will permit. In this way a better idea can be gained of the actual material in the foundation than by any other method.

Where conditions do not permit test pits, an iron rod may be driven to depths of from 10 to 20 feet, unless rock is encountered before that depth is reached. This method, however, gives very little idea of the material through which the rod is driven. A somewhat better way is to drive down 1-inch extra heavy iron pipe, which may be cut into 4-foot lengths coupled together as driven. A driving cap should be provided and the driving should be done with wooden mauls. Pipe has been driven in this manner in the winter months to a depth of about thirty feet or possibly more. The pipe, after being driven, may be pulled out with a small chain and lever, so that a sample of the material through which the pipe was driven may be brought up inside it. This material can then be examined as the pipes are uncoupled and cleared out. Material that sticks in the pipe may be loosened by placing the four-foot section of pipe in a small fire sufficient to generate steam from the moisture in the material, which, as it expands, forces the material out of the pipe. Great care should be exercised to have only sufficient fire to generate the steam slowly, or otherwise the material may shoot out the ends with considerable violence, or the pipe may burst and the flying fragments cause serious injury to persons in the immediate vicinity.

One of the best ways to test a foundation is with a wash drill outfit, consisting of a drill point to which is coupled 1-inch iron pipe in four-foot lengths. Water is forced through this pipe by a double acting force pump. Tests have been made with such an outfit to a depth of sixty feet and the wash drill may be used with or without a jacket pipe.

Figure 1 illustrates a wash drill outfit suitable for this use and which consists of a double acting force pump, with a cylinder 5 inches in diameter, a 5-inch stroke, a 2-inch suction and a 1½-inch discharge. The pump is fitted with two 12-foot lengths of suction hose with a strainer, two 12-foot lengths of pressure hose, twelve 4-foot lengths of 1-inch extra heavy iron pipe, and a drill point.

The kind of material in the foundation determines to some extent the size of the footings for the structure, with due consideration to the weight to be borne and the bearing power per square foot of the material. Rock makes the best foundation and should be used when it occurs at available elevations.

A great many tests have been made to determine the bearing power of other materials, and, while there is much variation in results, the following figures are given as indicating the range of values obtained and, in the absence of more definite information, they may be used as allowable working loads:

Material.	Bearing power (tons per sq. ft.)
Quicksand and wet soils	0.05 to 1.0
Dry earth	1 to 1.5
Moderately dry clay	2 to 4
Dry, stiff clay	4 to 6
Sand	2 to 4
Sand, compact and cemented	4 to 6
Gravel, cemented	8 to 10
Rock	200

There is, however, no definite rule by which the bearing power of a material can be determined absolutely without applying test loads and noting the amount of settlement caused by them. With the smaller highway bridges and culverts, which are the commonest built, an experienced builder is usually governed by his experience and good judgment concerning the suitability of a particular foundation to carry the proposed structure, but for any structure involving a considerable expenditure a careful test should be made.

Arch bridges or culverts especially require an unyielding foundation and are more than likely to fail unless such is provided. Consequently, they should not be built except where a good rock or gravel foundation is to be had, or possibly where a satisfactory foundation can be made by driving piles. Attention should be called to the fact that piles may be driven in an inclined position, and thus be able to resist the arch action directly.

The bearing power of piles may be determined for practical purposes, where comparatively stiff material is found, by the following formula:

$$\text{Safe load} = \frac{2\,WH}{S + 1}.$$

Here W = weight of hammer in tons or in pounds (the safe load is considered as in the same unit); H = its fall in feet; and S = the penetration in inches under the last blow. Results thus obtained, when compared with actual tests, show that this formula has a factor of safety varying from 2 to 7 or 8. It can be used properly, however, for comparatively stiff material only, for in soft material where long piles are to be used, it fails to give rational results.

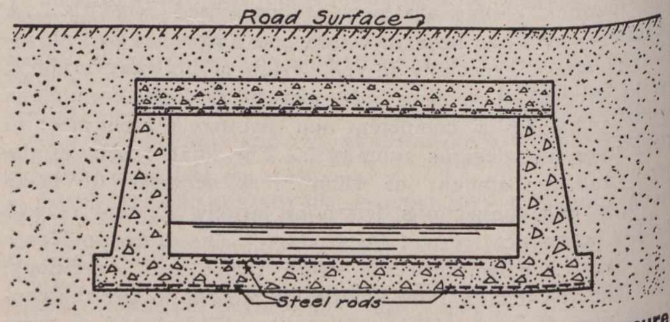

Fig. 1a.—Reinforced Concrete Floor, for Distributing Pressure Over a Greater Area and for Protecting Foundation from Erosion.

In locations where great depths of mud are found, piles are often driven that do not find a solid foundation, and the driving might be continued indefinitely, but, after leaving such piles for a few days, it is often found that several blows are required to start them again. This indicates that their bearing power has increased after the driving has stopped. It is a common practice to accept such foundations for certain structures as the best that can be secured, although they sometimes yield. In bridge construction, however, the success or failure of the structure depends much upon the foundation and too much care can scarcely be given to this part of the work.

It often happens that, after having tested the foundation and after considering the suitability of the material found, together with the elevation at which this material is available, it becomes desirable to shift the location of the bridge in order to secure a more economical substructure. For example, a suitable material for foundation may be found at a more convenient elevation in one place than in another, and this may materially reduce the cost of piers and abutments without injuring the alignment of the road seriously. In some cases it may even improve the alignment.

A survey and profile of the location should be made to establish the grade of the road. From these the amount of excavation and back fill may be determined, as well as