WATER RETENTION IN GOLF GREENS: Sub-Root Zone Layering Effects

by DON TAYLOR, University of Wisconsin,
and FRANK WILLIAMS and SHELDON NELSON, Brigham Young University

Editor's Note: The following article is based on research that was completed before the 1993 version of the USGA Recommendations for a Method of Green Construction *was published. The particle size distributions for the root zone material, intermediate layer, and gravel layer used in this study do not conform to current USGA recommendations. Nevertheless, results of the study reinforce the USGA's strong recommendation that all materials used be thoroughly tested before construction, that a quality control program be followed during construction, and that shortcuts or modifications not be taken. Leaving out the intermediate layer when a coarse gravel (6-9mm) is used, similar to one of the methods illustrated in this study, has never been recommended by the USGA but has been one of the most common shortcuts taken with USGA greens. As shown in this research study and in the field, this shortcut can result in excessive moisture being held in the root zone mix.*

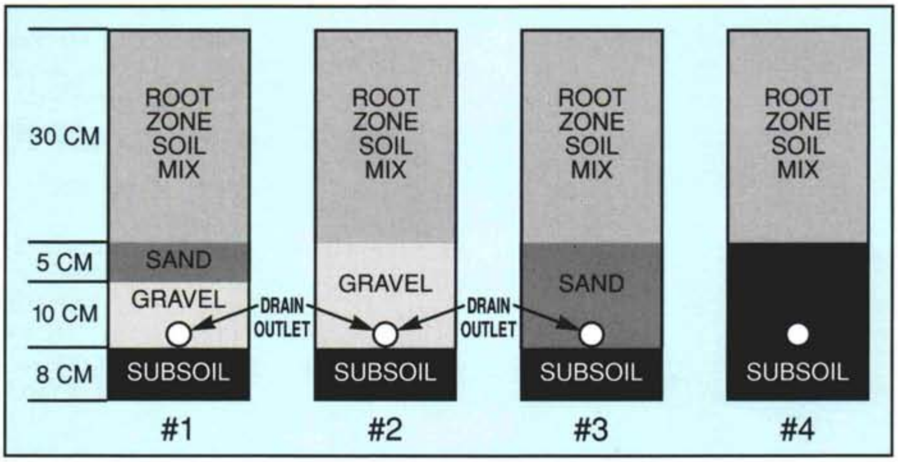

Figure 1. Diagram showing the four sublayer treatments.

GOLF GREEN construction methods, including the USGA specifications for golf green construction, almost always include a root zone soil mixture placed over coarse-textured layers such as sand or gravel. The coarse-textured sand or gravel layers have the dual purpose of quickly moving excess water to the drain tile and increasing the effective water-holding capacity of the root zone soil mixture.

The fact that soil layers of distinctly different properties can dramatically affect soil water relations has been shown many times.

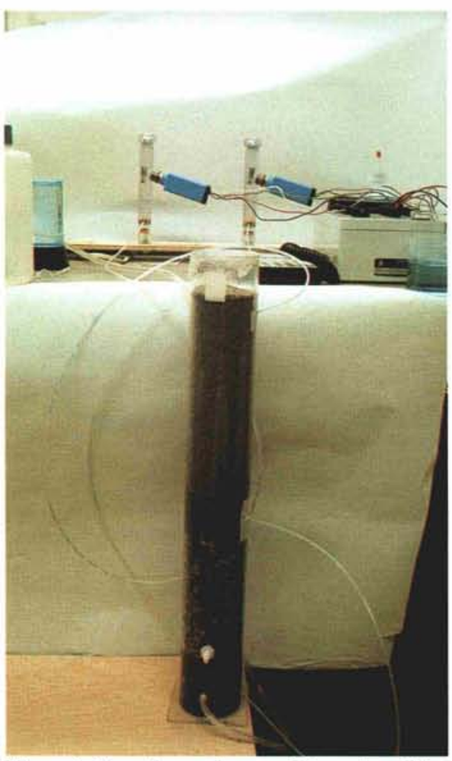

Figure 2. Experimental setup of the soil profiles.

When a finer-textured soil mixture layer is underlain by a coarse-textured layer such as gravel, water retention in the soil mixture layer is increased because the coarse-textured gravel will not transmit significant amounts of water until the soil mixture above is very wet. Once the layer above the coarse-textured layer is wet enough to cause water flow into the coarse layer, water moves rapidly within the coarse-textured layer.

Three major factors affecting the amount of water retained in the overlying fine-textured layer are (1) size of the particles of the underlying coarse layer, (2) depth to the coarse-textured layer, and (3) the desorption or water retention characteristics of the fine-textured soil layer (Miller, 1973). Since the amount of water retained in the root zone is affected by both the soil mixture properties and the coarseness of the underlying layer, golf green performance may depend not only on the root zone soil mixture, but also on the characteristics of the layer below.

Recently, the USGA specifications for golf green construction were modified to allow root zone soil mixtures to be placed directly on a fine gravel sublayer, without an intervening coarse sand layer, if the soil mixture and gravel layer met certain specified criteria (USGA Green Section Staff, 1993). The sandwiched coarse sand layer has traditionally been considered a filter between the soil mixture layer above and the gravel layer below, but it also has important effects on water retention in the root zone soil mixture layer.

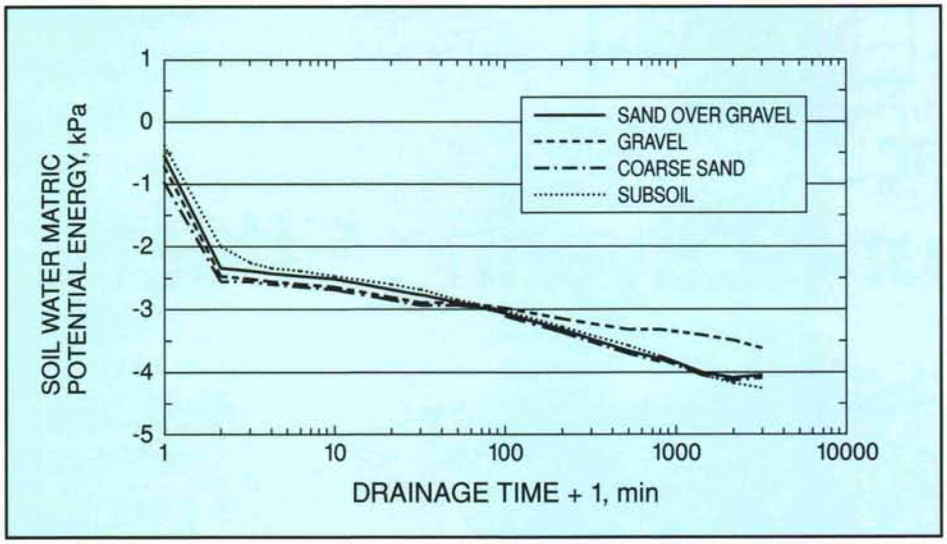

Figure 3. Matric potential energy values of soil water 2cm below the soil surface during the 48-hour drainage period. Values shown are the average of four soil mixtures.

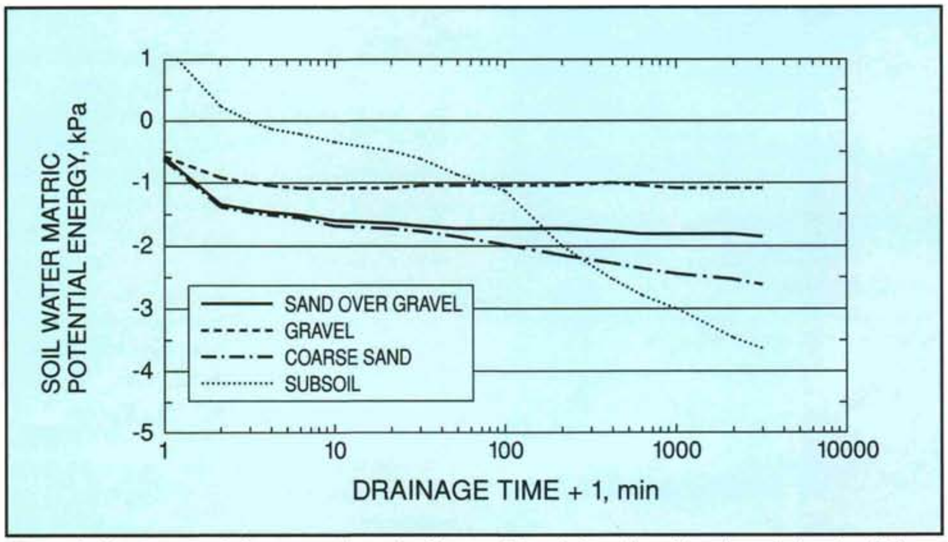

Figure 4. Matric potential energy values of soil water 28cm below the soil surface during the 48-hour drainage period. Values shown are the average of four soil mixtures.

We conducted an experiment to determine the degree to which drainage from and water retention in shallow root zone soil mixtures were affected by the properties of the underlying layers.

Materials and Methods

In this laboratory experiment, 30cm (11.8-inch) layers of four soil mixtures were packed over four distinct sublayering designs. Figure 1 shows the sublayer treatments. Water was ponded and maintained on the surface for an extended period of time. The profiles then were allowed to drain for a period of 48 hours, during which time soil water potential energy was regularly measured at depths of 2cm and 28cm (0.8 inch and 11.0 inches) below the soil surface. After 48 hours of drainage, samples were removed from the soil mixture layer and mass water contents determined. Soil water potential energies and mass water content values were used to evaluate effects of coarse-textured sublayers on water relations in soil mixtures.

Four soil mixtures were used in the experiment and consisted of:

1. An 80/20 by volume sand/sphagnum peat mixture composed from a primarily fine and medium sand (88.6% between 0.10mm and 0.50mm diameters), hereafter called the finer sand/peat mix.

2. An 80/20 by volume sand/sphagnum peat mixture composed from a predominantly medium and coarse sand (64.3% between 0.25mm and 1.0mm diameters), called the coarser sand/peat mix.

3. An 80/20 by volume coarser sand/loam soil mixture, resulting in a mixture with 3.3% clay, 6.7% silt, and 87.6% sand on a mass or weight basis.

4. A 60/40 by volume coarser sand/loam soil mixture, resulting in a mixture with 6.1% clay, 13.1% silt, and 78.8% sand on a mass or weight basis.

A more complete analysis of the sublayer materials used and the soil mixtures is given in Taylor, et al. (1993).

After packing the sublayers and soil mixture layers in a plexiglas cylinder, tensiometers were installed 2cm (0.8 inch) and 28cm (11.0 inches) below the soil surface. The lower tensiometer was 2cm above the soil mixture/coarse layer interface. Tensiometers were attached to pressure transducers and a data logger to facilitate regular measurement of soil water potential energy during the 48-hour drainage period. Figure 2 shows the experimental setup.

Results and Discussion

Soil water matric potential energy measures how tightly the water is held to the soil particles. A value of 0 bars (0 kPa) indicates the pores in the soil are essentially full of water and that some of the water is held very loosely to the soil, a condition called saturation. Figure 3 shows the matric potential energy of the water 2cm below the soil surface during the 48-hour drainage period. For simplicity, the average of the four soil mixtures is shown. In this experiment, water near the soil surface drained very quickly in the first minute or two following the disappearance of the surface water, then gradually slowed down during the remainder of the 48 hours of drainage. The almost identical curves for the four sublayer treatments indicate that drainage near the surface was determined by root zone soil mixture properties rather than by the sublayer characteristics.

The sublayer did, however, make a substantial difference in drainage properties at the bottom of the soil mixture layer, as shown in Figure 4. At a depth of 28cm below the soil surface, 2cm above the soil mixture/sublayer interface, soil above gravel quickly drained to about -0.011 bars (-1.1 kPa) and stayed there for the remainder of the drainage period. When the sublayers consisted of sand over gravel, the lower part of the soil mixture drained to about -0.018 bars (-1.8 kPa) and remained there. A sublayer of coarse sand or of loam soil caused the soil mixture to continue draining throughout the 48 hours of drainage. By the end of the drainage period, matric potential energies were down to about -0.026 bars (-2.6 kPa) and -0.032 bars (-3.2 kPa), respectively, for the coarse sand and loam soil sublayers.

In other words, drainage at the top of the root zone soil mixture layer was determined principally by the soil mixture characteristics, whereas drainage at the bottom of the soil mixture layer was determined principally by the coarse-textured sublayer. A sand/soil root zone mix over a gravel sublayer resulted in the most poorly drained situation at the bottom of the root zone, with sand over gravel next, and a coarse sand or loam subsoil layer resulted in more drainage out of the soil mixture.

Similar results were obtained in measuring the amount of water remaining in the soil after 48 hours of drainage. Figure 5 shows the water retained in the four root zone mixtures at three depths, averaged over the four sublayer treatments. Notice that at all depths the 80/20 finer sand/peat mixture retained the most water, followed by the 80/20 coarser sand/peat and the 60/40 sand/soil mixtures, the 80/20 sand/soil mixture retained the least amount of water.

Figure 6 shows the water retained in the profiles for the different sublayers, averaged over the four soil mixtures. In the upper part of the soil mixture layers, the sublayer had minimal effects on water retained, but in the lower part of the profile, the sublayer had a dramatic effect on water retained. The results showed the same effect as did the potential energy readings: root zone mixture over gravel was the wettest, followed by root zone mixture over coarse sand over gravel, and root zone mixture over coarse sand and root zone mixture over loam soil were the driest.

Implications of the Research

This research demonstrates the important fact that coarse-textured sublayers, such as gravel or coarse sand over gravel, increase the water retention in overlying root zone mixture layers. They do this principally by creating a wet zone at the bottom of the root zone mixture layer while having little impact on water retention in the upper portion of the soil mixture layer. The wet zone in the lower portion of the root zone soil mixture layer can cause problems in performance of the green if the turf rooting depth cannot extend to its optimal depth in the soil because moisture conditions are too high. This would likely happen if the soil mixture layer is too shallow or if the soil mixture contains excessive quantities of fine materials (clay, silt, very fine sand, or organic matter). The higher the water retention of the root zone mixture used, the thicker the root zone mixture layer needs to be when placed over coarse-textured sublayers. Even with an ideal soil mixture, our opinion is that a 12-inch layer of root zone mixture is the absolute minimum that should be used.

The experiment also demonstrates that the type of material used in the sublayer can have a definite impact on the drainage characteristics of the root zone profile. Soil mixture over gravel will result in the wettest conditions in the lower portion of the soil mixture layer, followed by soil mixture over coarse sand over gravel. In this experiment, a sublayer of only coarse sand resulted in rather uniform moisture conditions throughout the overlying root zone mixture layer.

Careful selection of both soil mixture and subsurface layer components is critical to avoid drainage problems in golf greens. Gravel sublayers certainly move water to drain tile quickly once water begins flowing in the gravel, but they maximize retention of water in at least a portion of the soil mixture above the gravel. If the soil mixture itself holds too much water, the underlying gravel layer simply compounds the problem of too much water.

References

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Figure 5. Soil water content at three depths after 48 hours of drainage. Values shown are the average of four subsurface treatments.

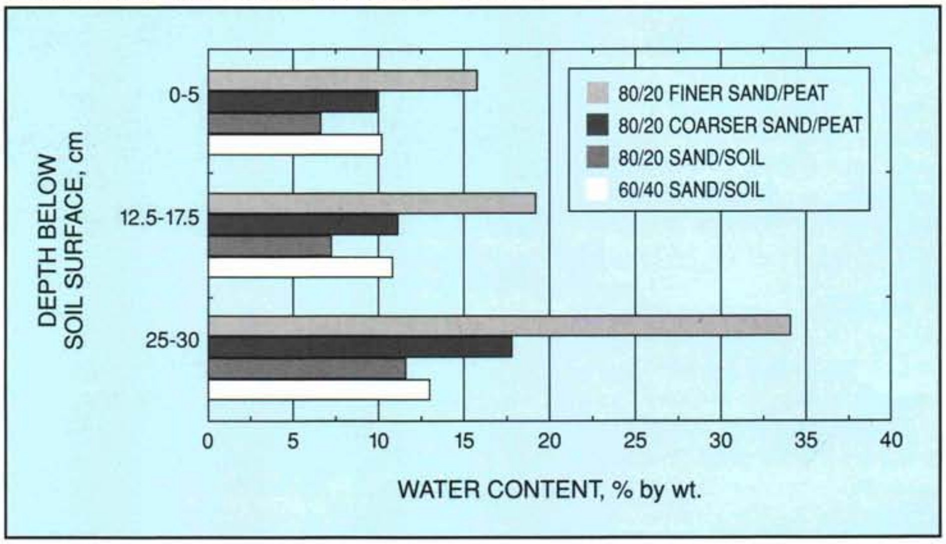

Figure 6. Soil water content at three depths after 48 hours of drainage. Values shown are the average of four soil mixtures.