Engineering Characteristics and Maintenance of Golf Putting Greens

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Objectives:

1. *Create an experimental design matrix of various sands.*
2. *Determine friction angles for each of the six sands.*
3. *Determine the bearing capacity for each of the six sands.*
4. *Develop trends relating grain size and gradation to friction angle and ulimate bearing capacity.*

Results indicate that putting green stiffness increases with sands that have higher coefficients of uniformity. In addition, it has been shown the turfgrass roots add significant strength and stiffness to the root-zone sand. Field-testing continues to show variation in stiffness for putting greens constructed on sands that meet the USGA gradation guidelines. Further field testing will make it possible to predicted stiffness based on laboratory data within some degree of certainty. From this, we will develop guidelines that superintendents can utilize to design a sand mixture that will achieve desired results and still meet USGA guidelines.

A deformation model was developed in the past year of study. It models the golf putting green as a soft spring layer (thatch) over a stiff elastic base (sand-based root zone). Given values representing the stiffness of the two layers and the size of the loaded area, the model will predict the vertical deformation of the soil as a function of load pressure. The required stiffness values can be estimated by field-testing. Values are selected by trial and error until the model prediction matches the observed pressure displacement curve. The deformation model is an integral part of the analysis to date and will be the guiding factor as the recommendation model is completed.

Comparison of Field Bearing Tests and Laboratory Bearing Tests. The testing conditions in the lab are somewhat different than those in the field. In the lab there is no thatch layer covering the sand. Also in the lab, the sand is contained in a rigid mold that will not allow lateral deformation or strain of the sand. This leads to a well defined peak stress at failure and a non-ambiguous bearing capacity. In the field, the thatch layer applies a tensile confinement that allow large magnitudes of deformation to occur at increasingly greater pressures on the sand without producing a well-defined peak stress at failure. Also, in the field, the sand-based root zone can strain or deform somewhat laterally, similarly reducing the tendency to exhibit a peak.

Lab bearing and field bearing results have been compared. The lab bearing results for both the confined (surcharge) and unconfined (no surcharge) bearing tests reach an ultimate strength and have a distinct peak stress and failure. The ultimate bearing capacity for the confined lab bearing test is approximately 198 psi, occurring at a vertical displacement of 0.15 inches. The field bearing test results shows no peak value failure and does not reach a specific ultimate strength. In fact, had the test been continued for larger pressures the soil would continue to deform at approximately the same rate and would not reach a distinct failure point. The sand-based root zone does not reach a distinct failure point because of the tensile confinement applied by the thatch layer. Also, the root zone material has the freedom to deform laterally and redistribute the pressure to the adjacent soil. Although the field and lab tests are not exactly equivalent, it is noted that the lab results with and without surcharge tend to act as upper and lower bounds, bracketing the field results.

It is also shown that the slope of the pressure-displacement curves, or rate at which the pressure increases with increasing displacement, is highest for the confined lab bearing test and lowest for the field bearing test. The high rate of increase in pressure due-to increasing displacement for the confined lab test occurs because the sand is confined from both lateral deformation (due to the rigid mold) and vertical deformation (due to the applied surcharge). The root zone material is allowed to deform laterally, thus leading to its lower rate of increase in pressure due to increasing displacement.

Stiffness of Soils. An important characteristic of soils shown in the previous section is that soils can support loads and the magnitude of the peak supportable load, or ultimate bearing pressure, is determined by the physical properties of the soil and the degree of confinement. A second important property of soils often used by engineers is the stiffness of the soil. The stiffness of the soil is essentially a measure of how much pressure can be put on a soil at a certain limiting deformation. It is the rate of change in pressure due to increasing displacement. The soil modulus is described by therelationship:

k = *delta*P/*delta* y

Here *delta* P (psi) is the change in stress on the soil (in our case, the putting green) and *delta* y (inches) is the change in vertical displacement measured under the change in load. The units of k are pounds per inch cubed. The value of k depends on the elastic properties of the soil, but is dependent of the dimensions of the loaded area.

The typical bearing results show that the confined lab bearing test yields the greatest stiffness and the field bearing test yields the lowest stiffness when comparing the three typical bearing test results.

Typically, geotechnical engineers study soils at their failure conditions, governed by local shear strength and by general shear failure under a loaded area. Engineers use a factor of safety and limit the allowable load to a third or a quarter of the ultimate bearing capacity to be conservative in their design. Although we are interested in what soil properties contribute to increased bearing capacity, we are more concerned about the behavior 'of the soil and golf putting green before failure occurs. An advantage to measuring or predicting the soil stiffness is that the deformation characteristics at pressures below the ultimate bearing capacity may be analyzed. Those greens with greater stiffness deflect less under load.