Analyze this

ASSESSING SOIL PHYSICAL PROPERTIES HELPS DETERMINE STRATEGIES FOR IMPROVING GREENS

by DR. NORMAN HUMMEL

Excess soil moisture at the exclusion of soil air can be devastating to a green. After the summer of 2004, superintendents in the eastern half of the United States know this all too well. Knowing and understanding the physical properties of the soil in greens might help superintendents develop a strategy to improve them. In some cases, soil physical test results might provide the information needed to convince membership or owners to take more drastic steps to improve greens, including reconstruction.

The physical properties of soils encompass many things, including those related to the solid, liquid and gaseous phases in the soil. The properties normally related to greens performance include drainage (soil permeability), aeration, water retention and factors that affect these, such as particle size and soil density (compaction).

Soil drainage is measured in the lab by determining how fast water moves through the soil under saturated conditions. Called the saturated hydraulic conductivity or infiltration rate, it's probably the property of which most people relate. If the infiltration rate is low in a lab test, chances are good drainage will be a problem in the green.

Soil bulk density is a property routinely measured that has a profound affect on other physical properties. The density is the dry weight per unit volume of soil and is an indicator of soil compaction. The higher the num-

Photo: Hummel & Co.

Soil physical properties include the relationship of solid, liquid and gaseous phases in the soil.

Photo: Scott Bauer

Soil physical test results can provide information needed to convince memberships or owners to take more drastic measures to improve greens.

Soil properties – three case studies

Case study	Sample depth (in.)	SOIL SEPARATE Sand (%)	Silt (%)	Clay (%)	PHYSICAL PROPERTIES Infiltration rate (in./hr.)	Aeration porosity (%)	Capillary porosity (%)	Organic matter (%)
1. Native soil green	0-3"	92.5	4.2	3.0	5.6	27.5	25.6	3.74
	4-7"	27.4	36.2	35.0	0.0	8.2	29.9	1.92
2. Sand based green	0-3"	96.5	1.4	1.6	3.7	8.8	35.6	2.09
	4-7"	97.3	0.9	0.9	13.7	22.9	19.7	0.56
3. Old USGA green	0-3"	85.2	7.1	5.1	0.3	5.0	51.9	10.03
	4-7"	85.7	5.9	4.9	2.5	4.6	27.4	0.91

ber, the more compacted the soil will be and the less favorable the other physical properties are likely to be. Greens can be built with the perfect topsoil or sand-based mix, but they will perform poorly if compacted.

Related to bulk density is the total porosity, which is the total void space that exists between sand and soil particles. It's directly influenced by the soil density. The higher the density, the lower the total porosity. Organic matter content also will influence the total porosity – increasing with increasing organic matter in the soil.

Photo: Hummel & Co.

Loose soil samples from existing greens aren't useful to assess soil physical properties such as infiltration rate and porosity.

The pores or voids that exist in the soil vary in size. Larger diameter pores tend to conduct water downward under saturated conditions. When they're drained, they tend to be occupied with air, providing the plant roots with needed oxygen. These pores are called macropores or collectively, the aeration porosity. The smaller diameter pores tend to retain water against the force of gravity because of stronger capillary forces. A portion of this water will be available for plant use. These pores are micropores or collectively, the capillary porosity.

When soils or sand-based mixes from greens are tested, it's important that the distribution of air and water filled pores are determined because they also relate to soil health.

Sampling

If a new green was built, a loose sample of mix would be sent to the lab, where the mix would be evaluated on laboratory-compacted samples. One shouldn't send loose samples from existing greens to labs to assess soil physical properties such as infiltration rate and porosity. Doing so won't provide any pertinent information about the greens because the sample won't be tested at the density it exists in the green. A good assessment of soils from existing greens should be done on undisturbed samples.

Using special sampling equipment or techniques, samples are removed from greens as cores that are shipped to the lab intact. This enables the lab to test the samples with the soil or mix as it exists in the field, providing a better evaluation of the physical properties.

While there's special equipment available for pulling undisturbed soil samples, these generally aren't cost effective for superintendents to purchase and involve some technique to pull a good sample. Instead, there's been good experience having samples pulled with PVC pipe, which should be beveled on the forward edge so that soil is displaced to the outside as the pipe is driven into the ground. Drilling holes in the top to insert a metal rod assists in pulling the sample out.

Once in the lab, the pipes are cut into sections. Then the soil properties are evaluated in one to several depths in the profile.

Why soil properties change

Throughout the life of a green, soil physical properties will change because of several factors. Nature brings about changes: freeze-thaw cycles, micro and macroorganisms, and the dead and decaying turfgrass plants. Management practices such as topdressing, aerification and watering have a profound impact on soil physical properties as well.

The following three cases show how soil physical properties change, the problems created and possible solutions to the problems.

Case study 1: Native soil green with topdressing cap

This case is a common scenario seen in older, native soil greens. The green was originally constructed with a fine textured soil. A sandy layer about 3-inches thick has accumulated from years of topdressing applications. (See the top-left photo on page 63.) From 3-inches to about 6-inches deep, the soil was a fine textured soil that was determined to be a clay loam. Below six inches was a lighter-colored subsoil.

Selected data from this case are included in the table above. Looking at the infiltration rate, one can notice how good it is three inches in the surface. The results on the aeration and capillary porosity are good as well. The benefits of years of topdressing are well documented by this data.

Unfortunately, below three inches, the soil is impermeable. Hopefully, this green was designed with good surface drainage. Back when the green was built, the fact that the soil was slowly permeable might not have been a concern. Excess water from rainfall and snow melt would simply run off. Now the top three inches has been modified and is quite permeable, so water will move through it. Unfortunately, without internal drainage the water has no where to go. Common symptoms of this scenario are wet greens surfaces and shallow rooting, especially during wet years.

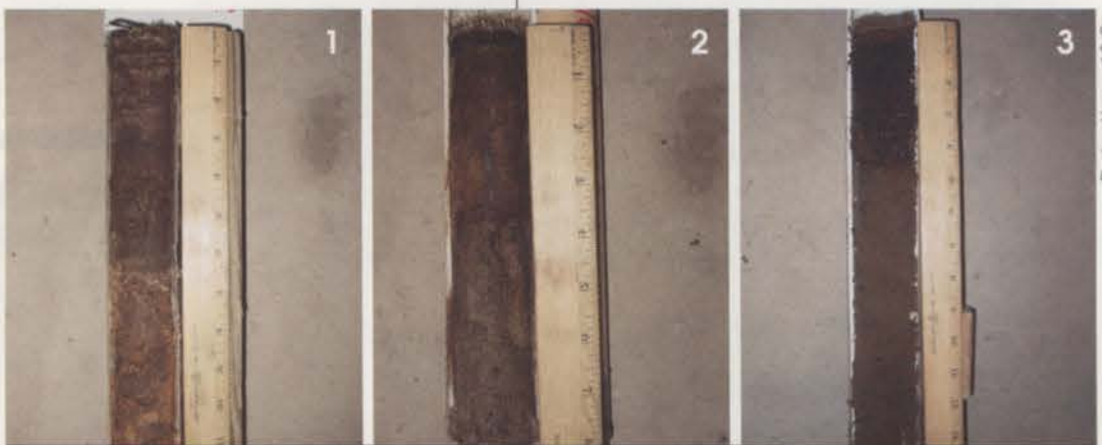
There are a number or options to improve this. Considering how impermeable the subsoil is, an intervention like a drill and fill or deep-tine aerification wouldn't be of much help.

The most definitive option would be to reconstruct the green to contemporary standards, such as USGA greens. Short of re-

Photo: Hummel & Co.

Special equipment can be used to pull undisturbed soil samples from greens.

construction, a bypass drainage system can and should be installed. A bypass system is a series of narrow vertical trenches installed in a green on 6-foot to 10-foot centers. Small diameter pipe is installed, and the trenches are backfilled to the surface with a rich, well-drained sand based mix. Some installers will use straight sand to backfill the trenches, but the drain lines often are visible when sand is used. Bypass drainage systems have been installed on hundreds of greens with good to excellent results.



1. The soil sample on the left shows a sandy layer that has accumulated from years of topdressing.
2. The one in the middle has excess surface organic matter that causes shallow rooting.
3. The one on the right has a root zone comprised of coarse sand, topsoil and peat.

Case study 2: Sand based green with organic fouled surface

One of the most common problems seen with sand-based greens is the excessive accumulation of organic matter. When in excess, organic layers can decrease drainage and increase capillary porosity at the expense of aeration porosity. Gas exchange across the surface is likely compromised as well. Symptoms of excess surface organic matter include shallow rooting, wet surfaces, and in some cases, black layer. (See the top-middle photo above.)

This case involves a golf course built in the early 1990s with United States Golf Association greens. Throughout time, a layer of organic matter had accumulated to the point where the physical properties in the surface were compromised. The results in the data table (page 60) show that the infiltration rate in the surface three inches was low. The aeration porosity was low, and the capillary porosity was high – classic data where surface organic matter is high.

Taking a look at the data from samples taken from 4- to 7-inches deep, one can see that all of the physical properties are favorable. Therefore, the problems on this green appear to be limited to the surface. Reconstruction isn't necessary unless there are other issues with the green, such as excess slope, small size or inadequate cupping space.

There are two options to improve this situation. The more common approach would be for the superintendent to embark on an aggressive aerification and topdressing program. While disruptive to playing conditions, this can reduce the organic matter at the surface and improve the surface growing environment throughout time. There are times, however, when the amount and/or depth of organic matter might be too much to remove by these conventional means.

Another approach, which was taken in this case, is to remove the surface organic layer. New mix is brought in to bring the surface of the green to grade. The new mix is lightly tilled into the surface of the existing mix to prevent an interface. After the green surface is floated out, the green is seeded, sprigged or sodded. Aside from giving the green a fresh start, this option offers the opportunity to introduce newer turf cultivars.

Case study 3: Old USGA greens

The USGA specifications for greens construction have been used in the industry since the early 1960s. Many changes have been made since the original specs. It's likely that a USGA green built in 1960 is much different than one built nowadays.

In this case, a USGA green was built in the early 1960s, and the root zone was composed of a mix of coarse sand, topsoil and a small amount of peat. Throughout the years, a sand-based topdressing heavily modified with peat humus had been used to the point that a 3- to 4-inch layer existed at the surface of the green. (See the top-right photo above.)

The results in the data table (page 60) show that the top three inches of the green had a high organic matter content. As a result, the infiltration rate was low, the aeration porosity was low, and the capillary porosity was high. Unlike the first case study, the topdressing used on this green did little to improve the physical properties in the green. Rooting in this green was shallow.

The physical properties in the subsurface layer also were poor, despite the mix being about 85 percent sand. While not shown in the table, the density on the mix was extremely high, about 1.8 g/cc. The mix was compacted severely, and as a result, had a low infiltration rate. Compacted soils will have a low total porosity, with most of the pores being small capillary pores. The results on the aeration and capillary porosity reflect this.

Speculation only can be made about the history of this green, but it looks like this has always been a problem green. The composition of the original mix is such that it would be prone to compaction, and compacted it is. When new, the green surface probably was hard and wouldn't hold a shot. To correct this, a topdressing program was initiated and carried out for several years using the high organic topdressing material. The green is likely soft now.

While a program of aerification and topdressing might be helpful, the surface and subsurface conditions of this green warrant nothing short of reconstruction.

Problems with greens can be caused by many factors, poor soil physical properties only being one. These three cases are examples of where soil physical testing identified a problem and offered guidance for corrective action. GCN

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