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An American National Standard

Standard Guide for Construction of Sand-based Rootzones for Golf Putting Greens and Tees[1]

This standard is issued under the fixed designation F2747; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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 (Withdrawn 2016)[3]
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/ft^3 (600 kN-m/m^3))
D854 Test Methods for Specific Gravity of Soil Solids by Water Pycnometer
D1883 Test Method for California Bearing Ratio (CBR) of Laboratory-Compacted Soils
D1997 Test Method for Laboratory Determination of the Fiber Content of Peat Samples by Dry Mass
D2944 Practice 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
D2980 Test Method for Saturated Density, Moisture-Holding Capacity, and Porosity of Saturated Peat Materials
D4427 Classification of Peat Samples by Laboratory Testing
D4972 Test Methods 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

[1] This guide is under the jurisdiction of ASTM Committee F08 on Sports Equipment, Playing Surfaces, and Facilities and is the direct responsibility of Subcommittee F08.64 on Natural Playing Surfaces.

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[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.

F1647 Test Methods for Organic Matter Content of Athletic Field Rootzone Mixes
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 Combative Sports
F2651 Terminology Relating to Soil and Turfgrass Characteristics of Natural Playing Surfaces

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.

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),

(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
Uniformity Factors	D_{90} of gravel/D_{15} of gravel	≤2.5
	>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

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

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 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.

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

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

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 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 it's 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.

5.5.4.3 *Porous Inorganic and Other Amendments*—Porous inorganic amendments such as vitrified or calcined diatomites and clay, or zeolites are sometimes used in place of or in addition to peat, soil, or other organics in a rootzone mixture. However, the particle size of the amendment and the performance characteristics of the rootzone mixture must meet the recommendations in Table 2, or Table 3, Table 5, and Table 6. It should be noted that these amendments have considerable differences among products and within the same product class. Also, many of these products also have closed internal porosity (pores which may not be open to the surface of particle) which imparts an effectively low particle density. As such, the internal air-filled porosity values may influence the air-filled porosity

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

TABLE 5 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)