Soil Testing 101

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Before the drums start rolling or the plates start vibrating, it's imperative that a site's soil be thoroughly tested to determine its material composition, moisture content and density.

The results of this testing establish the maximum density of the soil and define the compaction work that will be required on the project. Typically, state highway transportation specifications require 95% compaction based on standards set by the American Society for Testing and Materials (ASTM) and the American Association of State Highway and Transportation Officials (AASHTO).

Optimum Moisture

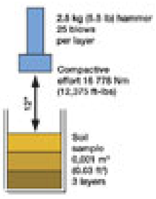

Figure 1. Standard Proctor test.

Soil is not a solid mass; rather, water and air are present between the soil particles. If excessive water is present, the soil particles will not bond; too little water causes soil particles to resist adherence. To ensure soil compaction meets project specifications, the optimum moisture content of soil must be determined during the testing process

Soil's moisture content varies based on geographical location and soil type. The optimum moisture for a given soil type is established in a laboratory setting. A series of soil samples are compacted at different moisture contents, beginning somewhere below the optimum moisture point. A curve is then plotted on a graph comparing the soil density at the different moisture levels.

Moisture content affects various soils differently. For example, granular soils have a wider tolerance to changes in the moisture content, while soils high in silt or clay content tend to be more sensitive to the range of moisture content.

The optimum moisture content is the highest point on the curve that maximum density of the tested soil has reached. Because of the uncontrolled nature of a construction jobsite, this density cannot be reproduced 100% as it can in a laboratory setting. A 5% margin of error is generally allowed.

Testing Types

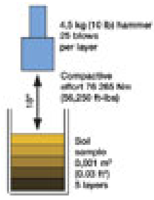

Figure 2. Modified Proctor test.

There are several methods of testing for soil density, which date back more than 75 years. In 1933, Ralph Proctor was the first to establish the relationship between soil material to be compacted and its maximum density, or optimum moisture content. Proctor's tests were adopted by the U.S. Army Corps of Engineers and today are considered standard testing procedures by ASTM and AASHTO.

Standard Proctor Test. In this test, a soil sample is taken from the jobsite and placed in a container equal to .03 cubic feet (0.001 cubic meters). A 5.5-pound (2.5 kilogram) weight with a striking face of 3.1 square inches (20 square centimeters) is then dropped 1 foot (304.8 millimeters) 25 times. This is repeated three times on additional layers (see Figure 1 above). The soil material is then weighed, minus the container and recorded as wet weight / cubic meter. The material is then oven-dried for 12 hours.

Modified Proctor Test. The modified Proctor test is done in much the same way as the standard test, except a 10-pound (4.5 kilogram) hammer is dropped 25 times from a distance of 18 inches (457.2 millimeters). This process is repeated over five layers (see Figure 2 above). The modified test is normally used in testing soil for higher shearing strength, or the maximum strength needed to support heavier loads such as a busy interstate highway.

In-Place Density

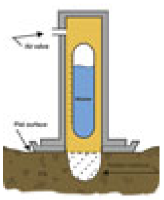

Figure 3. Liquid method.

After compaction, it is necessary to determine if the compacted fill's density meets specifications. This can be accomplished onsite using two basic methods to test the exact in-place volume of the soil.

Liquid Method. For the liquid method, water from a calibrated vessel is forced into a rubber balloon in a hole where a soil sample was taken (see Figure 3 on page 18). The amount of water used equals the sample's in-place volume. Disadvantages to using the liquid method are that the balloon can break or the water can freeze in colder temperatures.

Sand Cone Method. For the sand cone method, the hole from which the soil sample was removed is filled with dry sand from a graduated bottle. The sand has a uniform known density, so its dry weight volume is then known (see Figure 4 on page 18). The disadvantages of this method are the degree of human error, the discomfort of working with sand in windy places and the moving of 100-pound (45.4 kilogram) sand bags and bottles around the test site.

With both types of tests, soil samples are taken from the excavated material, weighed and oven-dried to obtain the water content. The percentage of moisture in the material is determined by subtracting the sample's dry weight from its wet weight, and then dividing this value by the dry weight. The density and moisture content of the field sample is compared against the laboratory standard Proctor value to determine compliance with the project specifications.

Nuclear Soil Density Testing

Nuclear soil density testing involves using different types of nuclear density meters to determine if compacted fill meets specifications. (See Figure 5 below for illustrations of these methods.)

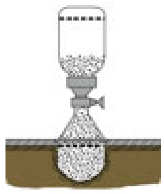

Figure 4. Sand cone method.

One type uses a radioactive measuring probe in combination with a Geiger counter to measure either density or moisture. With this meter, an external detector probe is inserted into the soil to the desired depth. Gamma rays emitted from the probe are absorbed by the soil and water atoms—the denser the soil and the more water present, the more rays are absorbed (and the lower the count shown on the meter).

Another type of nuclear density testing method uses a non-penetrating meter. It measures the bulk density and moisture of soil by resting on the surface and registering the amount of gamma rays reflected back to the instrument from the depths of the soil being measured. The gamma rays diminish in strength depending upon the density of the soil.

Nuclear testing minimizes the human error that is possible with conventional test procedures, thereby increasing the consistency of density and moisture test results. It provides a means of performing density tests on large-sized aggregate base courses and on frozen material, both of which are difficult to handle by other test methods. Nuclear testing can also save money in the long run due to its greater speed and quality control.

A disadvantage of nuclear testing is the possibility of radiation exposure to the operator. However, by exercising common sense and being cautious, individual radiation exposure can be maintained well within the Atomic Energy Commission’s safety levels.

Visual Tests

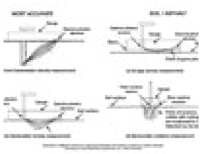

Figure 5. Nuclear soil density testing methods.

Sometimes it is not possible to have accurate soil test data available in the field. In those cases, a contractor should try to gain some idea of the soil types and conditions on the site. Simple visual tests can be helpful for determining this.

One method is to pack a soil sample by hand into the shape and size of a golf ball, then place the ball between the index finger and thumb and squeeze. If the material falls apart into fairly uniform fragments, then the soil is close to optimum moisture content. If the material weeps or does not break but flattens out, the soil is over optimum moisture. When the soil cannot be formed into a ball or is difficult to shape, it is probably under optimum moisture and moisture must be added.

Another method for determining the amount of coarse and fine material is to place a soil sample into a glass of water and shake thoroughly, then allow it to settle for 90 seconds. If the water clears during this time, the material is very granular with very little if any plastic material or fines. If the water is muddy or cloudy, there is a significant percentage of cohesive or plastic soil, such as clay, which will usually require soil manipulation.

The success of many projects is largely dependent upon achieving optimal compaction of the site. Through compaction, the soil is at its maximum density and thereby capable of supporting the static and dynamic loads for which it is designed, as well as placement of materials such as hot mix asphalt. Achieving successful compaction demands a clear understanding of the soil’s material composition, moisture content and density—made possible only by means of thorough, proven testing methods.

Information and photos for this article provided by Volvo Construction Equipment.