USGA Golf Putting Green Construction Materials

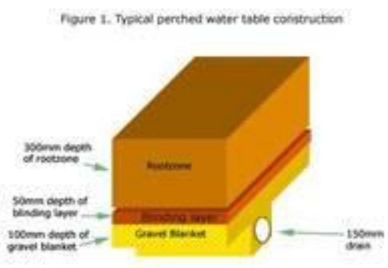
USGA Golf Putting Green Construction Materials

By John Farrell B.Sc Technical Director, Baileys of Norfolk Ltd.

John Farrell has been a Technical Director of Baileys of Norfolk for over ten years. Baileys provide top dressing materials to the sports turf industry and were founder members of the BRTMA (British Rootzone Turf Dressing Manufacturers Association). John is currently studying an MSc in Sports Surface Technology at Cranfield University and had previously obtained a BSc in Natural Resource Management at the University of East Anglia. John is keen to inform members about technical information about top dressings and rootzones. John gets many students asking him to provide information about USGA putting green Specifications. Below is an introduction to the technical aspects and design features of USGA putting green constructions. The article will also look at and discuss the option of developing this specification into a two layer construction. Recent research evidence has found that by using the correct particle size materials may give greenkeepers the option to construct a green using a rootzone and gravel layer only.

The putting greens rootzone specification:

After many years of research, ***A Method of Golf Putting Green Construction*** was first published in September 1960 by the USGA Green Section. The strategy was based on developing a growing medium that provided resistance to compaction and drained readily, yet retained an adequate level of capillary moisture and nutrients to sustain turfgrass growth with normal maintenance.



The USGA specification is a perched water table construction (figure 1), comprising a sand rootzone mix of at least 300mm in depth, an intermediate layer (blinding or choker layer) of 50mm and a 100mm gravel carpet. The system has the advantage of high infiltration and percolation rates during wetter periods, however, in the drier summer period, greens will tend to dry very quickly and should be monitored for signs of stress. The leaching of nutrients (particularly nitrogen) can also be a problem and should be considered in the maintenance procedures.

<u>**The USGA Golf Putting Green Specification:**</u>

Table 1. USGA rootzone mix.

Particle Size Distribution & Physical Properties		
Particle Size Category	Particle Size (mm)	USGA Rootzone Recommendation (by weight)
Stones	>8	No particles in this category
Coarse gravel	8 - 4	No particles in this category
Fine gravel	4 - 2	Not more than 10% of the total in this
V. coarse sand	2 - 1	Range. Preferably no Fine gravel
Coarse sand	1 - 0.5	At least 60% of the material must fall
Medium sand	0.5 - 0.25	in this range
Fine sand	0.25 - 0.15	Not more than 20% fine sand
Very fine sand	0.15 - 0.05	No more than 10% for range. No more than 5%
Silt & Clay	<0.05	very fine sand, no more than 8% silt & clay
Physical Properties of Rootzone Mix		Physical Property Recommended Range
Total Porosity		35 - 55%
Air-filled Porosity		15 - 30%
Capillary Porosity		15 - 25%
Saturated Hydraulic Conductivity		
Normal Range		15 - 30 cm/hr
Accelerated Range		30 - 60 cm/hr
After USGA Recommendations for a Method of Putting Green Constructing. USGA Green Section Staff. March/April 1993.		

Table 2. Gravel and intermediate layer.

Particle size distribution recommendations	
Material	Description
	Not more than 10% of the particles greater than 12mm
Gravel	At Least 65% of the particles between 6mm and 9mm
	Not more than 10% of the particles less than 2mm
Intermediate Layer	At least 90% of the particles between 1mm and 4mm
After USGA Recommendations for a Method of Putting Green Constructing. USGA Green Section Staff March/April 1993.	

Construction without the use of an intermediate Layer:

Originally, the USGA golf putting greens construction method called for a three-layer system. The 1993 revision of the specification proposed the use of a two-layer system if appropriate gravel was used. According to James T Snow, the use of an intermediate layer has been one of the most contentious parts of the recommendations, and it simply had been left out by many contractors, architects, or superintendents for the sake of economy.

A set of recommendations, which are based on engineering principles have been adopted by the USGA, a two layer construction can be justified if the following criteria are met:

Table 3. Size recommendations when no intermediate layer is being used.

Criteria	Recommendation
Bridging Factor	The D_{15}gravel is less than or equal to 5 times theD_{85}rtz
Permeability Factor	The D_{15}gravel is greater than or equal to 5 times the D_{15}rtz
Uniformity Factor	The D_{90}gravel divided by the D_{15}gravel is less than or equal to 2.5

After USGA Recommendations for a Method of Putting Green Constructing. USGA Green Section Staff March/April 1993.

Diameter values are used to calculate the relationship between the rootzone & gravel; for example, the D_{15} gravel is defined as the diameter where 15% of the gravel particles are smaller than the D_{15} value. The D_{85} Rootzone is defined as the diameter where 85% of the rootzone particles are smaller than the D_{85} value.

Material requirements and Selection:

Soil science plays a vital role in determining the suitability of sports surface construction materials. Scientific research has identified the rootzone physical requirements needed to construct sports surfaces, soil analysis is an essential tool in determining whether a material is going to meet the required specification. Testing materials before their use in construction will help to ensure that quality materials are used and design specifications are met. Quality control testing during construction can provide assurance that consistent materials are being used, and provide reasonable expectations for consistent performance.

Calculating the material requirements. How many tonnes?

To calculate the number of tonnes required, the volume which the rootzone will occupy needs to be determined. The area multiplied by the depth will give a measurement of volume, for example:

A green of 500 m^2 with a rootzone depth of 300 mm = 500 x 0.3 = 150 m^3

There are approximately 1.5 tonnes per m^3, so, 150 x 1.5 = 225 tonnes rootzone

The gravel blanket requirements can be calculated in a similar way, remembering the depth required is 100mm. The gravel blanket material is also used to fill the drainage pipe trenches this must be included in the calculation.

Accessing the suitability of a two-layer system:

Golf putting greens can be constructed without the use of an intermediate layer, by doing so the cost of purchasing and installing the intermediate layer is eliminated. The concept of the intermediate layer is to prevent the migration of the rootzone mix into the underlying gravel blanket. The particle size distribution relationship between the rootzone mix and the gravel blanket needs to meet well established civil engineering principles which were originally designed to prevent the migration of soil particles into drainage systems.

Research has determined that the pore spaces in the gravel blanket need only prevent the migration of the coarsest 15% of the rootzone mix. Both the resistance to flow and the capillarity retention become greater with decreased grain size. A bridging effect is produced at the interface between the rootzone and gravel blanket, creating smaller pore spaces, which in turn prevent the migration of smaller rootzone particles. If the coarsest 15 % (the D_{85RTZ}) of the rootzone is being prevented form migrating through the gravel blanket, then the gravel pore spaces must be smaller than the D_{85RTZ} value.

For the bridging to occur, the $D_{15(gravel)}$ must be less than or equal to five times the $D_{85(Rootzone),}$ written as,

$D_{15\ (gravel)} \leq 5 \times D_{85\ (Rootzone),}$

The rate of flow of water through the gravel blanket will be greater than that through the rootzone. The ability of soil to allow drainage, to hold water for plant use and to hold water so firmly that plants cannot use it, depends on the sizes, shapes and continuity of the soil pores. Water will move in soils as a result of gravitational forces and in response to the adhesion of water to particle surfaces and the cohesion forces between the water molecules. In the perched water table construction, the porosity of the rootzone will facilitate the adhesive nature of water and cohesive forces of water molecules. The large pore spaces in the gravel blanket will encourage the transmission of water to the drainage system.

Water moves from areas of high energy to areas of lower energy, if the pore water pressure in the rootzone is greater than the atmospheric pressure acting on it, the water will be held in the rootzone. As the rootzone becomes saturated, the atmospheric pressure becomes greater than the pore water pressure and the water will move into the gravel blanket (an area of lower energy). To ensure this filtering effect the **$D_{15(gravel)} \geq 5 \times D_{15(Rootzone).}$**

In order to remove water from the soil the force producing drainage must be greater than the retentivity and the resistance to flow. Gravity is the force most often employed. Water moves from the soil into the drain under the influence of its own weight.

The gravel blanket should also have a D_{90}/D_{15} uniformity coefficient of less than or equal to 2.5, which is an expression of the uniformity of the particle size distribution. The usual approach is to use a gradation index or coefficiency of uniformity, which expresses the size ratio of the larger to smaller grains. The uniformity coefficient is written as: **$D_{90(gravel)} / D_{15(gravel)} \leq 2.5$**

The particle size distribution analysis for both the USGA rootzone and the gravel blanket will determine their suitability for use in a two-layer construction system. The particle size distribution analysis data is usually expressed as the percentage (by mass) of material retained in a sieve at each particle size category. For example: the rootzone analysis in figure 2, 41.33 % of the material is classified as medium sand (particles with a diameter between 0.5 and 0.25 mm).

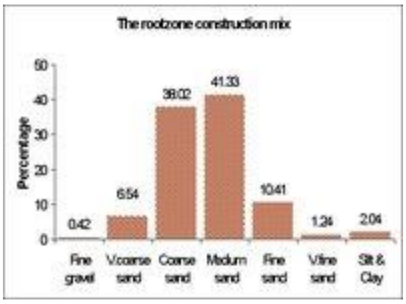


Figure 2. Histogram: particle size distribution analysis rootzone mix.

The particle size distribution analysis of a gravel blanket reveals a predominance of material between 2 - 8 mm. The histogram below shows the results of the particle size distribution analysis.

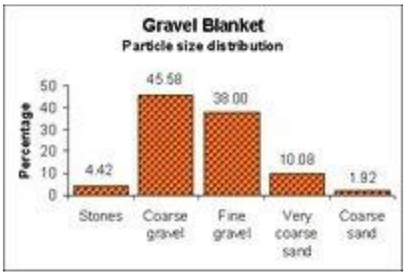


Figure 3. Histogram: particle size distribution analysis for the gravel blanket.

Determining the D_n values for the rootzone and gravel blanket:

To determine D_n values for the rootzone and the gravel blanket, the particle size distribution analysis data needs to be converted from the percentage of material retained to the percentage of material passing through each sieve at each particle size category. The percentage passing for the gravel and the rootzone are recorded in table 4.

Table 4. The rootzone & gravel blanket particle size distribution analysis (percentage retained).

Particle Size Category	Particle Size (mm)	Gravel % retained	Rootzone % retained
Very small stones	> 10	100	100
Stones	8 - 10	95.59	100
Coarse gravel	8 - 4	50.00	100
Fine gravel	4 - 2	12.00	99.58
V. coarse sand	2 - 1	1.92	93.04
Coarse sand	1 - 0.5	0	55.02
Medium sand	0.5 - 0.25	0	13.69
Fine sand	0.25 - 0.125	0	3.28
Very fine sand	0.125 - 0.05	0	2.04
Silt & Clay	<0.05	Receiver	Receiver

Grading curve to determine the suitability of the materials used in a two layer system:

The data obtained from converting the retained value to percentage passing values can be plotted to create a grading curve (see figure 4). By plotting the particle size distribution analysis data for both the rootzone and the gravel blanket the D_n values can be determined. The appropriate D_n value can now be calculated against the recommended criteria.

Figure 4. Bridging permeability and uniformity. The relationship between rootzone and gravel blanket**.**

Using a science-based approach confirms that the gravel blanket can be used without the need for an intermediate layer.

Rootzone and topdressing compatibility:

It is of great importance that the topdressing used in the future maintenance of golf putting greens is compatible with the rootzone used to construct the course. The USGA specification is based on sound physical principles and if an incompatible topdressing is used it may compromise the greens performance characteristics. Inappropriate topdressing can cause layering within the rootzone profile, which can inhibit turfgrass root development and may cause roots to break, weakening the establishment of the turf. Inappropriate topdressing can also cap the surface of the green, thereby reducing porosity and inhibiting water and air movement. A properly constructed putting green based on the detailed Texas/USGA method specifications should last for hundreds of years, if properly maintained, especially in terms of using a topdressing mix that is comparable to the existing rootzone mix originally installed on the green.

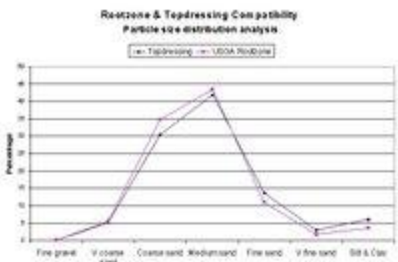


Figure 5. Rootzone & topdressing compatibility.

By using the same raw materials to manufacture the rootzone and topdressing a high degree of compatibility can be achieved between the two materials. Using a topdressing that is compatible with the rootzone will ensure that the texture of the golf putting green remains within the USGA guidelines. Figure 5, plots the particle size distribution analysis data for a rootzone and topdressing, the results illustrate the closes relationship between the two materials.

Conclusion:

Soil science is the most important tool available to anyone considering the construction of a sports surface. Without scientific analysis the suitability of materials to be used cannot be evaluated. Soil science can determine the appropriateness of raw materials, it can be used to monitor the rootzone manufacturing process, and can verify the suitability of a finished product. Particle size distribution analysis is a primary indicator of material suitability, If the rootzone meets the desired particle size distribution, then further analysis, such as hydraulic conductivity and porosity can be evaluated. If a material does not meet the particle size distribution criteria it should be rejected and no further testing of that material need take place.

One area of concern is the way in which particle size distribution is described in the sports surface construction and management sector, professional jargon such as 80/20 70/30 60/40 are all terms used to describe rootzones. Whilst one might have a notion of what these terms mean and what performance might reasonably be expect from them, they are not robust enough to adequately describe the particle size arrangement needed when determining the suitability of a rootzone. The use of Particle size distribution analysis allows all parties involved in the construction process to be much more precise in the way they describe their requirements.

Rootzone manufacturers need to demonstrate an ability to provide a reliable, prompt, competent service, and have the infrastructure to manufacture a product to a required standard; a soil analysis laboratory should be a part of that infrastructure. Whether constructing an 18-hole golf course or a village bowls green, the rootzone material should meet a defined recommendation. The use of a rootzone material, which has not been tested, can lead to the failure of the surface. Although the initial installation cost may be higher, the long term costs, of rebuilding a failed green, or the lost revenue, because the rootzone surface is unplayable due to poor performance characteristics, more than justify the use of a quality controlled sports surface construction material.

PERCOLATION RATE (SATURATED HYDRAULIC CONDUCTIVITY)

The rate at which soils, sands and root zones drain (normally expressed in mm/hour).
This can be affected by the depth of the root zone. Samples are usually equilibrated overnight to 30cms tension - this being the standard depth of a USGA (United States Golf Association) green, from the surface to the gravel drains.

Percolation Rates for different sand types under 30cm Tension as tested by European Turf Laboratories.

Sand type	mm/hr
Lough Neagh sand	232.0
Zone 3 sand	463.5
HS Masters sand	1000+