Installing sand-channel drainage can improve the performance of poorly drained areas, but special attention must be paid to the physical properties of the backfill material to ensure best results.

Understanding Water Relations in Mixes for Sand-Channel Drains

Common misconceptions about managing soil water often lead to poor performance of sand-channel drains, especially on putting greens. Know which soil physical properties matter the most when selecting backfill material for drainage trenches.

BY NORMAN W. HUMMEL, PH.D.

Managing soil water is one of the most important aspects of managing golf course turf, but it is probably one of the least understood. One common misconception is that soil permeability (infiltration rate) is the same as water retention. Soil permeability is not the same as water retention. A rootzone mix with a high infiltration rate is not necessarily a dry mix. Conversely, not all mixes with low infiltration rates are "wet." Not understanding the difference can and will result in problems.

One example where we see the consequences of this is in backfill materials for sand-channel drainage projects on putting greens. A common concern that superintendents have when installing sand-channel drains in greens is that drain lines will dry out before surrounding areas and require frequent hand watering. This is a valid concern as the backfill material will dry

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out sooner if the mix does not hold as much plant-available water as the surrounding rootzone mix.

Materials like 6-2-2 (sand-soil-peat by volume) mixes are often recommended for sand-channel backfill materials with no mention of sand size, soil texture, or organic type in the mix. As a result, mixes for sand-channel drains have been found to contain combined silt and clay contents ranging from under 1 percent up to 13 percent, and organic matter content ranging from less than 1 percent to more than 4 percent by weight. Such huge variation in mixes is certain to result in performance differences in the field.

Another guideline typically used to define sand-channel backfill materials is that the mix should have an infiltration rate (permeability) of two to four inches per hour. It is important that backfill mixes drain adequately, and this guideline provides some assurance that a mix will drain as desired. This guideline, however, says nothing about the water-retention characteristics of the mix. Testing the permeability of a mix offers little help in assessing the risk that the mix will dry out once it is used to backfill trench lines.

There are two main forces that act on water in soil. The first is gravity. Drainage water moves down through larger-sized pores (macropores) in a sand-based mix due to the force of gravity. The water that moves due to the force of gravity is called gravitational water and, provided an adequate drainage system, rapidly drains from soils under saturated conditions. In the laboratory, the rate at which gravitational water moves through a rootzone mix is measured as the permeability, saturated hydraulic conductivity, or infiltration rate of the mix. The infiltration rate of a mix is dependent upon both the size of pores and the continuity of pores. Pore continuity refers to how soil pores are interconnected. Does water have a straight shot downward through interconnected pores or is the path winding?

In general, pore size is influenced by sand size, silt and clay content, and the amount and type of organic matter used in the mix. Larger pores will conduct water faster than smaller pores under saturated conditions. The continuity of pores is influenced to a large degree by the uniformity of a given sand. A fine-textured, uniform sand may not have large-diameter pores, but the infiltration rate may be very good because the pores are interconnected.

To ensure a successful drainage project, especially on greens, understanding the water-retention characteristics of the rootzone mix used to backfill trenches is critical. A water-release curve, as determined by an accredited soil physical testing laboratory, is valuable when selecting the proper backfill material.

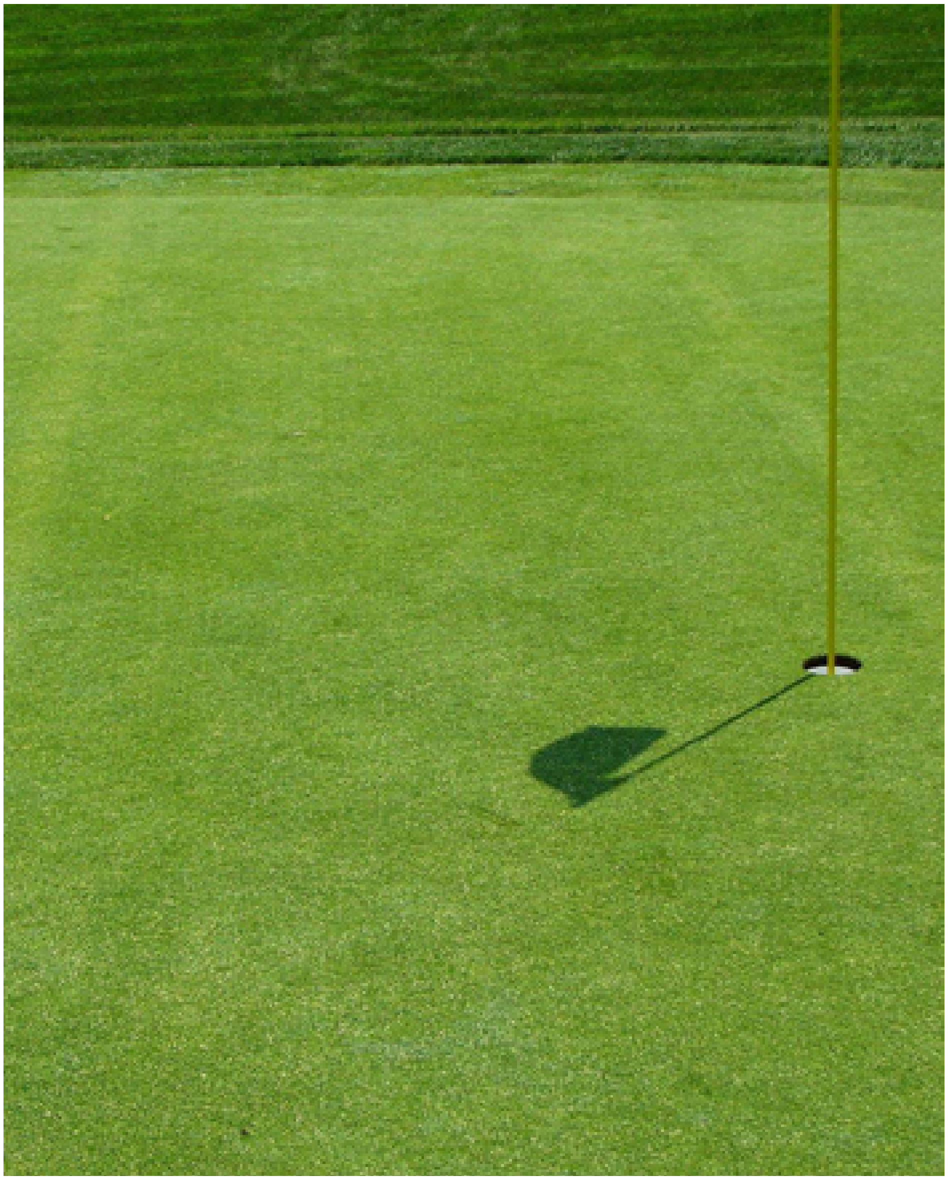
Table 1
Select physical properties of five mixes submitted for sand-channel drains

Mix (by volume)	Silt and Clay (percent by weight)	Organic Matter (percent by weight)	Ksat (inches/hour)	Capillary Porosity (percent by weight)
6-2-2 (1)	3.6	1.43	3.3	21.7
6-2-2 (2)	6.4	2.35	3.3	21.1
6-2-2 (3)	4.4	4.06	3.1	32.0
6-2-2 (4)	3.8	1.84	3.2	24.8
60-20-10-10	11.00	2.25	2.4	34.6

Water is retained against the force of gravity in a mix as water forms films on sand and soil particles, in wedges where two or more soil particles meet, or in organic matter. The amount of water retained by a soil is influenced primarily by pore size and surface area. Smaller-sized pores hold water against the force of gravity due to capillary forces, or the attraction of water to sand and soil surfaces. The strength of capillary forces increases with decreasing pore size. A portion, but not all, of the capillary water held in a mix will be available to the plant. The amount of plant-available water held in a mix will influence the performance of a sand-channel trench backfill mix.

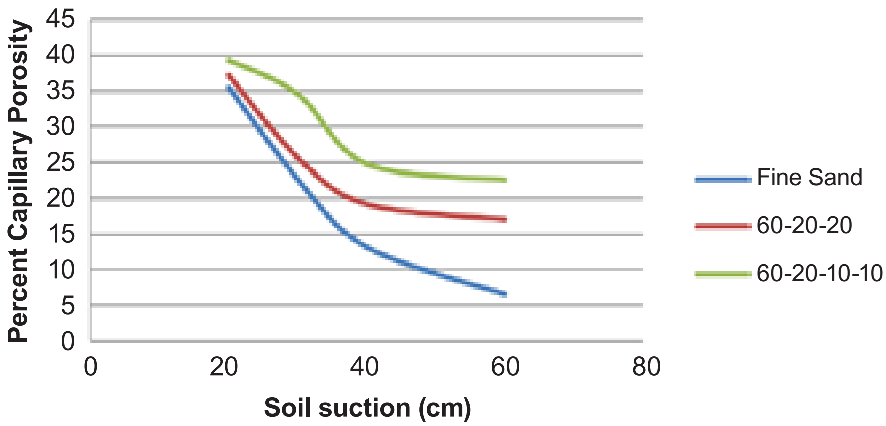
The water-retention characteristics of rootzone mixes can be assessed in the laboratory. The simplest test for water retention is to determine the capillary porosity of a mix in the same manner used to evaluate putting green rootzone mixes. A mix that has a high capillary porosity presents a lower risk of producing dry drain lines than a mix with low capillary porosity, regardless of infiltration rate. This is a critical point to understand.

Table 1 shows some properties of five sand-channel drain mixes. Despite these mixes having very similar infiltration rates, the capillary porosity, or water retention, varies considerably. The 10-percent difference between the 6-2-2 (2) and 6-2-2 (3) mixes means that the 6-2-2 (3) mix will hold an additional 0.1 inch of water for every one inch of rootzone depth. The difference in water retention could be significant,



Drain lines may become visible if the rootzone mix used to backfill trenches dries out considerably faster than surrounding soils. Even if a drainage mix has good water retention, fertility differences may develop where sand-channel drains are installed due to differences in cation exchange capacity (CEC).

Figure 1
Water-release characteristics of three mixes for sand-channel drains



depending on rooting depth within the sand channels.

The capillary porosity may tell you the amount of water a soil mix can store, but it doesn't tell you how much of the water is available to plants. Another test to consider is a water-release study, or curve. In the water-release test, samples are subjected to increasing amounts of energy in the form of vacuum pressure to remove water from the pores. At each incremental increase in energy, water is extracted from increasingly smaller pores. Figure 1 shows water-release curves for a uniform, fine-textured sand and two sand-channel drain mixes. The X-axis is the soil suction, or the amount of energy applied to each sample. The Y-axis is the capillary porosity, or the amount of water retained by each sample when exposed to corresponding levels of soil suction.

As energy used to remove water from the sample is increased, the water content decreases. Figure 1 shows that the fine sand releases water fairly quickly across the suction range tested. The capillary porosity of the sand decreases by 30 percent between 20 and 60cm of suction. Since it takes so little energy to extract the water from the fine sand, all of the removed water can be considered plant-available. The 60-20-20 and 60-20-10-10 mixes hold water a little more tenaciously, as much less water is released within the same suction range. The 60-20-10-10 mix holds more water than both the 6-20-20 mix and the fine sand at all test points. Both the 60-20-20 and 60-20-10-10 mixes hold a fair amount of water at 60cm soil suction, but we still don't know how much of the remaining water is plant-available.

To determine plant-available water, the mixes are subjected to a much higher amount of energy, simulating the energy level (water potential) beyond which water is held too tightly to be plant-available. This level of energy is often referred to as wilting point. For sand-based mixes, the energy potential of -3 bars (same as 3,000cm soil suction) is used to simulate wilting point. Most sand-based mixes hold very little water at the wilting point. Even sand-based mixes that hold water at the wilting point are unlikely to have the ability to conduct or wick water through capillary pores fast enough to replenish water around plant roots. In other words, as long as an evapotranspiration demand exists, plant wilt is likely to occur, although the wilting may be temporary.

Table 2 shows the water content of the fine-textured sand and two sand-channel drain mixes at different energy (or water) potentials, including -3 bars. The difference in water content between the point at which all large pores are drained, i.e., field capacity, and the wilting point is the best estimate of plant-available water. To determine plant-available water for the three samples, water content at 30cm soil suction was used to represent water retention at field capacity.

The results clearly show that the infiltration rate is not the same as water retention. The fine sand had an infiltration rate that was 10 times that of the two mixes sold for sand-channel drains. Still, the plant-available water was comparable to the 60-20-10-10 mix and 50 percent higher than the 60-20-20 mix. This might suggest that the fine sand is superior to the 60-20-20 mix for a drainage application, and it may be, but there are other factors to consider. For one, the fine sand is likely to have a significantly lower cation exchange capacity (CEC) compared to the other two mixes. Therefore, even though the fine sand has good water retention, it may cause fertility differences to develop where sand-channel drains are installed. Turf cut at fairway height is much more forgiving than a

Table 2
Determination of plant-available water for three samples

Sample	Ksat (inches/hour)	Water Content at Water Potential of: 30cm	3 bars	Plant-Available Water (inches water/inch mix)
Fine Sand	30.8	22.7	5.8	0.17
60-20-20	3.2	25.7	15.1	0.11
60-20-10-10	2.4	34.6	18.5	0.16

green in this regard, thus fine sands are often used in fairway-drainage applications.

Another factor to note is the tension at which water is held. The water-release curve (Figure 1) shows that water in the fine sand is not held as tightly as water in either of the sand-channel mixes. Therefore, water is more likely to wick out of the sand and into finer-textured soils that may abut drainage trenches. Thus, while laboratory data may show that the fine sand has better water retention, its performance in the field may not be ideal. However, based on the data presented in this example, I would be confident that the 60-20-10-10 mix would outperform the 60-20-20 in the field.

The point of this example is to demonstrate the ability to make better assessments of water-retention characteristics of mixes used for sand-channel drains by using laboratory test results rather than arbitrary recommendations. Unfortunately, there is no guarantee that a mix used for sand-channel drains will perform flawlessly, regardless of how much testing is done up front. However, knowing a little more about the ability of a mix to provide plant-available water can provide superintendents with a better assessment of the likelihood that a mix will dry out rather than considering infiltration rate alone.

As a sidebar to this discussion, the same principals apply to other applications of sand on the golf course. In the past, some bunker sand suppliers have made their sands finer to obtain a higher penetrometer reading, which indicates a reduced likelihood of "fried-egg" lies. Like the fine sand discussed in this article, the infiltration rate of fine bunker sands may be very good, but the water retention is high. Because of this, fine bunker sands may have the potential to stay wet, especially in the bottoms of the bunkers. Installing the sand at shallow depths compounds the problem.

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After sand-channel drains are installed, it is important to maintain pore continuity in the soil so that water can easily move downward through the soil profile. A proper sand-topdressing program and aeration will help dilute the accumulation of organic matter to prevent it from sealing sand-channel drains.