MASONRY AND FOUNDATIONS.

THESIS

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Eng

Part 1 Masonry.

Masonry is the art of raising structures in stone, brick, and mortar. It is classified, from the nature of the material used, as brick, stone, and mixed or that which is composed of both brick and stone. In a wall of masonry, the term face is usually applied to the front of the wall and the term back to the inside; the stone that forms the front is termed the facing, that of the back, the backing, and the interior the filling. If the front or back of the wall has a uniform slope from the top to the bottom this slope is called the batter or bâtir. The term course is applied to each horizontal layer of stone in the wall; if the stones of each layer are of equal thickness throughout it is called regular coursing; if the thicknesses are unequal, the term random or irregular coursing is applied. The divisions between the stones of the course are termed joints, and the upper surface of the stones of each course is called the bed or build. Stretchers are blocks which have their greatest dimensions along the face. Headers are blocks which have their least dimensions along the face. If the header reaches from the face to the back, it is termed a through; if it does not it is termed a binder.

Dimension stones are cut stones all of the dimensions of which have been prescribed beforehand.

Brick Masonry

With good bricks and mortar, this masonry offers great strength and durability, arising from the strong adhesion between the bricks and mortar. The composition of the mortar will vary with the strength desired and with the locality. The mortar should contain only enough water to make a rather stiff paste; and to prevent the mortar from drying too quickly, the bricks should be soaked in water for several hours before using them. This is preferable to adding water to the mortar, as an excess of water weakens it. Care should be taken to use only the best of bricks. All misshapen, unsound and broken bricks should be rejected. In laying brick care should be taken to break joints, the joint of one course being at least one fourth of a brick from the joint in the next lower course; and to have all joints well filled with mortar. The plane of the courses should be perpendicular to the line of pressure. The mortar in the joints should not be thicker than one fourth of an inch. The total volume generally equals one fifth that of the brick.

The bricks used being uniform in size and figure are to be built according to a uniform system which is called the bond of the brick work. The most usual kinds of bonds are the English and the Flemish. The first consists of entire arranged as headers and stretchers. The courses may be alternately headers and stretchers, or a course of headers may be laid at regular intervals. One course of headers to two of stretchers makes the transverse and longitudinal strength of the wall equal. The English bond gives the greatest strength but it requires great care in order to break joints properly.
In the flemish the bricks are laid alternately as headers and stretchers in the same course. The Flemish presents a finer architectural appearance and the proper breaking of the joints is more easily obtained. The crushing strength of brick-work in tons per sq. ft. according to Trautwine is ordinary 20 to 30, good in cement 30 to 40, first rate in cement 50 to 70. The durability of masonry varies greatly. First class masonry when not subjected to too great strains appears to be as durable as stone. Brick masonry is measured in cubic yards or in rods. A rod of brick masonry is 1½ bricks thick and has an area of 30¼ sq. yds. To express the volume of a wall in rods it is

necessary to reduce the wall to an equivalent wall 1½ bricks thick. The number of bricks in a cubic yard is about 510, the number in a square yard of wall 1½ bricks thick is 189. The cost of brick-laying including mortar and scaffolding averages about $8. per 1000. In civil engineering brick is used extensively for sewers, for lining tunnels, and for paving.

Stone Masonry

Stone masonry is classified according to the form of stones used as rough or rubble, hammered or squared, and ashlar or cut stone masonry.

Rubble masonry is composed of unsquared stones. The stone is prepared simply by knocking off all the sharp weak angles of the block. The larger masses are firmly imbeded in mortar and the interstices between them are filled by thrusting small fragments of stone into the mortar. Finally the whole course may be carefully grouted, but it is better to fill all voids with ordinary mortar. To connect the parts together well throughs or binders should be used in every course. Uncoursed rubble is laid without any attempt at regular courses. Coursed rubble is leveled off at specified heights to a horizontal surface. The resistance of good rubble masonry to crushing is about .4 that of single blocks of the composing stone. The volume of mortar used is about ½ that of the stone. Rubble masonry is used for retaining walls and for wing walls of moderate strength.

Squared stone masonry is composed of stones roughly squared and dressed. According to the character of the face, this is classified as quarry-faced or pitch-faced. If laid in regular courses of the same rise throughout the length of the wall it is range-work. If laid in courses that are not continuous throughout the length of the wall, it is broken range work. If not laid in courses at all it is random work.

Ashlar masonry is composed of cut stone or stone that has been accurately squared and dressed. As a rule, the courses are continuous throughout; but sometimes they are broken by the introduction of smaller stones of the same kind; then it is called broken ashlar. If the stones are less than one foot in height it is called small ashlar. Ashlar masonry is used for piers, abutments, arches and parapets of bridges, for hydraulic works, and in general for works in which great strength and stability are required.

Rankine gives about ⅛ of an inch as the proper thickness of the mortar in the joints, and the volume about ⅕ that of the stone. The bond is sometimes strengthened by fitting projections of one course into corresponding indentations of the next. Iron cramps of suitable shape are also used. If the batter of a wall should be greater than 60°, the horizontal joints must not be carried out in the same plane to the face or back but be broken off at right angles to it so as to form a small abutting joint of 4 inches thickness.

Part 2 Foundations

Foundation is generally used as if synonomous with substructure. The bed of the foundation is the soil on which the foundation rests. Soils, Before commencing a structure an accurate knowledge of the soil should be obtained both in respect to the thickness and position of the strata and in regard to the supporting power. The first may be determined by examining out-crops, by digging pits, or by boring. The supporting power may be determined by making an excavation, inserting a square timber of known crossection, loading it, and noting the amount that it settles. Soils for foundation beds may be classified as Rock, Solid ground, Compressible ground, and very Compressible ground.

Rock of moderate hardness and sufficient thickness furnishes the best supports for structures, If the rock extends to the surface, it will be necessary to blast it out to a depth below the action of frost, unless its composition is such as to resist atmospheric action, It is necessary that the surface should be horizontal though not smooth. Large cavities may be arched over or filled with beton or concrete. If the surface is inclined the rock may be benched or terraced. The surface should be covered with mortar to fill all roughnesses and furnish an even bearing, Water should not be permited unless it can be carried off by special drains.

According to Rankine, the safe load in tons per square foot is rock moderately hard (hard as best brick) 10., rock as hard as good concrete 3¼, very soft rock 2. . On harder stone the weight may be increased to ⅛ or 1/10 of the ultimate resistance to crushing.

Solid Ground, This comprises gravel and dry sand kept from spreading laterally and well drained, firm earth and hard clay. The conditions are horizontal beds not in danger of sliding, sufficient thickness especially if underlaid by a softer material, facility for drainage, and freedom from lateral spreading, the prevention of which is very important in sands and gravels. The foundations must be carried below frost. In central Illinois, the depths usually considered safe vary from three to five feet, according to the importance of the building. The safe loading may be taken at 2 to 2.5 tons per square foot. Experience shows a wide range however and in important constructions experimental determinations should be made.

Compressible Grounds, These include beds of tolerably hard clay, and gravel and sand saturated with water. These furnish very weak supports and the dificulty is much increased by the liability to lateral yielding. The maximum safe load in tons per square foot, according to Baumann for Chicago is 1.5

Very Compressible Ground. This consists of soft quick sand, soft marsh, and mud. It is the worst kind of ground and

should be avoided if possible as foundations in it are very costly. Foundations in it may be constructed by excavating the soft material to firm soil, by driving piles or by sinking sinking caissons &c.
The proper area or spread of the foundation is determined by the weight to be supported and the supporting power of the bed. Where the weight to be supported varies the area should vary accordingly. In all foundations in earth, the bed should be compacted by ramming, driving small piles, or punching holes and filling them with wet sand well rammed, in order to prevent excessive settling. When unequal settling is likely to occur on account of lack of homogeniety of the bed, a grillage or platform of timber, a bed of beton, or a bed of well packed sand may be used to distribute the load more evenly. Timber is objectionable as it soon decays unless constantly wet. The effect of quick-sand is to produce unequal settling by its lateral yielding, when the ground above is unequally loaded.
Lateral yielding is prevented by driving sheet piling, by constructing retaining walls &c.

Piles, Timber piles are usually as long as they can be cut from trees. The materials used are elm, fir, beech pine, hemlock, and oak. Cast iron piles are also used. As timber is best preserved under water, piles are usually cut off somewhat below low-water mark. They are generally pointed to facilitate driving. When they are to be driven through stony ground, the point should have an iron protection. When continually under water and not exposed to the attack of the pile worm, piles will last a great length of time. They are sometimes preserved by carbolizing. There are various machines for driving, including hand, horse-power, steam and powder machines. A hand machine was used at Westminster bridge for driving thin sheeting piles and worked by five men. The ram weighed 100. pounds and gave 15 to 20 blows per minute of 5 to 6 feet fall.

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		wt of ram,	ht of fall,	blows per min.
Some of the steam hammers used are	Common	1¼ tons	6	5
	Nasmyth's	15 cwt.	3	60
	Scott's	1½ tons	6-15	15-20
	Sisson & Whites	1 ton	5	10

In the powder machine, the ram falls onto the pile and explodes a cartridge placed in a receptacle on top of the pile. The cartridges are added one by one. It can readily make 30 to 40 blows per minute of 5 to 10 feet fall. The force of the blow is regulated by the size of the cartridge.

At present, the water jet is quite extensively used in sinking piles in sandy ground. A pipe is attatched to the end of the pile and a jet of water forced through it loosening the ground in front of the pile which sinks some distance from its weight. Few blows are required to finish the driving. There is thus a saving of power and the pile is less battered by the ram and the number of piles rendered unfit for use in driving is lessened. The water jet is also used in sinking caissons, cribs &c.

Trautwine gives as the cost of piles in Philadelphia for 1873, hemlock 6 to 8 cents per linear foot, bay yellow 10 to 15 cents, southern yellow pine 18 to 25 cents.

The distance driven at each blow depends upon the resistance of the soil, the weight of the ram, the height of the fall, the elasticity of the pile and ram, and the rapidity of the blows. The supporting power is determined by the resistance to the last blow. It is taken at 1/8 or 1/10 of the resistance. The T. A. S. C. E. Nov. '83. quotes an experiment in which by adzing off the head of the pile after it had become battered, the distance driven by each blow was greatly increased, and by sawing off the head the increase was greater. Hence the last blow should be struck on a perfect head. Neglecting elasticity, the resistance is $P = \frac{h}{s} \frac{G^2}{G + G_1} + G + G_1$, h = height of fall, s = distance driven. G = weight of ram. G_1 = weight of pile. Considering elasticity $P = \frac{G h}{1 + \left(\frac{1}{H} + \frac{1}{H_1}\right) \frac{P}{2s}}$.

Mitchels screw piles are large and thin screws with small shanks, the threads being formed of thin blades. They are attatched to the end of a shaft and are sunk in sand, clay, &c by giving a rotary motion to the shaft. The screws vary from 18 inches to 6 feet in diameter. The sinking of screw piles is greatly facilitated by applying a water jet to the upper surface of the thread. The ultimate sustaining power of these varies from 1 to 6 tons per square foot. They are extensively used in foundations for light-houses and other structures along the sea shore.

Foundations under water, Dams. The use of dams is to form an inclosure for water as in resivoirs and to stop the flow of water to obtain a proper fall for water power. The primary objects in their erection are a foundation sufficiently firm to prevent settling, the prevention of leaks through their banks ~~or~~ under their bases; and in the dams for the latter use, the prevention of wear of the bottom of the stream in front of the dam by the action of the water. The foundation may be on rock, firm earth, or piles driven into softer earth. Leaks are prevented by well compacted gravelly earth, puddle, timber, sheeting piles &c. The wearing away of the bottom of the stream is prevented by a platform, an inclined front, or a terraced front and a platform.

Coffer Dams. These are inclosures from which the water may be pumped out allowing the work to be done in the open air. In still shallow water, a bank of clay and gravel, or where there is much current banks of bags partly filled with these materials will answer every purpose; or a single or double row of sheet piles driven a few feet into the soil, the upper end remaining above high water may be used. The piles are protected by puddle to prevent leaking. As the water is pumped out it is necessary to put in cross braces to resist the pressure of the water and puddl when the coffer dam is empty. Another method is a strong water-tight crib which is built, floated into position, sunk, and leaking at the bottom prevented by sheet piles and puddle. In using the coffer dam the water is pumped out, the bed of the foundation prepared, and the masonry laid either on the natural bed or on a bed of beton or concrete.

Caisson. A caisson is a strong water-tight box without a lid. It is built on the land and floated into position either empty or with a part of the masonry constructed in it. It is sunk into position on the river bed or on a bed previously prepared for it. The bottom is strongly built so as to support the superincumbent masonry. The sides are so constructed that they may be removed after the caisson has come to a bed. The sinking is regulated by the rapidity of laying the masonry inside. Where the bottom of the stream can be depended upon for a foundation bed, this method saves the trouble and expense of pumping out the water, as in the use of the coffer-dam.

Pneumatic Processes. These have been largely used of late years for sinking largl cylinders and inverted caissons in deep water. They are the vacuum and the plenum.

The vacuum process consists of exhausting the air from the cyl-

inder, thus using the pressure of the atmosphere on top to force it down. The water is drawn into the foundation at its base, thus loosening the soil and causing the cylinder to sink rapidly.
This process is adapted to soft or wet sandy soils, but is not sufficiently powerful in very compact soil, nor does it answer where obstructions from bowlders logs &c occur, the removal of which requires men to enter to the bottom of the cylinders. This they can not do in the rarefied air.
The plenum process consists in forcing air into the cylinder or vessel so as to exclude the water, and forcing it down by a load which is placed upon it. An air lock is connected with the main vessel in a suitable way and so arranged that men may pass through it into the main vessel. This process enables the workmen to remove not only the soil, but any obstructions such as logs and bowlders, and enables the engineer to have complete controll of the sinking.
Pneumatic piles are constructed of joints of iron cylinders and are sunk either by the vacuum or the plenum process. They are guided to position by means of anchors and outside

piles. Care must be taken that the sinking is vertical. This is governed by the rate of excavation and by striking blows on the higher side. After the piles have reached a firm bed they are filled with beton or concrete, and masonry.

Inverted Caisson. This consists of a solid framework of heavy timbers with large air tight cavities. It is constructed, floated to position anchored and guided to position by means of piles. It is sunk by means of the plenum process, the masonry being built on top of the timbers and having a hollow center. The descent is regulated by means of supporting screws. Workmen are allowed to pass into the air chamber by means of air locks.

These were formerly placed at the top, but Eads made a great improvement by placing them permanently at the bottom. The soil is excavated by workmen in the air chambers and is now elevated by means of a sand pump worked by the combined action of a stream of water and the enormous pressure of the air. Great difficulties are met in the depth to which they are sunk and the inability of the workmen to endure the pressure. As a protection against ice, scour, &c a group of piles should be driven above the caisson. As the tendency to scour is much increased by obstructing the current with piers, they should be sunk to firm bottom.

End