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Fairways comprise a major portion of the total golf course acreage which must be mowed and maintained to exacting standards. A 1990 survey of Wisconsin golf courses found the fairway acreage for an 18 hole facility to range from 20-36 acres with an average of 27 acres (Erdahl, 1990). Due to the large acreage involved, golf course builders and landscape architects have felt constrained to use the existing topsoil and have not seriously considered fairway soil modification. Careful consideration of the characteristics of the existing top soils and the irrigation water quality is necessary to build and maintain high quality fairways. Proper topsoil selection for fairway areas can prevent many of the typical problems, reduce the amount of maintenance, and increase the overall caliber of the golf course.

A large part of the ultimate fairway quality is determined during the construction phase. Typically, the existing topsoil is removed from the fairway areas and stockpiled. The fairways are cleared of unwanted trees and other large vegetation or obstacles such as rocks and boulders. The fairways are then rough graded to achieve the desired contours and shapes. This often involves doing a significant amount of cut and fill work. As a result, the fairway subsoil's are often very heterogeneous. They often consist of a mixture of B and C soil horizons, are highly compacted, have very low amounts of native fertility and poor physical properties. After the rough grade is established, any necessary subsurface drains are added. Finally, a 4 to 6 inch thick layer of the stockpiled topsoil is replaced on the fairway areas and they are rough graded to the final contours. The irrigation system is installed and the fairways are given their final grading, smoothed, fertilized, and planted.

Golf course superintendents have faced a variety of problems caused by using the existing topsoil including: excessive wetness, slow drainage, poor aeration, and severe compaction of landing zones and other high traffic areas. These problems result in an increased number of course closings, restricted cart usage during wet seasons and increased maintenance costs. To help alleviate these problems, some golf course superintendents have turned to the use of conventional and deep-tine aerification (Cornell, 1987; Erdahl, 1990; Pool, 1994). Others have implemented programs of heavy topdressing with sand to try to rapidly build up a 4-5" thick sand cap on their fairways (Sayre, 1991). While these techniques are definitely of value, the presence of slowly permeable subsoil's and the lack of adequate subsurface drainage often limit their usefulness. The net result of poor fairway conditions is decreased revenues and increased expenditures both of which cut into the bottom line profit of the golf course.

Irrigation water quality also has a direct effect on fairway quality. As our water resources become increasingly limited, many golf courses will be forced to use lower quality water for irrigation. Many rivers in the U.S. are experiencing a long term trend of increasing salt concentrations. Therefore, facilities utilizing these more saline water sources for irrigation are applying an escalating amount of salt to their soil. If the rights to surface water have been previously allocated to other users, new courses must use either effluent water (reclaimed or recycled water) or well water for irrigation. Effluent

waters are typically higher in total salts and sodium as compared to surface water or municipal water systems. Irrigation with effluent water has been shown to result in soils having higher electrical conductivity, ESP and SAR (Hays et. al., 1990a & b). Many golf courses are drilling high capacity water wells which extend into deep aquifers to obtain an adequate volume of groundwater for irrigation. In some areas these aquifers often have poor water quality due to high amounts of sodium. The increased salt load from these lower quality water sources will damage the soil structure of many finer textured soils which will in turn intensify the problems of compaction and poor drainage. To compensate for the accumulation of salts, fairways need to be built with the capacity to leach out some of the excess salts. Therefore, it is important that fairways be constructed with high quality soils having adequate drainage characteristics.

Architects, owners and superintendents are now attempting to develop innovative ways to solve fairway soil problems before they occur. One promising solution is a technique known as "Sand Capping". This procedure involves removing and stockpiling the existing fairway topsoil for use elsewhere on the golf course. The fairways are rough graded, and an extensive network of subsurface drains are installed at 25-50 ft. spacing to remove excess drainage water. Then the entire fairway is covered with a suitable thickness of carefully selected sand. The exact thickness of the sand needed will depend on the physical properties of the available sands; however, a minimum thickness of 6 inches is needed to provide adequate moisture retention and rooting depth for the turf. Greater depths of some sands may be needed but are often cost prohibitive.

The key to the successful use of sand capping is proper sand selection. A good fairway capping sand needs to be coarse and contain low amounts of silt and clay. In addition, the sand needs to have a high saturated hydraulic conductivity and acceptable pore space relations. These values are determined by laboratory measurement of the physical properties of the sand at a range of tensions from saturation to 40 cm. The amounts of capillary and air-filled pore space are plotted as a function of tension (depth of sand). From the plot, the range of depths over which the sand has both 15-25% capillary porosity and 15-30% air-filled porosity is identified. This represents the ideal placement depth for this particular capping sand. Since fairway areas are somewhat less critical than putting greens and in general receive less compaction than the greens, it should be possible to allow the amount of air-filled porosity to decrease to 10%, the capillary porosity to increase to 30%, and still maintain adequate turf quality. Therefore, the range of depths over which the sand has 15-30% capillary porosity and 10-30% air-filled porosity is also identified and is called the **acceptable placement depth**.

The particle size distribution and physical measurements for three sands are shown in tables 1 and 2 respectively. Sand #1 was a very coarse material and contained 27.4% of the particles in the fine gravel fraction. In addition, it contained 25.9% very coarse sand and 20.7% coarse sand. Due to the coarseness of Sand #1, it had a high saturated hydraulic conductivity of 79.4 in/hr. Sand #1 retained a substantial amount of water (as indicated by the high capillary porosity) at saturation and 10 cm tension but released a major portion of it by 20 cm tension. Based on these measurements, sand #1 should have ideal porosity relations when placed at a depth of 16-19 cm (6-7.5"). The high saturated hydraulic conductivity will insure adequate lateral movement of drainage water to a nearby subsurface drain line.

Sand #2 was a very uniform, medium sand and contained 75.4% of the particles in the medium sand fraction. Sand #2 contained 8.3% of the particles in the fine sand fraction but contained a very small amount of silt and clay. Due to the very uniform particle size distribution, Sand #2 had a very high saturated hydraulic conductivity of 96.0 in/hr which is greater than that of Sand #1. Sand #2 retained a substantial amount of water at saturation to 20 cm tension but released a major portion of it by 30 cm tension. Sand #2 should have an ideal porosity distribution when placed at a depth of 22-27 cm (8.6-10.6"). If the air-filled porosity is allowed to go to 12% and the capillary porosity is allowed to increase to 30%, then Sand #2 may be placed at a minimum depth of 19 cm (7.5").

Sand #3 had a wide distribution of particle sizes with 17.3% very coarse sand, 29.2% coarse sand, and 29.1% medium sand. In addition, Sand #3 contained 13.1% fine sand, 6.7% very fine sand, and a total of 4.1% silt plus clay. The wide spread in particle sizes allows this sand to pack together more tightly. Therefore, Sand #3 had the lowest saturated hydraulic conductivity of 32.5 in/hr. Sand #3 retained a substantial amount of water from saturation to 20 cm, but released a major portion of it by 30 cm tension. Based on this, Sand #3 should have ideal porosity relations when placed at a depth of 27.5-34.5 cm (10.8-13.6"). If the air-filled porosity is allowed to decrease to 10% then Sand #3 may be placed at a minimum depth of 24 cm (9.4").

As evidenced by the above data, potential fairway capping sands can be evaluated for their performance at a variety of depths. Based on the results of such tests, the sand which is best suited for fairway use can be identified from a group of locally available sand products and can be placed on the fairways at the optimum depth to insure the best possible performance. This will help insure that the golf course owners obtain the best quality fairways per dollar invested.

Using fairway capping sands which meet the above criteria will produce fairways having increased drainage and aeration, and reduced compaction. In addition, the sand will allow the golf course superintendent to leach excess salts from the upper portion of the root zone. However, sand capped fairways will require different management techniques as compared to fairways constructed with native top soils. Because sands retain less water, sand capped fairways will have to be irrigated more often. Smaller but more frequent fertilizer applications will be needed due to the low cation exchange capacity of sand. The use of slow release fertilizers will help reduce leaching losses of highly soluble nutrients, particularly nitrogen and potassium.

The cost of fairway sand capping is high and depending on the cost and availability of the sand, may run upwards of 1 million dollars for a typical 18 hole golf course. However, for golf courses being built in areas that have poorly suited native soils, are located in very high rainfall areas, or anticipate salinity problems due to poor quality irrigation water; the investment may make the difference between a luxuriant high-end golf course and a mediocre quality course that few people want to play.

Table 1.
Particle size distribution for three sands.

Fraction	Size Range (mm)	Sand #1 (% by weight)	Sand #2 (% by weight)	Sand #3 (% by weight)
Fine Gravel	>2 mm	27.4	0.7	0.5
Very Coarse Sand	1-2 mm	25.9	3.9	17.3
Coarse Sand	0.5-1.0 mm	20.7	6.8	29.2
Medium Sand	0.25-0.5 mm	14.9	75.4	29.1
Fine Sand	0.15-0.25 mm	5.1	8.3	13.1
Very Fine Sand	0.05-0.15 mm	3.3	2.8	6.7
Silt	0.002-0.05 mm	2.1	1.6	3.5
Clay	<0.002 mm	0.6	0.5	0.6

Table 2.
Amounts of capillary and air-filled pore space for 3 sands over a range of tensions.

Tension (cm)	Sand #1		Sand #2		Sand #3	
	Capillary Porosity	Air-Filled Porosity	Capillary Porosity	Air-Filled Porosity	Capillary Porosity	Air-Filled Porosity
0	31.9%	2.9%	40.9%	2.7%	35.9%	0%
10	28.6%	6.2%	40.7%	2.9%	34.8%	1.1%
20	13.1%	21.7%	29.3%	14.3%	30.9%	5.0%
30	8.2%	26.6%	11.0%	32.6%	17.5%	18.4%
40	8.0%	26.8%	6.1%	37.5%	11.9%	24.0%

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