Engineering Characteristics and Maintenance of Golf Putting Greens

Michigan State University
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Start Date: 1996
Number of Years: 5
Total Funding: $115,000

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.*

This project is a continuation of previous putting green construction project conducted at Michigan State University. This project has allowed for application and expansion of the previous two years of research. 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.

Laboratory Testing: In order to ensure consistency of measurements in the laboratory, six sands were produced rather than selecting market sands. These sands were made from commonly available construction sand (MDOT 2NS) which has a wide range of particle sizes. Three different gradations of sands were designed, a coarse, intermediate and fine. Each of these three classifications was again divided into a high coefficient of uniformity (C_u) and a low coefficient of uniformity (C_u).

A direct measure of a soil's strength against failure under surface compression is its bearing capacity. This can be directly tested in the lab with the Modified California Bearing Ratio (CBR) testing device (ASTM 1883). This device has a small plunger that is forced into a sample volume of sand. Attached to the plunger is a load cell that records the force pushing down on the soil sample. The depth the plunger has punctured into the soil can then be measured to determine the amount of force necessary to cause failure within a soil. Figure 1 indicates the pressure as a function of piston displacement. The peak of the test graph designates the ultimate pressure that the soil can withstand before it fails. The bearing capacity test was run approximately 290 times on the sand samples under all types of conditions.

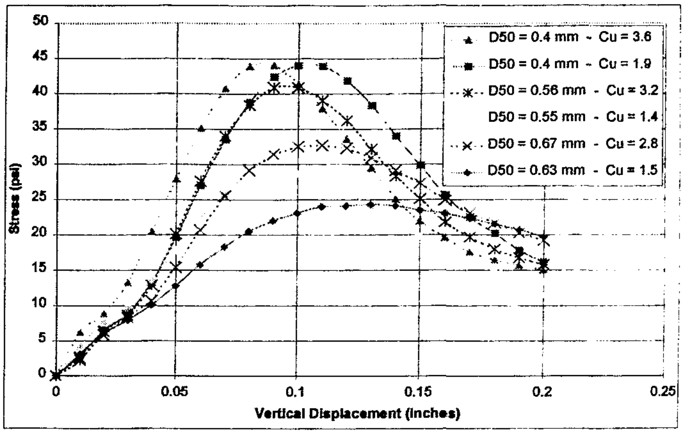

Figure 1. Bearing Capcity of sands with different coefficients of uniformity (cu) meeting USGA Specifications.

The bearing capacity tests also show the benefits of sands with a high coefficient of uniformity (C_u). The well-graded sands were capable of withstanding an ultimate pressure on the order of 45 psi. The poorly graded sands, under the same conditions, could only withstand pressures up to 25 psi. This is below the tire pressure found in some golf course maintenance vehicles and indicates that a golf putting green may suffer deformation during normal servicing. It should be reiterated that although these sands display such a wide variety between their ultimate bearing capacities, they all fall within USGA gradation specifications and would be considered acceptable sands for golf putting green construction.

Field Testing: The field CBR device is designed to model the California Bearing Ratio testing device. The field CBR device can be attached to a three-point hitch or loading bucket of most tractors. The device has a plunger that is forced into the ground. A load cell measures the force on the plunger directly. This force is recorded with the corresponding vertical displacement of the plunger into the ground, measured by a dial gauge on a reference beam.

The force on the load piston divided by the area of the load piston gives us the stress on the surface of the putting green. Force is recorded at every 0.01 inch of displacement for consistency. The stress (force) at each 0.01-inch of displacement is plotted versus the vertical displacement as shown in Figure 2. The initial part of the curve, is the stress on the thatch layer that offers little resistance to deformation. However, the underlying sand-based root zone can take significantly more stress with less deformation than the overlying thatch.

The slope of a line drawn tangent to the curve, k_s, is the stiffness of the green and is referred to in geotechnical engineering as the modulus of subgrade reaction. For example, a green with k_s of 100 pounds per square inch would be displaced 0.10 inches under a load of 10 psi.

As the putting green is loaded and then unloaded, some consolidation of the thatch and sand occurs. For example, one

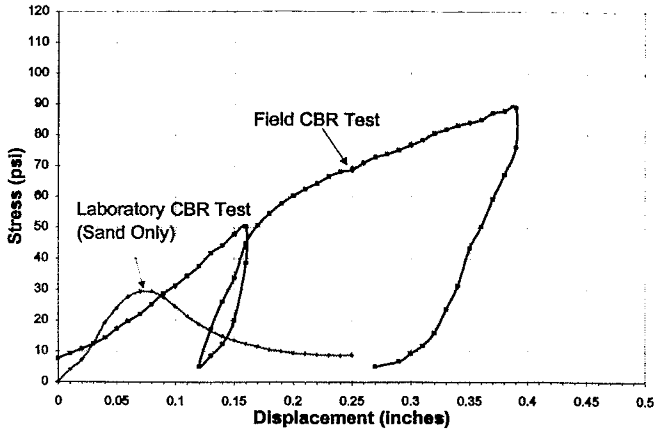

Figure 2. Laboratory and Field California Bearing Capacity (CBR) tests performed at Michigan State University.

sand and thatch consolidated approximately 0.12 inches when subjected to a 50-pounds per square inch load. When reloaded, the stress-displacement curve followed the same line back to 50 pounds per square inch stress since the thatch and sand have already 'felt' that stress. Beyond 50 pounds per square inch, the thatch and sand experience new, higher stresses, and will continue to consolidate until the sand begins to fail. Engineers often refer to the load and reload curve as an elastic rebound curve.

A problem associated with testing existing golf putting greens to evaluate the stiffness of the sand root-zone is separating the contributing strength of the root system. Referring to Figure 2, it is clear that the same soil tested in the field with an established root system has significant reserve strength over the same sand tested with no turf. Regardless of where we evaluate the modulus of subgrade reaction in Figure 2, it is consistently greater than that of the sand measured in the laboratory. This suggests that the root system adds strength and stiffness to the elastic and plastic properties of the root-zone sand. This additional strength and stiffness is most likely due to the tensile strength of the root system that reduces local shear failure within the root-zone sand.

Initial findings suggest that golf putting greens can be modeled as an elastic spring that has some stiffness, k_s. The stiffness or modulus of subgrade reaction of the root-zone sand increases with higher coefficient of uniformity, C_u. The median grain size has no effect on the stiffness of the sand. Field tests show that the stiffness of the green is dependent on soil properties but it also has increased strength and stiffness due to tensile strength contributed by the root structure. The short-term growing season of established root-zones have no effect on the stiffness of the putting green.

Methods for Classifying Sand Shape and the Effects of Sand Shape on USGA Specification Rootzone Physical Properties

The Pennsylvania State University

Dr. Charles Mancino

Start Date: 1996
Number of Years: 2
Total Funding: $38,254

Objectives:

1. *To determine if a simple, inexpensive and quantitative procedure can be used to give a reliable estimate of sand shape without having to examine individual grains.*
2. *Determine the effect of sand shape on the physical properties of rootzone sands and whether particle size distributions of USGA rootzone sands should be modified to account for differences in sand shape.*

A series of experiments were conducted to determine a method for assessing the shape of sand grains in a non-subjective manner. Methods tested in the past have included the direct shear strength method, the rotatable drum method, dense soil angle of repose, and cone penetrometry. These methods have not been capable of separating all classes of sand according to shape. In 1998, sand shape was assessed through computer imaging and analysis, cubical triaxial testing and further evaluation of cone penetrometry.

The use of computer imaging to determine sand shape was performed to compare sphericity ratings for samples of angular, sub-angular, sub-rounded, and rounded sands as calculated by an experienced technician and an image processing and analysis program *ImageTool* is a public domain freeware program. The comparison of measures of sphericity, however, resulted in a low coefficient of determination R^2 0.521. This R^2 value is too small to have confidence that the results produced by *ImageTool* and the technician will be similar. The reason for the low values is due to the failure of the software to properly define the edges of the scanned sand grains. The program tends to make the image more angular. Another inexpensive software program, *ArcView*, will be tested next. The *ArcView* package may be able to produce better results using algorithms to generalize or smooth the shape of the grains before analysis.

A cubical triaxial tester was used with the four sands to measure bulk mechanical behavior and how it relates to grain surface texture. The tester showed substantial differences between the sands with the sub-round sand having the best compaction resistance. The angular sand was the most compressible with the round and sub-angular materials being intermediate. In regards to soil strength, at lower pressures the subround sand was strongest while the round sand was weakest. At higher pressure, it was the angular sand and sub-rounded sand with the highest strength. Overall, the sub-round and