

MATERIALS TEST REPORT FOR
Nakheel Golf

REPORT TO:

Steve Beck
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DATE RECEIVED: October 12, 2005
TEST DATE: December 23 – January 17
REPORT DATE: January 18, 2006
Condition of sample: Normal

PARTICLE SIZE ANALYSIS (ASTM F-1632)

Lab ID No.	Sample	Soil Separate %			Sieve Size/Sand Fraction Sand Particle Diameter % Retained						
		Sand	Silt	Clay	No. 10 Gravel 2 mm	No. 18 V. coarse 1 mm	No. 35 Coarse 0.5 mm	No. 60 Medium 0.25 mm	No. 100 Fine 0.15 mm	No. 140 V. fine 0.10 mm	No. 270 V. fine 0.05 mm
19854-1	Dune Sand	98.3	0.9	0.8	0.0	0.0	0.0	7.5	22.4	39.1	29.3

PARTICLE SHAPE/PARTICLE SIZE PARAMETERS/pH

Lab ID No.	Sample	Sphericity/Angularity	pH ¹	D85	Cu	Grad. Index
19854-1	Dune Sand	Low to high/sub- rounded to well rounded	8.1	0.19	1.76	2.8

1 ASTM D4972



TABLE 1: PHYSICAL PROPERTIES (ASTM F-1815-97 with water release, Modified¹)

Lab ID No.	Sample	Bulk Density (g/cc)	Particle Density (g/cc)	Ksat Infiltration (mm/hr)	Total Porosity %	Aeration Porosity ² %	Capillary Porosity ² %
19854-1	Dune Sand	1.62	2.70	168	40.0	8.5	31.5
19854-1c	95-5 Sand - Raw Pozzolan	1.65	2.70	91	38.8	9.4	29.4
19854-1d	90-10 Sand - Pozzolan T-178	1.64	2.70	132	39.2	6.4	32.8

¹ Compacted at 40 cm tension

² Determined 0.06 bar

TABLE 2: VOLUMETRIC WATER CONTENT AT INCREASING MATRIC POTENTIALS

Lab ID No.	Sample	Volumetric Water Content of Soils and Amended Soils at Different Matric Potentials (bars)				
		0.03	0.06	0.1	0.33	1.0
19854-1	Dune Sand	32.6	31.5	30.5	24.1	14.7
19854-1c	95-5 Sand - Raw Pozzolan	33.8	29.3	24.2	23.8	7.7
19854-1d	90-10 Sand - Pozzolan T-178	36.3	32.8	29.1	26.7	24.0
						3.0
						5.2
						6.3
						7.3

TABLE 3: PLANT AVAILABLE WATER (mm water/m of soil)

Sample	Plant available water	Water in Management Range	Unavailable water
Dune Sand	263	168	52
95-5 Sand - Raw Pozzolan	230	216	63
90-10 Sand - Pozzolan T-178	255	88	73

Comments: The Dune Sand sample (Lab ID No. 19854-1) was tested as received and after amending it with Raw Pozzolan in a 95-5 volume mix ratio and T-178 in a 90-10 mix ratio. A particle size analysis of the sand was reported to Nakheel on October 28, 2005. The amount of amendment added to the sand in this mix was small enough that there would be little expected change in the particle size of the mix.

The physical properties of the sand and mix samples, as determined on compacted cores, are found in the tables on page 2. The sand sample had a saturated hydraulic conductivity (infiltration) rate that was good. When compacted to the density reported, the sand should be free draining, although organic matter accumulation is likely to decrease this with time. The addition of the Raw Pozzolan, which was fine in texture, resulted in a significant reduction in the infiltration rate. The T-178 resulted in a slight reduction in the infiltration rate.

The significance of this change in infiltration rate is that if at some point in time they have to use effluent or other low quality irrigation water, they will want to start out with an infiltration rate as high as possible to maintain their ability to leach salts as necessary.

The total porosity was acceptable in the sand and mixes. The aeration porosity is made up of relatively large pores that conduct water under saturated conditions. When drained, they are filled with air providing the oxygen that is necessary for root growth. The capillary porosity is made up of small pores that hold water against the force of gravity, retaining much of it for plant use. Ideally a growing medium would have an equal distribution of air and water filled pore space after free drainage.

The aeration and capillary porosity on these samples are reported in Table 1 on page 2 at 0.06 bars. You can see that at this point, the aeration porosity was low and the capillary porosity high in the Dune sand and the mixes. The addition of the amendments resulted in slight changes in these values.

We performed a water release curve on the sand and mixes. We applied increasing levels of energy to the samples to extract water from them, simulating a dry down cycle. By doing this, we can characterize the water retention characteristics of the sand and estimate how much of the water held is going to be plant available.

The attached chart shows the volumetric water contents of the sand and mixes in simulated dry down cycles. The results show that the sand holds water rather tenaciously at the lower tensions. Water is released steadily throughout the dry down cycle, this reflected in the downward deflection in the curve with increasing tensions. The addition of the amendments changed the curve considerably.

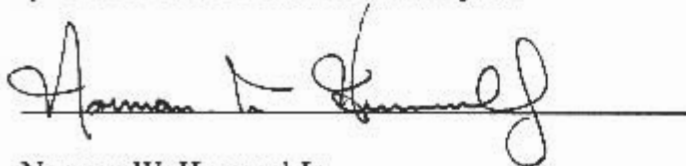
There are a number of ways you can look at this data. In a deep profile, any water lost between saturation (0 tension) and 60 cm tension (0.06 bars) reflects gravitational water or free drainage. When you look at the curves on all of the mix and the sand in this range, you can see that the slope is very steep; that is, water is released or drained quickly from the sand and mixes. This portion is of little agronomic interest.

Of greater importance is the water than is released from the sand and mixes from 0.06 bars on. I defined plant available water in these very sandy materials as that being released between 0.06 bars and 3 bars. All of the samples were almost powdery dry at 3 bars. I believe that a superintendent is most likely to maintain soil moisture in the range of 0.06 to somewhere between 1 and 3 bars. Therefore, in Table 3 on page two, I listed the amount of volumetric water released between 0.06 bars and 1 bar (water in management range) and 0.06 bars and 3 bars (plant available water). Arguably, some of the water held at tensions greater than 3 bars could be considered plant available, but it is unlikely a superintendent would let the sand or mixes get this dry in the field.

The two curves generated by the two amendments were interesting. The addition of the Raw Pozzolan resulted in a generous release of water between 0.06 and 1 bar, and then little beyond that. As a result, the data in the table shows that the water made available within the "water management range" was higher than the sand alone. The unavailable water was comparable to the sand alone. The T-178 released water slowly in the 0.06 to 1 bar range, but then gave it up in the 1 to 3 bar range at a rate greater than the sand itself. These data suggest that if you have a tendency to keep your turf on the dry side, there may be some merit to the T-178.

The results suggest that the addition of either the raw Pozzolan or the T-178 can beneficially change the water release pattern of the sand depending on the range the superintendent is most likely to maintain the turf at.

I hope that this information is helpful to you. Please let me know if you have any questions on these results. Thank you.

A handwritten signature in black ink, appearing to read "Norman W. Hummel Jr.", is written over a solid horizontal line.

Norman W. Hummel Jr.
President

Water Release Characteristics of Dune Sand with and without Raw Pozzolan and T-178

