CHARACTERIZING SOIL STABILITY IN HIGH SAND CONTENT SOILS AND MIXTURES

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INTRODUCTION

Soils are an intragal part of the turfgrass system and the particle-size of that soil (sand) is the most important physical property. Particle-size distribution (texture) influences or controls porosity, bulk density, cation exchange capacity, plant available water-holding capacity, soil strength, and soil stability. Particle-size is the primary property specified within the USGA specifications for putting green construction because of it's influence on soil behavior. These specifications, listed below in Table 1, center on not having a large amount of very large particles (VCoS and Gravel) nor a large amount of (<10 VFS, silt and clay) fines, a majority of particles in the medium and coarse sand size range is preferred. This produces a rootzone mixture with a large proportion of macropores that allow for rapid water movement and drainage. Since putting greens constructed on these materials have a low plant available water holding capacity, the different materials (rootzone, intermediate, and gravel) are stratified, or layered, to increase the ability of the sandy rootzone to hold plant available water.

Table 1. USGA Specifications for the particle size of the rootzone mixture to use in Putting Green Construction.

Name	Diameter	Recommendation (by weight)	
F. Gravel	2.0-3.4 mm	Not more than 10% of the total particles in this range, including a maximum of 3% fine gravel (preferably none).	
VCoS	1.0-2.0 mm		
CoS	0.5-1.0 mm	A minimum of 60% of the particles must fall in this range.	
MS	0.25-0.5 mm		
FS	0.15-0.25 mm	No more than 20% can fall in this range.	
VFS	0.05-0.15 mm	Not more than 5%	Total particles in this range shall not exceed 10%.
Silt	0.002-0.05 mm	Not more than 5%	
Clay	under 0.002 mm	Not more than 5%	

The uniformity of the soil and distribution of grain size among the different particle size classes dictate the porosity and soil stability (Adams et. al, 1985; Baker, 1983; Gibbs et. al, 1989). Sands that are uniform (tending to one or a few "adjacent" size classes) lack the right amounts and sizes of particles that will fit together (smaller particles fitting into the void space of the larger particles) and provide stability against movement. We have tried to explain the stability problem with uniform sands as being similar to tossing round marbles on the floor and then trying to walk on them. Being rounded and of similar size leads to an unstable footing. If the marbles were broken (angular) and of different sizes they would fit , or lock, together and produce a more stable surface. Sands complying with USGA specifications do not necessarily produce a stable surface.

Sand particle shape has also been included and discussed in the USGA specifications primarily because of the stability, or lack of, associated with shape. Rounded particles are the least stable and very angular particles are the most stable because of the differences in friction resistance associated with those shapes. Although, in topdressing applications angular particles can be extremely abrasive to the turfgrass and cause considerable physiological stress. Rounded particles are less abrasive but are also less stable. One of the struggles of the turfgrass manager is to obtain the sand material with the optimum characteristics.

Products have been developed and added to soil in an attempt to increase stability (Adams et. al, 1989; Beard et. al, 1988; Gibbs, 1990). Meshed products and many kinds of fibers have been added with what I think is limited effectiveness. Root systems (Reid et. al, 1982) of the turfgrass plant (if there is one) behave in this way and act somewhat like reinforcing rod in concrete to increase strength. In fact, many types of fibers have been added to concrete to increase the strength with some success.

The objective of this research was to characterize commonly used sands and mixtures using routine soil mechanics procedures. Conventional laboratory testing was used to measure frictional resistance and geotechnical modeling was used to predict behavior of the sands in this study.

METHODS AND MATERIALS

Four sands were selected based on their use and particle-size distributions. The sands varied from 2NS, a sand mixture specified by the Michigan Department of Transportation, to TDS 2150, a sand quarried from the dune deposits along Lake Michigan near Grand Haven, Michigan. The characterization data for these sands are included in Appendix A.

To predict bearing capacity of these sand materials a computer algorithm of Terzaghi's bearing capacity equation was used. The variables used to study the changes in bearing capacity were angle of internal friction, inclination, and water content (matric potential).

RESULTS

SAND CHARACTERIZATION

Comparing the sieve results in Appendix A with the USGA recommendations indicates the 2NS and Mortar sands do not fit the recommendations. Both sands do not have the required 60 % in the Medium and Coarse sand fractions while the 2NS also has more than the maximum of 10% above 1.0 mm in size. These two sands are too well-graded (wide distribution) to fit the USGA specifications.

The other two sands selected, Michigan #40 and TDS 2150, fit within the USGA specifications. They are uniformly graded and similar in particle-size distribution.

From an engineering perspective, the 2NS and the mortar sand are generally found to be the better materials when considering them for use in construction. This because as the particle-sizes that make up a sand become more widely distributed the sand becomes more stable. Greater stability results from the smaller sized particles filling the voids of the larger sized particles. The problem that arises when considering well-graded sands for putting greens or athletic fields is the relationship between gradation and porosity. As the sand becomes more well-graded it becomes less porous reducing the hydraulic conductivity and slowing drainage.

Michigan #40 and TDS 2150 sands theoretically do not have the problem of low porosity because they are poorly-graded samples that fall within the USGA specifications. But, these sands have lower strength and less stability because of the uniform distributions.

The difficulty in the design of the sand mixture arises because strength is inversely related to porosity and the greater the porosity, generally the better the environment for turfgrass growth. The success of the turfgrass depends upon its ability to flourish in the sand mixture, while at the same time the stability of the sand mixture depends, in part, on a well established rootzone system.

We have begun to quantify the relationships between sand-size distribution, angularity, pore-size distribution, soil strength and compressibility. It is already known, at least qualitatively, the wider the distribution of sand, the greater the stability. With further research we hope to quantify these relationships in the form of improved material specifications to give turfgrass managers better tools to make sand selections.

BEARING CAPACITY

The bearing capacity of a soil, often termed its stability, is the ability of a soil to carry a load without failure. The load carrying capacity of sand varies not only with it's strength but also with the magnitude and distribution of the load.

The variables that govern the final bearing capacity of a soil (sand) are: particle angularity; relative density; porosity; particle-size distribution; and water content (matric potential).

Holubec and D'Appolonia (1973) found the increase of angularity of sand particles had a positive impact on the strength of the soil. Angularity is a measure of the curvature of the corners to the average curvature of the particles. Comparing sands with increasing angularity, they found a positive correlation between angularity and the resultant friction angle. Sands with greater angularity have a greater friction angle and are more stable.

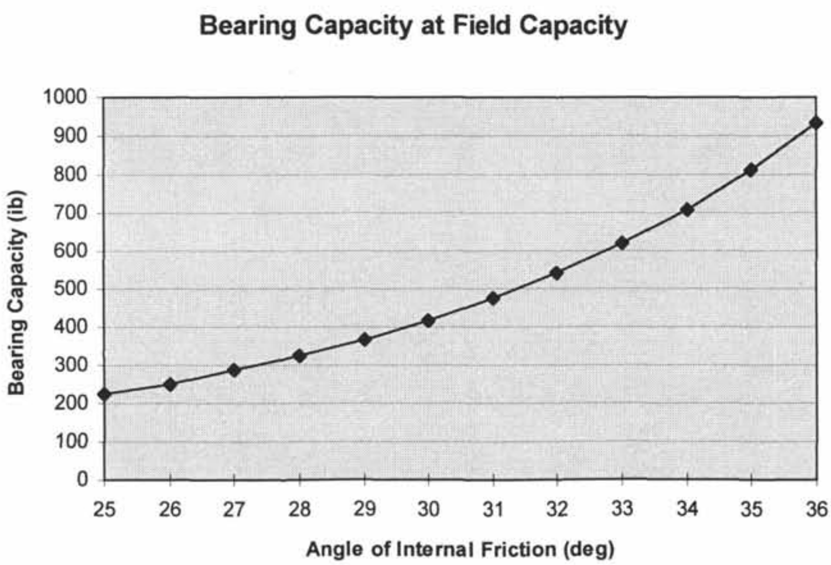
The relative density of a cohesionless soil is defined by its degree of compaction. In other words, relative density describes how close to maximum compaction a particular sand might be. Many have shown a direct correlation between relative density and friction angle. As relative density increases so too does friction angle and stability increases.

Relative density and porosity are inversely related in as far as bulk density and porosity are inversely related. As density increases, porosity decreases, and bearing capacity (stability) increases. Of course, maintaining porosity (and particularly macroporosity) for rapid drainage and maintaining oxygen content in the soil is extremely important for turfgrass growth and vigor. Therefore, a balance between density, porosity, and bearing capacity needs to be achieved.

The importance of particle-size distribution has already been discussed. The last variable deemed to be important is the water content of the soil (sand). Dry sands and saturated sands have no pore water tension. But as sand dries from saturation, tension develops which causes the soil to behave as if it possesses cohesion. As turfgrass managers very seldom do we allow soil water content to vary from field capacity and luckily enough that is close to the point were maximum strength from pore water tension is found. Therefore, water content is a variable we manage for turfgrass growth and not for maximum soil stability.

Utilizing the ultimate bearing capacity equation the theoretical supporting capacity of the selected sands were determined as a function of the angle of internal friction and the water tension. Figure 1 shows how many pounds distributed over 3" by 12" (about shoe size) surface area could carry. We found curvilinear relationships between friction angle and bearing capacity. As friction angle increased so too did the bearing capacity. The actual number of pounds of bearing capacity are not as important (these are modeled numbers) as the relative amount from one sand to another. Given TDS 2150 has a friction angle of about 28 degrees and 2NS sand has a friction angle of approximately 33 degrees, 2NS will support about 1.9 times more weight than TDS 2150 under the same environmental conditions.

Figure 1. Modeled bearing capacity at the water content of field capacity.



CONCLUSIONS

The research conducted in 1995 has shown what soil variables are important when considering bearing capacity (stability) and what the relative magnitude of importance is of these variables. Also, we modeled bearing capacity and were able to interpret strength of the four selected sands from their angle of internal friction.

Because of the support from the Michigan Turfgrass Foundation for this research work, we were able to submit to the United States Golf Association (USGA) for research support in the continuation of this work looking specifically at golf putting greens. With your continued support and that of the USGA our goal of developing criteria for the selection of agronomically sound, technically stable sands and mixtures will be completed.

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