are overburnt, very hard, very brittle, and usually distorted, cracked, and even vitrified; they should not be used in any structure subject to shock, but are often used for paving brick.

42. Size of Bricks.—In the United States the size of bricks is not regulated by law, consequently the dimensions vary not only with the maker, but also with the locality. In the New England states, the average size of common brick is about $7\frac{3}{4}$ in. × $3\frac{3}{4}$ in. × $2\frac{1}{4}$ in.; New York and New Jersey bricks will run about 8 in. × 4 in. × $2\frac{1}{2}$ in., and the walls laid in them will run 8, 12, 16, and 20 inches in thickness for 1, $1\frac{1}{2}$, 2, and $2\frac{1}{2}$ bricks. Most of the Western common bricks measure $8\frac{1}{2}$ in. × $4\frac{1}{8}$ in. × $2\frac{1}{2}$ in., and the thickness of the walls measures about 9, 13, 18, and 22 inches for thicknesses of 1, $1\frac{1}{2}$, 2, and $2\frac{1}{2}$ bricks. On the seacoast of some of the Southern States, the bricks are made with a large percentage of sand, and will average 9 in. × $4\frac{1}{2}$ in. × 3 in.

43. Strength and Quality of Brick.—Whenever possible, the mill engineer should see that the bricks to be used meet the following requirements:

1. They should be sound, free from cracks or flaws, and from stones and lumps of any kind, especially pieces of lime.
2. They should be uniform in size, with sharp angles and edges, and the surfaces true and square to each other; this insures neat work.
3. Good building brick should be quite hard and well burned. A simple, and generally satisfactory test for common brick is to strike two of them together, or to strike one with the edge of a mason's trowel; if the brick gives a ringing sound it is generally sufficiently strong for any ordinary work. A dull sound shows it to be soft or shaky.
4. A good brick should not absorb more than one-tenth its weight in water. Weigh the brick, immerse it in water for 24 hours, and then weigh it again; from the increase in weight the percentage of water it has absorbed may be found. Very soft, underburned bricks often absorb from 25 to 35 per cent. of water; weak, light-red bricks, often used in filling the interior of walls, will absorb about 20 to 25 per cent.; while the very best brick may absorb not more than 5 per cent., and should, if possible, be used for outside walls and foundation walls and piers.

5. Bricks that are to be used for piers and the foundations of heavy buildings should not break under a crushing load of less than 4,000 pounds per square inch.

6. A good brick, 8 inches long, 4 inches wide, and $2\frac{1}{2}$ inches thick, should not break under a center load of less than 1,600 pounds, the brick lying flat, supported at each end only, and having a clear span of 6 inches, and a bearing at each end of 1 inch. A first-class brick will carry 2,250 pounds in the center and not break. Tests have been made with brick that carried 9,700 pounds before breaking.

THICKNESS OF BRICK WALLS

44. Before considering the actual construction of the brick walls of the mill, some attention should be paid to the thickness of walls for mill structures required by law. For this purpose, an extract is given from the building law of New York, relating to the thickness of brick walls in proportion to their height; as the laws of other cities do not vary materially from this, it can safely be taken as a standard.

"The walls of all warehouses, stores, factories, and stables 25 feet or less in width between walls shall not be less than 12 inches thick to the height of 40 feet (see Fig. 24).

"If over 40 feet in height and not over 60 feet, the walls shall not be less than 16 inches thick to the height of 40 feet or to the nearest tier of beams to that height; and thence not less than 12 inches to the top (see Fig. 25).

"If over 60 feet in height and not over 75 feet in height, the walls shall not be less than 20 inches to the height of 25 feet or to the nearest tier of beams to that height; and thence not less than 16 inches thick to the top (see Fig. 26).

"If over 75 feet in height and not over 85 feet in height, the walls shall not be less than 24 inches thick to the height of 20 feet, or to the nearest tier of beams to that height; thence not less than 20 inches thick to the height of 60 feet, or to the nearest tier of beams to that height; and thence not less than 16 inches thick to the top (see Fig. 27).

"If over 85 feet in height and not over 100 feet in height, the walls shall not be less than 28 inches thick to the height of 25 feet, or to the nearest tier of beams to that height; thence not less than 24 inches thick to the height of 50 feet, or to the nearest tier of beams to that height; thence not less than 20 inches thick to the height of 75 feet, or to the nearest tier of beams to that height; and thence not less than 16 inches to the top (see Fig. 28).

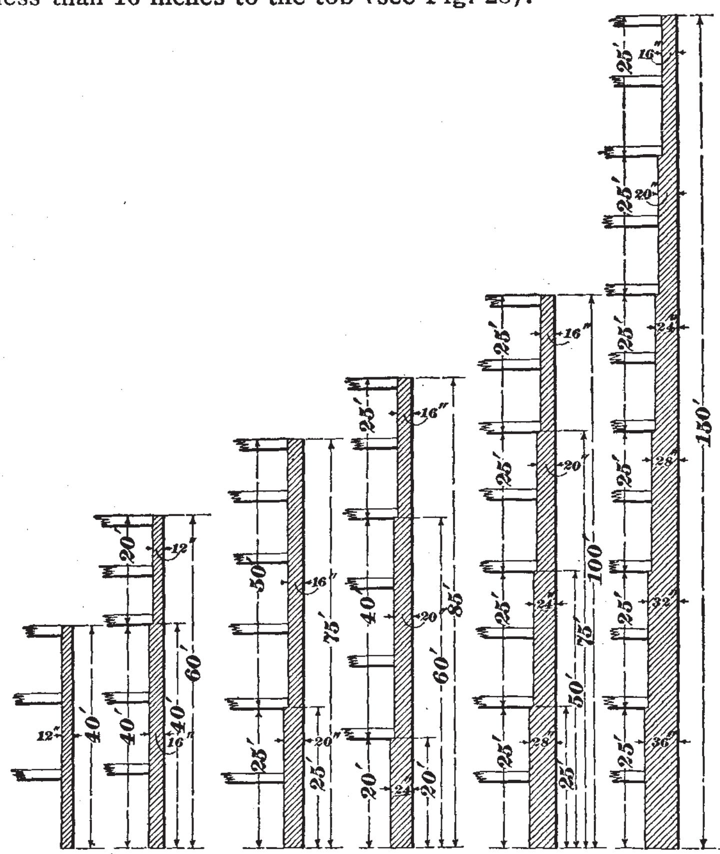


FIG 24 FIG. 25 FIG. 26 FIG. 27 FIG. 28 FIG. 29

"If over 100 feet in height, each additional 25 feet in height, or part thereof, next above the curb, shall be increased 4 inches in thickness, the upper 100 feet of wall remaining the same as specified for a wall of that height (see Fig. 29).

"If there is to be a clear span of over 25 feet between walls, the bearing walls shall be 4 inches more in thickness than is

TABLE III

THICKNESS OF MILL WALLS IN INCHES

Height of Building	City	Stories				
		First	Second	Third	*Fourth*	*Fifth*
Two stories	Boston . .	16	12			
	New York .	12	12			
	Chicago . .	12	12			
	Minneapolis	12	12			
	Memphis .	18	13			
	Denver . .	13	13			
Three stories	Boston . .	20	16	16		
	New York .	16	16	12		
	Chicago . .	16	12	12		
	Minneapolis	16	12	12		
	Memphis .	22½	18	13		
	Denver . .	17	13	13		
Four stories	Boston .	20	16	16	16	
	New York .	16	16	16	12	
	Chicago . .	20	16	16	12	
	Minneapolis	16	16	12	12	
	Memphis .	27	22½	18	13	
	Denver . .	21	17	13	13	
Five stories	Boston . .	20	20	20	20	16
	New York .	20	16	16	16	16
	Chicago . .	20	20	16	16	16
	Minneapolis	20	16	16	12	12
	Memphis .	31½	27	22½	18	13
	Denver . .	21	21	17	17	13

heretofore specified, for every 12½ feet, or fraction thereof, that said walls are more than 25 feet apart."

Table III gives the thickness of walls, in inches, required by law for mills, in the six cities mentioned.

The tops of the second-floor beams are taken as 19 feet above the surface of the ground, and the heights of the other stories are 13 feet 4 inches, including thickness of floors, as the New York and Boston laws give the height of the wall in feet and not in stories. The Chicago ordinances provide that the maximum heights of stories, in accordance with the thicknesses given in Table III, are 18 feet in the first, 15 feet in the second, 13 feet 6 inches in the third, and 12 feet above.

As the weight of textile machinery and the high speeds at which it is run has a tendency to produce an excessive vibration, the walls of textile mills are frequently made thicker than is required by the building laws. At times also large amounts of raw stock and finished goods are carried, so that the weight supported, per square foot of floor area, is probably greatly in excess of that in many other industries. Thus, a four-story textile mill intended to carry a large amount of machinery and stock might have walls 28, 24, 20, and 16 inches thick at each respective story. If the mill is to be extremely wide, the walls should be made 4 inches thicker at each story.

BRICKLAYING

45. To build any kind of a brick structure, so as to make a strong and durable piece of work, it is necessary to have a bed of mortar between the bricks; brickwork consists, therefore, of both bricks and mortar. The strength and durability of any piece of work will depend on the quality of the brick, the strength and quality of the mortar, the way in which the bricks are laid and bonded, and whether or not the bricks are wet or dry when laid.

The function of the mortar in brickwork is threefold: (1) To keep out moisture and, by filling all crevices, to prevent as far as possible excessive changes in temperature; (2) to unite the bricks into one mass; (3) to form a cushion to fill up any irregularities in the brick, and distribute the pressure evenly. The first object is best attained by grouting, or thoroughly flushing, the work; the second depends largely on the strength of the mortar; and the third is effected chiefly by the thickness of the joints.

Common brick should be laid in a bed of mortar at least $\frac{3}{16}$, and not more than $\frac{3}{8}$, inch thick. Every joint and space in the walls not occupied by other material should be filled with mortar. The best way to allow for the thickness of the mortar joint is to measure the height of eight courses of brick in the wall; this should not be more than 2 inches greater than eight tiers of the same brick laid dry, that is, without mortar. A *course* is a horizontal row of bricks plus the thickness of the mortar joint. As common brick is usually quite rough and uneven, it is not always easy to determine the thickness of a single joint, but the variations from the above rule, in any eight courses that may be selected, should be very slight.

46. The best method of building a brick wall in which each course consists of two outside courses and one inside, is as follows: The two outside courses are laid in mortar, spread with a trowel so as to form a bed for the brick to lie on. The bricks in each outside course are laid up against the last ones previously laid in that course after some mortar has been scraped against their adjoining sides. The brick to be laid is pressed into its place with a sliding motion, which forces the mortar to completely fill the joint. Having continued the outside courses of brick to an angle or opening, the space between the bricks should be filled with a bed of soft mortar, and the bricks of the inside course pressed into this mortar with a downward slanting motion, so as to press the mortar up into the joints; this method of laying is called *shoving*. If the mortar is not too stiff, and is thrown into the space between the inner and outer courses of brick with some force, it will completely fill the upper part of the joints in the inner course, previously laid, which were not filled by the shoving process. A brick wall laid in this way will be very strong and difficult to break down.

Another method of laying in the brick between the inside and outside courses in a wall is to spread a bed of mortar, and on this lay the dry brick. If the bricks are laid with open joints and thoroughly slushed up with mortar, it makes good work; but unless the workmen are carefully watched, the joints do not get filled with mortar, and the wall will not be as strong as when the bricks are *shoved*.

Some bricklayers lay the inside courses dry on a bed of mortar, as described in a previous paragraph, and then fill all the joints with very thin mortar; this is called *grouting*. No more mortar should be used than will fill all the joints. This method is not as good as the others because the thin mortar lacks cohesion, and does not bind the brick together as well as does stiffer and more tenacious mortar. Grouting should never be done in freezing weather; the mortar contains so much water that it freezes very readily and is then useless as a bond.

Bricks should be laid as clean as possible, and for well-appearing work the most nearly perfect and best-colored bricks should be reserved for the outside work. For the inside of the walls the color is not so important, but all unburnt, unsound, or badly misshaped bricks should be rejected.

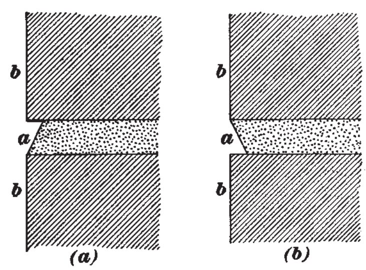


FIG. 30

47. Joints in Brickwork.—For inside walls that are to be plastered, the mortar projecting from the joints is merely cut off flush with the trowel. All outside and inside walls, where the bricks are left exposed, should have the joints *struck*, as shown in Fig. 30 (*a*), where *a* shows the mortar joint, and *b* the bricks in the wall. This *striking* the joint is done with the point of the trowel, which is held obliquely. This method makes the best job for outside work, as the water will not lodge in the joint and soak into the mortar, as it will when the joint is struck as shown in Fig. 30 (*b*). The second form, however, is easier to make.

For particular outside work where it is desired to give the walls a more finished appearance the joints instead of being struck are *jointed*. This is done as fast as a few courses are laid, with a blunt instrument known as a jointer, which is drawn along the joints, smoothing and slightly concaving the mortar.

48. Bricklaying in Extremely Hot or Cold Weather. Mortar, unless very thin, will not adhere to a dry, porous brick, because the brick robs the mortar of its moisture and therefore prevents the proper setting. On this account, bricks should never be laid dry, and in very hot, dry weather should be as wet as possible. When porous bricks are used this is of great importance in obtaining a strong wall. However, when the weather is not extremely hot, care should be taken not to make the bricks too wet, or they will keep the mortar soft and the increasing weight of the wall, as it is built, will be apt to throw it out of true. During long, wet periods the piles of bricks should be covered with boards or canvas in order to keep them from being soaked with water.

Brickwork should never be laid in lime mortar when the thermometer is below 32°, as freezing lime mortar unfits it for useful purposes, and work can never be done as economically in cold weather as at other times. Lime mortar is damaged when it alternately freezes and thaws. The sun shining on one side of the wall may cause the mortar to soften, while that on the other side will be frozen; this may cause serious damage by causing the wall to buckle. In constructing large buildings in winter, if one-fifth cement is added to the lime mortar, it will not be damaged by freezing. The surface of the bricks must be clean and free from frost, snow, and ice, when they are laid, or the mortar will not adhere to them.

Sometimes salt is mixed with the mortar to prevent it from freezing, but it is undesirable, as it usually causes *efflorescence*, or the white deposit often seen spread over a wall.

Portland cement mortar and Portland cement-and-lime mortars are not affected by changes in temperature.

BOND IN BRICKWORK

49. The proper construction of a brick wall involves many things besides the mere laying of one brick on top of another, with a bed of mortar between.

All corners and joints should be carefully plumbed, the courses of brickwork kept perfectly horizontal, which necessitates uniform mortar joints; the wall surfaces, both exterior and interior, must be kept in perfect alinement; and all walls must be carried up approximately together. All these conditions may be complied with, and yet the work may be imperfect; the merit of the brickwork must be judged by the thoroughness of its bond, both lengthwise and crosswise. This bond must be maintained by having every course perfectly horizontal, both longitudinally and transversely, as well as perfectly plumb. Aside from the quality and character of the material, the *bonding* of a wall contributes most of its strength.

50. Bond, in brickwork, is the arrangement of the bricks in such a way as to tie together all parts of the wall by means of the weight resting on the bricks, as well as by the adhesion of the mortar; and also for distributing the effects of the weight over an increased area. When the bricks are placed lengthwise on the face of the wall, as at *a*, Fig. 31, they are termed *stretchers;* when placed crosswise and their ends only exposed to view in the face of the wall, as at *b*, they are called *headers*. Bricks laid with their long axes in the direction of the length of the wall, or stretcher bricks, give the wall strength in the direction of its length, while header bricks, or those with their long axes laid across the wall, give it strength in a transverse direction.

To obtain the best results in bonding throughout the mass of the wall, strict attention must be given to the location of every joint in the brickwork. On the face of the wall, the vertical joints in each course throughout the height should be kept perpendicular, or directly over those in the second course below; this is called *keeping the perpends*. Unless the closest attention is paid, the lap is ultimately lost through irregularity of the brick and mortar joints, and extra *bats*, or *closers*, are necessary. The joints across the top of the wall should be kept in line, so that if the *perpends* are observed on one face of the wall, the other face will also work up correctly. Even when the wall is exposed only on one face, it is just as essential to have the joints on top of the wall kept in line, as otherwise its effective longitudinal bond will soon be lost, since at best the heading bond furnishes a lap of only 2 inches.

The importance of having the bond preserved in the whole wall can be understood by reference to Fig. 31, which repre-

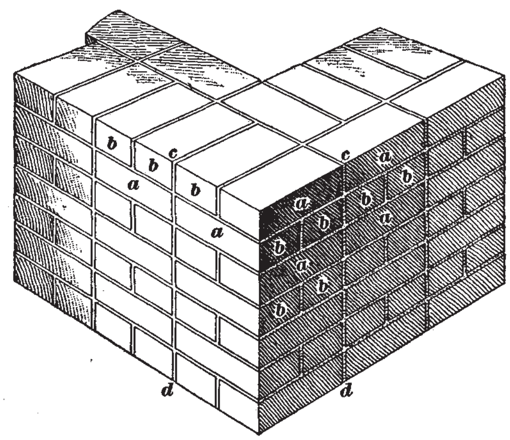


FIG. 31

sents a section of a wall consisting of alternate courses of stretchers and headers. By placing the brick as shown, no longitudinal bond exists and the wall is simply a series of isolated piers that join each other at the vertical lines *c d* and have no bond or union between them other than that obtained by the adhesion of the mortar. This method manifestly lacks strength and efficiency. In order to overcome this difficulty, and to secure a continuous bond in the length of the wall, recourse is had to a different arrangement of the bricks and to the use of blocks that vary in size from the ordinary brick. These blocks are called *closers*, the term meaning that they perfectly finish or close the length of the courses that have been adjusted to obtain the bond. The vertical joint that is shown at *c d*, Fig. 31, is avoided and no two adjacent courses have joints that are immediately over each other. The closers are made by cutting the bricks with a smart blow with the edge of the steel trowel into such blocks as the situation requires; these are called *bats* and are designated according to the proportion they bear to the whole brick.

51. The different bats, or closers, used in brickwork are shown in Fig. 32; (*a*) represents a whole brick of the usual size. When the brick is cut longitudinally on line *a b*, as

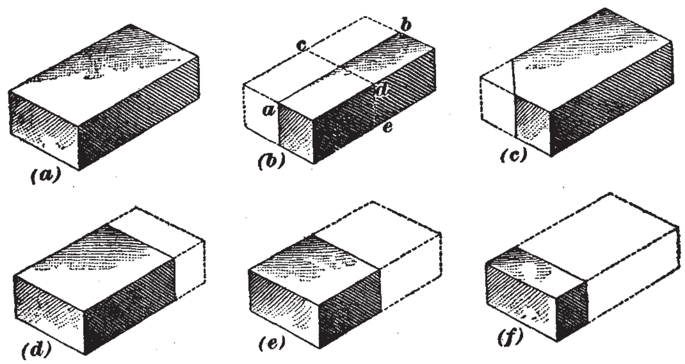


Fig. 32

at (*b*), each half is called a *queen closer;* but as it is difficult to cut the full length in this manner, the usual mode is first to cut the brick on the line *c d*, and then to cut each half on the line *a b*. When the brick is cut as at (*c*), it is called a *king closer*, and is a form well adapted for closers at door and window jambs, etc. When one-fourth of the whole length of the brick is cut off, as at (*d*), the remainder is called a *three-quarter bat;* and in like manner the portion remaining, as in (*e*), is called a *half bat;* and at (*f*), a *quarter bat.*

There are several methods of placing the bricks in the wall when closers are used to properly secure the lap, each method having its own name to indicate the kind of bond used. Assuming the wall to have the properties of a column, its bearing capacity will necessarily depend on the strength of its least dimension, which is its thickness, so that the bond that secures a thorough union of the constituent parts in this direction will always be the most desirable.

52. Heading Bond.—When all the courses present the ends of the bricks in the face of the wall, the wall will then be composed entirely of headers; this method, however, is only adapted for use in sharp-curved walls, as it possesses little longitudinal bond.

53. Stretching Bond.—When all the courses consist of stretchers, the wall formed should only be used for partitions that are but 4 inches in thickness; where the wall is thicker

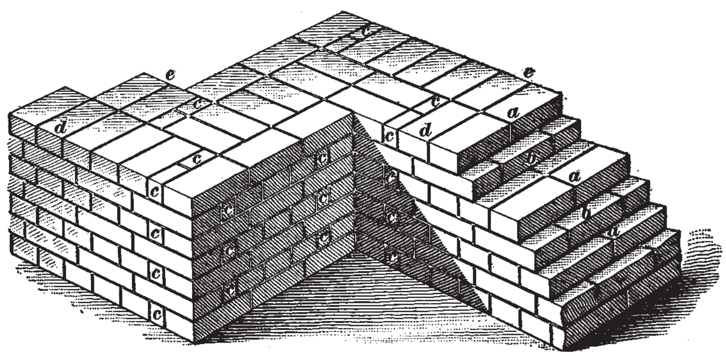


Fig. 33

than this, the method cannot be followed, as there will be no transverse bond whatever.

54. English Bond.—Though not much used in this country, this is probably the best and strongest method of bricklaying. A wall bonded by this system shows header and stretcher courses alternately, as shown in Fig. 33. The longitudinal bond is obtained by the use of quarter-bat closers *c* placed in alternate courses, as shown. This is without doubt the best and simplest method to follow in all work where strength is required, as by its use a complete and thorough transverse bond is procured. The heart of the wall consists entirely of heading bond, and the joints of the heading course, as at *a*, are well bonded by the headers of the stretching course as at *b*. The English bond can also be accomplished by the use of the three-quarter bats, and many authorities prefer them to quarter-bat closers, as by using three-quarter bats only one mortar joint is required in place of two.

An objection frequently urged against the appearance of the English bond on the face of the wall, is the recurrence of so many headers, which give the work the appearance of being constructed of so many tile-like blocks. The use of diminutive blocks of either brick or stone, in heavy walls, always tends to reduce the apparent strength of the structure, and it loses much of the effect of permanence, a very effective factor in good design.

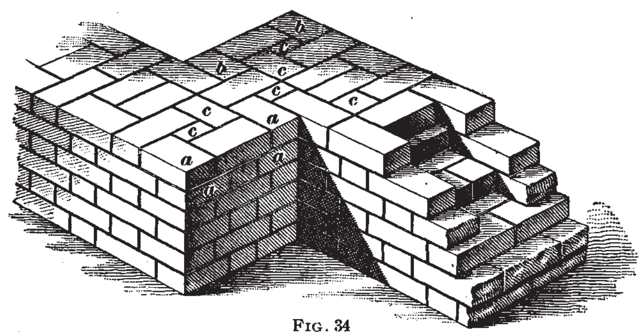


FIG. 34

55. The **Flemish bond** is used to overcome this belittling effect, as only two-thirds of the number of headers that occur in English bond are exposed, and each course is composed of a header and stretcher alternately. The method of laying brick in Flemish bond is shown in Fig. 34. The lap is obtained by the use of three-quarter bats, both at the external and internal angles of the wall, as shown at *a* on the external, and at *b* on the internal angles. The closers occur in the heart of the wall and are quarter, half, and three-quarter bats, as shown at *c*.

Owing to the headers and stretchers being placed on the inner side of the wall immediately opposite those on the outer face, both faces will appear exactly alike when thus arranged; the wall is then said to be built in *double Flemish bond.* Fig. 34 shows that only one-half of the body of the 4-inch thickness is bonded to the adjacent thickness; in other words, the upper bed of each face stretcher is only bound to the inner thickness by means of the width of one header; in this respect, the strength of wall is sacrificed for the sake of appearance. A vertical strip 2 inches wide occurs on each side of the face headers, that has no bond other than that of the adhesion of the mortar. To obviate this defect, the outer face is sometimes built in Flemish bond and the inner face in English bond.

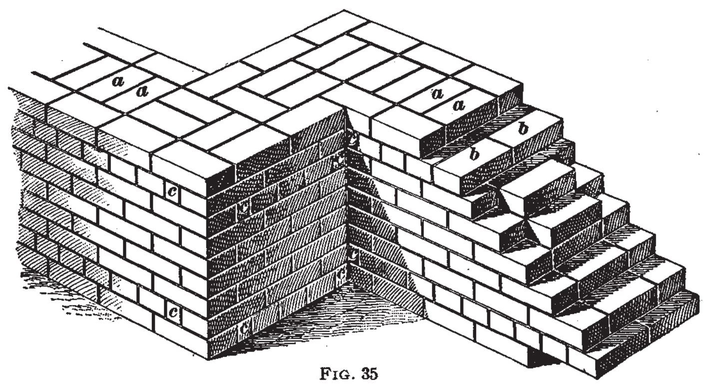


FIG. 35

56. Garden, or Running, Bond.—The bond most generally used in the United States is shown in Fig. 35. It enables the bricklayer to build a larger amount of wall in a given time than can be accomplished by the use of either the English or Flemish bond and is sometimes called *American bond.* It consists in laying from five to seven courses in height as stretchers, bonding with a row of headers at regular intervals. The longitudinal lap is secured by closers *c*, *c*; the heading course in the heart of the wall is shown at *a*, *a*, and bonds the heading course *b*, *b* exposed on the face. This is known as **garden,** or **running, bond.** Its principal defect is that the wall is practically composed of a series of 4-inch slices from $12\frac{1}{2}$ to $17\frac{1}{2}$ inches in height, that ordinarily have no transverse bond other than the mortar. It fulfils the requirements, however, if every joint throughout the body of the wall is well filled with good mortar, the vertical joints being well rammed with the edge of the trowel.

In mill structures it is customary to make every fifth or seventh course a header, or bonding, course, the former method making the stronger wall and the latter the quicker to build.

CARRYING UP THE WALLS

57. It is very important that the walls of a building should be carried up as evenly as possible, no wall being built more than 3 feet above the rest unless separated by an opening. If one part of a wall is built up ahead of another, unequal settlement is produced. The joints in the brickwork of the higher part will have set before the remainder has been added, consequently the work laid last is very likely to settle away from the other. This not only weakens the wall, but also mars its appearance. If it is absolutely necessary to carry one part of a wall higher than the rest, the end of the high part should be stepped, or *racked back*, and not run up vertically, with only toothings left to connect it with the rest of the work.

JOINING NEW WALLS TO OLD

58. In joining a new wall to an old, when the walls come at right angles, the new work should not be toothed or bonded into the old work, unless the new work is laid in cement mortar. All masonwork built with lime mortar will settle somewhat, owing to a slight compression of the mortar joints, and this settlement is apt to cause a crack where old and new work are bonded together. In place of toothing, or bonding, a groove should be cut perpendicularly in the old wall, usually the width of a brick, to make what is called a *slip joint*. This method of bonding is shown in Fig. 36; *a* is the groove, or chase cut, where the new wall is to enter in the old wall; *c* is the new wall, and *d* the old wall. The new wall has a series of bricks *b* that fit into the slot *a*.

In cheap construction, where new work is bonded into old, the method most commonly used is to nail a piece of 2″ × 4″ timber against the wall, as shown in Fig. 37, where *a* shows the 2″ × 4″ timber spiked to the old wall, and entering the center of the new wall; at *b* is shown the old, and at *c* the new wall.

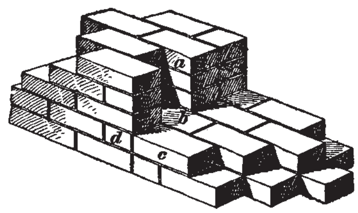


FIG. 36

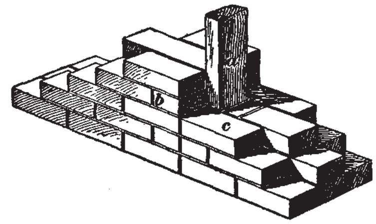


FIG. 37

The average settlement of brick walls where the foundation is stable and the mortar good is 1 inch in from 40 to 60 feet, or as some engineers reckon $\frac{1}{4}$ inch to the story. If a wall is built rapidly the settlement will be found to be much greater than if it is built slowly, since the weight is then put on the mortar before it has time to set.

OPENINGS IN BRICK WALLS

59. Openings for windows and doorways should be built into the walls where required. For their corners round-cornered bricks, or those molded with one corner rounded off, are appropriate, since they are not so easily defaced as square-cornered bricks. Segmental arches should be turned over the window frames and generally over doorways, although occasionally semicircular arches are used for doorways and other large openings. The two forms of arches used over the windows of mill structures are the *rowlock* and the *bonded arch*. In the **rowlock arch,** shown in Fig. 38, each course of bricks is turned independently, while in the **bonded arch,** shown in Fig. 39, the two courses are bonded together. The bonded arch is considered the stronger, but the rowlock arch is generally used as it is sufficiently strong for mill purposes and has the additional advantage of being easier to lay.

Arches should be laid with close joints, or the shrinkage of the mortar will cause the arch to crack and perhaps in extreme cases to drop out. They should not be laid too flat, or they will crack, especially if laid with thick joints.

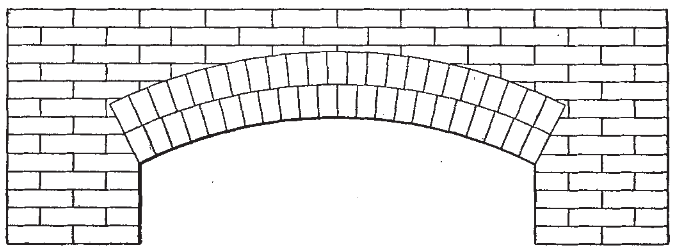


FIG. 38

The rise of any large arch should be at least one-sixth of the length of the span. It is laid with a center, or framework, that supports it while being laid, and which should not be removed, or *struck*, until the weight of the masonry above has been added.

A large arch with light abutment walls, that is, walls at each side, is liable to spread and crack. This may be prevented by embedding an iron rod, with a plate attached to each end, in the brickwork just above the arch. The use of iron in brickwork should be limited, however, not only because of the danger of its rusting, but also because the expansion of the iron pieces, when heated, is liable to crack the walls.

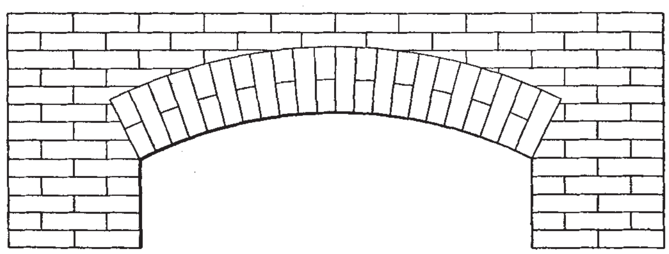


FIG. 39

BRICK PIERS

60. Brick piers are built in the same manner as brick walls. When less than 3 feet square and supporting a beam, girder, arch, column, or lintel carrying a wall, they should contain bond stones at least 4 inches thick, or cast-iron plates of sufficient strength and the full size of the piers, at least every 30 inches in height. In height, isolated brick piers should not exceed twelve times their least square dimension. The

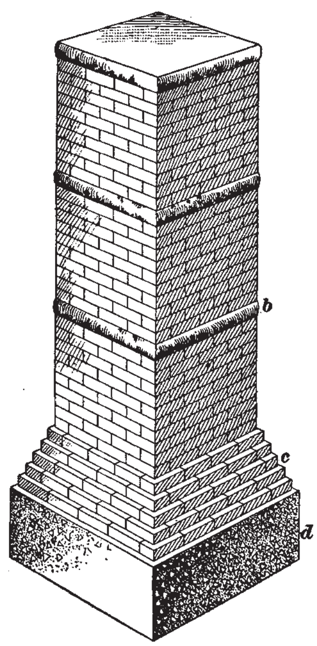


Fig. 40

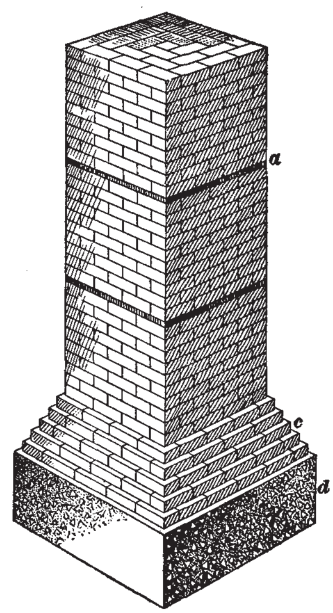


Fig. 41

object of bonding a pier carrying a heavy weight is to distribute the load over the whole area, thereby causing it to bear equally on each brick used in the construction. The bond stones should be either granite, bluestone, or one of the durable limestones. The blue Vermont marble is also used, but the softer sandstones and freestones should be avoided.

Fig. 40 shows a pier bonded with 4-inch bond stones *b*, a stepped-up brick foundation at *c*, and a concrete footing at *d*. Fig. 41 shows a brick pier with 1-inch iron bonding plates at *a*, and stepped up brick foundation and concrete footing at *c* and *d*.

FIRE-WALLS

61. Fire-walls are brick interior walls arranged to separate portions of the mill in which processes involving a greater risk of fire are carried on, from other portions of the mill. They should be carried down to secure foundations like the other walls of the mill and carried up through the roof, so as absolutely to intercept the progress of a fire and prevent its spreading and destroying the entire plant. They should contain as few openings as possible, and these should be thoroughly protected with automatic fire-doors, the construction of which will be explained later.

CHIMNEYS

62. If the boiler plant of the mill is to be equipped with forced- or induced-draft appliances, a comparatively short stack will suffice to carry off the smoke and gases incidental to the combustion of fuel beneath the boilers. If, however, natural draft is to be relied on, a **chimney** of sufficient height to insure the combustion of the fuel will be required. Iron stacks are occasionally used, but brick chimneys are to be preferred, since they are more stable and retain the heat of the gases to a greater extent, thereby increasing the draft of the flue. The footing for a brick chimney should consist of a bed of well-rammed concrete, at least 3 feet thick, of sufficient area to safely support the structure; this area will vary according to the size of the chimney and the character of the soil on which it rests. The foundation of the chimney may be either stone or stepped brickwork laid in cement mortar and resting on the concrete footing. The chimney should be built tapering and the top provided with an iron cap to prevent moisture from working into the brickwork and to prevent the topmost bricks from becoming loose and being blown off. A round chimney is to be preferred as it has only 55 per cent. of the wind pressure that a square chimney is subjected to and costs but little more to build. Fig. 42 (*a*) shows an elevation of a 106-foot chimney, while Fig. 42 (*b*) is a section showing the proportions of the brickwork and the diameter of the flue: *a* is a bed of concrete on which the foundation *b* is built; *c* is the outside wall of the chimney; *d*, the flue; *e*, an iron cap; and *f*, the opening at the bottom, which is connected with the boiler by an iron pipe.

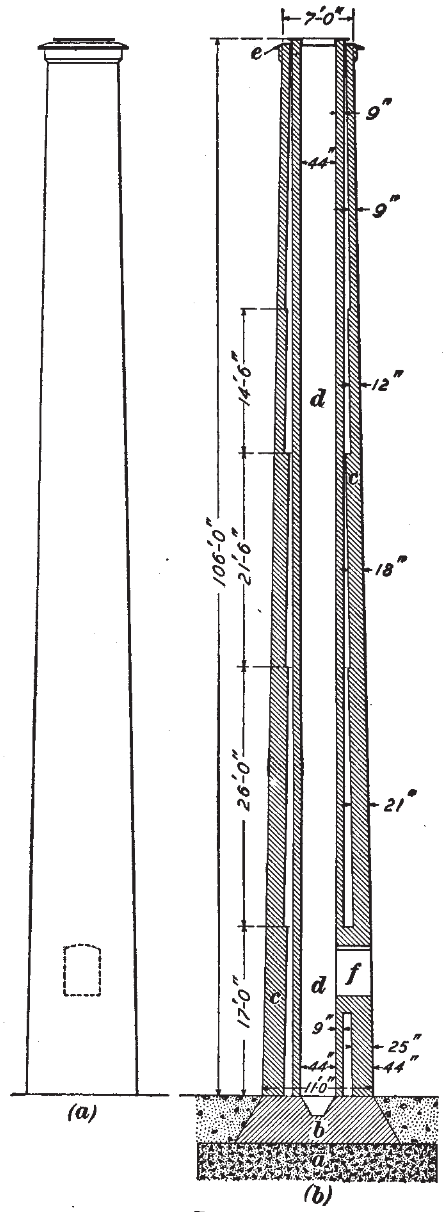


FIG. 42

MEASURING BRICKWORK

63. The method of measuring brickwork usually followed is by the thousand bricks as laid in the wall. Most mason contractors, in estimating on the cost of brickwork, take the entire superficial area of the wall in square feet, measuring it on the outside of the wall, so that the angles are taken twice. This is done to allow for the extra labor in laying up the angles. The bricks are then computed as laying $7\frac{1}{2}$ bricks to the square foot for a 4- or $4\frac{1}{2}$-inch wall, 15 for an 8- or 9-inch wall, $22\frac{1}{2}$ for a 12-inch wall, 30 for a 16-inch wall, and so on, adding $7\frac{1}{2}$ bricks per square foot for every additional thickness of 4-inch wall.

These figures apply to the Eastern and New England states. In the West and South, the bricks are larger, and give from one-quarter to one-third less bricks per square foot in the wall than in the East, and the price is regulated accordingly. In some parts of the West and South two measurements are used; the first, or *kiln count*, represents the actual number of bricks purchased and used, while the second, or *wall measure*, designates the number of brick in the wall, estimating $22\frac{1}{2}$ bricks to every superficial foot of 12-inch wall.

Among some builders the custom prevails to reduce all brickwork to cubic feet and estimate in that way; as for example, a wall 24 feet long, 12 feet high, and 20 inches thick will contain 24 feet $\times$ 12 feet $\times$ 1 foot 8 inches = 480 cubic feet, at $22\frac{1}{2}$ bricks per cubic foot equals 10,800 bricks.

When estimating the amount of brick required for a mill, from 2 to 3 per cent. should be added for outside walls; on inside work, or other work where many bricks must be broken, from 4 to 5 per cent. should be added, in order that no shortage will be occasioned by bricks that should be rejected.

A first-class mason well tended, that is, well supplied with brick and mortar, should easily lay from 1,000 to 1,200 bricks per day on outside work, and on inside work, or as it is sometimes known *backing-up* or *filling-in*, from 1,500 to 2,000 bricks. On less particular work, such as the massive work necessary for engine beds, etc., a good mason will often lay 3,000 and even 4,000 bricks per day of 8 hours. The weight of brickwork laid as explained is about 125 pounds to the cubic foot.

Where the size of the structure being built is sufficient to warrant it, a brickwork inspector, preferably a practical mason, should be employed to inspect all brickwork and see that it is properly laid. Of course on small buildings this is not practical and the engineer must keep an eye on this himself.

STONE TRIMMINGS

64. In all structures, a certain amount of stone is laid in connection with the brickwork. In mills this stonework is ordinarily confined to door and window sills, steps, and other minor parts, and is known as **stone trimmings.** Window sills, especially, should be a single stone let into the wall 3 or 4 inches on each side and extending under the window frame far enough to prevent water from working into the wall. If the window sill is made of brick, the rain water will soak into the wall and weaken it. If of cut stone, window sills should have a bevel, or wash, to throw the water from the wall; if a window sill is simply quarry-faced, it should be set so as to utilize whatever natural bevel there is to the stone. All stone should be laid in cement mortar.

Granite is the best stone to use in mill work, and as economy and an appearance of solidity are desired, it should not be too smoothly finished. For steps and door sills six-cut work is often used, while window sills are appropriate if simply quarry-faced. Occasionally a date stone or keystone for a large arch must have a smooth surface, in which case a ten-cut stone should be used.

The terms *quarry-faced*, *four-cut*, *six-cut*, etc. when applied to stone work refer to the method of cutting and finishing the stone. A **quarry-faced stone** is one that is left rough, just as it comes from the quarry. Sometimes the edges of the stone are pitched off to a line. Quarry-faced stones are also called *rock-faced* and *pitch-faced* work. The terms **four-cut, six-cut, eight-cut,** etc. indicate the degrees of smoothness of the face of a stone obtained by hammering and other finishing processes. A six-cut stone is smoother than a four-cut stone, and an eight-cut stone has a finer surface than a six-cut stone, etc.

It is not recommended that granite lintels be used over windows and doorways, as brick arches are a much better construction for mill purposes and more efficient where the weight of the wall above is to be supported. The different qualities of granite vary somewhat in hardness, but as the cost of cutting depends on the hardness, it is unwise to select stone any harder than is necessary. All granite, some kinds to a greater extent than others, has a tendency when exposed to heat and water to flake off, or *exfoliate*. Occasionally a granite bond is run entirely around the mill, either at the ground level or at the level of the first or second story, the wall being offset from the outside instead of from the inside to form a ledge for the stones to rest on. This of course is a little different from the ordinary mill construction, where the walls are perpendicular on the outside, and is done for purely ornamental purposes.

INTERIOR CONSTRUCTION

SLOW-BURNING CONSTRUCTION

65. Ordinarily in the interior construction of a building a large number of small pieces, such as floor timbers, studs, braces, etc. are used, which burn rapidly and fiercely when once a fire is started, while the spaces between the beams and studs form flues that give draft to the fire and rapidly spread it throughout the structure. In a mill constructed in this manner a fire rapidly consumes the floors and allows the heavy machinery to crash to the basement and destroy the whole structure. To avoid this destruction modern mills are constructed on what is known as the **slow-burning construction.**

The fundamental principle of this construction is the omission or alteration of every detail that would tend to make combustion rapid or easy. The beams, columns, etc. are so proportioned that they retain strength enough to do the work required of them even after one-third of their bulk has been charred or burned. Instead of a large number of small pieces, a small number of very large pieces are used.

The ultimate objects of this construction may be summed up as follows: To make the mill strong enough to stand any ordinary stress, even after its timbers are partly burned; to make the floor so tight and strong that when a fire starts in one story, the water poured in to quench it will not run through and ruin goods on the floor below; to avoid any corners, pockets, or flues where a fire could get started without being immediately discovered; and, above all, to provide a building where every part is easily accessible and a fire can be attacked and extinguished at close quarters without flooding the entire structure.

66. The details of this construction can best be understood by referring to Fig. 43, which is a perspective view of a portion of a two-story mill with a basement constructed on the slow-burning principle. In this figure, a is the stone foundation wall and b the brick walls of the mill. Brick piers a_1 support the first-floor timbers c, which are $12'' \times 16''$ Georgia pine. Resting on each pier is a cast-iron pintle d that supports a 10-inch, round, Georgia pine column e that carries the second-floor timbers f. Placed on each column e is an iron cap on which rests a pintle d_1 that supports a column e_1 that carries the roof timbers g. The outside ends of the floor and roof timbers are supported by the brick walls of the mill.

In mill work the *span*, or distance between the walls and columns or between the centers of the columns measured across the mill, is usually 25 feet or thereabouts, while the *bay*, or distance between the centers of the piers or columns measured lengthwise of the mill, is usually 8, 10, or 12 feet, although the latter is unusual. The construction of the mill is spoken of as an 8-foot bay or a 10-foot bay construction, etc.

Sometimes the floor timbers vary in size, becoming smaller at each story, but as a general rule it is better to make the floor and roof timbers the same size throughout the mill. The same is true of the columns, which are sometimes made of a smaller diameter in the top stories than in the lower.

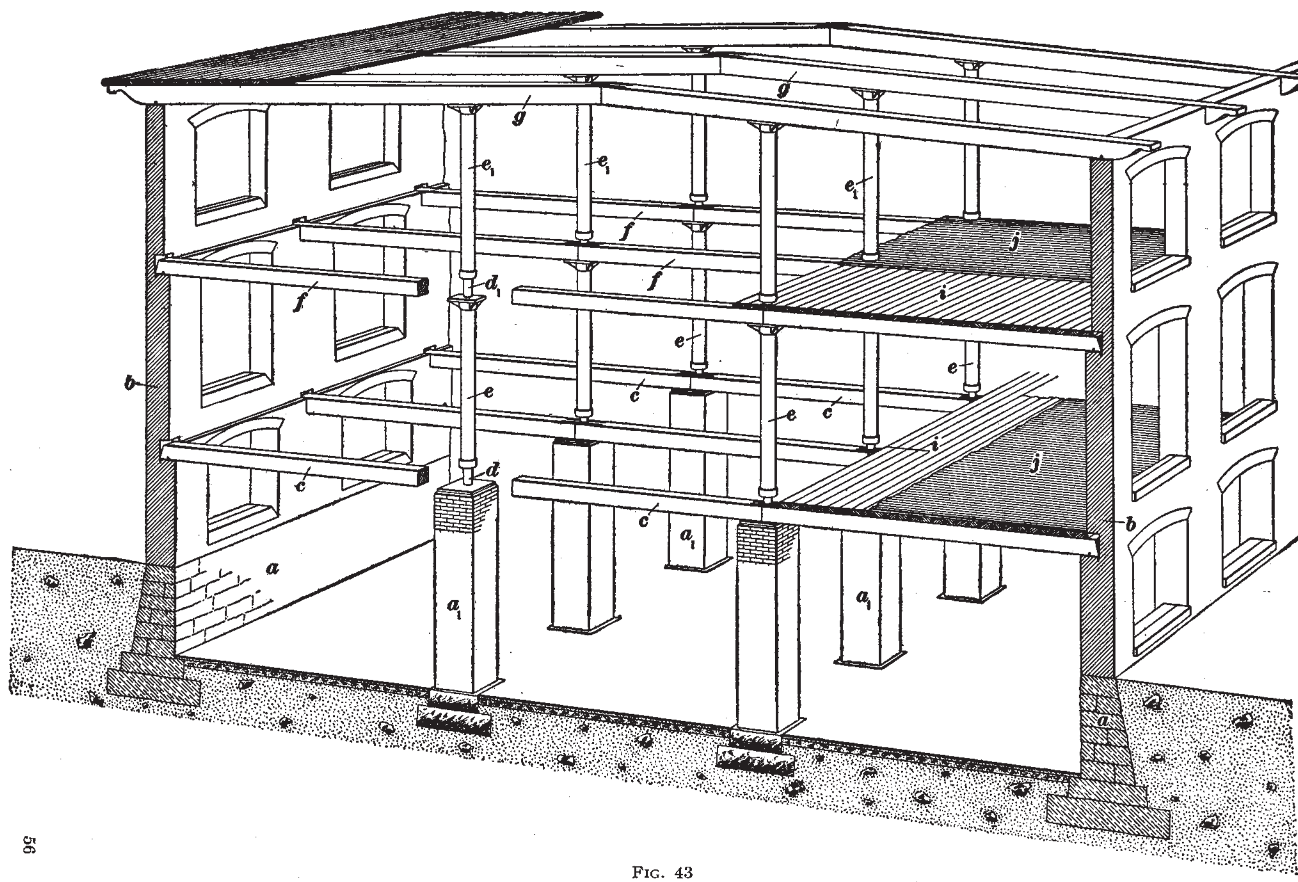


Fig. 43

67. Floor Work.—The floors of a mill are supported by wooden or iron columns, or in the case of the first floor usually by brick piers. Fig. 44 shows the method of supporting the first-floor timbers on a brick pier a_1. A base d_3, in which the column e that supports the second-floor timbers rests, is cast in one piece with a pintle d that rests on an iron plate or cap d_2 placed on the pier. As the pintle d is shaped like a cross, the floor timbers c, c are fashioned to fit around it. Occasionally a round pintle having a hole through the center is used, in which case a half-round groove is made in the end of each floor timber. In order to hold the floor timbers firmly together and to preserve the continuity of the bond between the two walls of the mill, they are fastened together by means of dogs k; these are made of $\frac{3}{4}$- or 1-inch wrought iron and are about 2 feet long after bending, each end being turned up, nearly, but not quite, at right angles to the bar. The bent ends are driven into holes in the tops of the timbers, and since they are bent not quite at right angles, draw the timbers together as they are driven in. The bent portion of the dog is usually from 2 to 3 inches in length, and holes of corresponding depth are bored in the floor timbers. Two of these dogs are generally used at each junction of the floor timbers, one being placed on each side of the pintle.

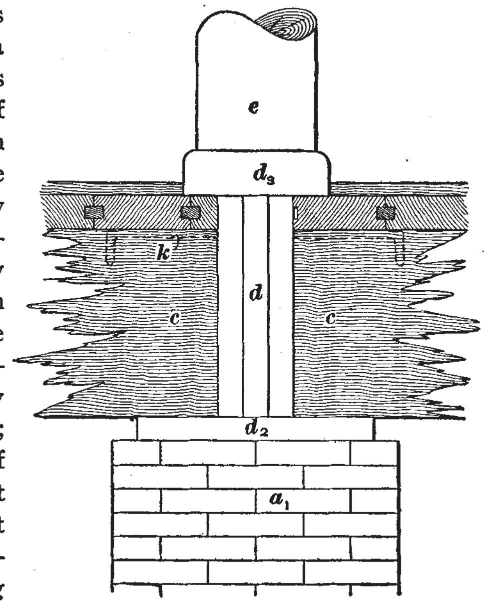


FIG. 44

Fig. 45 shows the method of supporting the floor timbers by means of a wooden column. The column e_1 that supports the floor above, or the roof, rests in a base d_3 that is cast in one piece with the pintle d_1 that rests on a cap d_2 placed on the column e. The pintle shown in Fig. 45 is round in section, while that shown in Fig. 44 is cross-shaped in section. The floor timbers f, f rest on the cap d_2 and are bonded together by dogs k, k, as in the previous instance.

The ends of the floor timbers that are laid into the walls of the mill are beveled off and rest on an iron anchor h built into

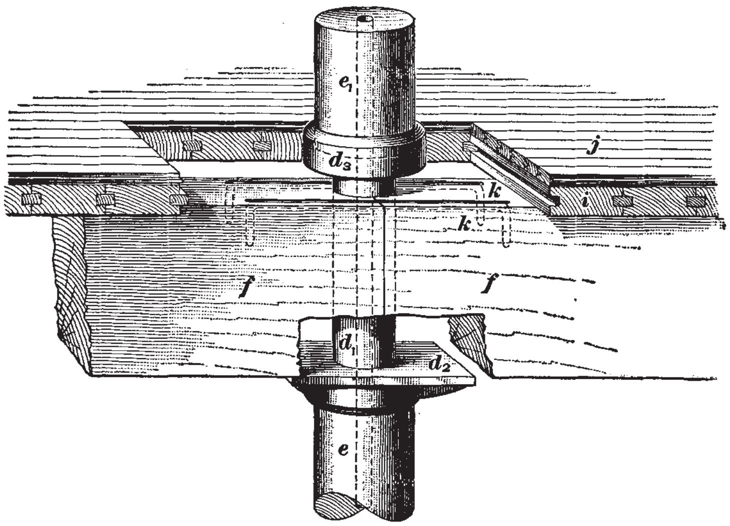


FIG. 45

the brickwork, as shown in Fig. 46. This anchor has a projecting flange extending into the brickwork and a flange that engages with a groove cut in the bottom of the floor timber. This groove is sometimes wide enough for a wedge to be driven in between the side of the groove and the projecting flange to bind the timber tight, but this is not always done. This projecting flange serves to anchor, or tie, the timber to the wall; and as the timbers are tied together by iron dogs, the walls of the mill are securely bonded together. The anchor shown in Fig. 46 is used because the beam, should it become burned through at its center and fall down, can easily fall out of the wall without disturbing the brickwork and thereby endanger the stability of the wall. The advantage of this is illustrated in Fig. 47, where (*a*) shows a perspective view of a beam falling from a wall to which it has been securely anchored by an ordinary type of anchor, such as is bolted to the beam, while at (*b*) the beam is seated on a cast-iron anchor similar to that described in connection with Fig. 46, from which it can fall without damaging the wall in any way, and it leaves the anchor intact to receive a new beam when repairs are made. In order that this arrangement shall work perfectly, sufficient clearance must be left for the end of the timber to cant out of the wall without striking the brickwork.

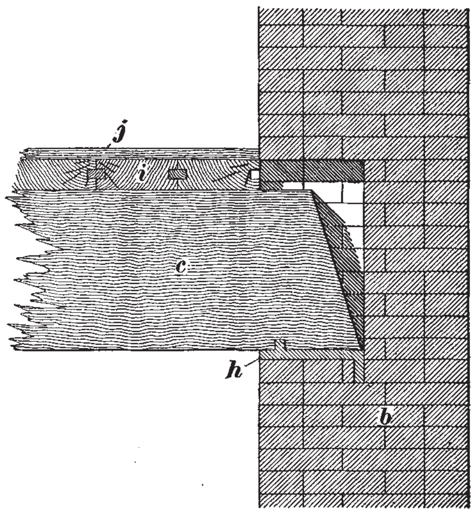


FIG. 46

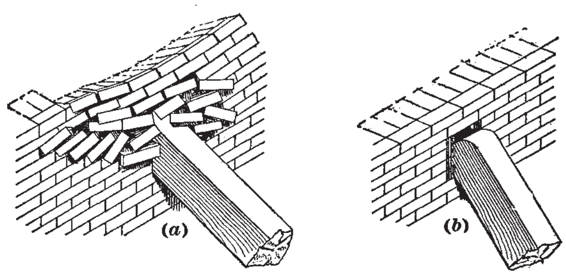


FIG. 47

68. On top of the floor timbers a double floor is laid, as shown in Fig. 43, the first floor consisting usually of 3-inch splined spruce planks *i*, although a thickness of 4 inches is sometimes used and in some cases pine is the material. These planks are usually 6, 8, or 10 inches in width. The second course usually consists of a $1\frac{1}{4}$-inch hardwood floor *j*, preferably of maple, the individual boards being $3\frac{1}{2}$ inches in width and tongued and grooved so as to be matched together.

Splined planks have a groove cut in each edge into which a spline is driven. Thus they serve the same purpose as though tongued and grooved, and are cheaper because there is not so much timber wasted in cutting them. They should be planed on one side and should be long enough to span two bays; that is, 16, 20, or 24 feet, as the case may be. By this means the joints can be broken on the timbers and the strength greatly increased when laying them. About 6-inch spikes should be used in fastening them to the timbers; one keg of 100 pounds will lay about 1,400 square feet of floor.

Between the plank and hardwood floors one or two thicknesses of building paper, or in some cases asbestos felt, is usually laid. The strips of paper should be lapped one-half their width, and make a tight floor through which dirt and dust cannot sift and fall into the bearings of the machinery below and one which is also practically waterproof. A water-tight floor is a great advantage in cases where a fire occurs and is confined to one room.

In some cases a layer of mortar $\frac{3}{4}$ inch thick is spread over the planking and the top floor laid on this. The idea is to make a fireproof construction, but as the mortar crumbles and sifts through the floor, and as its presence is undesirable when repairing the floor or in cutting belt holes, this practice is not to be recommended.

The top floor should be laid across the plank floor, in order to give the mill stiffness and solidity. Its boards are generally laid at an angle of 90° with the bottom planks, but are sometimes laid at an angle of 45°, although this is not advisable, as it is much more difficult to repair worn portions of the floor.

69. The maximum weights per square foot of floor area that textile mill structures are liable to be called on to support are given in Table IV.

In actual practice, the floor pressure of textile mills is rarely more than an average of 25 pounds per square foot over the entire mill; the weight of the floor itself, however, is about 20 pounds per square foot. Storage, shipping, and finishing rooms are generally loaded much more heavily than the other rooms of a mill.

70. Columns.—Engineers have arrived at no definite conclusion in regard to the relative merits of iron and wooden columns. The iron columns, of course, take up less space and hence have a much neater appearance and also

TABLE IV

Type of Structure	Weight per Square Foot Pounds
Cotton mill	50
Woolen mill	50
Worsted mill	60
Storehouse for cotton	150
Storehouse for loose wools	100
Storehouse for baled wools	150
Storehouse for woolen cloth (2 cases high)	150
Storehouse for worsted cloth (2 cases high)	200
Storehouse for machinery	200

make the rooms lighter. To offset this they are untrustworthy in case of a fire, as when they become heated if struck by a stream of cold water they immediately crack and collapse, thus letting down the floors above and rendering the damage much more extensive, since if they had remained intact, the fire might possibly have been confined to one room. Wooden columns, when exposed to fire, char on the outside for a depth of 2 or 3 inches; this charred portion seems to protect the rest of the column from burning. In damp places, however, wooden columns are not to be recommended; either iron columns or brick piers should be used.

Wooden columns, although necessarily much larger, are much more to be depended on, as they usually give evidence, by cracking or by the fibers breaking down before giving away. Iron columns are liable to contain flaws, and their section tends to be irregular; thus they are liable to give away without warning.

The best material for wooden columns is Southern pine, which can be obtained straight-grained and free from knots and seams. Oak is not as reliable as Southern pine, as it is apt to be knotty and the grain uneven, causing the column to warp in seasoning. Wooden columns should not be painted until thoroughly seasoned; otherwise, they are much more liable to rot.

Columns are bored in order to remove the heart of the tree, which has no particular strength and is subject to dry rot. An 8-inch column should have about a $1\frac{1}{2}$-inch hole bored through it, this being done from one end only; sometimes with larger columns a 2-inch hole is bored. The reason for not boring a hole in each end is that it is almost impossible to make the two holes meet exactly, and thus the section of the column at some point is liable to be reduced in area. A $\frac{1}{2}$-inch air hole should be bored at the top and is also recommended at the bottom of the column, in order to give free circulation of air, which is necessary to prevent dry rot. Care should be taken to have not only columns but all timbers in a good air circulation, as timbers in confined spaces are subject to dry rot, which will sometimes totally destroy the timber in a short time.

Although cast-iron columns are not recommended in fireproof constructions or in textile structures, they are found in many mills and in some cases are indispensable. The great difficulty with cast-iron columns is not so much in flaws in the metal as unevenness of section, caused by the cores floating when the column is cast. This is liable to make the column very thin on one side, and consequently extremely unreliable. All cast-iron columns should be tested with a pair of long calipers before being used, in order that it may be determined whether the section is uniform or not.

Care should also be taken that the ends of a column are square with its axis. In the mill under consideration round wooden columns are used, the round column having more resistance to fire than the square column. If square columns are to be used in mill construction, the corners should be chamfered so that they will not become defaced from contact with trucks, etc. For the same thickness, a square column is stronger than a round one, but round ones are generally used in textile mill buildings.

71. Roof Work.—For textile mills the so-called *flat roof*, shown in Fig. 43, having a pitch of only $\frac{1}{2}$ inch to the foot for drainage, is most appropriate. It is supported by timbers exactly the same as the floor timbers of the mill except for this pitch; that is, they rest on a cast-iron cap placed on wooden columns, the cap being secured to the timbers either by projecting flanges that enter slots in the timbers or by being bolted to them. The roof timbers should be covered with about 3-inch white-pine planks, rough on the upper side and planed on the lower. The planks should be 6 or 8 inches in width and grooved to be fitted with splines. They may be heavily beaded on each edge and in the center of each plank on the under side, in order to give the appearance of sheathing, if so desired. They should be the length of two bays and laid so as to break joints, as were the floor planks.

The so-called *gravel roof* five- or six-ply in thickness is recommended for mill structures. It is made as follows: Three thicknesses of tarred paper are laid so that each layer overlaps the one underneath it one-third of its width; this should be tacked down with $1\frac{1}{2}$-inch nails and $1\frac{1}{4}$-inch tin washers about every 2 feet. It is covered with a thin layer of hot coal-tar and then with two or three thicknesses of the tarred paper, depending on whether it is five- or six-ply roofing. Over this another layer of hot tar is placed and clean gravel spread over the whole roof. This makes a very durable roof and one that is largely used for protection from rain and snow.

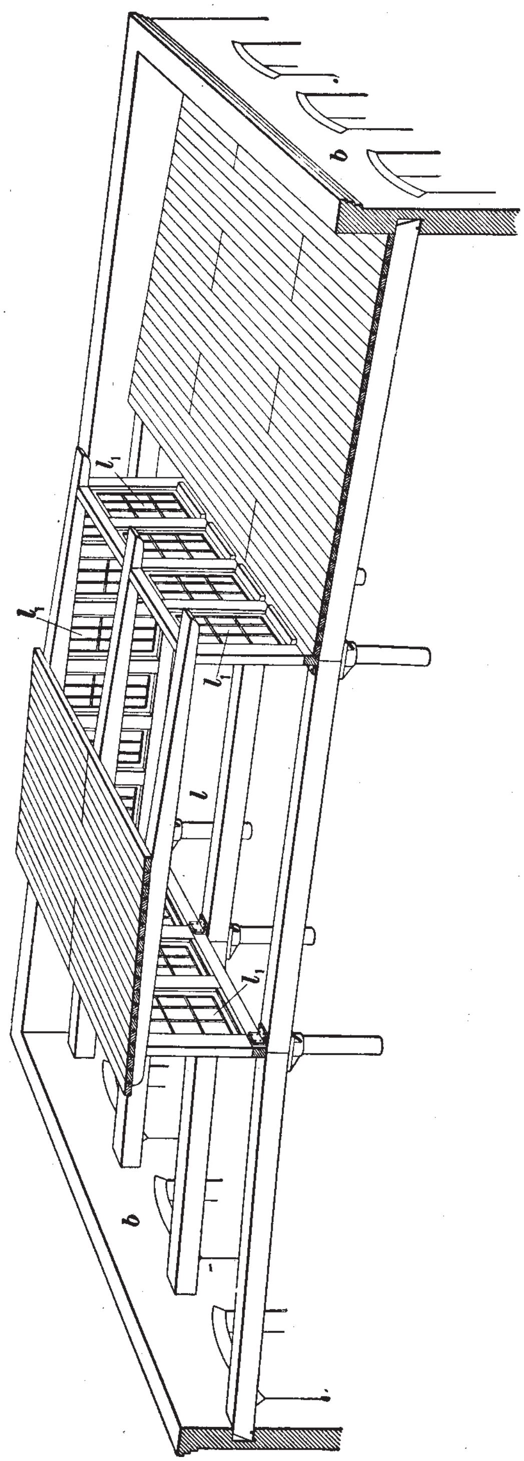


FIG. 48

Another roof that is very durable and that is often used is the *tin roof*. For it the planks are first covered with three thicknesses of tarred paper the same as for gravel roofs; over this a layer of tin with waterproof joints is laid, and afterwards painted.

72. When the mill is more than 50 feet in width it is advisable that a **monitor** be built in the center of the roof for light and ventilation. As shown in Fig. 48, this is a framed structure l raised in the center of the roof and provided on the sides and ends with windows l_1. As the roof planks do not extend under it, a large amount of light is thrown into the center of the upper story, making a very light room for particular processes. The windows are usually swiveled on iron rods, so that they may be opened to allow the heated air to pass out, and ventilate the room. The roof may be constructed exactly the same as the roof of the mill proper and should have the same pitch. Monitors are sometimes built in small detached portions and sometimes as a continuous structure running nearly the whole length of the mill in the center of the roof. Fig. 48 shows a parapet wall extending above the roof, but this is not necessary with a monitor roof nor even customary.

73. Doors.—The outside doors of the mill may be made of any ordinary pattern, but should be especially heavy and strong. All doors should open outwards in order to prevent any possibility of a crush in case of fire or accident. All doors or openings through fire-walls should have automatic fire-doors to prevent the passage of the fire from one room to another. These doors are best constructed of wood and covered with sheet tin with the joints clinched. Iron and steel doors are unreliable, since they warp badly with even a small fire and allow free passage of the fire through the fire-walls.

Fig. 49 shows the ordinary construction of an automatic, or self-closing, fire-door. The door b is constructed of two or three thicknesses of pine boards nailed either at right angles or diagonally across each other. Sometimes asbestos felt is inserted between or over the boards, although this is not customary. The whole door is covered with sheet tin, the separate sheets being clinched and nailed to the door so that when the rib or clinch formed at the juncture of the sheets is turned over it will cover the nail heads. The door is hung on wheels *f* that run on an inclined track *e*, the slant of which should be at least $1\frac{1}{2}$ inches to the foot; it thus has

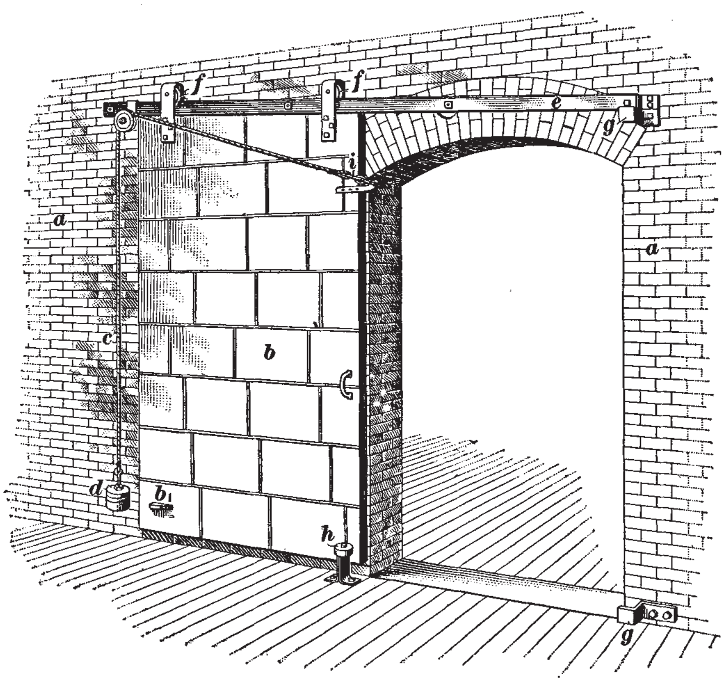


FIG. 49

a tendency to close the doorway, but under ordinary conditions this tendency is counterbalanced by a weight *d* that is attached to the door by a rope *c* and a fusible link *i*. The fusible link is made of an especially prepared metal that melts and allows the door to close when it is subjected to a temperature of 160° F. The two iron pieces *g* engage the edge of the door when it is closed, and a roller *h* engages with a wedge b_1 and holds the door firmly over the opening.

This door may be opened and closed ordinarily without disturbing the fusible link in the least. Fire-doors should be closed each night, but in case of neglect the automatic feature is an almost sure protection against the spreading of fire.

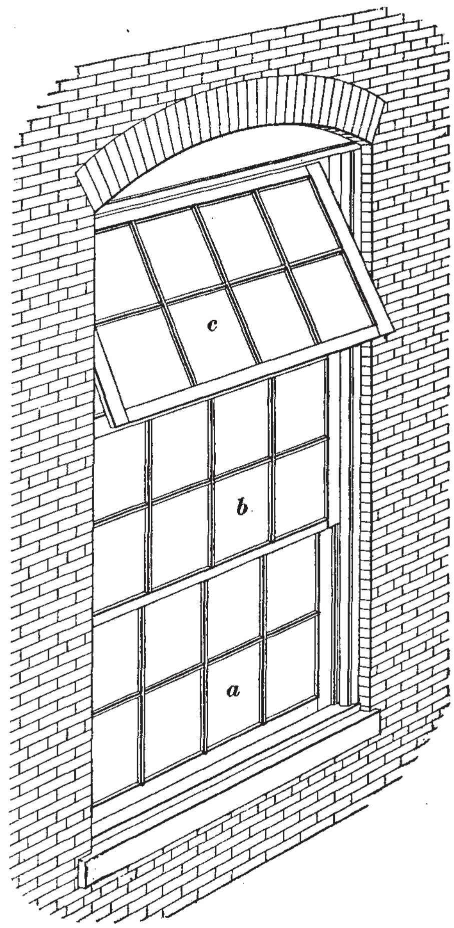


FIG. 50

74. Windows. The windows in a textile mill should be of the greatest possible area consistent with preserving the strength of the walls. Fig. 50 shows one of the ordinary type; it is composed of two sashes *a*, *b* and the transom *c*. The sashes are balanced by weights attached to cords running over pulleys in the window frame, and may be raised or lowered, but the transom *c* is pivoted so as to be swung open to ventilate the mill.

Sometimes the openings for the windows in the walls of textile mills are made extremely wide and separated by a mullion, since with very wide windows the weight of the sashes is so great as to make them hard to raise. The sashes and window frames for a mill structure should be made nearly double the weight that is required for ordinary dwelling houses, and should always be set with rectangular glass, as glass curved at the top to the arc of the arches, or *segment glass* as it is known, increases the cost of resetting to some extent and is of no particular advantage. Generally a good quality of American glass is suitable, but the use of corrugated or prism glass is being advocated at the present time, and many new mills are equipped with it. While this type of glass is not transparent, but rather might be termed translucent, it makes the rooms much lighter, since the light is diffused throughout the room without casting dark shadows. The sashes and frames of the windows should be kept well painted and the glass periodically washed.

75. Stairways. — Stairways should be separated from the mill proper by fireproof walls or should be located in a separate tower in order to prevent a fire from spreading from floor to floor. For the same reason not only stairways, but all openings from one floor to another should be avoided unless separated from the main mill by fireproof walls. Especially is this true in regard to belt ways and dust flues. Belts that are allowed to run through the floors for many stories sometimes carry the fire with them, and hardly anything will transmit a fire from one part of a room to another or from one floor to another as quickly as a moving belt, owing to the current of air set in motion by it. The belt tower is usually located in the center or at one end of the mill, and is usually arranged so that one line of shaft on each floor can be driven from the engine or from a head-shaft, as by this means the greatest economy of the transmission of power is obtained.

The best method of making stairways is to divide the flight by making a landing half way up. This construction makes short, straight flights and there is much less danger of crowding in the case of fire, while at the same time they will be found convenient on all occasions. In cases where spiral staircases must be used, although they are not to be recommended, care should be taken to have the central pier large enough to insure a proper width of tread on the inside of the stairs.

MILL ENGINEERING

(PART 1)

EXAMINATION QUESTIONS

(1) State some of the natural and artificial advantages that should be taken into consideration in locating a mill.

(2) What is the object of footings?

(3) What proportions of sand, stone, and cement are suitable for the concrete footings of a moderately high mill?

(4) Describe, briefly, how foundations are supported when the soil is marshy.

(5) State the requisite qualities of good building bricks.

(6) Discuss, briefly, the character of the following soils: (*a*) rock; (*b*) gravel; (*c*) clay; (*d*) quicksand.

(7) How should footings partly on rock and partly on gravel be built?

(8) What is the danger in uneven settlements of a mill foundation?

(9) (*a*) How are stone foundation walls bonded? (*b*) Why should the joints in a stone foundation wall be carefully broken?

(10) What precaution should be taken in laying brick in hot weather?

(11) (*a*) What is meant by Flemish bond? (*b*) What is meant by running bond?

(12) (*a*) How thick should be the bed of mortar between the bricks in a wall? (*b*) What is a good proportion of lime and sand for lime mortar?

(13) Describe how the floors are constructed and supported in a mill built on the slow-burning principle.

(14) (*a*) What is a stretcher brick? (*b*) What is a header brick?

(15) What is a monitor and what are its chief objects?

(16) (*a*) Describe an automatic fire-door and state its purpose. (*b*) Why are iron fire-doors unsuitable?

(17) What is meant by bond in brickwork?

(18) What can be said of stairways in mill structures?

(19) What are fire-walls and what is their object?

(20) What is meant by the term slow-burning construction?

(21) What is the object of shoeing piles?

(22) Discuss the relative advantages of iron and wooden columns.

(23) (*a*) Why should a hole be bored through a wooden column? (*b*) Should this hole be bored from one or both ends? Explain.

(24) Describe the construction of a gravel roof.

(25) Why should the outside doors of a mill open outwards?