Understanding Your Soil Test Report
Norman W. Hummel Jr.

Soil physical testing is an important first step in the successful construction of quality planting soils for golf, sports fields, and landscapes. Due to the technical nature of the soil physics testing, some people have difficulty understanding the testing, what are reasonable expectations of soil testing, and what the test values mean. I prepared this article to offer an explanation of the more common soil physical tests.

PARTICLE SIZE ANALYSIS

The particle size analysis determines the distribution of different sized particles in a soil or planting mix. The particle size of a soil or sand-based mix has probably the greatest impact on how the soil will perform in the field.

We determine the gravel content, and the sand, silt, and clay percentages. Using U.S. Department of Agriculture designations, gravel is defined as any particle larger than 2 mm in size. Sand is any particle 0.05 mm (50 µ) to 2 mm in size. Silt is any particle 0.002 mm (2 µ) to 0.05 mm (50 µ), while clay is any particle less than 2 µ in size (microscopic).

In sand-based root zones or in soils high in sand, the size distribution of of the sand will influence performance. Therefore, we sieve the sand into 5 fractions: very coarse sand (1 to 2 mm), coarse sand (0.5 to 1 mm), medium sand (0.25 to 0.5 mm), fine sand (0.1 to 0.25 mm), and very fine sand (0.05 to 0.1 mm). Some specifications including the USGA Greens construction guidelines will use the 0.15 mm sieve to separate the fine and very fine sand fractions.

Reporting of particle size may vary. Typically sand based mixes the sum of gravel, sand, silt, and clay should be 100%. In the testing of soils, the gravel is often pulled out and reported separate from the sand, silt, and clay, which will add up to 100%. The reason for this is that with soils we will report a soil textural class (USDA) based on the percentages of sand, silt, and clay, not including gravel.

Particle shape - The particle shape is the predominant shape of sand particles in a sand-based mix. Shape is of most concern when sand shapes are uniform, and at the extremes. Sands that are very rounded and spherical may be unstable. At the other extreme, sands that are flat and angular may pack excessively, even though the size distribution may be favorable.

D85 – Particle diameter of a particular root zone mix whereby 85% of the sand particles are finer and 15% are coarser. This number is used to determine if a sand-based root zone mix will meet bridging requirements with a drainage stone.

Uniformity coefficient (Cu) - It is a numerical expression of the particle size uniformity. Research conducted in Minnesota several years ago found that the acceptable range is 2 to 4 for sand-based mixes. The higher the value, the less uniform the sand or mix, and the greater the potential for particle packing. Sands with Cu values less than 2 may not pack at all, resulting in unstable surfaces during grow in , and sometimes beyond. For soil amending sands, a coarse uniform sand is preferred. The Cu is determined by the following equation:

$$Cu = D_{60}/D_{10}$$

Gradation Index (GI) – Is another numerical expression of particle size uniformity of the sand in the middle 80% of the particle size range. It is the D90/D10. Other indices such as these are frequently used by some designers, including D80/D30 and D70/D20.

The two test methods most commonly used for particle size analysis are:

ASTM F-1632. Standard Test Method for Particle Size Analysis and Sand Shape Grading of Golf Course Putting Green and Sports Field Rootzone Mixes.

ASTM D422. Standard Test Method for Particle Size Analysis of Soils (Hydrometer method).

ASTM F-1632 is the preferred method for very sandy soils (> 85% sand) or sand-besed mixes because it is more precise in the separation of silt and clay

PERFORMANCE TESTING

Performance testing ususally refers to determination of soil physical properties that provide a reasonable assessment of how an engineered soil or root zone miz may perform in the field. In reality, it is a risk assessment that provides some assurance that such soils will perform as expected.

There are different performance test procedures for different types of mixes. For example, ASTM F1815 was designed specifically for sand based root zone mixes for sports fields and golf greens. It would not be an appropriate test method for a finer textured soil (< 85% sand). Samples are subjected to a standard compaction treatment prior to running the tests.

For native and engineered soils we often run a proctor density test on the samples per ASTM D698. A proctor test is one whereby we can determine the maximum density that a soil can be compacted to using this method. Cores can then be packed to some percentage of this maximum density, usually 85 to 90%, to simulate the soil density the soils should be compacted to in the field. Performance tests similar to those run by ASTM F1815 can then be run on the soils at those densities.

Listed below are the tests performed in ASTM F1815 or on soils compacted to a known density.

Saturated Hydraulic Conductivity - This is a measure of the engineered soil's ability to conduct water under saturated conditions, this being one dimensional flow (downward). Sometimes called infiltration rate, it is expressed in inches per hour.

Particle Density (ASTM D5550 and others) - The particle density is the density (mass per unit volume) of dry, solid soil particles. If you could melt the soil or root zone mix down into a solid mass of known volume, without any pore space, this would be its particle density. Silica sands are about 2.65 g/cc. Calcareous sands are usually higher. The addition of peat or compost decreases the particle density. This value is used for calculating total porosity.

Bulk Density - The bulk density is the mass per unit volume of soil. Soils and root zone mixes are not solid mineral masses. There is a matrix of pores that exist between the soil particles that is very important in the quality of the soil or root zone mix as a growing medium. The higher the bulk density, or the closer this value gets to the particle density, the more dense or compacted the soil. Bulk density is used to calculate the total porosity.

Total Porosity - This is the percentage of a volume of soil or mix that is occupied by space (voids) between or within the mineral or organic components of the root zone mix. An ideal sand based root zone mix would have 40 to 50% of the volume being pore space.

Aeration (Non-capillary) Porosity - This is the percentage of space within a volume of soil or mix that is occupied by air after free drainage (field capacity). We are referring to the larger diameter pores, which actually conduct water downward due to the force of gravity when the soil is saturated. When all free drainage is complete, or all gravitational water removed from these pores, they are occupied by air. These pores provide the gas exchange in the soil, bringing needed oxygen to the roots. Ideally, half of the total pore space would be these larger air-filled pores.

Capillary Porosity - This is the percentage of space in a volume of soil or mix that is occupied by water after free drainage. Water is held in these small pores, against the force of gravity, due to capillry forces. It is within these small pores where the water holding capacity of a soil is provided. Ideally, half of the total pore sapce would be made up of these smaller pores.

Pore Space Distribution/Field Capacity/Percent Saturation - Field capacity is the hypothetical condition whereby all of the larger diameter pores are drained and the capillary pores are filled with water. The percentage of air and water filled pore space or the pore space distribution is determined at "field capacity". In the lab, we subject the samples to some amount of suction or pressure to extract water from the samples to simulate field capacity. Per ASTM F1815, the pore space distribution of a sand based mix is usually determined at 30 cm of soil suction (0.3 kpa). For engineered or native soils, we often do this at 100 cm (1/10 bar, 1 kPa), or 300 cm pressure (1/3 bar, 3.3 kpa). The percent saturation is the percentage of the total pore space that is occupied with water.

PERFORMANCE TESTING - GREEN ROOF MIXES

Performance testing on green roof mixes is performed by ASTM E2399. Test determined by this method includes saturated hydraulic conductivity, and air and water content (porosity) at maximum water capacity. The air and water content are determined after the core is allowed to drain for two hours. Since load bearing is often limited in green roof systems, densities of the drained soils are determined as well.