



Standard Guide for Construction of Sand-based Rootzones for Golf Putting Greens and Tees¹

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1. Scope

1.1 This guide covers techniques that are appropriate for the construction of high performance sand-based rootzones for golf greens and tees. This guide provides guidance for the selection of materials, including soil, sand, gravel, peat, etc., for use in designing and constructing sand-based golf turf rootzones.

1.2 Decisions in selecting construction and maintenance techniques are influenced by existing soil types, climatic factors, level of play, intensity and frequency of use, equipment available, budget and training, and the ability of management personnel.

1.3 This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This guide is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.

1.4 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*²

- C88 Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
- C131 Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
- D422 Test Method for Particle-Size Analysis of Soils
- D653 Terminology Relating to Soil, Rock, and Contained Fluids
- D698 Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft³ (600 kN-m/m³))
- D854 Test Methods for Specific Gravity of Soil Solids by Water Pycnometer
- D1883 Test Method for CBR (California Bearing Ratio) of Laboratory-Compacted Soils
- D1997 Test Method for Laboratory Determination of the Fiber Content of Peat Samples by Dry Mass
- D2944 Test Method of Sampling Processed Peat Materials
- D2974 Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils
- D2976 Test Method for pH of Peat Materials (Withdrawn 2013)³
- D2980 Test Method for Volume Mass, Moisture-Holding Capacity, and Porosity of Saturated Peat Materials
- D4427 Classification of Peat Samples by Laboratory Testing
- D4972 Test Method for pH of Soils
- F1632 Test Method for Particle Size Analysis and Sand Shape Grading of Golf Course Putting Green and Sports Field Rootzone Mixes
- F1647 Test Methods for Organic Matter Content of Athletic Field Rootzone Mixes

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ The last approved version of this historical standard is referenced on www.astm.org.

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[F1815 Test Methods for Saturated Hydraulic Conductivity, Water Retention, Porosity, and Bulk Density of Athletic Field Rootzones](#)

[F2060 Guide for Maintaining Cool Season Turfgrasses on Athletic Fields](#)

[F2107 Guide for Construction and Maintenance of Skinned Areas on Baseball and Softball Fields](#)

[F2269 Guide for Maintaining Warm Season Turfgrasses on Athletic Fields](#)

[F2397 Specification for Protective Headgear Used in Martial Arts](#)

[F2651 Terminology Relating to Soil and Turfgrass Characteristics of Natural Playing Surfaces](#)

4.3.1 During construction, consideration should be given to factors such as the physical and chemical properties of rootzone materials, surface and internal drainage as well as stones and other debris.

4.3.2 Maintenance practices that influence playability include mowing, irrigation, fertilization, and mechanical aeration. These factors are addressed in other standards (Guides [F2060](#), [F2269](#), and [F2397](#)).

4.4 Those responsible for the design, construction, or maintenance, or a combination thereof, of golf putting greens and tees will benefit from this guide.

4.5 A successful project development depends upon proper planning and upon the selection of and cooperation among design and construction team members. A sand-based putting green/tee rootzone project design team should include a golf course architect/designer, an agronomist or soil scientist, or both, and an owner's design representative. Additions to the team during the construction phase should include an owner's project manager (often an expansion of role for the owner's design representative), an owner's quality control agent (often the personnel that is employed in advance with the intent of becoming the finished project's golf course superintendent/greenskeeper), an owner's testing agent (often an expansion of roles for the project's agronomist/soil scientist) and the contractor.

4.5.1 Planning for projects must be conducted well in advance of the intended construction date. Often this planning requires numerous meetings to create a calendar of events, schedule, approvals, assessments, performance criteria, quality control (QC) protocols, material sourcing, geotechnical reports, and construction budgets.

NOTE 1—Other specifications on soils for golf green and putting green construction that have been published were considered during the development of this standard.

5. Construction

5.1 The steps involved in the construction of a new putting green or tee include:

- (1) Survey and stake the site to establish subgrade and finish grade elevations,
- (2) Construct and prepare subgrade, subgrade being correct and certified,
- (3) Install subsurface drainage system,
- (4) Frame out putting green/tee perimeter as appropriate,
- (5) Install irrigation system (irrigation system may be installed prior to rootzone installation),
- (6) Prepare for rootzone installation,
 - (a) secure suitable sand, properly tested and approved,
 - (b) blend any amendments with sand to project specifications, approve using QC program,
 - (c) install approved gravel (if included in design),
- (7) Install rootzone blend,
- (8) Bring green/tee to final grade and contour as per specifications, compact to specifications,
 - (a) a pre-plant fertilizer application may be applied at this point as specified,
- (9) Establish turf by appropriate methods (seed, sprigs, plugs or sod),

3. Terminology

3.1 Definitions:

3.1.1 Except as noted, soil related definitions are in accordance with Terminologies [D653](#) and [F2651](#).

4. Significance and Use

4.1 A dense, uniform, smooth and vigorously (or healthy) growing natural turfgrass golf green or tee provides the ideal and preferred putting or teeing surface for golf. Sand is commonly used to construct high performance putting green and tee rootzone systems. Sand is chosen as a primary construction material due to its compaction resistance and improved drainage and aeration compared to other soil materials. A loamy soil that may provide a more stable surface and enhanced growing media compared to sand under optimal or normal conditions will quickly compact and deteriorate in condition if used in periods of excessive soil moisture, such as during or following a rain event. A properly constructed sand-based rootzone on the other hand will resist compaction even during wet periods. Even when compacted, sands will retain an enhanced drainage and aeration state compared to native soil rootzones under the same level of traffic. As such, sand-based rootzones are more conducive to providing an all-weather type of putting or teeing surface. Once compacted, sands are also easier to decompact with the use of mechanical aeration equipment.

4.2 Properties of both the soil and grass plants must be considered in planning, constructing, and maintaining a high quality putting green or tee installation. Turfgrasses utilized must be adapted to the local growing conditions and be capable of forming a thick, dense, turf cover at the desired mowing height. Unvegetated sand is not inherently stable and therefore it is imperative that grasses are utilized to withstand the rigors of play. Sand does however have incredible load bearing capacity and if a dense, uniform turf cover is maintained the sand-based system can provide a firm and uniform playing surface.

4.3 A successful sand-based rootzone system is dependent upon the proper selection of materials to use in the project. The proper selection of sand, organic amendments, soil, and gravel is of vital concern to the performance of the system. This standard guide addresses these issues.

(10) Apply fertilizer as appropriate based upon soil test recommendations, and

(11) Turf to be established based upon grow-in recommendations from a competent agronomist for the turf species utilized and the climate of the site.

5.2 Survey and Stake—This procedure should be done to conform to project Golf Course Architect’s specifications as appropriate for the grade contour. When constructing a replacement green or tee, this step may be deleted or modified as appropriate. Care should be taken to protect staking during the construction process.

5.3 Construct and Prepare Subgrade—Contour the subgrade to specifications at a suggested tolerance of +25 mm (1 in.) within 3 m (10 ft) of linear direction as specified in 5.5.7. The subgrade should be installed finished to a depth such to accommodate the final profile depth of rootzone and a gravel layer (if included). The subgrade should be compacted sufficiently (suggested 85 % minimum to 90 % maximum standard proctor density (Test Methods D698)) to prevent future settling. Subgrade should be designed to conform to the surface contour of finished putting surface.

5.4 Subsurface Drainage System—Many types of designs exist for subsurface drainage with the most common including a grid or herringbone pattern. Most commonly used drainage systems for sand-based putting greens and tees utilize perforated drainlines with 10 cm (4 in.) diameter in a 4.5 to 6 m (15 to 20 ft) spacing between drainline laterals. This spacing typically depends upon site conditions such as height above groundwater, surface grading, and soil type of the subgrade.

5.4.1 Drainline Trenches—Trenches constructed for drainlines should be excavated into a properly prepared, graded and compacted subgrade. Drainage trenches should be deep enough to conform to the drainage contours. All drainage trenches and drainline installations should maintain a minimum positive slope gradient of >0.5 % towards drainage outlets with trench bottoms compacted to subgrade specifications. Drainage excavations should be made such that a minimum of 5 cm (2 in.) of bedding material can be contained around the installed drainline (below, to each side, and above). For example, a 10 cm (4 in.) diameter drainline installation will require a minimum dimension of 20 cm (8 in.) wide by 20 cm (8 in.) depth (for example, 10 cm drainline + (5 cm/side × 2 sides) = 20 cm; 10 cm drainline + 5 cm top + 5 cm bottom = 20 cm). Once drainage trenches are excavated, all excavated material should be removed from the subgrade surface and disposed off the green or tee construction site. The subgrade should have no elevations of subgrade soil material such to hinder the flow of water along the subgrade interface into the drainage trench. Once drainage trenches have been excavated, the trench bottoms should be sufficiently compacted to the subgrade compaction specifications prior to installation of drainage system. Subgrade shall be re-surveyed and certified prior to gravel or rootzone import.

5.4.2 Surface Drainage—To maintain adequate surface drainage, all green/tee installations should include a minimum of 0.5 % slope gradient (contours) to remove water off of the putting green/tee in case of a storm event with severe rainfall intensity.

NOTE 2—In planning and designing projects, consideration shall be given to the permeability of the rootzone when determining the slope of the finished surface and the need for adjacent surface drainage systems. Further consideration shall be given in cold climates where frost penetration may impact the permeability of the rootzone when determining the slope of the finished surface and the need for adjacent surface drainage systems. Generally, the need for improved surface drainage increases as the permeability of the rootzone decreases.

5.4.3 Sub-Surface Drainage Material—Three recommended options exist for the use of drainage material. Option 1: sand rootzone material is utilized to backfill around drainlines within the drainage trenches. Option 2: gravel material is utilized to backfill around drainlines in the drainage trenches. Option 3: gravel is utilized to backfill around drainlines in drainage trenches and to form a drainage layer overlying the subgrade before placement of rootzone sand blend. Option 3 is the method recommended by the USGA for putting green installations. All backfill treatments shall be compacted to specifications prior to further installation procedures. It is recommended that backfill for trench bottoms is installed and compacted prior to installing drain pipe into the trenches. It is recommended that the trench bottom remain unobstructed and no soil pilings, wood blocks, concrete or metal blocks are utilized to permanently adjust and maintain the slope of drainlines. Any blocks which were temporarily used for this purpose must be removed from underneath the drainlines and any cavities backfilled before proceeding. It is recommended that drainage trenches (bottom and sides ONLY) should be lined with a woven geosynthetic filter fabric to prevent contamination (lateral movement of subgrade materials into trench fill). Geosynthetic filter fabric should NOT be used to cover the drainage trench. Many geosynthetic filter fabrics are prone (or designed) to plug from fine particulates as they “filter” them from passing through the fabric. Therefore, these fabrics should never be used to wrap a drainline, cover a drainage trench, to cover a gravel drainage layer, or to separate the rootzone from a gravel layer. Other geosynthetic fabrics (non-woven, heat-set needle-punched geotextiles) which are designed not to clog may be used with caution with studies and field experience having shown that these materials have been used successfully for these applications. It is recommended that all drainlines are installed straight (without ‘snaking’) within the trenches. It is recommended that sleeves (of oversize PVC piping) should be installed across the drainage trenches at appropriate points as indicated by the irrigation design to facilitate irrigation pipe installation at points where the irrigation line crosses over the drainage trenches.

5.4.3.1 Option 1—Rootzone sand (with or without other rootzone amendments) may be utilized to backfill drainage trenches. If sand is utilized for this purpose, the drainage pipe used in these installations must be of a type that has slitted perforations with slit openings meeting a specification of

TABLE 1 Gravel Filter/Drainage Layer Specifications^{A,B}

Performance Factor	Criteria	Acceptable Value
Filtering Factors	D ₁₅ of gravel/D ₈₅ of rootzone mix and	<5
	D ₅₀ of gravel/D ₅₀ of rootzone mix	<25
Permeability Factor	D ₁₅ of gravel/D ₁₅ of rootzone mix	≥5
	D ₉₀ of gravel/D ₁₅ of gravel	≤2.5
Uniformity Factors	>12 mm fraction	0 %
	<2 mm fraction	≤10 %
	<1 mm fraction	≤5 %

^A US Department of Defense, USACE. 1984. Drainage and Erosion Control - Mobilization Construction, Chapter 5, Backfill for Subsurface Drains. Engineering Manual EM 1110-3-136. US Government Print Office, Washington, DC. Also: <http://www.usace.army.mil/inet/usace-docs/eng-manuals/em1110-3-136/c-5.pdf>

^B USGA, Green Section. 1993. USGA Recommendations For A Method Of Putting Green Construction. USGA. Golf House, Far Hills, NJ. Also: <http://www.usga.org/green/coned/greens/recommendations.html#gravel>

$$\frac{D_{85} \text{ sand} > 1.5}{\text{slot width}}$$

to reduce the potential for particle migration into the drainage system.⁴

5.4.3.2 *Option 2*—Gravel may be utilized to backfill drainage trenches. If gravel is used for backfill, it should conform to the specifications in **Table 1** below. Soft gravel minerals (such as limestone, sandstone, or shale) are not acceptable for use and all questionable gravel material should be tested for weathering stability using the sulfate soundness test. (Test Method **C88**). A loss of material greater than a 12 % by weight is unacceptable. Likewise, any gravel material that is suspect in its mechanical stability should be tested utilizing the LA Abrasion test. (Test Method **C131**) A LA Abrasion test value greater than 40 is unacceptable.

5.4.3.3 *Option 3*—Gravel may be utilized to backfill drainage trenches and to form a drainage layer beneath the sand rootzone. If gravel is used for this purpose, the same gravel should be utilized for drainage trench backfill and the drainage layer and should conform to the specifications given in **Table 1** below. Soft gravel minerals are not acceptable for use and all questionable gravel material should be tested for weathering stability using the sulfate soundness test. (Test Method **C88**). A loss of material greater than a 12 % by weight is unacceptable. Likewise, any gravel material that is suspect in its mechanical stability should be tested utilizing the LA Abrasion test. (Test Method **C131**) A LA Abrasion test value greater than 40 is unacceptable. A gravel drainage layer should be a minimum of 7.5 cm (3 in.) with 10 to 15 cm (4 to 6 in.) preferred. During installation, the gravel is typically dumped from the delivery trucks on the perimeter of the site and then distributed over the construction site by a small, tracked crawler tractor (or similar), being careful to avoid driving over and crushing the drain lines. Gravel should be contoured and compacted to specifications at a suggested tolerance of +12.5 mm (½ in.) within 3 m (10 ft) of linear direction and as specified in **5.5.7**.

NOTE 3—If gravel is utilized as a drainage layer, it will improve the drainage of the system under conditions of saturated flow only. Saturated

flow conditions typically only occur during intense or prolonged rainfall events. Under unsaturated conditions, the use of a gravel layer will impede drainage and will serve to retain additional moisture within the rootzone profile. This condition is commonly referred to as a ‘perched’ or ‘suspended’ water table. The water perched in the rootzone at the interface with the gravel will be retained in a condition nearing saturation. While such conditions may be beneficial in terms of water conservation, care must be exercised in the design of the rootzone system such that excessive moisture is not retained that could lead to anaerobic rootzone conditions. Such conditions are common with poorly designed gravel underdrained sand-based rootzone systems. If a gravel underdrain system is used, the design parameters should be adjusted to assure a minimum of 15 cm (6 in.) of well aerated rootzone. If the capillary rise of salts or other contaminants from the subgrade are of concern on a particular project, the use of a gravel layer is recommended to prevent this occurrence.

(1) *Determination of Well-Aerated Rootzone Conditions*—

This section relates to the implications of variable profile depth of rootzones. A well-aerated rootzone is normally that portion of the rootzone that retains >20 % air-filled porosity (AFP) after gravitational drainage ceases (as determined at 30 cm tension). To determine the depth of sand required to obtain the desired well-aerated profile depth, a soil moisture retention curve of the rootzone material must be determined. Considering that the perched water above a gravel layer will be retained at a tension of approximately 10 cm tension, the moisture retention status of the rootzone material should be considered at tensions greater than 10 cm until the proportion of air-filled pores within the rootzone material reaches 20 % or greater.⁴ For example, let’s hypothesize that a soil moisture retention curve shows that a material reaches 20 % AFP at 21 cm tension. To provide a 15 cm well-aerated rootzone, our profile depth would be 21 cm (AFP threshold tension) – 10 cm (tension of perched water) + 15 cm of well-aerated rootzone, for a total rootzone depth of 26 cm. Moisture retention points should be determined utilizing methodologies in Test Method **F1815**.

5.5 *Sand-Based Rootzone*—Sands for the rootzone shall meet the performance specifications established in this guide. Additions of peat or soil, or both, may be included in small proportions as part of the rootzone blend if uniformly blended and as long as resultant blend meets the performance specifications established in this guide.

5.5.1 *Sand Type*—Quartz sands are recommended; if a sand contains more than 5 % calcium carbonate equivalent, the sand has the potential for particle cementation due to dissolution and reprecipitation of carbonates. Other sands are not recommended due to their propensity to weather (by either mechanical or chemical means, or both) over a relative short period of time (1 to 5 years). For example, granitic material often contains appreciable amounts of feldspar or mica which is much more readily subject to weathering. Caution should be given to sands that contain appreciable proportions of mica minerals. Mica grains have a flat or plate-like morphology and redistribution of these grains within a rootzone profile may create layers that impede drainage and aeration.

5.5.2 *Particle Size Distribution*—Particle size analyses (Test Methods **D422** or **F1632**) are based on the oven-dried mass of a weighed sample; a shaker is the preferred method of dispersion to prevent fracturing of sand particles that may falsely influence the sand size distribution. There are many published specifications within the turf industry for sand size

⁴ Taylor, D. H., Nelson, S. D., and Williams, C. F., “Sub-Root Zone Layering: Effects on Water Retention in Sports Turf Soil Profiles,” *Agron J.*, Vol. 85, pp. 626–630, 1993.

distribution in sand-based rootzone constructions. **Table 2** and **Table 3** include recommended sand particle size distribution (without amendments) but is not inclusive of all size distributions of sands that could be used to produce a high performance sand-based green or tee. **Table 2** is the recommended sand specification for rootzones when the resultant blend is composed of a sand and peat mixture. **Table 3** is the recommended sand specification for rootzones when the resultant blend is composed of a sand and soil mixture (or sand-soil-peat mixture).

5.5.3 Sand Shape—Although acceptable sand-based rootzones can be constructed with sands of all shapes, this factor is worth consideration in putting green/tee construction. Sand shape is generally classed by angularity and sphericity. Angularity is characterized as well-rounded, rounded, subrounded, subangular, angular and very angular. Sphericity is characterized as high sphericity, medium sphericity, and low sphericity. Sand shape should be classified according to Fig. 1 from Test Method **F1632**. While no sand will have sand grains of a uniform shape, there is normally a predominant shape of grains from a single sand source. The shape and dimension of sand grains affect its stability. For example, rounded grains are the least stable because they lack edges necessary for grain to grain interlock and as such the round sand grains tend to act like small ball bearings. Angular sands to have greater stability because they have the sharp edges that give grain-grain interlock and impart resistance to shear. Sands that have a predominance of grains that show extremes in angularity (extremely angular or extremely round) that fit outside the classification in Test Method **F1632**, should be avoided. Also extremely low sphericity particles (for example, plate-like particles) should be avoided.

5.5.3.1 Dune sand sources may contain sand grains that have internal fracture planes. Dune sands tend to have the most extreme expression of fracture planes and this is a common micromorphological identification feature for dune sands. The fracture planes develop during the saltation process. Under low energy (wind or gravity) events dune sands can become rounded as they roll and skip along the surface. However, during strong wind events the grains can be moved at a high velocity whereby the grains impacting upon each other develop ‘cracks’ or fracture planes within the grain. When rootzones are constructed with these sands, traffic and other weathering factors may cause the grains to fracture along these planes resulting in the formation of silt-size quartz grains which may

TABLE 3 Recommended Particle Size Distribution of Rootzone Sand In a Sand-Soil Rootzone Blend

Size Fraction	Particle Diameter Range (mm)	Specified Range (%)
Gravel	>4.75	0
Gravel	3.4 to 4.75	0
Fine Gravel	2.0 to 3.4	<5
Very Coarse Sand	1.0 to 2.0	<10
Coarse Sand	0.5 to 1.0	25 to 50
Medium Sand	0.25 to 0.5	>25
Fine Sand	0.15 to 0.25	<10
Very Fine Sand	0.05 to 0.15	<5
Silt	0.002 to 0.05	<5
Clay	<0.002	<3

then be prone to particle migration and subsequent accumulation in layers. Representative grains for all samples should be examined regardless of source under 20 – 50× magnification for sand size, shape and potential fracture planes.

5.5.4 Rootzone Amendments—Two types of amendments are commonly included in a blend with sand that together makes up the rootzone material (also termed rootzone mix or blend). Most commonly this would include a blend with soil or peat (or other organic material), or both.

5.5.4.1 Soil—Soils have been used for constructing sand-based rootzones for greens and tee construction as well as sports field constructions. However, soil has become less commonly used compared to peat amendments as pre-packaged peats have greater ease of handling of material and the potential for less material variability. Soil used as a blend component of a sand-based rootzone construction provides some enhanced capacity for moisture and nutrient retention and may improve the mechanical stability of the rootzone. Proportions of soil in a high performance rootzone mix typically range from 5 to 15 % by volume. The amount of soil to include in a blend depends upon the make-up of the soil component and the effects of the soil additions on physical performance characteristics of the resulting blend. Ideally, the soil component would be one that is composed purely of clay (plastic, clay-sized mineral). Clay minerals generally have good moisture and nutrient retention capacities and may improve rootzone stability by enhanced cohesive properties. When plastic clay mineral is properly included in a blend with sand in the appropriate proportion and properly blended, the clay will coat the sand and form bridges between sand grains without clogging up the large pores (interstitial pores or packing voids) of the sand matrix. If a pure clay mineral source is used, many sands will accommodate 10 to 15 % clay additions without clogging. However, care must be used in the blending and preparation process because a small increase in clay content can cause a drastic detrimental change in the performance of the rootzone. This is a primary reason for a well designed calibration and quality control program. Other soils may be used as a component of a sand-based rootzone blend but should be restricted to those soil textures that are low in silt content. Silt is normally a fine-grained, non-plastic soil material and is subject to migration and layering. Soils that exhibit a silt to clay ratio greater than 2 should not be used. Likewise, those soils with a fines (silt + very fine sand + fine sand) to clay ratio greater than 5 should be avoided. Generally, soils containing

TABLE 2 Recommended Particle Size Distribution of Rootzone Sand In a Sand-Peat Rootzone Blend

Size Fraction	Particle Diameter Range (mm)	Specified Range (%)
Gravel	>4.75	0
Gravel	3.4 to 4.75	0
Fine Gravel	2.0 to 3.4	<5
Very Coarse Sand	1.0 to 2.0	<10
Coarse Sand	0.5 to 1.0	25 to 50
Medium Sand	0.25 to 0.5	>25
Fine Sand	0.15 to 0.25	<15
Very Fine Sand	0.05 to 0.15	<8
Silt	0.002 to 0.05	<5
Clay	<0.002	<3

more than 6 % organic matter should not be used nor should any mucky-type soils. Mucky soils are those high-organic soils in which the organic material is so decomposed that no recognizable plant parts are present and which soil also contains more mineral content than organic content. Peat may be used to increase the organic matter content in a three-way blend of sand-soil-peat.

5.5.4.2 *Peat*—Peat is commonly used as an amending source in a sand-based rootzone. Proportions of peat included in a blend (usually 5 to 20 % by volume) should give an organic matter content of 0.3 to 2.0 % by mass. As with soils, peat amendment adds water holding and nutrient retention capacity, but will add little in terms of increased soil strength (cohesion). Peats can also slow water movement through excessively drained sands. Finer peats, whether by decomposition or by finer grinding, generally have a greater effect on slowing water movement. Three sources of peat have been used successfully to modify sands for rootzones. They are moss peats (sphagnum and hypnum), reed-sedge peats (derived from reeds, sedges, marsh grasses, and other plants of the wetland), and peat humus, which is decomposed peat (usually derived from moss or reed-sedge sources). Peats to avoid in modifying sands are woody peat (derived from trees and shrubs) and sedimentary peat (derived from plants that grow in water and found on pond and lake bottoms).

(1) Peats can be classified according to fiber content (Classification **D4427**). In general moss peats fall into the fibric classification (which indicates the greatest fiber content); reed-sedge peats into the hemic classification (a mid-range of fiber content); and peat humus into the sapric classification (lowest fiber content). Acceptable peats vary in their physical and chemical properties and information in **Table 4** can be utilized to select a peat for use in a rootzone blend (mix). Fibric peats are characterized by low ash contents, and low volume weights (bulk densities). Due to its lower volume weight, a greater amount of fibric peats (on a volume basis) will be required than with other peat sources in order to achieve a desired organic matter content (on a mass basis) in the blend. The low volume weight peats generally do not mix as readily as heavier peats when being mixed on-site by tillage, but this problem is largely negated by off-site mixing with various blending equipment. Off-site mixing is preferred for high performance sand-based rootzones. The fibric peats decompose more rapidly than hemic and sapric peats; however, their longevity is such that they provide benefits until organic additions from the turfgrass stand contribute significantly to the soil organic matter pool. With sphagnum moss peat, low pH

may create the need for lime additions to the mix, and relatively low nitrogen (N) content and wide C/N ratio could lead to N tie-up by microorganisms and the need for additional N fertilization.

(2) Potential problems encountered with fibric peats are reduced with hemic peats, which are denser, somewhat lower in acidity, higher in N content, and more readily mixed. Also sapric peats, or well-decomposed peats, have fewer problems with pH, N content, and volume weight; however, they contain more ash and some low quality sapric peats may contain mineral soils that result in unacceptably high ash contents. The organic matter in sapric peats, already being in a somewhat decomposed state, is more stable than organic matter in the more fibrous peats. Peats considered for inclusion in high performance sand-based rootzones can be classified according to Classification **D4427**, and further tested by methods listed in Section 5.4.5.3. Suggested recommendations for peat/organic amendments for high performance sand-based rootzones are given in **Table 4**.

NOTE 4—Often the use of composts are proposed as substitutes for peat products. While in some instances composts may produce satisfactory products for inclusion in a rootzone blend (mix), the variability of compost products tends to be much higher than those of natural peat deposits. This variability is especially true over time and from season to season. Composts also typically contain a higher ash content, may contain contaminants of soil or other earthy materials, may contain wood, and also may not be completely stable in terms of chemical and physical properties. Composts may also contain high elevations of trace metals or salts, or both (although testing can be used to determine the level of these constituents). The use of composts in a high performance sand-based rootzone should be approached with a high degree of caution and employed with thorough quality control in the sourcing and construction phases. Under strict control and testing, composts have and may be used for high performance sand-based rootzone constructions. It is recommended that only compost products be used that have been used successfully in high performance sand based green/tee mixes in the past, and only in amounts sufficient to meet the performance parameters outlined in this standard. Mix design and testing should be performed by laboratories experienced in evaluating composts and compost amended mixes.

5.5.5 *Quality Control (QC) Program for Rootzone Materials*—Every high performance sand-based rootzone should be constructed using a well designed and administered calibration and QC program. Such a program should determine the parameters to be included in QC testing, the procedures for sampling, sampling intervals, handling the samples (chain of custody), the limits (tolerances) or confidence intervals to accept or reject a sample, and the allowable variability of test parameters between samples. The soil bulk density value (or value range) at which the test results are to be obtained must be designated.

5.5.6 *Rootzone Blending*—Rootzone blending is perhaps the most critical aspect of the construction process. Once amendment ratios are known, the components of the blend should be prepared.

5.5.6.1 *Sand*—The sand should have been previously processed, stockpiled, approved and tested for quality control.

5.5.6.2 *Soil*—Any soil amendments should have been tested and approved, and then prepared for blending by first shredding, screening, and removing any objectionable stones or other items. Once the soil has been prepared in this manner,

TABLE 4 Suitability Ratings for Organic Amendments In Sand-based Putting Green and Tee Rootzones

Rating	C/N Ratio	Ash Content	pH
Preferred	20:1 to 30:1	<12 %	4.5 to 7.0
Acceptable	30:1 to 50:1	12 to 17 %	3.5 to 4.5
Marginal	50:1 to 80:1	17 to 30 %	3.0 to 3.5
Unacceptable, or use only with caution	<20:1 or >80:1	>30 %	<3.0 or >7.0

the soil should be transported to the blending site for stockpiling. Once the material arrives on site, it should be protected from weather, particularly rain. During the processing and transportation of the soil component, it may be beneficial to thoroughly mix the soil material as much as feasibly possible to reduce the potential for variability within the soil stockpile. Once thoroughly mixed and transported to the blending site, an additional sample should be taken and tested for conformance with the original tested material so that any adjustments in the blending proportions needed to compensate for variance in the soil stockpile may be made. It should be noted that soil components (particularly topsoils) are a potential source of weeds by seeds or plant parts. Consideration for eradication or fumigation of these materials may be warranted.

5.5.6.3 Peat—The peat product used for amending the sand should have been tested and approved prior to shipment of material to the blending site. Once the material arrives on site, it should be protected from weather, particularly rain. As peat is unloaded or unpackaged, it should be visually inspected for apparent uniformity within the shipment. If the project owner, golf course architect, or agronomist is sufficiently familiar with the peat material from past projects, the only QC testing that may be required for the peat is the calibration and QC for organic matter content of the resulting sand-peat mix. If the peat product/source is new or unfamiliar to the project personnel, additional QC tests should be performed at set testing intervals prior to blending. Peat QC test parameters may include ash content, organic matter, pH, fiber content, moisture content, volume weight, (Test Methods **D1997**, **D2944**, **D2974**, **D2976**, **D2980**, and Classification **D4427**) and C:N ratio. The above advice also applies to composts used as organic amendments.

5.5.6.4 Blending—The blending operation should only proceed once all of the materials have been tested, approved and transported to the blending site. It is recommended that blending operations proceed off-site as to the installation (not blended in place). Possible blending sites include: (1) the location for sand materials supply or stockpile; (2) in an area adjacent to the tee or green site (such as a paved parking lot). All materials should be blended in a slightly moist to moist condition. Excessively wet or excessively dry material may not break up properly and will not blend uniformly together. Blending should be performed using commercial soil blending equipment designed for this purpose. The golf course architect should calculate production to include a minimum of 5 % (10 % preferred) additional rootzone material to account for shrinkage. Any leftover rootzone material could be stockpiled by the Owner for use in future maintenance (topdressing) operations and for other repairs. The blending process should be initiated with the preparation of a ‘batch’ for calibration purposes. A calibration batch stockpile is normally composed of a minimum of 100 tons of rootzone blend. The calibration batch should be sampled and tested to assure the blending equipment is properly calibrated before proceeding further. Each test for calibration may delay the blending operation 24 to 48 h awaiting test results and recommendations from the testing laboratory. Another option would be to employ a commercial testing agent with the capacity to perform on-site

testing with mobile laboratory equipment. The mobile laboratory may be utilized throughout the calibration and blending process to facilitate the logistics of the operation. Unless the mobile lab is accredited, it is recommended that 1 of 10 tests conducted by the mobile laboratory are duplicated (10 % duplication) at the regular laboratory facility to ensure the accuracy of the on-site testing data.

5.5.6.5 Stockpile Storage and Transportation—Throughout the blending and QC process, all stockpiled material should be protected against the effects of weather until installed. If heavy rain is expected, the stockpiles should be covered if possible. To protect against wind erosion of soil or organic components, the stockpiles should be kept moist on the surface of the stockpile. Once stockpiled rootzone material is to be transported to the construction site, care should be taken to assure that the loading equipment and haul vehicles/containers are properly sanitized such to contain no foreign soil, aggregate, asphalt, etc. that might contaminate the blended rootzone material. When the stockpile material is being picked up for loading, care should be exercised to ensure that the bucket of the loading equipment is not picking up underlying soil or asphalt and that cleated tires or tracks are not ‘tilling’ other material into the rootzone mix.

5.5.7 Grading Requirements—All grades should conform as specified in the construction documents. The suggested method for grade evaluation and grade tolerances are:

(1) For general conformance, perform an as-built survey based upon an 8 m (25 ft) grid to be within:

- (a) Subgrade: + 25 mm (1 in.).
- (b) Gravel drainage layer (if used): + 12.5 mm (½ in.).
- (c) Surface/Finish: + 6 mm (¼ in.).

(2) For specific conformance and acceptability of grades between grid points (spot check), it is recommended that any observed (or suspected) high and low points be checked using a 3 m (10 ft) straight edge with tolerances based upon:

- (a) Subgrade: + 25 mm (1 in.) in any linear direction.
- (b) Gravel drainage layer (if used): + 12.5 mm (½ in.) in any linear direction.
- (c) Surface/Finish: + 6 mm (¼ in.) in any linear direction.

5.5.7.1 Grades shall be correct, certified and approved (at each phase: subgrade, gravel layer (if used), and finish grade) by owner or golf course architect, or both, prior to proceeding to the next phase of construction. Correct and certified grade shall be given by the production of an as-built drawing/diagram depicting elevation and location data that has been prepared and stamped by a licensed surveyor. The certified as-built drawing/diagram shall be submitted for approval to the owner or golf course architect, or both, as specified in the construction documents prior to proceeding to the next phase of the green/tee construction. All green/tee finish grades and contours should have a final inspection and approval from the golf course architect prior to seeding/planting.

5.6 Installation—Installation procedures include the installation of the drainage trench backfill material, installation of any gravel drainage layers, delivery and installation of the rootzone material, installation of the irrigation system, finish grading of the site, and then turf establishment. Rootzone installation depth shall conform to the golf course architect’s

specifications. Typical rootzone depths range from 15 to 30 cm (6 to 12 in.) for installations without a gravel drainage layer. If a gravel drainage layer is used, the rootzone depth must be correlated with the desired depth of well-aerated rootzone. Typically, the profile depth of a sand-based green/tee installed over a gravel drainage layer ranges from 23 to 40 cm (9 to 16 in.).

5.6.1 Installation of Drainage Materials—Drainage trench installation should be completed to the point of backfill and compaction (see 5.4.3) prior to installing the irrigation system. If a gravel drainage layer is a component of the system design, the installation of the gravel layer should be completed following the rough installation and pressure testing of the irrigation system.

5.6.2 Installation of the Irrigation System—The irrigation system shall be designed and installed to provide head to head coverage with uniform distribution.⁵ Suggested irrigation design uniformity values (CU_{IRR} or Christiansen's coefficient of uniformity) should be >85 %. Irrigation pipe should be installed deep enough to prevent damage from mechanical aeration maintenance practices. Normally, this would be at a depth of 36 cm (14 in.) or more from the finished grade. In the case of shallow profile designs (less than 20 cm (8 in.)), the irrigation lateral and mainlines may be installed within the subgrade below the depth of the entire drainage system. The installation of the irrigation lines below the drainage system serves to isolate the irrigation lines from potential damage from aeration or other maintenance practices.

5.6.2.1 Irrigation main lines and lateral lines (with sleeving, if included) should be installed prior to installing the gravel drainage layer (if used) or rootzone materials, or both. Irrigation lines crossing drainage trenches may be 'sleeved' across the drainage trench to facilitate subsequent irrigation system installation without disturbing the drainage trench system. Irrigation lines SHOULD NOT be installed within the same trenches as the drainage system in order to minimize the disturbance of one system to the other as they are being installed or repaired. Pressure in the irrigation system main lines should be checked (24 h static pressure) before backfilling and prior to proceeding with the next construction phase.

5.6.2.2 Complete Installation of Gravel Drainage Layer—If a gravel drainage layer is used as a component of the design, this gravel layer may be installed once the irrigation system rough installation and a pressure check are completed.

5.6.3 Delivery and Installation of the Rootzone—The rootzone material should be transported to the site and dumped around the perimeter. As stated in 5.5.6.5, the rootzone material should be protected from rain and becoming excessively wet prior to placement and compaction. The spreading, grading, and compaction of rootzone material in an overly wet state may lead to overcompaction of the resulting rootzone. A small crawler tractor (or rubber tracked skid steer loader) is ideally suited to spread the rootzone material working from the perimeter inward toward the center of the green/tee. Wheeled tractors/loaders or larger crawler tractors may cause excessive

pressure that could lead to crushing of the drainage pipes, rutting of the subgrade, or over compaction of the rootzone material. Under no circumstances should trucks or other equipment be allowed to travel over the uncovered subgrade. Once the delivery of the rootzone material is completed, the green/tee may be shaped, rough-graded and compacted as specified.

5.6.4 Final Green/Tee Preparations—Final green/tee preparations include bringing the green/tee to final grade and contour as well as pre-plant fertilization and pre-plant irrigation.

5.6.4.1 Finished Grade—Once the rootzone material has been installed and rough graded, the green/tee should be graded to final (finish) grade and contour. It is strongly recommended that laser guided leveling equipment is specified and utilized for this critical aspect of the construction process. A smooth and uniform grade is a very important aspect of proper conditions for enhanced putting green playability. The specified grade and contour should conform to a +6 mm (+¼ in.) within 3 m (10 ft) in any lateral distance for general and specific conformance as outlined in 5.5.7 or as per golf course architect's instructions. During the finish grade operation, compaction should be achieved by irrigating and rolling the surface utilizing a lightweight roller (providing ground pressure of 6 to 8 psi) with at least 2 passes in perpendicular directions. Finished grade should be within specified tolerances, correct and certified as specified (see 5.5.6) before turf installation.

NOTE 5—In general, as the soil component of a sand-based rootzone increases, rolling should be performed with lighter equipment while also giving a higher level of attention to the moisture content of soil component. In any case it is recommended that when using soil components that have an increased potential to compact in a blend with sand, rolling shall be done with caution.

5.6.4.2 Pre-Plant Operations—Pre-plant operations may include the use of a pre-plant fertilizer or other soil fertility amendments. Applications can be made as granular products that are spread across the green/tee or liquid formulations that are sprayed across the green/tee or injected into the irrigation system. After application, it may be desirable to lightly irrigate or 'water-in' the applied materials. Any pre-plant operations must be performed with care to avoid rutting or disruption of the final grade in any manner. Only lightweight or walk-behind equipment is advisable.

5.6.5 Turf Installation—The turf to be used in the putting green or tee project should be thoughtfully considered and specified by the project Golf Course Architect, Owner or Project Agronomist. Turf selection should be for a species and cultivar adapted to the local climate, capable of withstanding the stresses imposed on an putting turf, while providing good playability and aesthetic characteristics. Depending upon the turf species and cultivar selected, installation methods may include seeding, sprigging, plugging or sodding. Any turf installation methods used must be carried out in a manner that protects the integrity of the finished grade. No heavy machinery such as tractors, hydrospray tanks, or trucks should be allowed on the surface, unless equipped with turf-type tires.

5.6.5.1 Seeding and Sprigging—Seeding and sprigging are the two methods that offer the most flexibility because they do not pose the risk of contamination of the rootzone with

⁵ Christiansen, J. E., "Irrigation by sprinkling," *California Agricultural Experimental Station Bulletin 670*, University of California, Berkeley, CA, 1942.

attached soil. They can be spread or planted mechanically or by the use of hydroseeding/hydrosprigging techniques. If the project construction timeframe allows, seeding or sprigging are the preferred methods of establishment. Any mechanical sprigging equipment or seeders should be outfitted such to avoid disruption of finished grade. The use of heavy or large hydrosprig/hydroseed equipment intended for use in the hydroseeding or hydrosprigging of roadside and highway landscapes should be avoided except where the equipment can be kept off the green/tee and the hydroseed/hydrosprig material can be applied with a hose. Seeds or sprigs should be Certified turfgrass seed/sprigs (if available). Seeds or sprigs shall be free of, or below acceptable threshold levels for objectionable or noxious weeds, foreign turfgrass cultivars, off-types of the same species, insects, nematodes, diseases, or any other objectionable material.

5.6.5.2 Plugging—Warm season turf cultivars that propagate by spreading through rhizomes or stolons (for example, seashore paspalum and bermudagrass), may be established by plugging. Plugging has some distinct advantages as an establishment method. Installed plugs have an established root system and are therefore not as subject to stresses of drought should an interruption in water supply occur or irrigation water quantities are limited. If the growing medium of the plugs was a ‘soil-less’ mix, then minimum contamination of the rootzone can be expected. Plugs can be planted on a wide variety of spacings depending upon the desired rate of grow-in desired and the turf cultivar utilized. Typical plug planting spacing ranges from 20 to 40 cm (8 to 16 in.) on center. Plugs should be free of weeds, contaminants, off-type turf or any other objectionable material. Plugs for putting greens/tees are best planted by hand. Another method of plug establishment is sometimes utilized whereby a mechanical planter processes sod into irregular pieces and then plants them as ‘plugs’. This method of plugging irregular sod pieces may also be used for satisfactory establishment of turf and can be done mechanically with due caution to avoid disruption or rutting of the finished grade.

NOTE 6—Plugging as used in this standard defines the use of discreet media-rooted turf plugs (as often coming in a plastic media tray). This method of plugging should not be confused with the practice of planting irregular sod pieces, which is also referred to as plugging in some areas. Plugging by the use of irregular sod pieces is a practice more closely resembling a sprigging operation and the establishment of turf by this practice should conform to the specifications as given for mechanical sprigging.

5.6.5.3 Sodding—Sodding offers the quickest establishment of any turf installation method. Sod can come in rolls or slabs of various dimension and thickness. It is preferable to wash the soil from the sod before installation to avoid contamination of the rootzone. If washed sod is not available, then only sod grown in sand or loamy sand soil should be considered. Any sod-soil considered for installation in the project should meet the criteria outlined in **Table 5**. Big-roll sod is the preferred sod type in order to reduce the number of seams in the finished installation. Sod delivery and installation procedures should be such to avoid compaction and disruption of the finished grade. (Sod may also be planted mechanically as irregular sized pieces in a process called ‘plugging’, see **5.6.5.2**). Sod deliv-

TABLE 5 Sod-Soil to Rootzone Sand Compatibility Recommendations

Criteria	Preferred	Acceptable	Marginal	Unacceptable
D ₅₀ R/D ₅₀ S ^A	<2.5	2.5 to 5.0	5 to 10	>10
Silt and Clay (%)	<5	5 to 10	10 to 15	>15
Silt to Clay Ratio	<2	2 to 5	5 to 7	>7
Gravel (> 2 mm) (%)	0	0 to 2	2 to 5	>5

^A R = Rootzone; S = Sod-Soil

eries should be made off the green/tee and the sod moved in on a pallet by pallet or roll by roll basis as appropriate. Specialized sod handling and installation equipment only should be used during this process to protect the finished grade. For example, with big-roll sod installations, rubber-tracked handling and installation equipment is commercially available.

(1) **Recommended Sod Specifications**—If sod is the chosen turf establishment method, the following criteria are recommended for sod specifications:

(a) **Certified Turfgrass Sod**—Sod grown from certified (if available), high quality seed (stolons) of known origin or from plantings of certified grass seedlings or stolons. It shall be inspected by a golf turf consultant and an owner’s representative at the sod farm at which it is grown to ensure satisfactory genetic identity and purity, overall high quality and freedom from noxious weeds as well as excessive quantities of other crop and weedy plants at the time of harvest. All seed or original plant material in mixture should be certified. Turfgrass sod shall meet the published state or government standards for certification of the species and cultivar as specified.

(b) **Mowing Height**—The mowing height of the sod should correspond to the type of installation for which it is intended. For greens, the mowing height should be no greater than 6.25 mm (¼ in.) and for Tees the mowing height should be no greater than 12.5 mm (½ in.).

(c) The preferred specification for sod is sod that is custom-grown on sand that matches the sand used in the rootzone construction. It may not be possible to use sod grown on the rootzone sand, so the sod may be washed (soil-less) or a special “sand base” material meeting compatibility specifications in **Table 5**. Sod-soil containing greater than 15 % silt and clay is unacceptable. In most cases, sod should not contain a soil layer greater than 12.5 mm (½ in.). Thick cut (>12.5 mm or >½ in.) sod may be used in cases where insufficient time exists for establishment of sod before play is initiated. In any case, sod-soil should meet appropriate compatibility criteria as given in **Table 5**.

(d) **Strip Size**—Sod shall be big roll turf cut to the supplier’s standard width and length. Maximum allowable deviation from standard widths and lengths shall be ±12.5 mm (½ in.) on width and ±5 % on length. Broken strips and torn or uneven ends will not be accepted.

(e) **Time Limitations**—Sod shall be harvested, delivered, and transplanted within a 12 h period unless a suitable preservation method is approved by the golf course architect or project agronomist prior to delivery. Sod not transplanted within this period shall be inspected and approved by the Project Agronomist and golf course architect prior to its installation.

(f) *Thatch*—Sod shall be relatively free of thatch. A maximum of 12.5 mm (½ in.) (uncompressed) thatch will be permitted for tee installations and a maximum of 6.25 mm (¼ in.) (uncompressed) thatch for green installations.

(g) *Diseases, Nematodes, and Insects*—Sod supplier should be required to supply (and warrant) sod that shall be relatively free (below established acceptable threshold levels) of diseases, parasitic nematodes, and soil-borne insects.

(h) *Weeds*—Sod shall be free of objectionable grassy and broadleaf weeds.

(i) Sod supplier should identify specific fields for harvest, inspection, and submit a fertility and management program schedule for the 6 months prior to harvest.

6. Recommended Rootzone Performance Criteria

6.1 Several criteria should be considered for proper design of high performance sand-based rootzone construction. These include physical performance criteria and chemical performance criteria. The rootzone performance criteria should be evaluated by laboratory testing for the complete rootzone blend rather than on any component separately.

6.2 *Recommended Physical Performance Specifications*—Physical performance criteria (as determined at 30 cm tension for water retention and air-filled porosity) include permeability or saturated hydraulic conductivity, water retention, air-filled porosity and bulk density. Performance test criteria may be determined at other soil tensions as may be deemed appropriate by the rootzone designer for differing soil profile construction depths. The recommended physical performance criteria are given in **Table 6**. The physical performance criteria should be given priority over the sand size distribution specifications.

TABLE 6 Recommended Physical Properties of the Rootzone Mix (Test Method F1815, Test Methods D854)

Physical Property	Specified Range
Total Porosity	35 to 48 %
Bulk Density (kg · m ⁻³)	1.4 to 1.7
Air-filled Porosity	>20 %
Capillary Porosity	15 to 25 %
Saturated Hydraulic Conductivity (cm/hr)	≥25
(Saturated Hydraulic Conductivity [inches/hr])	(≥10)

6.3 *Recommended Chemical Performance Specifications*—Chemical performance criteria include pH, calcium carbonate equivalent, organic matter content, nutrient content and the presence of any heavy metals or phytotoxic ions/substances. The recommended chemical performance criteria are given in **Table 7**.

TABLE 7 Recommended Chemical Properties of the Rootzone Mix

Chemical Property	Specified Range
pH (D4972), by electrode in distilled water	5.0 to 7.5
Calcium Carbonate Equivalent, preferred	<5 %
Calcium Carbonate Equivalent, marginal	5 to 15 %
Organic Matter (F1647)	0.5 to 2.5 %
Nutrient Content	Adjust for local conditions
Heavy metals or other phytotoxic ions	Adjust for local conditions, do not exceed regulated thresholds

7. Keywords

7.1 athletic field; golf; green; natural turf; putting green; sand; soil; sports field; sports turf; tee; turf; turfgrass

RELATED MATERIAL

British & International Golf Greenkeepers Association (BIGGA), BIGGA, BIGGA HOUSE, Aldwark, Alne, York, YO61 1UF Also: <http://www.bigga.org.uk>

Golf Course Superintendents Association (GCSAA). GCSAA, 1421 Research Park Drive Lawrence, KS 66049-3859 Also: <http://www.gcsaa.org>

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