still other cases the natural cleavage permits its removal with wedges; in some of the softer rocks this method of breaking up into derrick or one-man or two-man sizes is less expensive than block-holing and using powder.

The safe loading upon rock beds depends entirely upon its nature, and ranges from 5 to 200 tons per square foot. In cities having building codes the safe-load limitations of the natural soils found within their limits are specified. Where there is no building code the safe loadings can be governed by the values given in Baker's "Masonry Construction." This table has been widely copied and may be found in many handbooks.

Sand or gravel, particularly when dry and well drained, is next to rock in desirability, and in some respects is the best substratum. It is easy to excavate, and if free from clay and loam the excavated material can be utilized in making mortar or concrete, thus reducing the expense of masonry construction. Other soils have to be removed and used for grading low places or back filling, and the disposal of the surplus soil may considerably increase the expense of excavating.

Mud, soft alluvial soil, quicksand, etc., often make foundation work difficult, particularly where heavy concentrated loads are to be carried. Piling or raft foundations then become necessary. Where the water level is permanent, wooden piles cut off below this level will endure as long as the structure above them.

There are two methods of capping a wood-pile foundation. One is to excavate between the piles for a depth of 2 feet or a trifle more; then fill in around the piles to a depth of a foot with clean sand and upon this a bed of concrete is laid. The depth of this concrete over the heads of the piles will depend upon conditions and the load. An interesting example of concrete mat over piles is found in the foundations of the Long Island City power plant of the Pennsylvania Railroad. The mat is 6 feet 6 inches thick at all points except under the four stacks, where it is 2 feet thicker. The site of this foundation is inclosed within sheet piling. In this case the thickness of the mat was partly dictated by the tidal conditions of the East River, on which the plant is located. The floor of the power-house basement had to be above high water while the piles had to be cut off below low water. Sheet piling is necessary in building foundations of this kind in order to prevent the earth about the excavation from caving in, and to prevent damage to adjacent structures. It also serves to limit the quantity of water flowing into the excavation and reduces the expense of keeping the pit dry. Where the surrounding soil is subaqueous, cofferdams constructed of sheet piling or cribwork are required.

The earliest method of capping a pile foundation consisted of laying heavy squared timbers on top of the piles to which they were secured by drift bolts. On top of these and at right angles to them another layer of squared timbers was laid. These two layers were usually of 12 x 12-inch material. The interstices between the timbers were then filled with sand, gravel or concrete and a flooring of 6 x 6-inch timbers was laid over the area. These timbers were solidly drift-bolted together and upon the surface thus prepared was laid the stone of concrete masonry for the foundation. This method was very expensive as the piles had to be cut off low enough to keep all of the timber work below the water line.

There are a number of formulas for determining the bearing power of piles. Most of these depend upon the distance the pile sinks under the last few blows of the pile-driver drop. These are very poor ways of determining how much the pile will sustain, though they are widely used by engineers who should know better. The writer has seen a pile sink 3 feet and more under one blow of the hammer and then come up nearly the same distance as soon as the hammer was lifted off its head. Holding this pile down with a heavy weight for a short time resulted in its becoming so firmly fixed in position that repeated blows with the hammer could not drive the pile down ¼-inch; when the endeavor was made to pull the pile the heaviest tackle available could not stir it. The use of formulas based upon the distance the pile sinks under one blow has often resulted in driving the piles down into themselves until they split and lost strength.

Quicksand, when it reaches a considerable depth, can be overcome by driving piles down to the firm underlying stratum. Thin layers can be removed by placing sheet piling around the area to be excavated; inflow will also be prevented by this means, as this is the main trouble in such cases.

Medium beds occasionally present themselves. The writer once put in a heavy foundation for a twin-reversing engine with 55 x 60-inch cylinders driving a 34-inch blooming mill, the entire area of which was underlaid by a bed of quicksand about 12 feet thick. The method adopted in this instance was to drive two rows of sheet piling about 3 feet apart, inclosing the area for the foundation. The space between the sheet piles was then excavated, the piles being held in position by heavy bracing. This excavation was carried down 2 feet into the firm layer of hard pan underlying the quicksand and then filled with concrete, this forming a concrete cofferdam around the foundation area. The space inclosed was then excavated to the required depth, which left 10 feet of quicksand below the foundation. This sand was so fluid that a man could not stand in it unless supported by a plank. The surface of the quicksand was then covered with two layers of tar paper at right angles to each other and a thin layer of concrete was deposited on the tar paper; then a 2-foot layer of concrete was deposited to form the foundation footing. This method of doing the work saved nearly 1,000 cubic yards of concrete, and the foundation proved all that could be desired. No appreciable settlement had occurred when the elevations were checked up by a bench mark after the machinery had been operated several years.

The holding-down bolts in these foundations were from 1 to 3 inches in diameter and from 4 feet 5 inches to 16 feet in length, 241 bolts being required for the engine, mill, tables and shear. Templets, made from drawings, were made in sections to locate these bolts and all holes were laid out by measurements from centre lines, a hole being bored in the templet for every bolt. The templets locating the heavy bolts were so supported on a scaffold that their lower surfaces were slightly above the elevation of the top of the foundation. A transit was used to line up the templet and after it had been accurately located it was nailed fast to the supporting scaffold. In the meantime the bolt pockets in the lower part of the foundation were brought up to the level for the foundation washers. These washers were set in position and located by plumbing down from the templet.

Sheet-steel galvanized-iron tubes 5 inches in diameter were provided for the 3-inch bolts and 4-inch pipes for the 2-inch bolts. The blocks turned to fit these pipes had been nailed to the under surface of the templet for holding the tops of these pipes in place. These tubes were then placed in position and their lower ends were built in with brick laid on top of the foundation washers. In setting these tubes care was used to get them centrally located with reference to the bolt holes in the washers and templet. After the tubes had been set the location of the templet was carefully checked.