Engineered Soils for Sports Field Constructions

by Michael DePew and Stephen Guise

Many types of root zone constructions exist for all levels of play on sports turf areas from recreational fields to professional stadiums to thoroughbred racetracks. The expected level of use and subsequent maintenance resources and management requirements should drive the decision as to the type of root zone system constructed at a given site. Levels of use can be categorized into two types: frequency of use and intensity of use. These levels of use and the performance expectations of the installation determine to a large extent the soil engineering principals that are most applicable to the field's design.

Levels of use

Frequency of use (use-frequency) can be evaluated as either total hours of play in a given cycle or by the hours of plays clustered at certain time intervals within a cycle. For example, two fields can each have 20 hours of use in a seven-day cycle, but if the one field has a high proportion of its usage time (say 14 of the 20 hours) clustered around day 6 and 7 of the cycle, it will have a different type of wear than if the field is used in equal time increments spread across each day of the cycle.

Intensity of use (use-intensity) factors include the level of competitiveness and number of hours per event and therefore total stress level per event on the field. Larger, more competitive athletes apply higher stress loads on a playing surface. However, lower competitive levels will tend to have wear patterns clustered around the center of the field while higher competitive levels will have wear stresses more widely distributed across the field. The relative importance to a facility of use-frequency versus use- intensity is an extremely important factor in root zone system design.

Soil Design Types

Sports turf root zone constructions may be placed into four basic categories: soil-based, sand-modified, sand-amended or sand-based fields. Each type of field design has its own particular strengths and subsequent limitations.

SOIL-BASED DESIGNS

Soil-based fields primarily refer to field constructions from native-type soil material. This type of native soil material can refer to either on-site top soil or imported soil. Generally speaking, we think of soil-based fields as loamy textures and finer. Sands and loamy sands, while they may be natural native soils, are generally thought of as sand-based or sand-amended fields.

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In general, soil-based fields may have certain advantages over other types of constructions. Soil-based fields have higher water and nutrient holding capacity and generally have higher use-frequency capacities. Soil-based fields generally provide a better growth media than other field design types. However, the effect of compaction can rapidly rank these field designs inferior to the other field design types.

Soil-based fields have the greatest potential for high soil shear strength characteristics if maintained in a non-compacted, well drained and well aerated state. In an uncompacted state, these fields will provide for excellent traction and playability. They are, however, the type of root zone system most prone to compaction, especially when their use capacity is exceeded in terms of either frequency or intensity. Soil-based constructions also have the greatest limitations to play over wide ranging moisture and environmental conditions. Soil root zones will deteriorate rapidly if played on in conditions of excessive soil moisture levels.

At high soil moisture contents the plasticity characteristics of the soil can be nullified as the soil behaves more like a liquid. When this occurs, soil material often is "pumped" to the surface and the entire field is prone to surface rutting and tracking. Under these conditions, the natural soil structural integrity is rapidly lost and cannot easily be restored. In most cases, it can never be restored without taking the field out of play and performing extensive renovation.

SAND-MODIFIED AND SAND-AMENDED DESIGNS

Sand-modified root zones are those native soil-based fields that have been modified on-site by additions of sand. Sand is normally added through topdressing programs alone or in combination with aeration practices. As sand is added to many native or plastic-type soil materials, the sand will increase the internal friction of the soil somewhat (decrease deformability). As more sand is added, the compaction resistance of the root zone will increase due to increasing internal friction. However, sand additions also decrease the plasticity of soil materials. If a soil does not contain a high enough sand proportion, the resulting rootzone will neither exhibit significant compaction resistance nor desireable plasticity characteristics. Caution must be exercised with the use of a sand modification program as the end result could make a problem worse rather than better. Of course, sand selection greatly impacts the resulting soil properties as well.

Enhancement of soil aeration and drainage would not be expected as a direct effect of sand additions. The enhanced aeration and drainage characteristics of a sand-modified system would be due to a longer period of time that the soil remains non-compacted. Actual increases in aeration and drainage characteristics would not be expected until sand proportions exceed a threshold proportion. Threshold proportions of sand and soil mixtures typically require 60 percent or more sand on a volume basis. Significant increases in drainage and aeration properties are not typically observed until sand volume proportions exceed 80 percent or more depending upon the particle size distribution of the sand and soil components.

Sand-amended root zones are those that have native soils mixed with sand during complete renovation or new field construction. To ensure proper and thorough mixing of the sand and soil components, off-site mixing and blending with a screw or drum type self-contained blender should be practiced over an on-site blending process that utilizes rototilling or rotary cultivation. New blending equipment such as the Netavator blender (distributed by Multi-Use Designs, Inc.) has slow speed reverse-tine tilling and shows good promise as a method for acceptable on-site blending of soils.

The performance of these types of constructions vary widely depending upon the various proportions of sand and soil as well as the relative particle size distribution of each of the components. The ratio of silt to clay and the mineralogy of the silt and clay fractions is an important design consideration. Organic components are sometime included as part of the mixture. Adequate performance of these constructions require considerable soil science expertise to ensure long-term success. An experienced and qualified sports turf agronomist should be consulted when considering these design specifications.

SAND-BASED DESIGNS

Sand-based root zone constructions can be expensive but may provide a greater performance potential. As such, they often receive the most recognition as a "desirable" athletic field construction. Sand-based root zones do generally have a much higher use-intensity than do other types of root zone constructions. Sand-based systems however, because of their granular make-up and lack of plasticity, do not necessarily have the highest use-frequency. While a soil-based root zone system can have dramatically higher use-frequency over sand-based systems, a sand-based system will perform over widely ranging and highly variable weather conditions. This includes live play even under severe and intense rainfall events. A soil-based system would deteriorate rapidly under the same severe conditions.

A well designed and constructed sand-based field will provide a root zone that has high aeration and drainage rates. The higher rates of aeration and drainage in sands is due to a greater proportion of macroporosity. This high macroporosity also results in reduced microporosity and likewise these root zones have reduced moisture retention and therefore if not managed correctly, can be droughty.

Sand-base root zones are commonly composed of low reactivity silicate minerals such as quartz. This inherent low reactivity results in a material that has a low buffering capacity. This low buffering capacity is exhibited both as low cation exchange capacity (CEC) and a soil system that is subject to vast and rapid soil chemical changes. To counter these effects, an organic amendment is often added. It should be noted however, that organic constituents vary widely as to their physical and chemical characteristics and therefore the performance characteristics of the resulting blend can vary widely.

To counter the effects of inherent droughtiness in sands, sand-based systems with an underlying layer of gravel have been employed. The ŒUSGA' specifications for putting green construction is the most widely recognized gravel underdrain design. A gravel (coarser) layer underlying a sand (finer) layer will impede drainage under non-ponded (unsaturated) conditions. This impedance of water movement effectively increases the water holding capacity of the root zone. The larger the contrast in pore-sizes between the coarser layer and the overlying finer textured layer, the more water that the root zone will retain. The danger then is having too large of particle size contrast or too shallow of root zone depth such that much or nearly all of the root zone stays excessively wet.

Excessive wetness within the rootzone profile may result in the inducement of anaerobic and reduced conditions in the profile and create an environment inconducive to turf growth, health and development. One signal of excessively wet conditions in a sand-based system is the production of excessive thatch in sod-forming grasses or elevated crowns in bunch-type grasses. While extensive and often drastic cultural techniques are employed to reduce thatch under these conditions, proper aeration and drainage in the root zone would eliminate the production of the excessive thatch. Black layer is another phenomana that can occur in a sand-based rootzone design due to excessive moisture. The excessive moisture leading to black layer formation can be due to either an over saturated gravel underdrain design or from layer features that can develop over time in poorly constructed/designed and or poorly maintained sand-based fields.

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To ensure that excessively wet and reduced sand-based root zones are not constructed, careful design and construction methodologies must be employed. While many root zone construction specification methods have been used and promoted, a new generation of sand-based root zone design specifications are now available for not only sand-based, but also sand-amended, sand-modified and soil-based constructions. Even the best sand-based constructions of the past have experienced poor performance following a period of relatively high superior performance. This period of good performance following construction is often termed the honeymoon period. Following this honeymoon period, the performance can rapidly and drastically deteriorate. The length of these honeymoon periods is highly variable but often last three to five years but may be less. Remedial efforts on these facilities often results in extensive renovation or complete reconstruction. To avoid these excessive costs and practices, proper root zone design along with testing and QC management during construction should be employed by a qualified sports turf agronomist.

ROOT ZONE AMENDMENTS FOR SAND-BASED CONSTRUSTIONS

Many amendments have been used and marketed to improve the performance of the different types of root zone constructions. These amendments vary from natural and synthetic organics to mined inorganic minerals and various other synthetic materials. In the past seven to eight years, many new synthetic materials have been introduced to improve the physical and mechanical performance of sports turf root zones.

A sand-based field offers the greatest flexibility in terms of providing an all weather playing surface. The down side to these systems is that poor soil plasticity characteristics may create situations where these constructions cannot meet overall performance expectations. The use of synthetic fiber reinforcement may significantly increase the mechanical stability of sand-based constructions. Fibers, grids, meshes and fabrics have all been utilized as an aid in increasing the stability of sand-based constructions. While many of these materials do provide for greater stability, they may also serve simply to stabilize the sand once it becomes compacted. Fabric layers may also increase stability somewhat but also create a potential problem by introducing a Œshear plane'. A shear plane can be detrimental because while overall stability is increased, when failure of shear does occur the failure event can be sudden and severe. In other words, the field may be more stable overall but when playing forces exceed the stability limits, the field can give way rapidly with severe divoting. The greatest potential benefit with synthetic materials for root zone stabilization has been derived from those synthetic products that provide a dynamic interlock system. Dynamic interlock spreads the applied forces over a larger volume of the soil profile. Dynamic interlock (as opposed to static interlock) also provides a characteristic Œrebound' effect in that the interlocked soil complex attmepts to resume its original (less compacted) state following removal of the loading force.

Other amendments are promoted for their effects at modifying soil moisture and soil chemical properties. Various internally porous amendments have been utilized to improve moisture relations within sand-based rootzones. These internally porous materials include such things as diatomaceous earth and calcined/vitrified clay minerals. Amendments utilized to modify chemical characteristics of sand-based constructions include small additions of soil and/or organic matter (such as peat or various composts). Of course, these materials also affect the soil retention properties of the soil profile as well. Zeolitic minerals have also been used to improve the nutrient retention properties of sand-based rootzones. The mechanical stability of amending materials should be considered before employing them in a sand-based root zone construction. Many materials have the potential of fracturing into finer sizes within the profile under traffic stress. Once fractured into smaller particles, these materials can be prone to migration and subsequent detrimental layering effects.

CONCLUSION

Whatever root zone design specification method is employed in root zone construction and establishment, a qualified sports turf agronomist can increase the likelihood of a successful and satisfactory sports turf installation. The design and type of sports turf root zone construction should be determined by the type of competition that is expected on the field, the frequency of use, the maintenance expertise and maintenance budget expected, and the turf quality and playability expectations of the owner and user(s).

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