just the condition in which it occurs. It is also an excellent thing in hard clay to take out some dry cores by using a drill rod at the end that has a serrated edge. Special attention is called to this because at times, if it is not done, we may work our way through a layer of clay adapted for a foundation, and perhaps be obliged to go 10 or 20 feet deeper before finding something else that is suitable. By operating with the wash drill process, the clay, of course, is reduced to a condition which does not indicate its real character. A core in the dry has to be taken in order to determine its supporting power. There have been many illustrations of this sort. In one case 30 feet depth was saved in a foundation by taking out occasional dry borings through hard clay. An important thing in wash borings over a site is to notice whether layers of corresponding material are uniform over the area or "peter out", from one side to the other; whether further tests should be made can thus be determined.

The next appliance to be considered is the shot drill. It is not intended to discuss the diamond drill, because the use, as a rule, is at least twice as expensive as that of the shot drill, and further, it generally applies to unusually deep foundations requiring extensive investigations. The shot drill is a more modern development due to the fact that diamond drilling has run up the price of the carbon quite materially. In the shot drill chilled steel shot is rotated underneath a soft steel rotating bit and thus mills away the rock. It is rotated at fairly high speed and under pressure. The amount of shot to be fed and the pressure to be applied requires some degree of experience and observation. One side of the cylinder, which is the bit, has a V-shaped inclined notch to allow the water that passes down the interior of the drill rods and comes up in the casing to escape without carrying away all the shot. It also enables the shot to be fed in through the water in the interior. There is usually a calyx or sludge received just above the lower section in which the material as it comes up enters a large chamber where the velocity of the water is reduced so that it drops the sediment. Hence we get a record in inverse order in which the material is milled, and at intervals it is taken out and examined. The diameters of the core range from 1½ up to 20 inches and in some cases even larger.

The Davis cutter works in a somewhat different manner. It has a series of long, sharp teeth with an angle that varies from 30 to 35 degrees. These teeth cut like chisel and hammer instead of milling. As each tooth takes hold of the rock it bends and then jumps. It has a rapid chipping action and operates in the same way as the ordinary shot drill except that it has a chipping instead of a grinding action.

It is a fundamental proposition that one cannot be sure of making economical designs of substructures with their foundations without adequate preliminary exploration. Many a time the expenditure of a little money—just a small percentage of the cost of the substructure—for exploration will save many times what would otherwise be expended in extra construction. It is often omitted because of time and labor, but the time as well as extra cost is paid for afterwards. Frequently it costs less than merely to make changes in the drawings, to say nothing of the changes in the structure itself. I know engineers who have built long culverts and arch bridges under high embankments where the loads were tremendous, in which, by making adequate preliminary explorations, they did not need to make a single change in the substructure, not a single modification in the number of piles required nor the distribution of these piles. Then, too, it frequently means a saving in cost of maintenance as well as in first cost of construction.

Another reason for adequate exploration is that the owner should assume the full responsibility for local conditions; the contractor should not be obliged to gamble on uncertainties relating thereto. It is a case of straightforward honesty to begin with, and certainly of economy. In the first place, we should make the exploration in order to determine the conditions, and if, in spite of that, there may be variations subsequently determined, the owner gets the benefit and should pay for the difference. All that is necessary is to make the contract in such a way that fair allowance will be given the contractor for either increased or decreased cost.

The next point to consider is the test for bearing capacity of the material on which it is expected to found. Ordinarily the best arrangement is to use a single vertical post of known area of rectangular or round section and supporting a balanced platform. It is not desirable to use four posts with a platform across them all because the same amount of care to prevent unequal settlement of the four posts will keep a single post from tipping over; also a smaller load is required and it usually takes less time. For large work we should use more than a 12-in. x 12-in. to give the best results, but for small work it is sufficient to use a 12-in. x 12-in. or even slightly smaller. The bearing should be tested at the bottom of the proposed excavation and it is necessary to explore a little distance below to be sure that it is not a thin stratum underlaid by poor bearing material. The wash boring should go considerably below the foundation bed. The load can be applied rapidly to the test post until it reaches ⅔ of the amount considered to be the safe bearing power; then adding smaller increments and allowing certain time interval between increments in order to determine whether the settlement is continuous. We proceed in this manner until we determine the heaviest load the foundation will carry without continuous settlement. More time is required in test loading in clay than for other soil, because clay in many cases has a habit of yielding; if it is plastic, the resistance may be very high under a quick test but yield continually under a slow, steady load.

Both timber and concrete pile foundations are very extensively used—more extensively than any other kind. In my judgment, the greatest sin of commission in regard to timber piles is over-driving. There are so many who think that a little extra driving is so much the better, and who say, "Just give a few extra taps for good measure." It may be the "few extra taps" that cause the damage.

In regard to the construction of ordinary light structures the problem is a difficult one on account of the way in which the work is done, and since it is frequently expensive to get the kind of equipment to do the best work. That is one of the arguments for doing things on a somewhat larger scale and in a co-operative way, so that pile drivers with steam hammers may be used instead of drop hammers. When one considers how long ago the steam hammer was invented, it is discreditable to engineers that it has not been more extensively used.

The greatest sin of omission in pile driving is the failure to use the water jet. Many a time piles can be driven without a hammer. If piles are driven through quicksand or through ordinary sand, the best way to drive them is by means of the water jet. Using this method, the pile is not injured, it generally costs less, and it can be done effectively. The water jet is well worthy