IN SEARCH OF THE

The ever increasing intensity of traffic on golf greens during the past three decades has necessitated the development and use of high-sand root zones, such as the Texas-USGA Method. Dr James Beard, one of the distinguished speakers at both the '95 National Education Conference and BTME seminar programme at Harrogate in January, outlines the construction methods and specifications for this green which he believes is suitable for golf courses around the world.

Pre-1940, greens were constructed with high clay content soils. This was for two primary reasons: (1) better stability of the surface, and (2) better water holding characteristics that assisted in sustaining an actively growing green turf in the dry summer period when there was no irrigation capability. The compaction proneness of clay was not an issue because traffic was light.

The late 1940s and early 1950s introduced an era of (a) increasingly intense traffic, (b) public demand for higher quality turfed greens, and (c) the development and widespread use of overhead sprinkler irrigation systems for greens. The increasing traffic combined with the traditional construction approach of relatively high clay soils led to soil compaction problems that became the limiting factor in turfgrass culture on recreational surfaces.

Because the increasing soil compaction problem was seriously limiting turfgrass growth, both practitioner trial-and-error approaches and detailed soil physics research with high-sand content root zones evolved. The primary objective in using sandy textured soils was to provide adequate drainage of excess water and the resultant aeration needed to support rooting and overall healthy turfgrass growth. This early interest in high-sand root zones for greens was pioneered in the United States. The first root zone construction system that was soundly based on scientific principles and backed by extensive laboratory and field research was the Texas-United States Golf Association (USGA) method of root zone construction developed at Texas A&M University under the direction of soil physicists ME Bloodworth and JB Page. For the first time, detailed construction specifications and a soil physical testing procedure were established for green root zone construction to identify root zone components and their percentage compositions that met those specifications.

This Texas-USGA Method of root zone construction has proven the test of time with numerous successful turfed root zones having been in place for more than 30 years. Note, a key to success is proper construction that follows all the specifications in detail. Also, while this method carries the name of the original research location and the funding agency, the method is uniquely designed for use throughout the world and has successfully functioned in a diverse range of climates.

The Texas-USGA Method

Suggested specifications for the Texas-USGA Method are based on the 1960 specifications, with subsequent evolutionary refinements. It consists of a 300mm (12in) settled root zone over a 50mm (2in) intermediate coarse sand zone, over a 100mm (4in) gravel or crushed stone drainage bed which overlays a drain line network (see Figure 1). It is important that the final surface grade ensures drainage of excess water across and off the surface, usually in multiple directions. The construction method for greens is as follows:

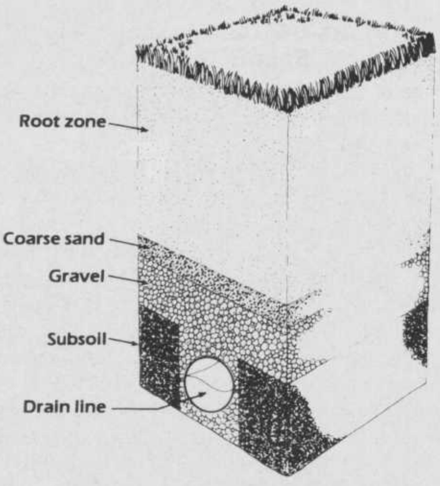


Figure 1: Profile of a Texas-USGA Method high-sand root zone modification with a water conserving perched hydration zone

Subgrade

Contour the subgrade so it conforms to the proposed finished grade, with a tolerance of +/- 25 mm (+/- 1in). The subgrade should be 450mm (18in) below the planned finish grade and should be firmed to prevent settling. Care should be taken to ensure that the final subgrade base contours, within the overall slope, drain off gravitational water to the nearest drain line.

Subsurface Drainage System

A herringbone or gridiron design is utilized, with 100mm (4in) diameter drain lines spaced at 4.6 to 6m (15 to 20ft) intervals at a minimum grade of 0.5 percent. The drain line trenches should be cut into the subgrade at as shallow a depth as possible. A 38 to 50mm (1.5 to 2in) depth of 6 to 10mm (0.24 to 0.39in) diameter crushed stone or gravel is placed in the bottom of the trenches and the drain lines laid. Then additional stone or gravel is placed around and over the drain lines to fill the trenches.

Drainage Layer

Angular, hard, noncalcarious, washed, screened river run gravel or crushed stone of 6 to 10mm diameter should be selected for covering the subgrade to a minimum settled depth of 100mm (4in). The proper sized crushed stone or gravel must be obtained to prevent migration of the sand into the gravel or stone bed and thereby preserve the integrity of two distinct layers: the upper high-sand mix over gravel or crushed stone. This drainage layer functions in the rapid lateral movement of gravitational water to the drain lines. Also, the porous crushed stone or gravel base prevents the upward capillary rise of salts from the soil base into the root zone. During installation, the crushed stone or gravel is typically dumped from the delivery trucks on the perimeter and then distributed over the construction site by a small, tracked crawler tractor, being careful to avoid driving over and crushing the drain lines.

Coarse Sand Zone

A 50mm (2in) deep layer of washed, screened, hard, angular coarse sand of 1 to 2mm diameter is carefully spread over the drainage layer. The specific size of the sand particles must be within 5 to 7 diameters of the underlying crushed stone or gravel. Thus, if 6mm stone or gravel is used, the particle size of the coarse sand zone should be not less than 1mm in diameter. This coarse sand zone has two key functions: (1) To prevent infiltration of the high-sand root zone mix into the spaces between the drainage layer particles and (2) To create a perched hydration zone of plant available water immediately above the drainage layer in the lower portion of the high-sand root zone mix. The distinct interface between the coarse sand zone and the upper 300mm (12in) of settled high-sand root zone mix disrupts the continuity of surface interfaces among the particles and the downward movement of water. When the perched hydration zone above the interface approaches water saturation, the force of gravity overcomes the interface perched effect and the excess water is released downward.

Installation of the coarse sand zone is best accomplished manually, taking care to not mix the sand with or into the drainage bed. The coarse sand is dumped from the delivery trucks on the outside perimeter, and is typically moved across the crushed stone or gravel by wheelbarrows over a path of plywood boards. This thin coarse sand layer presents some difficulties in installation. However, this intermediate zone is critical to the overall concept and is a modest long-term investment compared to turf failure and

ULTIMATE GREEN

rebuilding costs if improperly constructed.

Substitution of a nonbiodegradable screen-like material for the coarse sand intermediate zone has been proposed. Problems have been observed with these geofabrics which tend to become clogged to the extent that they are impermeable to water and may cease to drain. However, a more open, non-filter mesh or netting may be used between the intermediate coarse sand zone and the drainage layer when using gravel to provide a stabilizing effect during construction. This netting should not be necessary when using angular crushed stone due to the stability of this material.

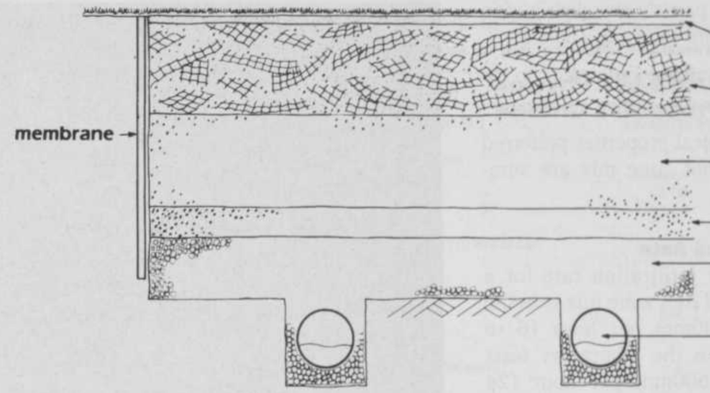


Diagram indicates typical Texas-USGA green construction incorporating mesh elements in sand rootzone. Note membrane to prevent sideways migration of water/clays from surrounding soil structure

Ringing the Perimeter

Polyethylene sheeting should be permanently inserted as a vertical barrier between the outer native soil and the root zone mix. This barrier prevents lateral water transfer into the adjacent dry soil, which would cause perimeter turf water stress. When the sheeting is extended 100 to 150mm (4 to 6in) above the surface during construction, it will also function in preventing erosion of unwanted soil onto the construction area.

Root Zone Mix Installation

Quality control is the key to successful execution of root zone modification. All root zone mixing should be completed off the construction site, termed off-site mixing. Although it sounds good, in practice the procedure of in-place rotary tilling of the organic and/or soil components into the high-sand component has not been successful. Every truck load of each component in the soil mix, as well as the gravel and coarse sand, should be checked at delivery to ensure that the specifications are met.

Off-site mixing includes soil shredding, screening to remove any objectionable stones, and addition of the specified proportions of each mix component. Because of the narrow range in acceptable limits of the physical properties, it is very important that the laboratory recommendations be explicitly followed in mixing the components of the root zone mix. Upon confirmation that the root zone mix has met the specifications, it is transported to the construction site and dumped around the perimeter onto the coarse sand zone. A small, crawler tracked tractor with blade then pushes the mix over the area being careful to avoid crushing the drain lines. Be sure the unit is operated with its weight on the root zone mix. This reduces the chance of disturbing the lower construction profile.

Caution: Use of wheeled tractors causes rutting and they are more likely to crush the drain lines than are tracked vehicles. Grade stakes placed in a grid pattern at 3 to 4.5m (10 to 15ft) intervals will aid in constructing the final contours to the specified root zone depth. Success has been achieved by carefully selecting the components of the root zone mix and by careful adherence to the construction guidelines.

Texas-USGA Root Zone Mix Specifications

One of the greatest problems encountered in maintaining turfgrasses is soil compaction. This pressing together of the soil particles into a more dense mass results in impaired drainage of excess water and a loss of proper aeration needed to provide oxygen for healthy root growth. As a consequence, there is a general decline in turfgrass health, vigor, and recuperative ability following turf injury from wear stresses.

Soil compaction and the resultant negative effects can be minimised by selection of a high-sand root zone of the proper particle size distribution and associated key physical and chemical characteristics. The result is minimum proneness to compaction, adequate drainage of excess gravitational water, and proper aeration to provide needed oxygen for root growth and related soil biological activity.

However, such high-sand root zones are very droughty due to poor water retention capacity unless a perched hydration zone, such as achieved through the Texas-USGA Method, is utilised in the construction specifications. In addition, high-sand root zones tend to have a low cation exchange capacity, thus, the leaching of essential plant nutrients is a greater concern, particularly during the initial years following construction. This potential problem can be minimised through the use of slow release nutrient carriers and/or the timely use of foliar feeding techniques.

Composition of the 300mm (12in) settled depth of root zone mix should be selected based on specific physical tests conducted in a reputable physical soil test laboratory. The test report specifies the particular materials and the percentages in which they are to be mixed. The desired characteristics for a Texas-USGA Method root zone mix are given in the following paragraphs.

Component Descriptions of Root Zone Mix

It is important that the three components selected for the root zone mix be free of toxic levels of materials such as heavy metals, persistent crop herbicides, and industrial organic chemicals. Minimal amounts of soluble salts, boron (B), and sodium (Na) are preferred.

Sand Component

Angular, hard, washed, screened silica sand is strongly suggested. Avoid high pH calcarious sands. The preferred sand component particle size is: 100 percent below 1mm (18 mesh), 65 percent below 0.5mm (35 mesh), 25 percent below 0.25mm (60 mesh), and 5 percent below 0.05mm (270 mesh). Note: the mesh sieve size refers to the US standard of the United States Department of Agriculture (USDA).

Organic Matter Component

It is suggested that the organic matter source selected be well decomposed and have no more than 15 percent ash or mineral content, preferably less than 10 percent mineral content. Examples include peat humus and reed-sedge peat. The organic material should be shredded to ensure mixing uniformity, but not to the degree that the material is pulverized thereby causing reduced soil water infiltration.

Soil Component

A sand, loamy sand, or sandy loam topsoil is suggested. The soil should be shredded to ensure mixing uniformity and should be screened to remove stone and other debris.

Composite Root Zone Mix Particle Size Distribution

It is suggested that the root zone mix contain less than 25 percent particles smaller than 0.25mm (60mesh), and contain less than 5 percent silt and 3 percent clay. The suggested specifications for the particle size distribution of the root zone mix are shown in Table 1.

Composite Rootzone Mix Physical and Chemical Properties Criteria

The physical or chemical properties preferred for the composite root zone mix are summarised in Table 2.

Mix Water Infiltration Rate

The preferred water infiltration rate for a laboratory compacted root zone mix is in the range of 150 to 300mm per hour (6 to 12in/hr). The rate in the laboratory tests should not exceed 600mm per hour (24 in/hr). The upper limit in the water infiltration rate is designed high enough to account for the normal on-site reduction in infiltration rate that occurs during the first 3 to 4 years due to increases in roots and organic material.

Mix Aeration Porosity

An acceptable total pore space volume is between 40 and 55 percent. The preferred distribution would be 22 percent capillary and 25 percent noncapillary pore space. Noncapillary pore space should be not less than 15 percent. The measurements are made on a root zone mix that has been allowed to percolate water for 8 hours and then is drained at a tension of 400mm of water.

Mix Water Retention Capacity

An acceptable laboratory-established 400mm water retention capacity would be between 12 and 25 percent by weight on a l05 to lll°C-oven dry soil basis. The available water in the soil is estimated to be that held at a tension of 400mm of water, which is the approximate distance from the surface to the drain line. The preferred water retention capacity is 18 percent, or 1.5mm of water held per 10mm of soil.

Mix Bulk Density

The preferred root zone mix should have a bulk density of 1.4 grams per cc; with a minimum acceptable bulk density of 1.2 and a maximum of 1.6 grams per cc.

pH

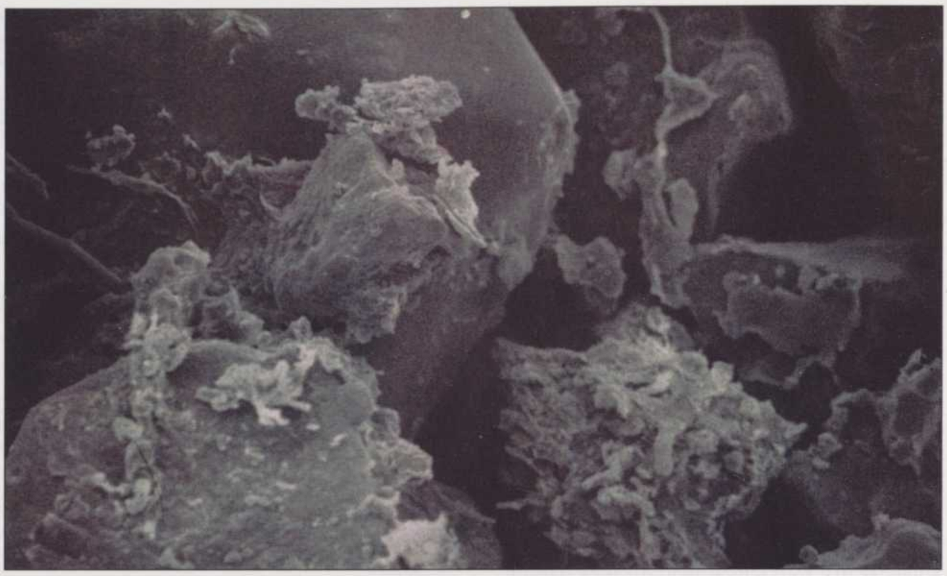
The acceptable pH range is 5.5 to 8.0, and the preferred pH range is 6.0 to 6.5.

Soil Salinity/Electrical Conductivity

The acceptable range is less than 4 millimhos per cm, with the preferred range being between 0 and 1.

Soil Sodium Level

The acceptable range is an exchangeable sodium percentage (ESP) of less than 15, with the preferred being a minimal sodium level.



Above: Electromicrograph of mature rootzone with mesh elements showing clay platelets on soil particles but not bridging between, allowing soil pore structure to remain open.
Below: Electromicrograph of mature rootzone without mesh elements, showing clay platelets covering soil particles and bridging pore structure. This inhibits water infiltration.

Root Zone Mix Analysis

The starting point in selection of a root zone mix involves obtaining detailed physical and chemical descriptions of the components being considered for a root zone mix and how they respond when mixed in various combinations. One or more representative samples of each sand, organic matter, and sandy soil component under consideration for use should be submitted to a reputable laboratory.

The primary laboratory physical determinations made are the particle size distribution, bulk density, and mineral composition. The next laboratory step is to combine various proportions of the sand, organic matter, and sandy soil, based on physical determinations. These trial mixes are compacted and then evaluated for water infiltration rate, moisture retention, bulk density, and pore space. Mixes are made and tested until one is found that conforms to the standards. Recommendations as to the relative volume of each component to be used are then given.

The crushed stone or gravel for the drainage layer and the coarse intermediate sand also should be tested for particle size diameter to assure that the root zone mix does not wash down and block the drains.

In addition to recommendations concerning the appropriate sand, organic matter, and soil materials and their mix proportions, a description of the chemical properties of each material is needed. Included are the pH, total salts, and levels of phosphorus (P) and potassium (K). A sodium (Na) analysis is occasionally needed.

Table 1: Suggested guidelines for particle size distribution of the Texas-USGA root zone mix

Gravel	Very Coarse	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt and Clay
> 2 mm	1 - 2 mm	1.0-0.5 mm	0.50-0.25 mm	0.25-0.10 mm	0.10-0.05 mm	< 0.05 mm
Maximum 3% Ideal 0%	Maximum 7%		Minimum 50%		Maximum 17%	Maximum 3% clay 5% silt
Maximum		Desired range		Maximum		
Not more than 10% of total		65% Minimum 75% Optimum		Not more than 25% of total, preferably 10% of total		

Table 2: Suggested physical and chemical guidelines for the composite root zone mix

Physical or chemical property	Units	Acceptable range	Preferred
Infiltration rate of compacted mix	mm per hour (in./hr.)	150-600 (6-24)	150-300 (6-12)
Aeration porosity:	% by volume		
Total pore space		40-55	47
Noncapillary pore space		15-30	25
Capillary pore space		15-25	22
Water retention capacity	% by weight (mm H_2O/10 mm of soil)	12-25 (1-2)	18 (1.5)
Bulk density	gram/cc	1.2-1.6	1.4
Soil reaction 6.0-6.5		pH	5.5-8.0
Soil salinity (electrical conductivity)	EC x 10^{-3} (millimhos/cm)	< 4	0-1
Soil sodium	ESP	< 15	—

Submitting Soil Materials for Testing

A laboratory physical analysis requires a minimum of 8 litres of sand, and 4 litres each of organic matter, soil, intermediate coarse sand and crushed stone or gravel. If there is a choice of sands, organic materials, and sandy soil, send samples of each along with a note indicating a preference based on cost, accessibility, and quantity available. The laboratory will attempt to use the preferred, most cost effective materials in the recommended root zone mix.

Representative samples of the materials must be collected. If the materials are stocked, make sure to composite several samples dug from within the side or top of the stockpile. Materials near the edge or on a sloping surface may not be representative. Make sure that a prospective vendor will have sufficient stocks of uniform materials over a long period so that if there is a delay of a few months, the materials available at the time of construction will be the same as the original samples tested. All samples should be packaged separately and securely. Strong plastic bags inside cardboard cartons or metal cans are most satisfactory. Use plastic labels inside the package and also to mark the outside of the package.

Construction Plan

Proper construction usually involves an extensive subsurface drainage system, specialised root zone modification, and subtle surface drainage contours. It is a critical aspect, since improper construction due to cost cutting results in higher long-term maintenance costs, problems in maintaining a quality playing surface, frequent loss of turf, and costly reconstruction. The steps in construction are:

1. Survey and stake
2. Construct subgrade
3. Install a subsurface drainage system
4. Modify root zone:
   (a) Construct drainage layer
   (b) Construct coarse sand zone
   (c) Mix and install specified root zone
5. Install irrigation system
6. Finish surface contours
7. Plant
   (a) Soil pH adjustment, if needed
   (b) Fertilisation based on soil tests
   (c) Plant
   (d) Post-plant care

Throughout the world tens of thousands of greens have been constructed this way during the past 30 years as it has many advantages.

High-Sand Root Zone Advantages

While there have been a number of high-sand content root zone specifications proposed, many being modifications of the Texas-USGA Method, they tend to be deficient in sound science with inadequate fundamental research to support the concept. Many proposed root zone mixes are only slight modifications of the Texas-USGA Method, but they result in significant changes from a practical soil physical performance standpoint. Among all these proposed root zone mixes, none have proven nearly as successful and reliable under a diverse range of climatic and soil conditions throughout the world as the Texas-USGA Method. The advantages of a high-sand root zone of the proper particle size distribution include:

1. Resistance to compaction problems.
2. Favourable soil water infiltration and percolation rates.
3. Increased effective precipitation due to reduced surface runoff.
4. Enhanced aeration that provides adequate oxygen for root growth.

The primary problem now developing is not the underground limitations of poor drainage and lack of aeration characteristic of the finer textured root zones, but rather the divoting and turfgrass wear of above ground shoots. Under an ever increasing intensity of traffic stress, this latter problem eventually leads to turf thinning and bare areas. The use of improved turfgrass cultivars with (a) more rapid shoot growth rates, (b) a greater green biomass, (c) higher proportion of sclerified tissue in shoots, (d) better recuperative potential, and (e) disease resistance has partially solved this problem.

The next step is to incorporate an effective method of stabilizing the high-sand root zones, while retaining a favorable environment for turfgrass root growth. That's why Samuel Sifers and I have been assessing the use of randomely orientated, interlocking mesh elements

The Mesh-Element Inclusion Concept

Since this system has proven very effective in improving the stability of soils for engineering applications, feasibility investigations were initiated concerning the use of randomly oriented, interlocking mesh elements, such as those made by British firm Netlon.

The polypropylene mesh elements consist of discrete 50 by 100mm (2 x 4in) rectangular elements, with open ribs extending from the perimeter. The square aperture between the individual ribs of the mesh element is 10 by 10mm (0.4 x 0.4in) or 100mm^2 (0.16 in^2). The open ribs extending from the perimeter of each mesh element facilitate an interlocking structure of multiple elements in a randomly oriented matrix. The result is a unique three dimensional matrix of a relatively fixed, but microflexible nature, which ensures that the mesh elements remain in a stable position within the root zone. The turfgrass roots intertwine the mesh element ribs to secure a strong turf anchorage effect. The rectangular shape and specific size of the mesh elements selected for these investigations are based on extensive studies comparing a range of alternative shapes and sizes in terms of the most effective configuration for overall soil stabilization.

Five key studies have been conducted since 1985 at College Station, Texas, including two long-term field investigations. The findings revealed these benefits:

- enhanced soil stabilisation especially in sandy soils and on steep slopes;
- improved load-bearing capacity;
- better resistance to surface rutting and deformation;
- reduced divot size;
- enhanced divot opening turf recovery;
- reduced lateral cleat turf tear;
- enhanced turfgrass rootzone – improved water filtration rate, soil water percolation rate, soil moisture retention and overall turfgrass health.

There was also less compaction and a reduced potential for black layer problems, especially on fine textured high-sand root zones.

These qualities mean that mesh elements are suitable for use not just on greens but also tees, buggy paths and for bunker and grassy mound banks.