Understanding Water Relations in Mixes for Sand-Channel Drains

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Managing soil water is one of the more important aspects of managing golf course turf but probably one of the least understood. One common misconception is the idea that soil permeability (infiltration rate) is the same as water retention. Soil permeability is not the same as water retention. A root zone mix with a high infiltration rate is not necessarily a dry mix. Conversely, not all mixes with low infiltration rates are wet. In the golf course maintenance world this is commonly misunderstood concept. Not understanding this can and will result in problems.

One example where we see the consequences of this is in trench backfill materials for greens drainage projects. One of the concerns a superintendent has in installing these drains in greens is that the drain lines will dry out before surrounding areas, requiring frequent hand watering over the drain lines. The trench backfill material will dry out sooner if the mix is not holding as much plant available water as the surrounding turf areas.

We often see recommendations for 6-2-2 (sand-soil-peat) mixes for trench backfill materials, with no mention of sand size, soil texture, or organic type in the mix. As a result, mixes for sand channel drains we have tested have had combined silt and clay contents ranging from under 1% to 13%, and organic matter contents ranging from less than 1% to over 4% by weight. Such huge variations in mixes are certain to result in performance differences in the field.

Another guideline typically used is that the trench backfill material should have an infiltration rate (permeability) of 2 to 4 inches per hour. It is important that these mixes drain adequately, and this guideline provides some assurance that it will. 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 this mix will dry out once it is in your trench lines.

There are two main forces that act of water in a soil. The first is gravity. Drainage water moves down through the larger sized pores (macropores) in a sand-based mix due to the force of gravity. This is drainage that occurs under saturated conditions. In the lab, we call this measurement the permeability, the saturated hydraulic conductivity, or infiltration rate of the mix. The infiltration rate of a mix is dependent on both the size of the pore and the continuity of pores. Pore continuity refers to how pores are interconnected. Does water have a straight shot down through interconnected pores or is the path winding?

In general, the size of the pore is influenced by the sand size, the 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 sand. A fine, uniform sand may not have very large diameter pores, but the infiltration rate may be very good because the pores are interconnected.

Water is retained against the force of gravity in a mix as water films on sand and soil particles, in wedges where two or more soil particles meet, or in peat or compost fibers. The water retention is influenced primarily by pore size and surface area. Smaller sized pores hold water against the force of gravity due to the capillary forces; that is the attraction of water to sand and soil surfaces. The strength of these 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 this plant-available water held in a mix will influence the performance of a trench backfill mix.

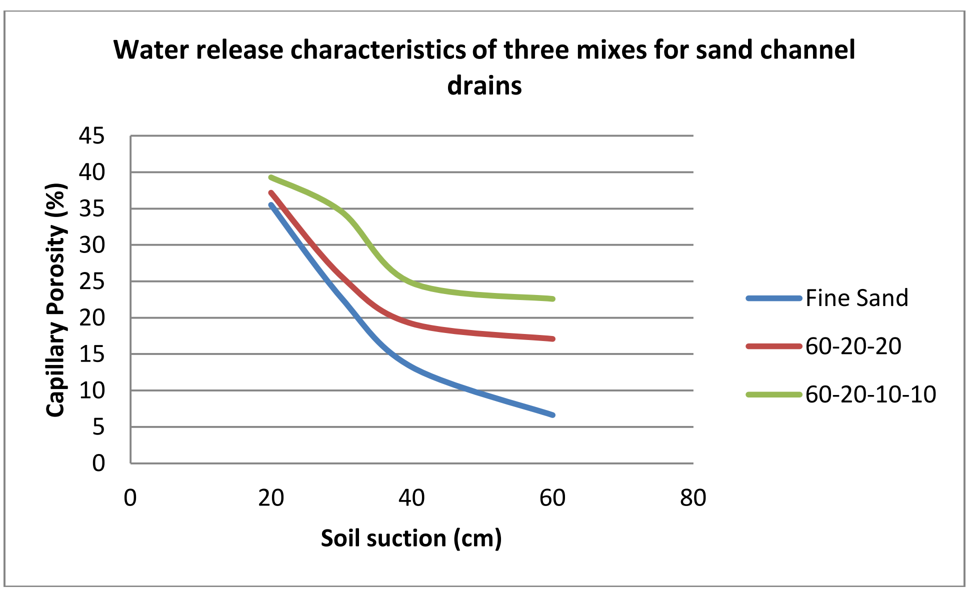
We can assess the water retention characteristics of these mixes in the lab. The simplest test is determining the capillary porosity of a mix in the same manner that we evaluate a greens mix. A mix that has a high capillary porosity would present a lower risk of producing dry lines than a mix with a lower capillary porosity, regardless of the infiltration rate.

Table 1 shows some of the properties of 5 sand channel drain mixes we have tested. Despite these mixes having very similar infiltration rates, the capillary porosity or water retention varied considerably. The 10% difference between 6-2-2 (2) and 6-2-2 (3) mixes means that the one mix will hold an additional 0.1 inch of water for every 1 inch of root zone depth. This could be significant depending on the depth of rooting in these channels.

Table 1: Select physical properties of 5 mixes submitted for sand channel drains.

Mix	Silt & Clay %	Organic Matter %	Ksat (in/hr)	Capillary Porosity (%)
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	11.0	2.25	2.4	34.6

The capillary porosity may tell you the amount of water a mix can store, but doesn't tell you how much of the water is plant-available. Another test to consider is a water release study or curve. In this testing we subject the sample to increasing amounts of energy in the form of a suction or pressure to remove water from the pores. At each incremental increase in energy we extract water from increasingly smaller pores. The chart below shows the water release curves for a uniform, fine sand and two sand channel drain mixes. The X- axis is the soil suction or energy amount applied. The Y-axis is the capillary porosity or water retention for each soil suction or water (energy) potential tested.



You can see that as we increase the energy or suction to remove water from the sample, the water content decreases. The chart shows that the fine sand releases water fairly quickly across the range tested. The capillary porosity on the sand decreases by 30% between 20 and 60 cm of suction. Since it takes so little energy to extract this water from the sand, you can consider all of this water plant-available. The 60-20-20 and 60-20-10-10 mixes are holding onto the water a little more tenaciously, as much less water is released within this range. The 60-20-10-10 mix is holding more water than the 6-2-2 mix and the fine sand at all test points. Both mixes are holding a fair bit of water at 60 cm soil suction. At this point, we still don't know how much of the water remaining is going to be available to your turf.

To determine plant-available water, we subject the mixes to a much higher amount of energy, simulating the energy level (water potential) beyond which the water is held too tightly to be available to the plants. You could call this the "wilting point". For sand-based mixes we use an energy potential of -3 bars, which is the same as 3000 cm soil suction. Most sand based mixes hold very little water at this point. Even those that do are unlikely to be able to conduct or wick water through capillary pores fast enough to replenish water to the mix around the roots. In other words, as long as the evapotranspiration demand is there, wilting is likely to occur, although the wilting may be temporary.

The table below shows the water content of the fine sand and the two sand channel drain mixes at different energy (water) potentials, including -3 bars. The difference in water content between the point where all the large pores are drained (field capacity) and the "wilting point" is our best estimate of plant available water. To determine plant available water on these three samples, I used the water content at 30 cm soil suction as field capacity.

Table 2. Determination of plant available water for three samples.

Sample	Ksat (in/hr)	Water content at water potential of:		Plant Available Water (inches water/inch mix)
		30 cm	3 bars	
Fine Sand	30.8	22.7	5.8	0.17
6-2-2	3.2	25.7	15.1	0.11
60-20-10-10	2.4	34.6	18.5	0.16

These 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% higher than the 6-2-2 mix. This would lead one to believe that the fine sand may be superior to the 6-2-2 mix for a drainage application, and it may be. There are other factors to consider, however. For one, the fine sand is unlikely to have anywhere near the cation exchange capacity than the other two mixes. Therefore, while you may have good water retention, you may have to then deal with fertility differences. Turf cut at fairway height is going to be much more forgiving than a green in this regards, thus fine sands are often used in fairway drainage applications.

Another factor to note is that the water in the fine sand is not held as nearly as tightly as it is in the other two mixes. The water release curve clearly shows this. Therefore, water is more likely to wick out of the sand into the finer textured soils that may line your drain trenches. So while the lab data may show better water retention, the performance in the field may not match this. Based on the data presented in this example, however, I would be confident that the 60-20-10-10 mix would outperform the 6-2-2 in the field.

The point of this is that we have the ability to make a better assessment of the water retention characteristics of a mix used for sand channel drains aside from some arbitrary recommendations. There is no guarantee that a mix used for sand channel drains will perform flawlessly regardless of how much testing is done upfront. Knowing a little more about the ability of a mix to provide water to the plant, however, can provide the superintendent with a better assessment of the risk a mix will be dry than looking at the infiltration rate alone.

As a sidebar to this discussion, the same principals apply to other applications of sand in the golf course setting. In the past we have seen some bunker sand suppliers making their sands finer to obtain a higher penetrometer (fried egg) reading. Like the fine sand discussed, the infiltration rate may be very good but the water retention high. Because of this, the bunker sands have the potential to stay wet especially in the bottoms of the bunkers. Placing the sand in shallow depth compounds the problem.