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Am American National Standard

Standard Guide for
Construction of High Performance Sand-Based Rootzones for ~~Sports~~Athletic Fields[1]

This standard is issued under the fixed designation F2396; 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 sports fields. This guide provides guidance for the selection of materials, including soil, sand, gravel, peat, and so forth, for use in designing and constructing sand-based sports 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 in parentheses are for information only.

1.5 *This standard may involve hazardous materials, operations, and equipment. 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 requirements 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
C1444 Test Method for Measuring the Angle of Repose of Free-Flowing Mold Powders
D422 Test Method for Particle-Size Analysis of Soils ~~D653Terminology 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))
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
D2980 Test Method for Volume Mass, Moisture-Holding Capacity, and Porocity of Saturated Peat Materials
D3080 Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions
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

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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.

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~~
F2107 Guide for Construction and Maintenance of Skinned Areas on Baseball and Softball Fields
F2269 ~~Guide for Maintaining Warm Season Turfgrasses on Athletic Fields~~ Guide for Maintaining Warm Season Turfgrasses on Athletic Fields
F2651 Terminology Relating to Soil and Turfgrass Characteristics of Natural Playing Surfaces

3. Terminology

3.1 ~~Definitions—Except~~ *Definitions:*

3.1.1 Except as noted, soil-related definitions are in accordance with Terminology ~~D653~~F2651.

~~3.1.1*clay*—clay can be defined in terms of a particular size fraction of a soil, a soil textural class, a soil particle size class, a soil textural group, soil mineralogy, or, in engineering terms, as materials that exhibit plastic soil properties when at appropriate water contents **(1, 5, 6)**.~~

~~3.1.1.1*Discussion*—Ideally, the term "clay" should be appropriately defined when used to describe soils or materials for rootzones. For example, a 90% sand/10% clay mixture could imply either 90% sand/10% clayey soil (or other soils with textures containing enough clay (<0.002 mm) to exhibit plasticity) or 90% sand (2 to 0.05 mm)/10% clay (<0.002 mm).~~

~~3.1.1.2*clay*—*(1) as a particular size fraction of a soil*; a soil separate consisting of particles <0.002 mm (fine earth fraction) in equivalent diameter; *(2) as a textural class*; soil material that contains 40% or more clay, <45% sand and < 40% silt; *(3) as a soil particle size class*; soil material that contains 35% or more clay, (clayey soils); *(4) as a soil textural group*; soil material that falls within the textural classes of "sandy clay," "silty clay," and "clay (clayey soils);" *(5) in terms of mineralogy*; soil particulates that are commonly occurring but not restricted to the <0.002 mm fraction (clay minerals). Commonly occurring in soil mineralogy classes as smectitic, kaolinitic, illitic (micaceous), gibbsitic, ferritic, or mixed. Soil mineralogy classes are defined predominantly by the type of soil mineral dominating (40% or more) the fine earth fraction; and *(6) in engineering terms*; soils containing enough soil material in the less than 0.4 mm fractions such that, when moist, they exhibit consistent characteristics of "moderately plastic" or "very plastic," forming a roll 4 cm or longer and 4 mm or thinner that supports its own weight **(1, 2, 3)**.~~

~~3.1.2*saltation*—a particular type of momentum-dependent transport involving: *(1)* the rolling, bouncing or jumping action of soil particles 0.1 to 0.5 mm in diameter by wind, usually at a height <15 cm above the soil surface, for relatively short distances; *(2)* the rolling, bouncing, or jumping action of mineral grains, gravel, stones, or soil aggregates affected by the energy of flowing water; and *(3)* the bouncing or jumping movement of material down slope in response to gravity **(2)**.~~

~~3.1.3*sand*—sand can be defined in terms of a particular size fraction of soil, a soil textural class, a soil particle size class, and a soil textural group.~~

~~3.1.3.1*Discussion*—Although no mineralogy term is associated with the definition of sand, common usage often utilizes the terms "quartz" or "silica" as synonyms for sand. While quartz is the most common silica mineral in soils and in the sand fractions in particular, quartz being a mineral highly resistant to weathering, the synonymy with the term sand is incorrect. A proper mineralogy class for quartz is "siliceous," defined as 90% or more of the 0.2 to 2.0 mm fraction composed of silica minerals (quartz, chalcedony, or opal) and other extremely durable minerals that are resistant to weathering **(4)**.~~

~~3.1.3.2*sand*—*(1) as a particular size fraction of soil*; a soil separate consisting of particles >0.05 mm and <2.0 mm in equivalent diameter; *(2) as a textural class*; soil material that contains 85 % or more sand, and not more than 10% clay; *(3) as a soil particle size class*; soil material that contains 70% or more sand, and not more than 15% clay (sandy soils); and *(4) as a soil textural group*; soil material that falls within the textural classes of "sand" and "loamy sand" (sandy soils) **(3, 4)**.~~

~~3.1.4*gravel*—commonly used to denote spherical, cube-like, or equiaxial aggregate materials with an equivalent diameter >2.0 mm and <7.6 mm. More correctly used, this classification refers to "rock fragments" classed as pebbles in the Glossary of Soil Science Terms (1997) **(3, 6)**.~~

~~3.1.5*skinned area*—area on sports fields that, by design, is devoid of turfgrasses or other vegetation; may be entire field or a portion of the field (for example, skinned infield in baseball or softball; skinned base paths in otherwise turfed infield). **F2107**~~

~~3.1.6*soil*—sediments or other unconsolidated accumulations of solid particles produced by the physical and chemical disintegration of rocks, and which may or may not contain organic matter.~~

~~3.1.7*soil profile*—vertical section of a soil showing the nature and sequence of the various layers as developed by deposition or weathering, or both, or as developed by construction procedures.~~

~~3.1.8*soil texture* (gradation) (grain-size distribution)—proportions by mass of a soil or fragmented rock distributed in specified particle size ranges.~~

~~3.1.8.1*soil textural class*—texture designation based on relative proportions of the various soil separates: sand (2.0 to 0.05 mm in diameter), silt (0.05 to 0.002 mm), and clay (<0.002 mm) **(1, 2, 3)**.~~

NOTE 1—Particle size ranges for sand, silt, and clay ~~as listed above~~used in this standard vary somewhat from ranges given in Test Method D422~~and Terminology D653~~.

4. Significance and Use

4.1 A dense, uniform, smooth, and vigorously growing natural turfgrass sports field provides the ideal and preferred playing surface for most outdoor field sports. Such a surface is pleasing to the spectators and athletes. A thick, consistent, and smooth grass cover also increases playing quality and safety by providing stable footing for the athletes, cushioning their impact from falls, slides, or tackles, and cools the playing surface during hot weather. Sand is commonly used to construct high performance sports turf rootzone systems. Sand is chosen as the primary construction material for two basic properties, compaction resistance and improved drainage/aeration state. Sands are more resistant to compaction than finer soil materials when played upon within a wide range of soil moisture conditions. 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 rainy season. A properly constructed sand-based rootzone, on the other hand, will resist compaction even during wet periods. Once compacted, sands are easier to decompact with the use of mechanical aeration equipment. 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 playing surface. Properties of both the soil and grass plants must be considered in planning, constructing, and maintaining a high quality sports turf installation. Turfgrass 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 in and of itself is not inherently stable; therefore, it is imperative that grasses with superior wear tolerance and superior recuperative potential are utilized to withstand heavy foot traffic and intense shear forces. Sand does, however, have incredible load bearing capacity and if a dense, uniform turf cover is maintained, the sand-based system can provide a very stable, firm, smooth, and uniform playing surface. 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 amendment, soil and gravel is of vital concern to the performance of the system and this guide addresses these issues.

4.1.1 During construction, consideration should be given to factors such as the physical and chemical properties of materials used in the area, freedom from stones and other debris, and surface and internal drainage.

4.1.2 Maintenance practices that influence the playability of the surface include mowing, irrigation, fertilization, and mechanical aeration and are factors addressed in other standards (see Guides F2060 and F2269).

4.2 Those responsible for the design, construction, or maintenance, or a combination thereof, of natural turf athletic fields for high-performance, all-weather purposes will benefit from this guide.

4.3 A successful project development depends upon proper planning and upon the selection of and cooperation among design and construction team members. A high-performance, sand-based rootzone project design team should include a project designer, an agronomist or soil scientist, or both, and an owner's 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 representative), an owner's quality control agent (often the personnel that is employed in advance with the intent of becoming the finished project's sports field manager), an owner's testing agent (often an expansion of roles for the project's agronomist/soil scientist), and the contractor.

4.3.1 Planning for projects must be conducted well in advance of the intended construction date. This often requires numerous meetings to create a calendar of events, schedule, approvals, assessments, performance criteria, material sourcing, geotechnical reports, and construction budgets.

NOTE 2—Other specifications on soils for athletic field construction have been published and have been considered during the development of this guide.

5. Construction

5.1 The steps to be used in construction of a new athletic field include:

5.1.1 Survey and stake the site to establish subgrade and finish grade elevations.

5.1.2 Construct and prepare subgrade, and provide a correct and certified subgrade.

5.1.3 Install subsurface drainage system, frame out warning tracks, skinned areas, and so forth, as appropriate.

5.1.4 Install irrigation system (irrigation system may be installed prior to rootzone installation).

5.1.5 Prepare for rootzone installation.

5.1.5.1 Secure suitable sand, properly tested and approved.

5.1.5.2 Blend any amendments with sand to project specifications, approve using QC program.

5.1.5.3 Install approved gravel (if included in design).

5.1.6 Install rootzone blend.

5.1.7 Bring field to final grade and contour in accordance with specifications, compact to specifications.

5.1.7.1 A pre-plant fertilizer application may be applied at this point as specified.

5.1.8 Establish turf by appropriate methods (seed, sprigs, plugs or sod).

5.1.9 Fertilize the installation as appropriate based upon soil testing.

5.1.10 Turf is to be established based upon grow-in recommendations from a competent agronomist or soil testing laboratory, as appropriate for the turf species utilized and the climate of the site.

5.2 *Survey and Stake*—This procedure should be done to conform to the project designer's specifications as appropriate for the sport. In the case of the construction of a replacement field, 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 in accordance with specifications at a suggested tolerance of

±12.5 mm ~~(1~~(½ in.) within 3 m (10 ft) of linear direction as specified in 5.5.6. The subgrade should be installed at a depth such to accommodate the final profile depth of rootzone and any gravel layer (if included). The subgrade should be compacted sufficiently (suggested 85 % minimum to 90 % maximum proctor density) to prevent future settling. Subgrade should be designed to conform to surface contour of finished playing surface.

5.4 *Subsurface Drainage System*—Many types of designs exist for subsurface drainage most commonly including a grid or herringbone pattern. The project specifications should include a subsurface drainage design to facilitate drainage for a 25 year storm event. Most commonly used drainage systems for sand-based athletic fields include utilizing perforated drainlines 10 cm (4 in.) in a 4.5 m (15 ft) to 6 m (20 ft) spacing between drainline laterals.

5.4.1 *Drainline Trenches*—Trenches constructed for drainlines should be excavated into a properly prepared, graded, and compacted subgrade. Drainage trenches should be of a depth such to conform to the drainage contours. All drainage trenches and drainline installations should maintain a minimum positive slope gradient of ≥0.5 % toward 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 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 field installations should include a minimum of 0.5 % slope gradient (simple slope or crown) to remove water off of the playing field in case of a storm event with severe rainfall intensity and to facilitate the use of tarps. It is recommended that an adequate number of small size surface drainage inlets be installed in the perimeter of the installation (in out-of-play areas) and tied into the drainage collection system for removal of surface runoff with the subsurface drainage water.

NOTE 3—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 finish 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 could utilize sand rootzone material to backfill around drainlines within the drainage trenches. Option 2 could utilize gravel material to backfill around drainlines in the drainage trenches. Option 3 could include the use of gravel to backfill around drainlines in drainage trenches and to form a drainage layer overlying the subgrade before placement of rootzone sand blend. 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 as installed and no soil pilings, wood blocks, concrete or metal blocks are used to adjust and maintain slope of drainlines. Any blocks used for this purpose must be removed from under 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. 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 around drainlines. If sand is utilized for this purpose, the drainage pipe used in these installations must be of a type that utilizes slitted perforations with slit openings meeting a specification of D_{85} sand/slot width >1.5, to reduce the potential for particle migration into the drainage system (**7**).

5.4.3.2 *Option 2*—Gravel may be used for backfill of drainage trenches. If gravel is used for backfill, it should conform to the specifications in Table 1. Soft gravel minerals (such as limestone, sandstone, or shale) are not acceptable for use and all

TABLE 1 Gravel Filter/Drainage Layer Specifications (7, 8)

Performance Factor	Criteria	Acceptable Value
Filtering Factors	D_{15} of gravel/D_{85} of rootzone mix	<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 %

questionable gravel material should be tested for weathering stability using the sulfate soundness test (see 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 (see Test Method C131). An LA Abrasion test value greater than 40 is unacceptable.

5.4.3.3 *Option 3*—Gravel may be used 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 used for backfill and the drainage layer, and should conform to the specifications given in Table 1. Soft gravel minerals are not acceptable for use and all questionable gravel material should be tested for weathering stability using the sulfate soundness test (see Test Method C88). A loss of material greater than 12 % by weight is unacceptable. Likewise, any gravel material that is suspect in its mechanical stability should be tested utilizing the LA Abrasion test (see Test Method C131). An 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 cm to 15 cm (4 to 6 in.) preferred. During installation, the gravel is typically dumped from the delivery trucks onto the perimeter, 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. Contour and compact the gravel in accordance with specifications at a suggested tolerance of ±12.5 mm (½ in.) within 3 m (10 ft) of linear direction and as specified in 5.5.6.

5.4.3.4 *Discussion*—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 on 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.

5.4.3.5 *Determination of Well-Aerated Rootzone Conditions*—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 40 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. 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*—Materials used to provide the sand for the rootzone shall meet the performance criteria established in this guide. Additions of peat or soil, or both, may be included in small proportions as part of the rootzone blend, if the inclusion of these materials will not bring the resulting blend out of specifications and if they are uniformly blended together to form a homogeneous blend.

5.5.1 *Sand Type*—Quartz sands are recommended; if 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) that may influence the performance of the construction. 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 with 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 oven-dried mass of a weighed sample; 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 distribution for sand-based rootzone constructions. Many of these specifications are primarily intended for golf green construction. As such, the amount of coarse material allowed is limited in order to produce a very smooth surface under extremely short mowing conditions to facilitate smooth roll of the small golf ball. Such conditions are not required for athletic field construction and the use of higher proportion of coarser sand material can be utilized. Table 2 includes a recommended sand particle size distribution (before amendments), but is not inclusive of all size distributions of sands that could be used to produce a high performance sand-based field. Additionally:

5.5.2.1 No more than 30 % in the combined very coarse sand, fine gravel, and gravel fractions.

5.5.2.2 At least 60 % of the total sand should be in the combined medium sand and coarse sand fractions.

5.5.2.3 No more than 15 % in the combined fraction less than 0.25 mm (fine sand, very fine sand, silt and clay fractions).

5.5.2.4 A Coefficient of Uniformity (CU = D_{60}/D_{10}) value of 2.5 to 4.5.

5.5.3 *Sand Shape*—Although acceptable sand-based rootzones can be constructed with sands of all shapes, this factor is worth consideration in athletic field construction. Sand shape is generally classed as to angularity and sphericity. Angularity includes

TABLE 2 Recommended Particle Size Distribution of Rootzone Sand[A]

Size Fraction	Particle Diameter Range	Specified Range (%)
Gravel	>4.75 mm	0 %
Gravel	3.4 to 4.75 mm	<5 %
Fine gravel	2.0 to 3.4 mm	<20 %
Very coarse sand	1.0 to 2.0 mm	<20 %
Coarse sand	0.5 to 1.0 mm	25 to 50 %
Medium sand	0.25 to 0.5 mm	>25 %
Fine sand	0.15 to 0.25 mm	<10 %
Very fine sand	0.05 to 0.15 mm	<5 %
Silt	0.002 to 0.05 mm	<5 %
Clay	<0.002 mm	<3 %

[A] See 5.5.2.1-5.5.2.4 for additional recommendations.

well-rounded, rounded, subrounded, subangular, angular, and very angular. Sphericity includes high sphericity, medium sphericity, and low sphericity. Sand shape should be classified according to Figure 1 of Test Method F1632. While no sand will have sand grains of 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 of the lack of edges to interlock the grains. As such the sand grains tend to act like small ball bearings. Angular sands to have greater stability because the sharper edges have a greater grain-grain interlock and 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. Likewise, extremely high or low sphericity particles should be avoided, including plate-like particles. Many dune sand sources may contain sand grains that have internal fracture planes. During the saltation process, dune sands can become rounded as they roll and skip along the surface as a function of the wind. 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. Sand grains should be examined under 20 to 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 make up the rootzone material. This would most commonly include a blend with soil or peat, or both.

5.5.4.1 *Soil*—Soil is commonly used as a component of a sand-based rootzone construction in order to provide some enhanced capacity for moisture and nutrient retention and sometimes to 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 to the physical performance characteristics of the resulting blend. Ideally, the soil component would be one that is composed purely of clay. Clay minerals generally have good moisture and nutrient retention capacities, and if present in high enough proportions may significantly improve rootzone stability by enhanced cohesive properties. When clay is included in a blend with sand in the appropriate proportion, 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 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 3 should be avoided. Generally, soils containing more than 6 % organic matter should not be used, nor any mucky-type soils. 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 15 to 20 % by volume) should give an organic matter content of 0.3 to 2.0 % by mass. As with soils, peat adds water 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. 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). Peats can be classified according to fiber content (see 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). The acceptable sources of peat range in their physical and chemical properties and information in Table 3 can be utilized during the selection of a peat. Fibric peats are characterized by low ash contents, and low volume weights (bulk densities). Because of a lower volume weight, a greater amount on a volume basis than