THE CHOKER LAYER

An examination of the water content of a USGA rootzone mixture in the presence and absence of a coarse intermediate layer.

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THE United States Golf Association has long been regarded as an innovator in putting green construction. Since the 1960s the USGA has suggested recommendations for putting green construction based on research conducted by a number of scientists at various institutions. These recommendations have been "the most widely used method for green construction throughout the United States and in other parts of the world" (Hummel, 1993).

The objectives of the USGA's recommendations for green construction are clear: Create a green that drains rapidly, resists compaction, and provides a suitable medium for plant growth. Additionally, a high level of uniformity exists within a golf course when all of its greens are of similar USGA specifications, a valuable characteristic when developing a turf management program because a turf manager is able to apply similar management practices to all of the greens, reducing confusion and headaches (in today's world, wasted time equals wasted money).

The components of a USGA green as initially described (USGA Green Section Staff, 1960) are: 1) the subgrade, 2) drainage pipes, 3) gravel layer, 4) intermediate layer, 5) rootzone mix. Each component is required to meet strict USGA recommended specifications to ensure a properly functioning green. (As of 1993, the need for the intermediate layer is determined by the properties of the gravel and rootzone mix.)

The trademark of the USGA green is an enhancement of the water-holding capacity of the rootzone mix relative to what would occur in the surface horizon if the same-textured rootzone mix extended to the subgrade of the green. This enhancement is created by placing the rootzone mix over a coarser-textured layer of sand, the intermediate layer or, as it is often called, the *choker* layer. Water held in the fine-textured rootzone layer does not pass into the coarse-textured layer "until the pressure head at the interface builds up sufficiently for water to penetrate into the coarse material" (Hillel, 1982). This essentially means that the pores in the rootzone mix must become nearly filled near the interface with the coarser sand before

The research study investigated the moisture-holding capacity of a green constructed with and without the intermediate layer, using a rootzone mix with physical properties recommended by the USGA.

water will move into the underlying coarse-textured layer. The enhanced water-holding capacity is often called a "perched water table." However, since the pores in the rootzone never remain saturated for an extended period of time, a true water table does not exist and the term "perched water table" will not be used herein. The enhanced water-holding capacity is important, because without it, the rootzone mix would be less able to hold sufficient water to maintain the turfgrass between reasonably scheduled irrigations during periods of heavy play and tournaments, or when regulatory agency irrigation restrictions are mandated.

The intermediate layer component (choker layer) of the USGA green has been the source of much debate. The intermediate layer is comprised of sand particles between 1mm and 4mm in diameter. Its original purpose was to prevent migration of sand particles from the rootzone mix into the gravel layer (Hummel, 1993). However, many golf course architects and superintendents have considered the intermediate layer to be the reason for the enhanced water-holding capacity of the rootzone. In fact, enhanced water-holding capacity will occur with or without the 1mm to 4mm particle-sized intermediate layer, as long as the rootzone mix is placed over a coarser-textured layer, such as the gravel layer.

The high cost of the intermediate layer has also made it the subject of controversy. The cost of the intermediate layer is high because guidelines call for a narrow particle range, requiring careful sieving by suppliers. Furthermore, the additional time and labor required to add this layer in green construction increases its cost. To reduce costs, many construction companies eliminate this layer during the construction of new greens; some such greens function correctly, but many fail.

The USGA recognized that it could better serve the industry by providing specifications for construction when the intermediate layer is omitted, and published revised specifications in 1993. When the intermediate layer is omitted, very strict gravel specifications must be met (Hummel, 1993).

Many in the golf course construction industry have discontinued the practice of installing the intermediate layer following the release of the new specifications; therefore, the effects of this practice should be examined. Miller and Bunger (1963) showed that the moisture content of the rootzone mix overlying a coarse sand material is less than that of a rootzone mix overlying a gravel material. The soil material used in their experiment was a sandy loam (54% sand, 36% coarse silt, 3% fine silt, and 7% clay), which is not a rootzone mix that meets USGA specifications.

An experiment was conducted to determine the moisture-holding capacity of a green constructed with and without the intermediate layer, using a rootzone mix with physical properties recommended by the USGA.

Table 1
Particle Size Distribution of USGA Rootzone Mix Used in This Experiment

Name	Particle Diameter	Specification	Used %
Fine Gravel	2.0-3.4mm	Not more than 10% of the total particles in this range, including a maximum of 3% fine gravel (preferably none)	.3
Very coarse sand	1.0-2.0mm		9.6
Coarse sand	0.5-1.0mm	At least 60% of the particles must fall in the coarse and medium sand classes	48.0
Medium sand	0.25-0.50mm		34.1
Fine sand	0.15-0.25mm	Not more than 20% of the particles may fall within this range	7.9
Very fine sand	0.05-0.15mm	Not more than 5%	0.0
Silt	0.002-0.05mm	Not more than 5%	0.0
Clay	Less than 0.002mm	Not more than 3%	0.0

VFS + S + C should not exceed 10% of total

Methods and Materials

The experiment was conducted using clear plastic columns having a diameter of 4.5cm and a length of 45cm. The columns were placed upright in a wooden rack. A rubber stopper having two holes was pushed into the bottom of each column and covered with a piece of wire screen. Gravel that met USGA guidelines was placed in the bottom of each column to a depth of 10cm (if no choker layer was to be used), or to a depth of 5cm (if choker sand was to be added). The choker sand was sieved to ensure that it would all be less than 4mm and greater than 1mm. In five columns, a layer of choker sand 5cm deep was added. The sand was packed gently with a wooden rod. The bulk density of each 10cm depth was determined (soil weight/soil volume) to verify the uniformity of packing. Then rootzone mix sand that met USGA guidelines (Table 1) was added to each column to a depth of 30cm. It was gently packed in place with a wooden rod after adding each layer of 5cm. When finished, there was 5cm of unfilled column remaining above the surface of the soil. The two treatments were replicated five times and the columns were arranged in a completely random fashion in the rack.

On the afternoon of the first day, water was added to the top of each column until it dripped out of the holes in the stoppers in the bottom of the columns. Water was repeatedly added throughout the evening and the next morning until 10:00 AM to ensure that the soil was saturated with water. The columns were then covered with aluminum foil to prevent evaporation and allowed to drain for 24 hours.

After draining, the columns were removed from the wooden rack. Using a hacksaw, the top, middle, and lower 10cm portions of the 30cm rootzone mix sand were excised. The length of the cut portion of the column was measured, since sometimes the top or bottom portion was a little more or less than 10cm, and the sand, still inside of the plastic column piece, was placed in an aluminum tray and weighed to the nearest 0.1gm on a top-loading balance. After recording the wet weight, the tray containing the column piece and column was placed in an oven set at approximately 70 degrees centigrade. A higher temperature was not used to prevent melting of the plastic column. Over the next two days, the samples were weighed several times to obtain a constant dry weight. After the first day, the sand was shaken out of the plastic column to speed up drying, but the empty column was placed back into the

Table 2
Bulk Density, Moisture Content, Pore Space, and Air-Filled Pore Space for Different Soil Depths With or Without the Intermediate Layer

Factor	Bulk Density	Soil Moisture By Weight	Soil Moisture By Volume	Total Pore Space	Air-Filled Pore Space
	g/cc	---------- %	----------	%	%
INTERMEDIATE LAYER					
None	1.53	16.52	22.95	42.2	45.1
With	1.55	15.03	21.11	41.5	49.5
Significance	NS	**	*	NS	*
DEPTH (cm)					
0-10	1.56	8.74	12.10	41.2	71.1
10-20	1.53	16.17	22.55	42.3	46.1
20-30	1.54	22.42	31.46	42.0	24.7
Significance	NS	**	**	NS	**
CHOKER DEPTH					
– 0-10	1.55	9.07	12.53	41.3	70.0
10-20	1.51	17.38	23.98	43.0	42.6
20-30	1.53	23.11	32.35	42.2	22.6
+ 0-10	1.56	8.41	11.67	41.0	72.1
10-20	1.55	14.96	21.11	41.5	49.5
20-30	1.54	21.73	30.57	41.8	26.9
Significance of the Choker × Depth interaction	NS	NS	NS	NS	NS

NS means there is no statistically significant difference for the treatment

* and ** refer to statistical significance at the 0.05 and 0.01 probability levels, respectively

tray with the sand. Finally, the sand itself was weighed separately from the column.

The moisture in each column piece was calculated by subtracting the weight of the dry sand, including the column piece and tray, from the weight of the wet sand, including the column piece and tray. The moisture content based on weight was calculated by dividing the moisture by the dry weight of the sand. The bulk density of each column segment was calculated by dividing the dry weight of the soil by the column segment volume. The moisture content of the soil on a volume basis was directly calculated by dividing the moisture weight in grams (which also is the moisture volume in cubic centimeters) by the volume of the column piece. The pore space was calculated *as 100 – (bulk density/particle density)*, assuming a particle density of 2.65g/cc. Finally, the percent of air-filled pore space was calculated as 100 – {(volumetric moisture/pore space)100}, where a mean value of 41.8 was used for the pore space term.

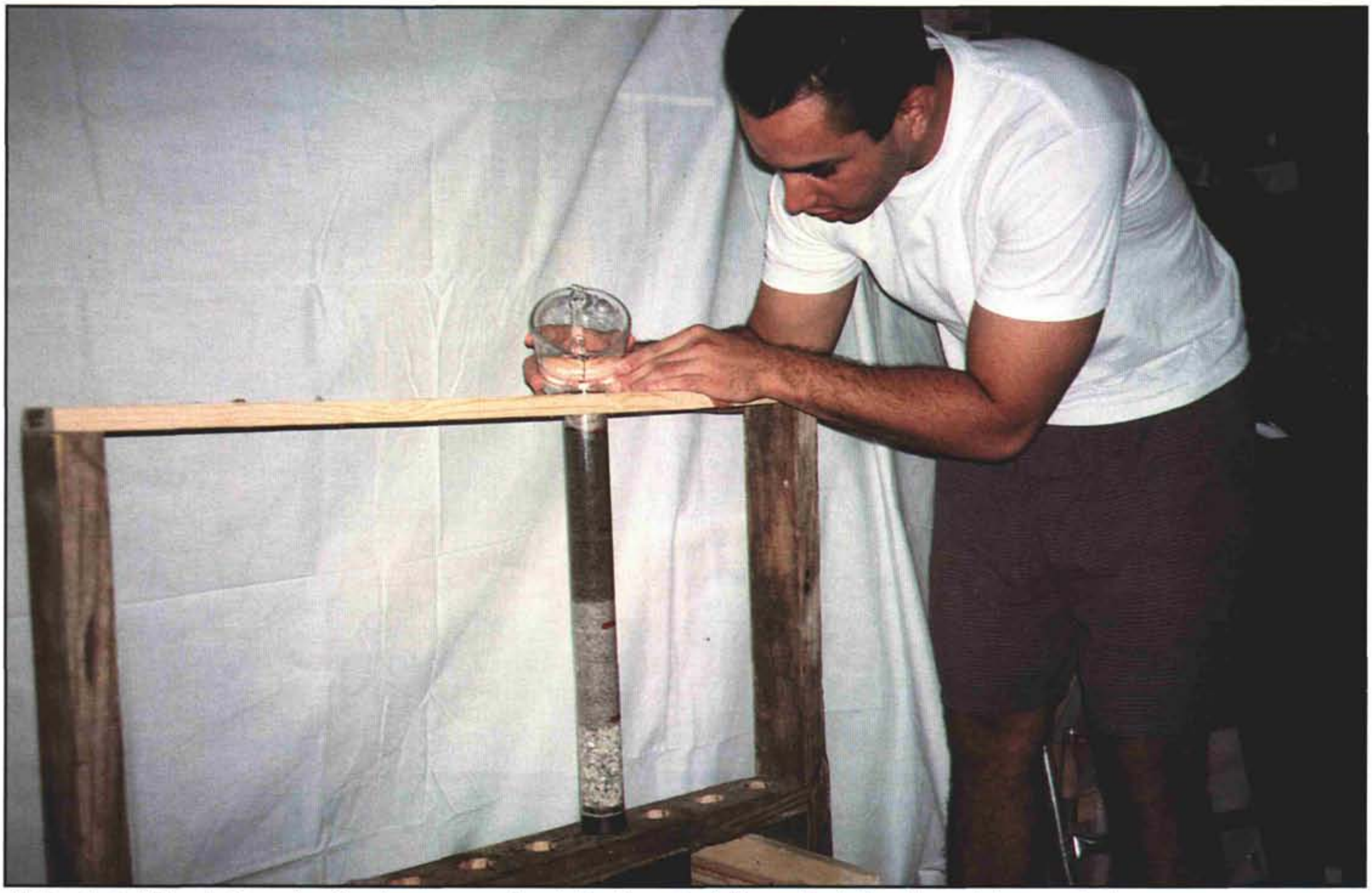
The data were analyzed as a factorial experiment with one factor being the presence or absence of the choker layer, and the other factor being the depth of the rootzone mix.

Results and Discussion

The presence or absence of the choker layer and the depth (rootzone mix section) significantly affected the moisture content (by weight or by volume) and the air-filled pore space of the rootzone mix, but did not affect the total pore space or bulk density (Table 2). The factors of choker and depth should not have affected the bulk density or the pore space (which is calculated from the bulk density) since the rootzone mix was packed above the choker layer and an effort was made to pack it uniformly throughout the soil profile. There were no significant interactions among the choker and depth factors.

It was expected that the lower portions of the soil profile would contain more water than the upper portions, and that is what was found. When the choker layer was absent, the rootzone mix contained more water at all three rootzone mix sections (Figure 1) and correspondingly less air-filled pore space (Figure 2), than when the choker layer was present. This occurred because the matrix suction at which pores fill with water decreases as the pore size increases. Thus, the larger pore-sized gravel layer draws less water from the overlying rootzone mix than does the smaller pore-sized choker sand. The results of this study are consistent with the results found by Miller and Bunger (1963). However, their data could not be used to calculate the magnitude of the difference in water content in a USGA green with and without the choker layer. The water-holding capacity of a soil can be related to rainfall, irrigation, or evapotranspiration by considering a column of soil with unit surface area. As shown in Table 2, the 0-10cm soil column with the choker held 11.67% moisture by volume (11.67cm^3 moisture/100 cm^3 soil). Therefore, a 0-10cm column of soil with a 1cm^2 surface area would hold 1.17cm of moisture (1cm × 1cm × 10cm × 11.67g water/100cm^3 soil = 1.67cm of precipitation, irrigation, or evapotranspiration per cm^2 soil surface). Using this reasoning and the data in Table 2, it appears that with a choker layer, the 30cm of rootzone mix held a total of 6.34cm of water per 1cm^2 of surface area (1.17 + 2.11 + 3.06), and without a choker layer the total was 6.89cm (1.25 + 2.40 + 3.24), for a difference of 0.55cm. So what is the importance of 0.55cm of water? During cool weather in Florida, predicted evapotranspiration (pET) for turf may be only 0.127cm per day (McCloud, 1971). By having an extra 0.55cm of water in the soil profile, a turf manager may be able to delay irrigations by approximately four days, if it is assumed that the turf can extract water from the entire 30cm of the soil profile. Probably the actual delay time will be less, since most of the turf roots will be in the upper part of the profile. On warm, sunny, windy days in Florida, the turf may have a pET of over 0.864cm per day. Under these conditions, the extra water held in the absence of the choker layer probably would not permit the turf manager to delay irrigating even one day. Thus, although the presence or absence of the intermediate layer (choker) was found to have a statistically significant effect on the moisture-holding capacity of the overlying rootzone mix, the effect is probably not of major agronomic importance.

It also is interesting to note that the 30cm profile averaged approximately 6.6cm of water per square centimeter of surface area across the two choker



At the start of the study, each soil column was saturated with water before calculating the moisture content.

conditions. A native deep sand soil probably would hold only 2cm to 3cm of water in the upper 30cm of profile (Smajstrla, 1996). Thus, the value of having a coarse-textured layer below a finer-textured layer for holding additional water was illustrated.

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Figure 1
Effect of USGA Profile Construction on Water Content by Volume

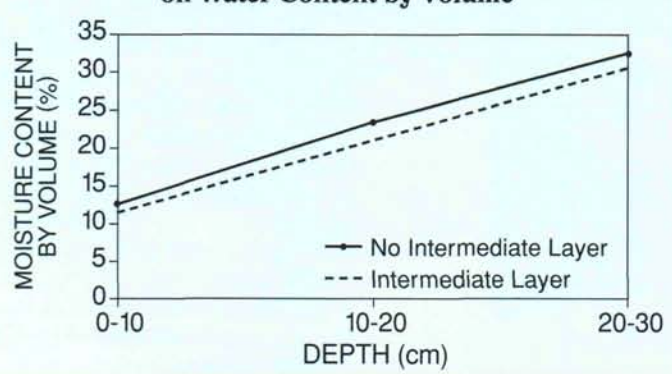

Figure 2
Effect of USGA Profile Construction on Air-Filled Pore Space (based on % of total pore space)