Our first edition of Contractor Focus appeared in the November 2004 issue covering important factors on layout and excavation of a job site. In this installment, we will continue by working up the pavement cross section focusing on preparation of subgrade soil. Preparation of the pavement foundation is one of the most important elements of every project. In terms of the labor component of the project, the subgrade and base preparation consume up to 70% yet is 100% hidden from the finished appearance. However, if improperly done, the effects become 100% visible!

Preparing the Subgrade

This article offers some practical tips for understanding how to compact the subgrade soil. Preparing the pavement subgrade and base can be viewed as “setting the table” for the rest of the job. The contractor must recognize the soil type, moisture content, grade, the amount of compaction and the type of compaction equipment required. A properly prepared subgrade will support the base above it and allow the base to distribute loads and stresses from the paver surface.

Soil Type—The soil type should be identified before the job starts, i.e. during the bidding stage. Different soils don’t react the same when moist and some take longer to compact than others. Therefore, understanding the soil type during the estimating stage can assist in gaining an accurate estimate of labor hours for excavation and compaction. It can also guide selection of compaction equipment. ICPI recommends that before estimating a job, a soil sample is taken to a depth that approximates the expected total excavation depth.

How does soil type affect the job estimate? Soils range in particle size from coarse to fine grained. Sands are coarse soils, with silts and clays having the smallest or finest particles. Generally the suitability of a soil for use under a pavement decreases with its particle size. In other words, fine grained silts and clays are the least desirable. They are also the most common soil types in North America. Some clay soils hold water particularly well. This means they might be difficult to compact, especially when nearly saturated. These clays have high plasticity, meaning they hold water and drain it very slowly.

A simple way to quickly assess soil type in the field is by visual appearance and feel. The particles of sandy soil can be seen without magnification. When rubbed between the fingers, sandy soil has a gritty texture. When individual particles can’t be seen, the soil is clay. A sticky texture indicates mostly clay, and a smooth texture indicates mostly silt. Silt particles are very small.

Soil type gives the contractor an idea how much water the soil will hold. This indicates how quickly the soil will drain. Slow draining soils may need thicker or stabilized bases, especially when combined with freezing climate. Knowing the ability of the soil to hold or drain water can be helpful if an open excavation unexpectedly fills with rainfall (typically overnight). The contractor then is faced with the following options. If there is time in the construction schedule and the weather is cooperative (two frequently unrelated events), the soil can be left to drain and dry, or be drained with ditches and/or pumps and left to dry.

If there is no time for drying, the soil should be drained, the saturated portion removed and replaced with base, or stabilized with cement. Otherwise, placement of aggregate base will suck water from the soil into the base during compaction and the...
A contractor can do field tests in a few minutes to determine the type of soil sampled from the job site. The tests are called the “patty”, “shake” and “snake” tests. For each test, take a soil sample and add enough water to make it into a “putty type” consistency. Form the soil into a ball, about the size of an egg. This is easily done for most clay and silt soils. Forming sandy soil may not be possible and may not be necessary since its gritty texture indicates its classification.

For the patty test (engineers call this the “dry strength” test), flatten out a sample about ¼ inch (10 mm) thick and let it dry in the sun. After it is dry, it will either break easily or be more difficult to break. If this is the case, it has a high clay content. If it breaks easily, it has a predominance of sand and some silt in it.

For the shake test (engineers call this the “dilatancy” test), cup the ball of soil in two hands and shake vigorously for about 30 seconds. If small drops of water are released to the surface and hands there is some sand in the soil. If no water is released, the soil is clay or contains some silt.

The snake test (engineers call this the “toughness” test) is done with clay or silt soils to determine how much water they will hold. This is seen by rolling the sample into a few moistened “snakes” about ½ in. (10 mm) in diameter. If snakes can be made greater than 2 in. (50 mm) long, the soil has potential to hold much water (a high plasticity soil). If the snake falls apart before it rolls into a 2 in. length, the soil is considered low plasticity and will drain water.

Compaction—Compaction mechanically increases the weight per unit volume or density of soil and base. Soils are a combination of sand, silt, or clay with water and air in tiny spaces between the particles. When compacted, the air voids are greatly reduced and the particles are arranged so they fit tightly together. Compaction achieves four main purposes. It increases the load bearing capacity of the soil; prevents settlement/rutting; reduces seasonal movement from moisture changes and freeze-thaw; and helps ensure that movement during freeze and thaw cycles is uniform.

The Importance of Moisture Content—The next step after identifying a soil is under- standing the optimum moisture at which the soil can achieve the highest density during compaction. Every soil has optimum moisture content. Higher or lower water content than optimum produces lower density during compaction. The optimum moisture in relation to density of a soil is tested in a soils laboratory using a standard Proctor density test. This test method is described in detail in ASTM D 698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft³ (600 kN-m/m³)). The Proctor test is named after its inventor.

The test method evaluates the density of a soil sample taken from the job site at various moisture contents and densities. The test finds the 100% Proctor density at its optimum moisture content. Sandy soils have lower moisture contents and higher densities than silts or clays. Once the Proctor density is established in the laboratory, tests can be done on the job site to compare the density of the compacted soil and its moisture to that established in the laboratory. The nuclear gauge test is used to rapidly check density and moisture content of compacted soil on the job site. See Figure 2. This test is done by a technician from a soils testing laboratory.

ICPI recommends that soils and base in residential applications are compacted to a minimum of 98% laboratory Proctor density. Figure 1 shows a typical moisture density curve for a silty clay soil. A range of moisture content is allowable to achieve 98% Proctor density. Generally, Proctor density tests are not needed for residential pedestrian applications. However, they are recommended for vehicular applications including residential driveways.
Determining the Right Moisture Content for Compaction

There is a simple test to find if the soil in pedestrian applications is at the right moisture content for compacting. It is called the drop test. Prior to soil compaction, remove a sample from the newly excavated subgrade surface and press it into a tennis ball sized clump. See Figure 3. Hold the ball about 2 ft (60 cm) above a flat rigid surface and drop it. If the sample breaks into at least three or four equal size particles, it is close to optimum moisture content and ready to compact. If it breaks into many small pieces, it is too dry and water may need to be applied to the soil prior to compacting. If the ball doesn’t break at all, it is too wet and the soil will likely need to dry prior to compacting.

Measuring Density in the Field

Contractors measure practically everything on the job site except the most critical component of any pavement, the density of the compacted soil and base! Having a laboratory Proctor density test done with field testing on residential driveways is a small price to pay to prevent future settlement and expensive call-backs.

Measuring density will help reduce liability. In addition, it will save you time if you are overcompacting. Contractors can promote this as a part of a quality job.

Choosing the Right Equipment

Soils with more than 50% clay or silt are called cohesive soils. Clay particles under a microscope often appear flat and elongated. They slide over each other when compacted, especially when compacted with a vibratory plate compactor. The best way to compact these types of soils is with a low amplitude vibratory roller or rammer as they effectively remove air and force the particles closer together. For very heavy clays, ICPI recommends a minimum 10,000 lbf (44 kN) reversible plate rammer. Adding a thin layer of base material over stable but sticky clay can reduce compaction time. Figure 5 shows this technique.

Non-cohesive soils (sands and sandy gravels) compact best with vibratory plate compactors and vibratory rollers. Under the force of these machines, particles in these soils are rearranged to fit more closely together. Contractors use large plate compactors (at least 8,000 lbf or 35 kN) or a walk-behind vibratory roller. For much larger jobs they will use a ride-on vibratory roller. A ride-on double drum roller compactor with 7,000 lbf to 9,000 lbf (30 to 40 kN) and a 32 to 36 in. (80 to 90 cm) minimum width or a single drum with rear rubber tires are recommended. Figure 4 shows various types of compactors.

Watch Out for Soft Spots

Sometimes during compaction soft spots will arise, often in heavy clay soils. In these cases it will be necessary to remove the soil and replace it with suitable base material or stabilize the area with cement. For isolated spots such as the one shown in Figure 6, an easy solution is to mix bagged Portland cement into the soil using a pick and shovel to strengthen it. Full remediation or stabilization of soil with cement for an entire site is beyond the scope of this article. The Portland Cement Association provides excellent guidelines on soil-cement remediation. Another solution is removing the soft soil, adding base material and compacting it. Replacing removed soil with cohesive soils is not recommended.

In Closing

Compaction of the subgrade sets the table for the construction of the remainder of the pavement. The next edition of Contractor Focus will discuss important steps involved in geotextile and base installation. Contractors interested in learning more about preparation and installation of soil subgrades and bases should consider purchasing the ICPI Continuing Education unit “Theory of Base Installation.” ICPI certified contractors can earn continuing education units by taking this self-taught course.

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