USGA

USGA Recommendations For a Method of

PUTTING GREEN CONSTRUCTION

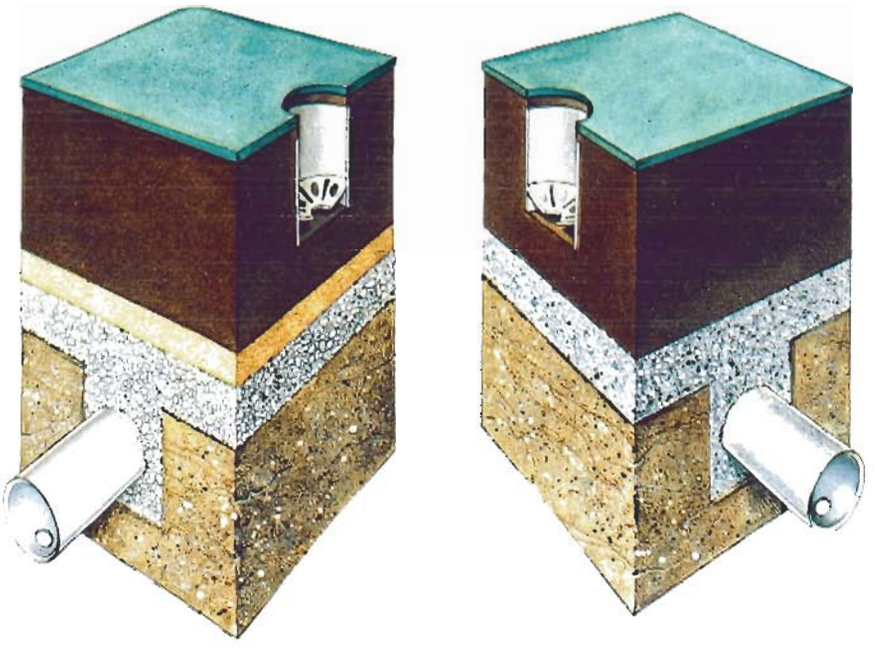
2004 revision of the USGA Recommendations for a Method of Putting Green Construction

by the
United States Golf Association
Green Section Staff

PG 1110

For more than 40 years *the USGA recommendations for green construction have been the most widely used method of green construction throughout the United States and in other parts of the world. When built and maintained properly, USGA greens have provided consistently good results for golf courses over a period of many years. These guidelines are periodically reviewed and updated as a result of scientific research and as new techniques and materials are proven reliable.*

This document specifically represents the USGA Green Section's recommendations for green construction. It does not include a discussion of construction techniques or methods. Additional documents are available from the USGA that describe construction methods, offering tips for success and providing guidance for green management.



Step 1 ■ The Subgrade

The slope of the subgrade should conform to the general slope of the finished grade. The subgrade should be established approximately 16 inches (400 mm) below the proposed surface grade - 18 to 20 inches (450 to 500 mm) when an intermediate layer is necessary - and should be thoroughly compacted to prevent further settling. Water collecting depressions should be avoided.

If the subsoil is unstable, such as with an expanding clay, sand, or muck soil, geotextile fabrics may be used as a barrier between the subsoil and the gravel blanket. Install the fabric as outlined in Step 2.

Construct collar areas around the green to the same standards as the putting surface itself.

Figure 1 – The subgrade must be smooth, firmly compacted, and be free of water-collecting hollows.

Step 2 ■ Drainage

A subsurface drainage system is required in USGA greens. The pattern of drainage pipes should be designed so that the main drain(s) is placed along the line of maximum fall, and laterals are installed at an angle across the slope of the subgrade, allowing a natural fall to the main. Lateral drains shall be spaced not more than 15 feet (5 m) apart and extended to the perimeter of the green. Laterals should also be placed in water-collecting depressions if they exist. At the low end of the gradient, where the main drain exits the green, drainage pipe should be placed along the perimeter of the green, extending to the ends of the first set of laterals. This will facilitate drainage of water that may accumulate at the low end of that drainage area. Drainage design considerations should be given to disposal of drainage waters away from play areas, and to the laws regulating drainage water disposal.

Figure 2 – Lateral lines should be spaced not more than 15 feet (5m) apart and have a natural fall to the mainline of at least 0.5%.

Drainage pipe shall be perforated plastic, minimally conforming to ASTM 2729 or ASTM F 405, with a minimum diameter of 4 inches (100 mm). Waffle drains or any tubing encased in geotextile sleeves are not recommended. Drainage trenches minimally 6 inches (150 mm) wide and 8 inches (200 mm) deep shall be cut into a thoroughly compacted subgrade so that drainage pipes maintain a consistent slope to the outlet of at least 0.5%. Spoil from the trenches should be removed from the subgrade cavity, and the floor of the trench should be smooth and clean. If a geotextile fabric is to be used as a

barrier between unstable subsoil and the gravel drainage blanket, it should be installed at this time. Under no circumstances should the fabric cover the drainage pipes or trenches. A layer of gravel (see Step 3 for size recommendations) should be placed in the trench to a minimum depth of 1 inch (25 mm). It may be deeper, as necessary, to ensure minimal slope requirements. All drainage pipes should be placed on the gravel bed in the trench. PVC drainpipe, if used, should be placed in the trench with the holes facing down. Pipe connections shall not impair the overall function of the pipeline. The trenches should then be backfilled with additional gravel, taking care not to displace any of the drainage pipes.

As an alternative to round pipe placed in a trench, flat pipe placed directly on the prepared subgrade may be employed, provided the flat pipe conforms to ASTM D 7001 (provisional), is a minimum of 12 inches (300 mm) in width, and is not covered by a geotextile sleeve. The flat pipe shall be stapled to the subgrade, or otherwise held in place to prevent shifting during construction. Rational combinations of round and flat pipe may be employed within a greens drainage system. All other guidelines for drainage system installation shall apply for this alternative construction method.

Step 3 ■ Gravel and Intermediate Layers

Place grade stakes at frequent intervals over the subgrade and mark them for the gravel drainage blanket layer, intermediate layer (if included), and root zone layer.

The entire subgrade then shall be covered with a layer of clean, washed, crushed stone or pea gravel to a minimum thickness of four inches (100 mm), conforming to the proposed final surface grade to a tolerance of ±1 inch.

Soft limestones, sandstones, or shales are not acceptable. Questionable materials should be tested for weathering stability using the sulfate soundness test (ASTM C-88). A loss of material greater than a 12% by weight is unacceptable.

The LA Abrasion test (ASTM C-131) should be performed on any materials suspected of having insufficient mechanical stability to withstand ordinary construction traffic. The value obtained using this procedure should not exceed 40. Soil engineering laboratories can provide this information.

The need for an intermediate layer is based on the particle size distribution of the root zone mix relative to that of the gravel. When properly sized gravel (see Table 1) is available, the intermediate layer is not necessary. **If the properly sized gravel cannot be found, an intermediate layer must be used.**

Figure 3 – Gravel drainage blanket installed to proper depth by using grade stakes.

TABLE 1

Particle Size Description of Gravel and Intermediate Layer Material	
Material	**Description**
Gravel: Intermediate layer is used	Not more than 10% of the particles greater than ½" (12mm)
	At least 65% of the particles between ¼" (6mm) and ⅜" (9mm)
	Not more than 10% of the particles less than 2mm
Intermediate Layer Material	At least 90% of the particles between 1mm and 4mm

TABLE 2

Size Recommedations for Gravel When Intermediate Layer is not Used	
Performance Factors	**Recommendation**
Bridging Factor	D15 (gravel) less than or equal to 8 X D85 (root zone)
Permeability Factor	D15 (gravel) greater than or equal to 5 X D15 (root zone)
Uniformity Factors	D90 (gravel) / D15 (gravel) is less than or equal to 3.0
	No particles greater than 12mm
	Not more than 10% less than 2mm
	Not more than 5% less than 1mm

A. Selection and Placement of Materials When the Intermediate Layer Is Used

Table 1 describes the particle size requirements of the gravel and the intermediate layer material when the intermediate layer is required.

The intermediate layer shall be spread to a uniform thickness of two to four inches (50 to 100 mm) over the gravel drainage blanket (*e.g.*, if a 3-inch depth is selected, the material shall be kept at that depth across the entire area), and the surface shall conform to the contours of the proposed finished grade.

B. Selection of Gravel When the Intermediate Layer Is Not Used

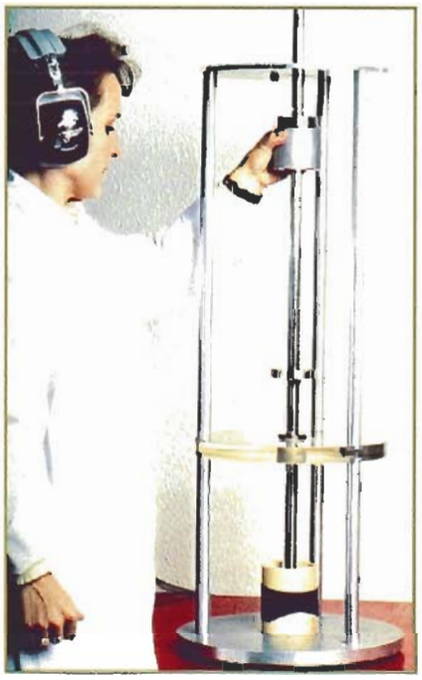


Figure 4 – Laboratory testing of gravel and rootzone materials is mandatory to ensure the success of a green built to USGA guidelines.

If an appropriate gravel can be identified (see Table 2), the intermediate layer need not be included in the construction of the green. In some instances, this can save a considerable amount of time and money.

Selection of this gravel is based on the particle size distribution of the root zone material. The architect and/or construction superintendent must work closely with the soil testing laboratory in selecting the appropriate gravel. Either of the following two methods may be used:

Send samples of different gravel materials to the lab when submitting samples of components for the root zone mix. As a general guideline, look for gravel in the 2 mm to 9.5 mm range. The lab first will determine the best root zone mix, and then will test the gravel samples to determine if any meet the guidelines outlined below.

Submit samples of the components for the root zone mix, and ask the laboratory to provide a description, based on the root zone mix tests, of the particle size distribution required of the gravel. Use the description to locate one or more appropriate gravel materials, and submit them to the laboratory for confirmation.

Gravel meeting the criteria below will not require the intermediate layer. It is not necessary to understand the details of these recommendations; the key is to work closely with the soil testing laboratory in selecting the gravel. **Strict adherence to these criteria is imperative; failure to follow these guidelines could result in greens failure.**

The criteria are based on engineering principles that rely on the largest 15% of the root zone particles "bridging" with the smallest 15% of the gravel particles. Smaller voids are produced, and they prevent migration of root zone particles into the gravel yet maintain adequate permeability. The D85 (root zone) is defined as the particle diameter below which 85% of the soil particles (by weight) are smaller. The D15 (gravel) is defined as the particle diameter below which 15% of the gravel particles (by weight) are smaller.

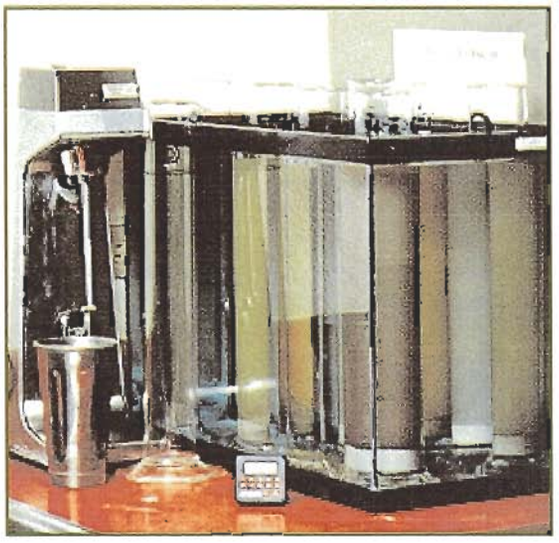


Figure 5 – Testing requires specialized equipment and skills and should be accomplished only by an accredited laboratory.

- For **bridging** to occur, the D15 (gravel) must be less than or equal to eight times the D85 (root zone).
- To maintain adequate **permeability** across the root zone/gravel interface, the D15 (gravel) shall be greater than or equal to five times the D15 (root zone).
- The gravel shall have a **uniformity coefficient** (Gravel D90/Gravel D15) of less than or equal to 3.0.

Furthermore, any gravel selected shall have 100% passing a 1/2" (12 mm) sieve and not more than 10% passing a No. 10 (2mm) sieve, including not more than 5% passing a No. 18 (1mm) sieve.

Step 4 ■ The Root Zone Mixture

Sand Selection:

The sand used in a USGA root zone mix shall be selected so that the particle size distribution of the **final root zone mixture** is as described in Table 3.

TABLE 3

PARTICLE SIZE DISTRIBUTION OF USGA ROOT ZONE MIX

Name	Particle Diameter	Recommendation (by weight)
Fine Gravel	2.0 – 3.4 mm	Not more than 10% of the total particles in this range, including a maximum of 3% fine gravel (preferably none)
Very Coarse Sand	1.0 – 2.0 mm	
Coarse Sand	0.5 – 1.0 mm	Minimum of 60% of the particles must fall in this range
Medium Sand	0.25 – 0.50 mm	
Fine Sand	0.15 – 0.25 mm	Not more than 20% of the particles may fall within this range
Very Fine Sand	0.05 – 0.15 mm	Not more than 5%
Silt	0.002 – 0.05 mm	Not more than 5%
Clay	less than 0.002 mm	Not more than 3%
Total Fines	very fine sand + silt + clay	Less than or equal to 10%

Soil Selection:

If soil is used in the root zone mix, it shall have a minimum sand content of 60%, and a clay content of 5% to 20%. The final particle size distribution of the sand/soil/peat mix shall conform to that outlined in these recommendations, and meet the physical properties described herein.

Organic Matter Selection:

Peats – The most commonly used organic component is a peat. If selected, it shall have a minimum organic matter content of 85% by weight as determined by loss on ignition (ASTM D 2974 Method D).

Figure 6 – Rootzone components must be blended uniformly. Mechanical blenders are best suited to this task.

Other organic sources – Organic sources such as rice hulls, finely ground bark, sawdust, or other organic waste products are acceptable if composted through a thermophilic stage, to a mesophilic stabilization phase, and with the approval of the soil physical testing laboratory. Composts shall be aged for at least one year. Furthermore, the root zone mix with compost as the organic amendment must meet the physical properties as defined in these recommendations.

Composts can vary not only with source, but also from batch to batch within a source. Extreme caution must be exercised when selecting a compost material. Unproven composts must be shown to be nonphytotoxic using a bentgrass or bermudagrass bioassay on the compost extract.

Inorganic and Other Amendments:

Porous inorganic amendments such as calcined clays (porous ceramics), calcined diatomites, and zeolites may be used in place of or in conjunction with peat in root zone mixes, provided that the particle size and performance criterion of the mix are met. Users of these products should be aware that there are considerable differences among products, and long term experience with some of these materials is lacking. It should also be noted that the USGA requires any such amendment to be incorporated throughout the full 12-inch (300 mm) depth of the root zone mixture. Polyacrylamides and reinforcement materials are not recommended.

Physical Properties of the Root Zone Mix:

The root zone mix shall have the properties summarized in Table 4, as tested by USGA protocol (proposed ASTM Standards).

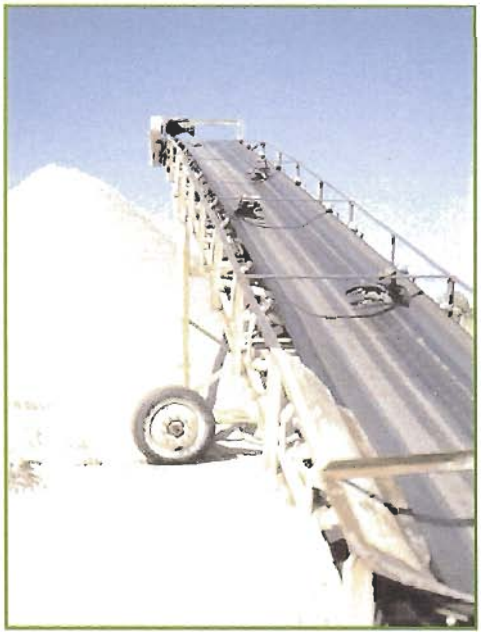


Figure 7 – The final product.

TABLE 4

Physical Properties of the Root Zone Mix

Physical Property	Recommended Range
Total Porosity	35% – 55%
Air-filled Porosity	15% – 30%
Capillary Porosity	15% – 25%
Saturated Hydraulic Conductivity	Minimum of 6 inches/hr (150 mm/hr)

Related Concerns

IT IS ABSOLUTELY ESSENTIAL TO MIX ALL ROOT ZONE COMPONENTS OFF-SITE. No valid justification can be made for on-site mixing, since a homogeneous mixture is essential for success.

A QUALITY CONTROL PROGRAM DURING CONSTRUCTION IS STRONGLY RECOMMENDED. Documents describing quality control programs in detail can be found on the USGA's Web site at *www.usga.org/green/coned.* Arrangements should be made with a competent laboratory to routinely check gravel and root zone mixtures during production and blending. It is imperative that these materials conform to the recommendations approved by the laboratory in all respects.

Care should be taken to avoid overshredding the peat, since it may influence performance of the mix in the field. Peat should be moist during the mixing stage to ensure uniform mixing and to minimize peat and sand separation.

Step 5 ■ Top Mix Covering, Placement, Smoothing, and Firming

The thoroughly mixed root zone material shall be placed on the green site and firmed to a uniform depth of 12 inches (300 mm), with a tolerance of ± 1 inch (25 mm). Be sure that the mix is moist when spread to discourage migration into the gravel and to assist in firming.

Step 6 ■ Seed Bed Preparation

Sterilization: Sterilization of the root zone mix by fumigation should be decided on a case by case basis, depending on regional factors. Fumigation always should be performed:

In areas prone to severe nematode problems.

In areas with severe weedy grass or nutsedge problems.

When root zone mixes contain unsterilized soil.

Check with your regional office of the USGA Green Section for more information and advice specific to your area.

Step 7 ■ Fertilization

Contact your regional USGA Green Section office for establishment fertilizer recommendations and grow-in procedures.

Conclusion

This document details the recommendations of the USGA Green Section for the construction of golf greens. A great deal more information regarding various construction techniques used to build the USGA green can be obtained from the regional Green Section offices and the Green Section's Construction Education Program. The Construction Education Program can be reached at the following address:

USGA Green Section
Construction Education Program
720 Wooded Crest, Waco, TX 76712
Voice (254) 776-0765 • Fax (254) 776-0227
www.usga.org/green/coned • jmoore@usga.org

Appendix I

Test Methods and Material Specifications

ASTM C 88-99a. Standard Test Method for Soundness of Aggregates by Use of Sodium Sulphate or Magnesium Sulfate. American Society for Testing and Materials.

ASTM C 131-03. Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine. American Society for Testing and Materials.

ASTM C 136-96a. Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates. American Society for Testing and Materials

ASTM D 75.-97. Standard Practice for Sampling Aggregates. American Society for Testing and Materials.

ASTM D 854-02. Standard Test Method for Specific Gravity of Soil Solids by Water Pycnometer. American Society for Testing and Materials.

ASTM D 2729-03. Standard Specification for Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings. American Society for Testing and Materials.

ASTM D 2974-00. Standard Test Methods for Moisture, Ash, Organic Matter of Peat and Other Organic Soils. American Society for Testing and Materials.

ASTM D 2976-71. Standard Test Method for pH of Peat Materials. American Society for Testing and Materials.

ASTM 4972-01. Standard Test Method for pH of Soils. American Society for Testing and Materials.

ASTM D 7001-XX. Standard Specification for Geocomposites for Pavement Edge Drains and Other High-Flow Applications

ASTM F 405-97. Standard Specification for Corrugated Polyethylene (PE) Pipe and Fittings. American Society for Testing and Materials.

ASTM F 1632-03. Standard Test Method for Particle Size Analysis and Sand Shape Grading of Golf Course Putting Green and Sports Field Rootzone Mixes. American Society for Testing and Materials.

ASTM F 1647-02a. Standard Test Method for Organic Matter Content of Putting Green and Sports Turf Root Zone Mixes. American Society for Testing and Materials.

ASTM F 1815-97. Standard Test Methods for Saturated Hydraulic Conductivity, Water Retention, Porosity, Particle Density, and Bulk Density of Putting Green and Sports Turf Root Zone Mixes. American Society for Testing and Materials.

Green Section Offices

National Office

United States Golf Association, Golf House
P.O. Box 708, Far Hills, NJ 07931-0708
(908) 234-2300

James T. Snow, *National Director*
Kimberly Erusha, Ph.D., *Director of Education*

Green Section Research

P.O. Box 2227
Stillwater, OK 74076
(405) 743-3900
Michael Kenna, Ph.D., *Director*

904 Highland Drive
Lawrence, KS 66044
(785) 832-2300
Jeff Nus, Ph.D., *Manager*

Construction Education

770 Sam Bass Dr.
McGregor, TX 76657
254.848.2202
Jim Moore, *Director*

Florida Region

P.O. Box 1087
Hobe Sound, FL 33475-1087
(772) 546-2620
John Foy, *Director*

127 Naomi Place
Rotonda West, FL 33947
(941) 828-2625
Todd Lowe, *Agronomist*

Mid-Atlantic Region

485 Baltimore Pike, Suite 203
Glen Mills, PA 19342
(610) 558-9066
Stan Zontek, *Director*
Darin Bevard, *Agronomist*

Manor Oak One, Suite 410
1910 Cochran Road
Pittsburgh, PA 15220
(412) 341-5922
Keith Happ, *Senior Agronomist*

Mid-Continent Region

9 River Valley Ranch
White Heath, IL 61884
(217) 687-4424
Paul Vermeulen, *Director*

2601 Green Oak Drive
Carrollton, TX 75010
(972) 662-1138
Bud White, *Senior Agronomist*

Northwest Region

5610 Old Stump Drive NW
Gig Harbor, WA 98332
(253) 858-2266
Larry Gilhuly, *Director*

P.O. Box 5844
Twin Falls, ID 83303
(208) 732-0280
Matt Nelson, *Agronomist*

North-Central Region

P.O. Box 15249
Covington, KY 41015-0249
(859) 356-3272
Bob Brame, *Director*

P.O. Box 5069
Elm Grove, WI 53122-5069
(262) 797-8743
Bob Vavrek, *Senior Agronomist*

Northeast Region

P.O. Box 4717
Easton, PA 18043
(610) 515-1660
David Oatis, *Director*
Jim Baird, Ph.D., *Agronomist*

1500 North Main Street
Palmer, MA 01069
(413) 283-2237
Jim Skorulski, *Senior Agronomist*

Southeast Region

P.O. Box 95
Griffin, GA 30224
(770) 229-8125
Patrick O'Brien, *Director*

1097 Highlands Drive
Birmingham, AL 35244
(205) 444-5079
Chris Hartwiger, *Agronomist*

Southwest Region

505 North Tustin Avenue,
Suite 121
Santa Ana, CA 92705
(714) 542-5766
Pat Gross, *Director*
Dave Wienecke, *Agronomist*