LANDSCAPED COMMERCIAL AREAS: GOLF COURSE AND ATHLETIC FIELD SOILS

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Summary

The principal goals of a golf course or natural turf athletic field are to be agronomically reliable and to provide quality play for a particular level of use, degree of maintenance and climate. Agronomic reliability reflects the density, persistence, health and recovery from wear of the intended turfgrass species in the face of biotic and abiotic stress. Quality of play, while judged relative to measurable performance standards also is tempered by player and spectator expectation. Situations where agronomic reliability and quality play are successfully balanced with degree of soil modification generally span a continuum of root zones containing at least 0.75 kg kg^{-1} sand with depths of 75 to 150 mm to entirely sand root zones having depths of 250 to 350 mm. Along this

continuum the Fineness Modulus and D_{90}/D_{10} values follow the trend from higher values to lower values within acceptable ranges. Organic matter contents also display a trend along this continuum ranging from amendment rates of 50 g kg^{-1} for lower sand content root zones to none for pure sand root zones. Finally, shallower and lower sand content root zones would be fitted with interceptor style drainage elements whereas the deeper and higher sand content root zones would be more reliant on subsurface drainage elements cut into the subgrade and optimally containing a gravel drainage blanket. These sand dominated root zones with a soil profile favoring a proper air and water balance is a proven first step to satisfy agronomic reliability and quality play goals.

1. Introduction

Soils are an integral component of every golf course and natural turf athletic field. Besides their obvious role in supporting turfgrass and other plantings, golf course and athletic field soils are shaped and contoured both to provide a quality playing surface and for golf, an interesting and aesthetically pleasing landform. Further, the soil media and profile of golf courses and athletic fields are often highly engineered to provide superior turf growth conditions and playing quality.

Golf course landscapes have a common ancestry found on the links, or windswept coastal sand dunes of Scotland and Ireland. Indeed, these landforms are so significant to enthusiasts of the game that various attempts to recreate links landscapes are common across golf courses around the world. Athletic fields, on the other hand, require a substantially level area for adequate play. Consequently, the creation of a golf course or athletic field is often accompanied by some degree of earthmoving. Clearly, processes involved in earthmoving result in a loss of natural soil horizonation and a mixing of soil materials from diverse locations and depths across the site.

Another goal in the creation of golfing and athletic field topography is to speed surface water runoff for effective surface drainage. In the case of golf course fairways, minimum slopes of 2% are typically required for surface drainage. Putting green slopes range from 1.5 to 10% where extreme values are only found at isolated locations within some greens. Surface slopes of athletic fields are typically 2% or less as per the requirements of the game.

Frequent human contact is a key feature of golf course and athletic field soils. Foot and vehicle traffic from both play and frequent maintenance apply an external stress to the soil surface. Further, these activities commonly occur over a much wider range of soil moisture conditions than found with agricultural traffic.

2. Soil Compaction

Soil compaction is a problem that occurs from human interaction with soil. Defined simply as an increase in soil bulk density, compaction is an interaction between the level of applied stress and the strength of the soil in resisting deformation. If the applied stress exceeds the soil compressive strength, compaction will occur.

Turf maintenance and play are the principal sources of axial stress in golf course and athletic field situations. For most routine maintenance, however, the physical weight of the equipment is small or alternatively low-pressure tires are used. Expectedly, little compaction is observed from equipment used in turf maintenance. Excessive and untimely foot traffic, on the other hand, is a major cause of soil compaction in turf areas. The magnitude of foot traffic on the golf course can be illustrated by considering that the average player takes about 50 steps on each putting green. For 200 rounds of golf per day, this would result in about 10 000-foot steps per green. Traffic on athletic fields, though not a daily occurrence, is usually higher depending on the level of use. Soil stresses resulting from foot traffic can, however, vary with the nature of the activity. For example, a 75-kg person in street shoes will create a ground pressure (stress) of 2.5 to 4.1 g cm^{-2} while standing upright. With this same individual walking and striking the ground with his heel and toe, the stress increases to 12.2 g cm^{-2}. A 75-kg player wearing studded shoes (where studs support the weight) while standing would exert 31.6 to 52.0 g cm^{-2} depending on the stud size and pattern. When walking this player would exert 95.6 to 156 g cm^{-2}, and while running the pressure increases 2 to 3 fold, yielding 239 to 390 g cm^{-2}. Another reference gives a value of up to 408 g cm^{-2} for a running player wearing studded shoes. Added to these values for a running player, planting of one's foot for rapid direction changes will add significantly to these loadings.

Clearly, compressive stress from foot traffic can become very large depending on the activity. It is important to remember, however, that the total load is small and the depth of this stress penetration in the soil will be shallow. Thus, foot traffic can create large surface stresses that can easily compact a soil but does so to a relatively shallow depth. A healthy turf with a thatch or mat layer can absorb significant impact from foot traffic. Excessive foot traffic on bare soil can, however, lead to devastating consequences.

The degree to which a soil will be compacted from foot traffic also depends on the strength of the soil. Soils with higher compressive strength will experience less compaction for a given level of stress. The principal factors that influence soil strength are texture and water content. In engineering applications soils are broadly classified as either cohesive or granular. Cohesive soils contain an appreciable quantity of silt and clay. Granular soils consist mostly of clean sands and gravels. Cohesive soils, when moist, have a lower compressive strength and are subsequently prone to greater compaction. Granular soils typically have higher compressive strength and can resist compressive stresses. This is the main reason that higher sand content soil materials are preferred as root zones for soils exposed to high levels of foot traffic.

But it is not foot traffic or soil texture alone that dictates the extent of soil compaction. Soil moisture has a large influence on the strength of a cohesive soil, with strength generally decreasing at higher water contents. Thus, play on a cohesive soil when at higher soil moisture leads to more severe compaction than when play occurs on the same soil when drier. The inevitable consequence of golf or other athletic activities is that they frequently occur regardless of the rainfall or soil moisture conditions.

By definition, soil compaction results in a loss of total porosity. More significant is that not all soil porosity is influenced to the same degree. Soil compaction results in the collapse of the larger sized or macro-pores with a corresponding increase in the volume percentage of smaller pores. A compacted soil will, therefore, exhibit reduced infiltration rates, reduced drainage, poor soil aeration, and a platy or massive soil structure. These marginalized soil physical conditions result in a less favorable environment for turfgrass roots, and for many beneficial soil microbes, earthworms, and arthropods. For this reason, compaction is probably the most serious damage that can occur in recreational turf soils.

3. Root Zones for High Traffic Areas

The close connection between foot traffic and compaction on golf courses and athletic fields would suggest that some degree of soil modification would substantially improve the soil and consequently turf growth and playing quality. This is particularly true for those areas exposed to the greatest traffic. On the golf course, the focal points of play are putting greens and tees, since play at each hole begins within the typically 400 m^2 teeing ground and ends within the typically 550 m^2 green. Between these beginning and end points, play and subsequent foot traffic is spread more widely. For athletic fields, even though areas of concentrated play depend on the sport (such as goal mouth areas in sports using goals), the degree of field use and performance expectations are commonly overriding factors dictating the degree of soil modification required.

Historically, the principal goal in soil modification is to replace the existing native soil that typically exhibits cohesive behavior with a root zone having properties of a granular media. This goal is achieved by establishing sufficiently high sand contents in the root zone. Sand contents exceeding 0.75 kg kg^{-1} generally assure both inter-particle contact of the sand grains and a sufficient proportion of pores between grains that are not occluded by finer textured materials.

For example, research has shown that depending on the sand texture, sand contents exceeding 0.75 kg kg^{-1} result in more than 15% of the total pore volume composed of larger sized (> 0.05-mm diameter) pores. Pores greater than 0.05-mm are responsible for rapid air and water movement. Generally, a soil should contain at least 10 to 20% of these larger sized pores to allow adequate water infiltration, drainage and gas exchange with the atmosphere. Studies also show that a soil containing this minimum sand content will yield saturated hydraulic conductivity values of about 50 mm h^{-1}, a commonly recommended minimum permeability for high traffic turfgrass root zones.

As sand content increases above this minimum, the porosity from larger pores and saturated hydraulic conductivity values increase as well; the rate and extent of which is highly dependent on the sand texture. Subsequently, above about 0.9 to 0.95 kg kg^{-1} sand, these physical properties slow in their increase and in some cases have been shown to plateau.

Again, depending on the performance expectations, degree of use and foot traffic levels, modified by conventional practices, it is recommended that the sand content for golf course greens and tees and athletic fields exceed 0.75 kg kg^{-1}. In terms of physical behavior, this range of soil textures from sandy loam to sand allows rapid water infiltration, drainage and gas exchange with the atmosphere. Further, these properties will not decline as a result of compressive stresses from foot traffic and maintenance equipment.

3.1. Sand Characteristics

Clearly, however, not all sand sources are deemed adequate for golf course and athletic field root zones. Properties of sand shown to influence physical properties are principally the grain size distribution and distribution uniformity; secondary consideration is given to grain shape and mineralogy. One method to describe the grain size distribution is calculation of the Fineness Modulus. This index is calculated by summing the percents by weight retained on mesh sieves having openings of 4.75, 2.36, 1.18, 0.60, 0.30, and 0.15 mm, and dividing by 100. Finer textured sands have smaller Fineness Modulus values whereas coarser sands have larger values. Fineness Modulus values of sand used for high traffic turfgrass root zones typically range from 1.4 to 3.1. The smaller values often conform to root zones composed entirely of sand and/or located where rainfall intensities are low. The larger Fineness Modulus values are often given for sands used in root zones containing up to 0.25 kg kg^{-1} silt and clay sized fractions and correspondingly higher organic matter contents. Consequently, recommended grain size distributions are often specific to the intended use and experts in the area may differ in their recommendations. Some specific examples are presented in the following section.

Uniformity of the sand grains is often expressed as a gradation index calculated as the diameter ratio of the larger to smaller grains. The D_{90}/D_{10} gradation index is obtained by dividing the D_{90} value (i.e. the diameter where 90% by wt. of the grains are smaller) by the D_{10} value (i.e. the diameter where only 10% by wt. of the grains are smaller). For a sand to be sufficiently uniform for most golf course and athletic field root zones the D_{90}/D_{10} value should be less than 8. Also, qualitatively the sand distribution should be unimodal and not gap graded. Sand shapes are classified as having varying degrees of sphericity and angularity where sphericity refers to how closely the grains conform to perfect spheres and angularity characterizes the microscale roughness of the grain surface. Although of secondary consideration, grains having low sphericity and high angularity, and vice versa, are commonly avoided for golf course and athletic field root zones. Finally, a sand mineralogy dominated by quartz is preferred.

One negative aspect of increasing sand content is a consistent reduction of plant available water and cation exchange capacity (CEC). Thus, increasing sand content of a soil typically results in the creation of a droughty soil and one having low nutrient retention properties. A root zone having low available water and CEC will require more frequent irrigation and fertilizer inputs and consequently a higher degree of maintenance to yield suitable turf growth conditions.

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Biographical Sketches

Ed McCoy is an Associate Professor in Soil Science at Ohio State University. Over the past 15 years he has conducted research on urban, golf course and athletic field soils; and teaches an undergraduate golf course soil course to turfgrass science majors. His area of focus in research is the near-surface hydrology of anthropogenic soils and soil profiles.

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John Street is an Associate Professor of Turfgrass Science at Ohio State University. As a turfgrass extension specialist over the last 22 years, he plans and conducts educational programs in turfgrass science and management. He has also conducted a wide variety of applied research projects focusing on turf fertilization and sports turf management issues.