THE EFFECTS OF ADDING SILT AND CLAY ON THE AGRONOMIC AND ENGINEERING PROPERTIES OF A SAND TEXTURED ROOT ZONE MATERIAL

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Introduction

Athletic fields are subjected to intense traffic under all types of weather and soil moisture conditions (Beard 1973). Turfgrass professionals face the challenge of developing the "perfect field" that will endure the rigors of athletic competition during any weather conditions.

An athletic field must provide firm footing, adequate resiliency on impact, and resistance to tearing during play. It must also drain well and resist the compacting effects of severe traffic (Turgeon 1991). The key to constructing the "perfect field" lies in the choice of the root zone material. Traditional fields developed on native soil with high silt and clay content will provide excellent stability but drain poorly, and the quality of the playing surface quickly diminishes in unfavorable weather conditions.

In the early 1960's, the inability to sustain optimal playing conditions and acceptable appearance resulted in the transition to artificial "turfs" at many college and professional stadia (Turgeon 1991). Artificial turf was considered advantageous for several reasons: it is immune to turf pests, it does not require cultural practices, and it is adaptable to all types of environmental conditions. However, the disadvantages of artificial surfaces exceed their advantages. The disadvantages include high initial cost of construction, short life span, and maintenance costs for cleaning and repairing. Most importantly, artificial surfaces contribute to increased player injury and cause substantial heat build-up at and above the surface during hot weather.

In the 1960's, Bill Daniel, at Purdue University, conducted extensive research on sands and contributed to the development of the United States Golf Association (USGA) specifications for golf green construction. By the early 1970's, the knowledge gained on behalf of the golf industry was applied to athletic fields in an effort to return to natural playing surfaces. At that time Bill Daniel designed the Prescription Athletic Turf (PAT) system to address drainage problems associated with natural turf fields.

Since the inception of the PAT system, its key component, a sand root zone, has become increasingly popular because it resists compaction and drains rapidly. Sand has many advantages, but it seems to create as many problems as it solves (Gibbs 1990). It is an unnatural growing medium that has little water holding capacity and can store few plant nutrients, making it poorly suited for turfgrass establishment. However, the problem of greatest concern is the sand's lack of stability. Many newly constructed fields have failed because of the instability of the root zone.

Currently, the only specifications used for root zone constituent selection for athletic fields are those of the USGA. However, it must be recognized that athletic field requirements differ from those of a golf course green. The activities performed on each surface are drastically different and this difference must be reflected in a separate set of specifications. The current goal is to adapt the specifications developed for golf green construction to athletic fields.

Over the past 10 to 20 years a tremendous amount of money has been spent to build the "perfect field" at college and professional stadia. Many of these fields have had significant problems or have failed. Sand root zones are believed to have caused many of these failures. Previous attempts at amending sand root zones to improve stability have resulted in limited success, but amending sand using silt and clay has not been investigated thoroughly. This is worth investigating because as the silt and clay content of a soil mix increase the stability increases. However, as the silt and clay content of the mix increases the hydraulic conductivity of the mix drops quickly. The research that has been conducted using silt and clay as an amendment has focused on its effect on hydraulic conductivity rather than the increase in stability. The percent silt and clay that can be added to a sand to increase stability while retaining adequate hydraulic conductivity has not been determined. Therefore, the objective of this study was to determine what percentage of silt and clay must be added to a well-graded sand to maximize soil bearing capacity while retaining a hydraulic conductivity value of 3-4 in/hr.

Materials and Methods

A well-graded sand and a sandy loam textured soil were selected from Great Lakes Gravel located in Grand Ledge, MI. A particle-size analysis was then completed on both the sand and soil to determine their percent sand, silt and clay. The particle-size analysis of the sand followed the procedures outlined by Day (1965). The Michigan State University Soil and Plant Nutrient Lab did the particle-size analysis of the soil (Day 1965). These analyses were necessary in order to calculate the amount of sand and soil that must be combined to yield the mixtures chosen for investigation. The sand and soil were then mixed on a volume basis using a cement mixer to produce eight different soil mixes.

The eight soil mixes were then subjected to five different analyses: particle-size analysis, Proctor compaction test, bearing capacity, hydraulic conductivity, and pore size distribution.

Particle-size analysis

A particle-size analysis was performed on each mix to determine the percent sand, silt and clay (Day 1965). The eight different mixes contained approximately 2, 5, 7, 8, 10, 12, 15, and 19% silt plus clay.

Proctor Compaction Test

The optimum water content of each mix was determined using the Standard Proctor Compaction Test (Proctor 1933).

Bearing Capacity

The bearing capacity was measured at three water contents (5, 9, 13% by weight) for mixes containing 2, 5, 7, and 8% silt plus clay and at five water contents (5, 7, 9, 11, 13% by weight) for mixes containing 10, 12, 15, and 19% silt plus clay. Soil bearing capacity was measured according to ASTM-D 1883-94, using the GeoTest (GT Instrument Corporation, model no. 55771, Evanston, IL). An automatic compactor was used to obtain a consistent compactive effort for each test (Ploog Engineering Company, Crown Point, Indiana ser.no. M100-21089573). The compactive effort was calculated to match that of the Standard Proctor Compaction Test, 592.7 kJ m^{-3} (Holtz and Kovacs 1981).

Hydraulic Conductivity

After each bearing capacity test was complete, the soil was loosened and compacted again using the automatic compactor. A 7.62 cm x 7.62 cm core was then extracted from the bearing capacity mold using a double-cylinder, hammer driven core sampler for the determination of hydraulic conductivity (Blake 1965).

Pore size distribution

The pore size distribution of each soil was then determined using pressure chambers according to Vomocil (1965). The cores were evaluated at the following pressures: 0.02, 0.04, 0.06, 0.08, 0.10, 0.20, 0.33, 1.0 bars.

Results

This study was conducted to determine the amount of silt and clay that can be added to a well-graded sand in order to increase its strength without severely reducing its hydraulic conductivity. The main physical property that determines the selection of a root zone material is hydraulic conductivity. The root zone material in athletic fields should have a hydraulic conductivity rate of 6-8 in/hr (Crum, pers. comm.) in the laboratory because infiltration rates will decrease by half once turfgrass is established (Brown and Duble 1975).

Water content at compaction in interaction with percent silt+clay was extremely influential in determining hydraulic conductivity (fig. 1). The mix containing 5% silt+clay had a hydraulic conductivity value exceeding 10 in/hr when compacted dry (5% water content), but hydraulic conductivity was reduced to less than 2 in/hr when compacted wet (13% water content). The mixes containing 10% silt + clay or less were the only mixes acceptable, in terms of drainage (6-8 in/hr), for an athletic field, but only when compacted at 5% water content or less (fig. 1). All of these results indicate the importance of using a dry root zone mix during field construction (5% water content or less), if the root zone material contains more than 2 percent silt+clay.

The strength characteristics of a soil are also affected by water content at compaction and silt+clay content (fig. 2). The mix containing 19% silt+clay was stronger than the 2% silt+clay mix by over a magnitude of 8 when compacted at 5% water content, but weaker than the 2% silt+clay mix when compacted wet (13% water content) (fig.2). A compromise must be met between hydraulic conductivity and strength. Given the sand and soil chosen for this study and the limitations of hydraulic conductivity, the highest percentage of silt+clay that can be used for an athletic field is 10%. The mix containing 10% silt + clay had twice the bearing capacity of 2% silt + clay when compacted at 5% water content or less (fig.2). More research needs to done to determine how the establishment of turfgrass and the application of traffic affect the hydraulic conductivity of the root zone over time.

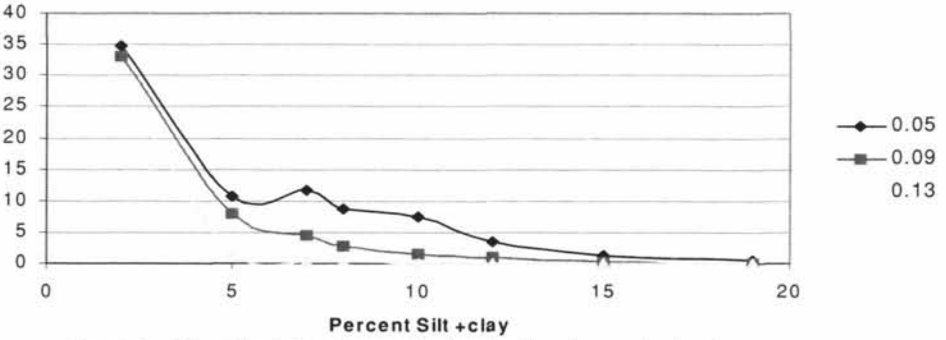

Figure 1. The effect of water content and silt +clay on hydraulic conductivity.

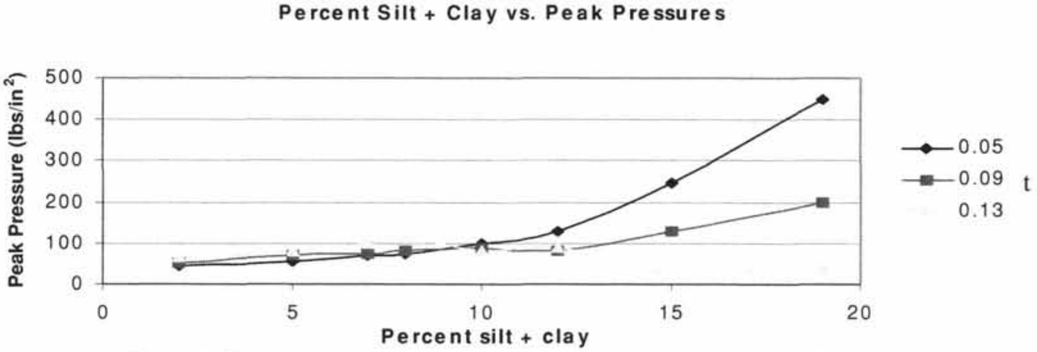

Figure 2. The effect of water content and silt+clay on soil strength.

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