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The contents of the two articles that follow were presented at the 1st Annual Golf Course Superintendents Institute and frst published in the proceedings of that meeting. The articles are reprinted here because of the usefulness to all designers, installers, and managers of high trafficked turfgrass areas.

SANDS AND THEIR PLACE ON THE GOLF COURSE*

*By William B. Davis***

Few landscape areas present the variety and complexity of problems that we find on a golf course. For those turfgrass managers who look on these problems as a challenge to their knowledge and skill, the job can be quite rewarding — both economically and for personal gratification. The types of knowledge and skills needed to be a turfgrass professional are many and it is the putting together of all the pieces in the right order that separates a good foreman acting as a superintendent from the professional superintendent. One of these pieces of knowledge is the understanding of sand and how it is used to produce the best golfing conditions for the clients.

All soils are composed of particles, and it is the percentage distribution of these sand, clay, and silt particles that determine the various soil types. Yet terms like sand, clay, soil, silt, loam and others are commonly used without taking into account the actual range or combinations of particles, textures and sizes that make up these soil types. (See Table 1.)

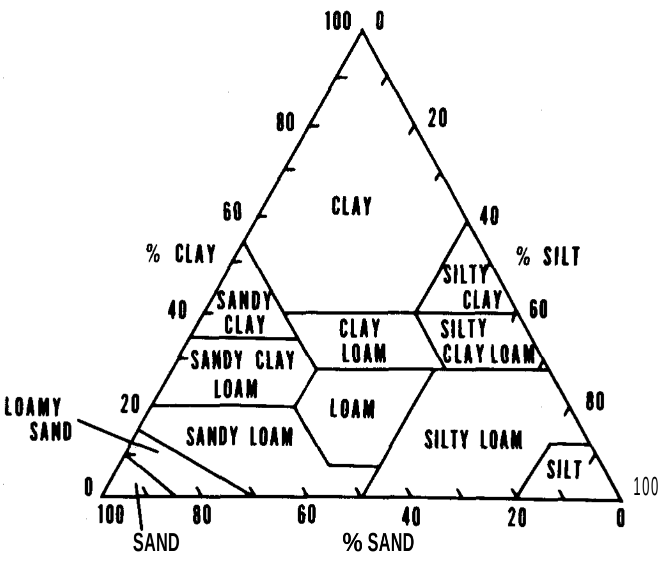
TABLE I-Textural Classification of Soil Particles

Name	U.S.	International
Fine gravel	2.00-1.00	
Coarse sand	1.00-0.50	2.00-0.20
Medium sand	0.50-0.25	
Fine sand	0.25-0.10	0.20-0.02
Very fine sand	0.10-0.05	
Silt	0.05-0.002	0.02-0.002
Clay	0.002	0.002

In fact, it is still not uncommon to see recommendations call for a special green mix consisting of five parts sand, three parts parent soil, and two parts organic matter. This type of recommendation is worthless unless a particular sand, a particular soil, and a particular organic amendment are specified.

Sands, which occur in varying percentages, are the larger of the various particles that make up all soils. For example, a soil can be classified as a clay, but still contain 40 percent sand. (See Figure 1.)

Figure 1



Sand particles can range in size from 0.05 to 1.00 mm, and the amount of each of the sizes can also vary. As a result, a soil can range from a nearly pure clay of <0.002 mm to a mixture of particle sizes, more than 75 percent of which might be in the sand range.

Organic matter can also vary quite widely and might also include 5 to 25 percent silt and clay. The 5-3-2 ratio, therefore, could range from a perfect greens mix to adobe bricks. To a professional superintendent, there is no such thing as soil, sand, loam, top soil, etc.-unless the distribution of particle sizes is given.

There was a day when a greenskeeper gave little thought to soil, sand, topdressing, disease, specialized equipment, etc. Golf was played on a native pasture with crude clubs and not so round balls, and sheep were used for mowing and fertilizing the grass. At that time, few people played the game, there were no golf carts, and the demands placed on the turf and the greenskeeper were small. Today it is a different story, and sand has become the single most important agent to meet the high use and turfgrass quality demands made by today's golfers.

The recreation called golf makes a unique demand on the space provided. For every 100 acres of highly managed turfgrass, we score the game one-fourth on the tees,

*From: Proceedings 1973 California Golf Course Superintendents Institute, 57-63.

*"Environmental Horticulturist, U.C. Davis

one-fourth on the fairways, and one-half on the greens. However, the average golfer plays more like one-sixth on the tees, one-third on the fairways, and one-half on the greens. On the other hand, the turfgrass area provided is proportioned more like 5 percent for the tees, 90 percent for the fairways, and 5 percent for the greens. It is this concentration of wear and traffic that has led to a great deal of trial and error research in special soil mixes for greens. The degree to which we properly use sands has been the primary component of our successes or failures.

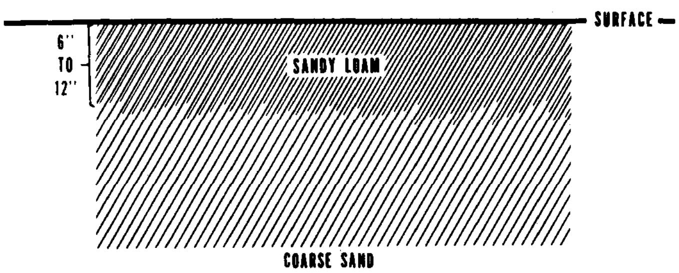
A review of the various greens mixes and construction techniques which have been used in California may help to point out the importance of sand and its role in golf greens. It is well to keep in mind that, regardless of the construction method, the success of a green depends on many factors, including water use, climate, water quality, degree of traffic, and, most important of all, the skill of the superintendent and his crew.

Modifying a Coarse Sandy Soil

Some golf courses have been constructed in old river bottoms or other areas where the parent soil was a coarse sandy one. Green construction consisted of mixing a nearby loam soil into the surface 6 to 12 inches. While there was usually no analysis of the parent coarse soil or the imported loam, the resulting surface mix produced a much improved media for growing grass and was easier to manage. By chance, in some areas the right mix resulted and a good green usually approached a sandy loam or loamy sand. No tile draining was needed because the coarse sandy soil has excellent drainage, but poor water retention. Also, there was no distinct interface between the surface mix and the coarse sandy soil below.

Under traffic, however, many greens built in this manner failed-some were too droughty, but most were subject to compaction. The water infiltration rate might run as low as 0.05 inches per hour, and a well-hit ball could bounce a mile if the greens were on the dry side. (See Figure 2.)

Figure 2

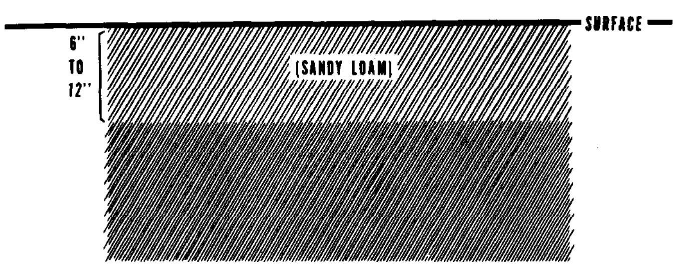


Modifying a Clay or Clay Loam Soil

Clay or clay loam soil construction was very common before the early 60's and many greens of this type still exist. A coarse sand, with or without some organic matter, was mixed into the surface 6 to 12 inches. Once again, this method usually resulted in a surface soil that classified as a sandy loam or loamy sand.

Under minimum traffic, careful irrigation, and no heavy periods of rainfall, these greens have served well. However, most have failed since the infiltration rate in the soil can become very restricted under heavy use, and rain or shine, people play golf. Even though the internal drainage of the surface mix might be faster than in the parent clay or clay loam soil, it is usually too slow to prevent the green from being spongy for several hours after water application. Since the excess water is held in the restricted pore spaces between the soil particles, the most adaptable grass for this situation becomes *Poa annua.* However, to maintain the shallow-rooted *Poa,* it is necessary to water frequently, compounding the management problems. (See Figure 3.)

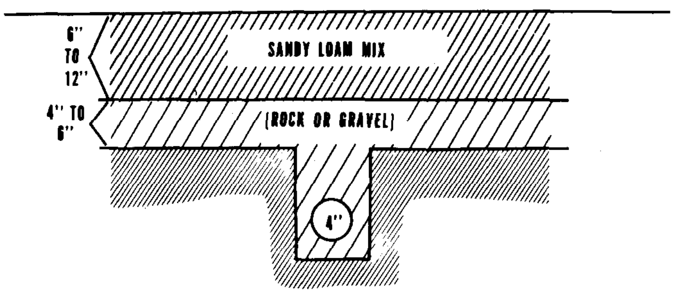
Figure 3



CLAY OR CLAY LOAM PARENT SOIL

In some cases, this type of construction was further modified by mixing the soil and sand off-site, then laying it on top of a blanket of rock and tile lines. Some of these greens proved to be very good, but again it was more by chance than by design since the mixes varied and the rock blanket in itself did not guarantee drainage. (See Figure 4.)

Figure 4



Tile drainage lines placed below this type of green have seldom made any improvement unless a water table came close to the surface due to impervious soil layers in the parent soil below.

U.S.G.A. Green Section Method

The extremes in success and failure in various modifications of soils for greens led the United States Golf Association to support extensive research to develop a complete method of green construction that would give a high-quality, predictable green. The first step in establishing the U.S.G.A. method was to field test many of the good greens, which had mainly been constructed by trial and error.

Extensive laboratory research resulted in the setting up of the U.S.G.A. method of green construction and of the laboratory methods for testing the surface mix. To use the method to get the right mix for a given green, it is necessary to send a small sample of your parent soil, sand, and organic matter you wanted to use to a U.S.G.A. designated laboratory. The laboratory would return to you the ratio of sand to soil to organic matter that would give you the best mix based on their laboratory testing procedure.

This surface mix must be placed 12 to 14 inches deep over a 2-inch special coarse sand, which, in turn, overlaid a 4-inch layer of crushed rock. Tile lines, 10 to 20 feet on centers and 4 inches in diameter, were placed under the rock blanket in trenches dug into the parent soil. The finished green then had a subsurface that was the same contour and slope as the finished surface.

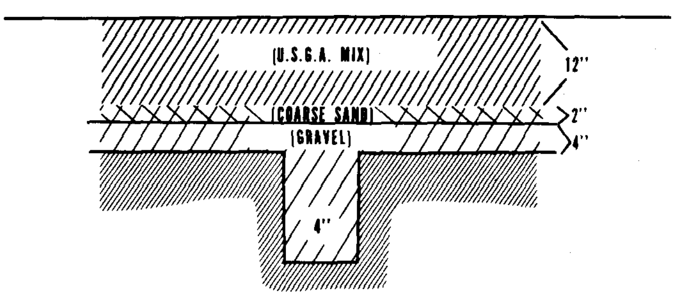
We had now put both science and art to work and many successful U.S.G.A. greens have been constructed in the past 15 to 20 years.

A poor U.S.G.A. green in many cases can be attributed to failure to adhere to:

- the complete method of construction;
- proper mixing of the sand, "soil," and organic matter; quality control of the "sand" and "soil";
- the specific laboratory ratio of sand, "soil," and organic matter; or
- good management.

NO matter how good the system, it can soon be wrecked by a nonprofessional. Basically, the U.S.G.A. surface mix is still a sandy loam or loamy sand and can be compacted, requiring more frequent aeration under conditions of high traffic. Its specifications are exact. (See Figure 5.)

Figure 5

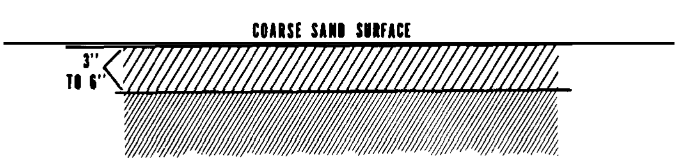


Refinements in the U.S.G.A. specification for putting green construction have been recently published and should be carefully read and studied.

The Coarse Sand Method

In the mid-50's, the great golf course boom got under way. From 1950 to 1960, over 300 courses were built in

Figure 6

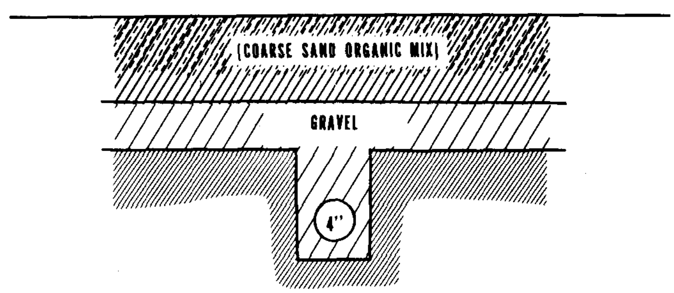


California. Problems with soggy greens, compacted surfaces, use of lower quality irrigation water, year-round play, high traffic, and high construction costs helped bring about the use of coarse sand for green construction. The green was formed from the on-site soil and a 3- to 6-inch surface of coarse sand was laid down. The sand usually came from the nearest sand and gravel company and, at best was a washed fine plaster sand; at its poorest, it was a concrete sand. (See Figure 6.)

In some cases, 2 to 4 inches of organic matter were laid on the sand surface and rototilled in, but many greens were established unamended. Tile lines were sometimes installed during construction, but many were put in later. The resulting surface mix was droughty and the subsurface soil was always saturated. Greens were easy to construct and easy to bring into play, but failures were excessive.

Some of these greens were improved by the addition of 30 to 50 percent organic matter, which improved the resiliency, reduced droughtiness, and improved the nutrient-holding capacity. Also, the depth of the surface mix was increased and a gravel blanket plus tile lines were added. Nevertheless, some of these greens were still failures because of the improper mixing of the organic matter. On the other hand, some of the greens are excellent, but on the same course with so-called identical construction, the 18 greens could range from excellent to complete disaster. (See Figure 7.)

Figure 7

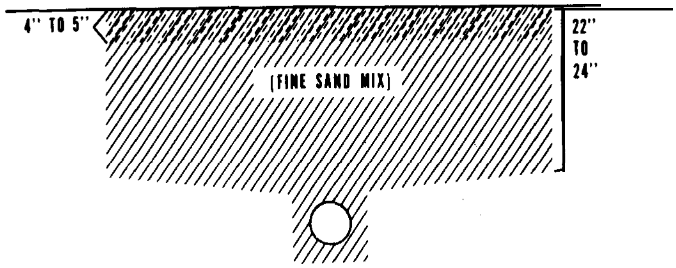


The Fine Sand Green

In the early 60's, the University of California at Los Angeles began research that involved a fine sand greens mix with a narrower range of particle distribution in the finer fractions. This entailed mixing 85 to 90 percent of the finest prescribed sand with a well-aggregated clay and 5 to 7. percent peat. The fine sand was placed 20 to 22 inches deep, directly over a tile system, and only the surface 4 to 5 inches were amended with the aggregated clay and peat.

Some excellent greens were constructed in southern California by this method, but they were costly due to depth and mixing costs. The recommendation called for a sand that had a particle size of 50 percent or more smaller than 0.4 mm; 25 percent or more smaller than 0.25 mm; and less than 10 percent smaller than 0.10 mm. Greens constructed by this methods were predictable;

Figure 8

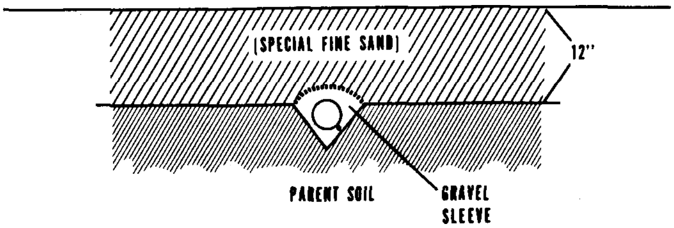


they drained well and rapidly, and once again there was a wedding of art and science. (See Figure 8.)

Work using the finer, narrow size sand particles has continued at the University of California at Davis. Basically, the sands used are fill sands, with 60 percent or more of the sand in the medium classification range of 0.50 to 0.25 mm. Many suitable sand deposits have been located and tested. These sands, unamended, are placed 12 inches deep with a simplified tile system beneath.

Several such greens have been constructed in the San Francisco Bay Area. Although the construction method and suitable sands are still being field tested, information to date indicates that the construction method is relatively inexpensive, drainage is excellent, and playability is very good. The greens are predictable and able to withstand high use, but they may be faulted by some superintendents because they have a low basic exchange, which require more nutritional management, a probIem not difficult to solve. (See Figure 9.)

Figure 9



What does this review of golf greens add up to?

1. Most greens mixes are 75 to 95 percent sand, with the particle size ranging from 2.0 mm to 0.05 mm.
2. Since sand is the most important component of a greens mix, it is essential to increase our knowledge and understanding the different sands available and how the range and size of sand particles affect the physical characteristics of the greens mix.
3. Amending a sand to improve its physical and/or chemical properties so it will give a good greens mix may be more difficult to achieve than using a sand that may need little or no amending.
4. If compromises are unavoidable, have we explored all the possible alternatives to come up with the best choice? Do we understand what changes in management techniques may be necessary to make a secondary choice work?
5. Under the conditions of use and management capabilities, what are the limits of compromise?

EXAMPLES OF REAL SOLUTIONS-THE FINE SAND GREEN*

By William B. Davis

Here is the word, this is the way . . . follow me, I have the answer. This is a questionable approach for an educator, consultant, or applied researcher unless he has the responsibility and authoritv for making the final decisions. However, when it comes to the construction of a new green, the authority and responsibility lie with the greens committee and the superintendent-primarily with the superintendent if he has done his homework. The outside consultant, the pro turned “golf course architect,” the club members, and the boys from the University may all play a role, but they are not the dicision makers. As a superintendent, you must justify costs, secure materials, supervise construction, manage the green, and live with your successes or failures. Therefore, to get the best for your club, you must know what your alternatives are and how to evaluate them.

The preceding paper reviews many of the common methods used to construct greens on California golf courses. The purpose of this paper is to give an in-depth review of the fine sand or fill sand green, which we have been studying for the past 3 to 4 years.

*From: Proceedings 1973 California Golf Course Superintendents Institute, 71-79.

JUST WHAT IS A FINE SAND GREEN?

In simple terms, the fine sand green is 12 inches of a specific, uniform grade sand placed on the pre-formed parent soil green area. It may or may not have a tile system, depending on the drainage characteristics of the parent soil.

The key to the success of this green is the narrow distribution range of the sand particle sizes-the primary type of sand is essentially non-compactible since it lacks a range of different particle sizes and contains very little silt and clay. The dominant particle size is small enough fraction being a medium sand (0.50 to 0.25 mm). This so that it has a relatively flat moisture-release curve when placed 12 inches deep and retains 1.25 to 1.50 inches of water in the surface 4 inches after gravitational drainage. Since the particle sizes are very uniform, so are the voids between the particles, thus allowing excess water to drain rapidly.

Table 1 gives the suggested distribution range of particle sizes for the type of sand needed to meet the specifications required for a suitable fine sand green. The primary sand fraction (medium sand) should be 60 percent or more of the range. However, 0 to 10 percent is allow-

TABLE 1

U. S. SIEVE SERIES AND TYLER EQUIVALENTS

Sieve Designation

Standard (New U.S. Nos.)	Alternate (Old U.S. Series)	Sieve Opening	U.S.D.A. Description	Range *
mm	inches	inches		
13.5	.530	0.530		
12.7	1/2	0.500		
11.2	7/16	0.438		
9.51	3/8	0.375		
8.00	5/16	0.312	GRAVEL	
6.35	1/4	0.250		
6.73	3 1/2 number	0.223		
4.76	4	0.187		0%
4.00	2	0.157		
3.36	6	0.132		
2.83	7	0.111	FINE GRAVEL	
2.38	8	0.0937		
2.00	10	0.0787		
1.68	12	0.0661		
1.41	14	0.0555	VERY	0-10%
1.19	16	0.0469	COARSE SAND	
1.00	18	0.0394		
0.841	20	0.0331		
0.707	25	0.0278		
0.595	30	0.0234	COARSE SAND	
0.500	35	0.0197		
0.420	40	0.0165		
0.354	45	0.0139		
0.297	50	0.0117	MEDIUM SAND	60%+ 8595%
0.250	60	0.0098		
0.210	70	0.0083		
0.177	80	0.0070		
0.149	100	0.0059	FINE SAND	
0.125	120	0.0049		
0.105	140	0.0041		
0.088	170	0.0035		a
0.074	200	0.0029	VERY	
0.063	230	0.0025	FINE SAND	
0.053	270	0.0021		
0.044	325	0.0017		2-8%
0.037	400	0.0015	SILT & CLAY	

* Suggested ranges for high trafficked turfgrass areas

able in the very coarse to fine gravel range, although these coarser sand particles do not work well in a putting surface when used as a topdressing. In the very fine sand. a silt and clay range of only 2 to 8 percent is suggested. Sand to meet these specifications can be screened and washed from sand deposits throughout the state. but there are some natural deposits in existence that can be used as found.

Where natural deposits are available, the cost is lower. Table II lists some of these natural deposit sands, and several have been used in the construction of greens, football fields, and other high-trafficked turf areas. Note that, if the secondary sand fractions are mostly fine to very fine, very small percentage of silt and clay can be tolerated. If the second fractions of the sand move in the direction of a coarse sand, more silt and clay are acceptable.

If you have a sand of which all is in the primary fraction (medium sand), the green would then have an infiltration rate of 65 inches per hour. When subject to excessive compaction by a kneading compactor, it would still

TABLE II

EXCELLENT UNIFORM SANDS

SOURCE	Fine Gravel	Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Salt	Clay	
Dillon Beach Sand Marin County	0.0	0.3	2.3	68.3	24.6	0.9	0.8	2.8	95.2
Antioch Fill Sand Alameda County	0.0	0.1	1.0	71.6	21.7	1.2	1.6	2.8	93.3
Guadalupe Sand Santa Barbara Cty.	0.0	0.0	0.9	76.6	17.9	0.2	0.0	4.4	95.4
Monterey Sand Monterey County	0.0	0.1	7.2	73.6	15.4	0.6	0.9	2.2	96.2
Filler Sand Placer County	0.9	0.4	5.2	60.3	26.9	2.9	2.3	1.1	92.4
Wind Blown Sand Santa Maria Cty.	0.0	0.0	1.8	82.3	11.3	0.0	0.5	3.6	94.4

GOOD UNIFORM SANDS

SOURCE	Fine Gravel	Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Salt	Clay	
			(Fine)						
Alturas Modoc County	0.0	0.0	0.2	7.4	82.2	5.7	1.8	1.0	89.2
			(Intermediate)						
Santa Cruz #1 Fine Santa Cruz County	0.4	2.1	14.1	63.8	16.0	1.2	1.0	1.4	93.9
Rio Vista Asta Contra Costa Cty.	0.5	1.7	10.1	53.3	29.9	0.2	2.7	1.6	93.3
Coloma Sand San Mateo County	0.9	0.3	17.5	52.9	23.0	0.8	1.3	2.0	93.4
Lappis #10 Monterey County	0.0	0.0	19.2	75.3	4.1	0.0	0.7	0.7	98.3
			(Coarse)						
Santa Cruz 1050 Santa Cruz County	0.0	0.9	32.9	59.8	4.3	0.1	0.4	1.6	96.0
Marina Sand Monterey County	0.5	3.3	51.6	31.0	10.0	0.4	0.2	3.0	92.6
Sand City Dunes Monterey County	0.0	0.1	47.6	45.0	5.0	0.1	0.0	2.2	97.6

be 64 inches per hour since the sand is essentially non-compactible. The pore spaces of the sand need to be uniformly small enough to hold water, but of a size that allows excess water to drain rapidly.

What About Nutrition?

We usually think of sands as being pure quartz or nearly so, but most of the sands in California do have a percentage of secondary minerals. A laboratory test usually shows them to be lacking in any basic or cation exchange, but, when tested in the greenhouse, they are not as deficient as the laboratory test would lead us to believe. For example —

Without nitrogen, none of the 40 sands tested would produce a bentgrass plant beyond the point of germination.

Most sand showed some degree of phosphorus deficiency, as measured against maximum yield.

About one-half the sands showed a deficiency of potassium.

Most sands showed some sulfur deficiency, and several were so deficient that grass would not survive beyond the seedling stage.

Only two sands showed any significant increase in yield when a combination micronutrient additive was supplied.

In field tests on greens, park sites, and football fields where several fine sands have been used, ammonium sulfate $[NH_4(SO_4)_2$ a one has produced excellent turf over an 18 month period. Certainly a pre-plant treatment of phosphorus and potassium would be recommended. With present day technology, nutrition is no more of a problem than it is on any other green. In fact, the real problem lies in getting the turf manager to supply the right amount of nitrogen during the establishment period of the grass.

High amounts of soluble nitrogen, if applied pre-plant, are soon leached and are therefore not recommended. If solubles are used, applications should be frequent and light for the first 4 to 6 months (1/2 pound nitrogen per 1,000 square feet every 10 days to 2 weeks). There are several excellent slow-release and/or coated fertilizers presently available that, when correctly used, do an excellent job.

The experimental green at Davis has been maintained for nearly 3 years using 12 pounds of nitrogen per year. Nutrition is not a problem on a fine sand green-unless you choose to make it so.

What About a Drainage System?

If a water table will be created at the interface between the surface greens mix and the parent soil, a tile system should be placed so as to remove this excess water. If 1 inch of drainable water from a surface mix with a high drainage rate comes in contact with a parent soil that takes water at only 0.1 inch per hour, excess water will form a water table at the interface and will remain there for several hours. This water table could cause the entire surface mix to retain too much water for the best growth of the grass plants. As you know, water runs downhill, and the water table, with no tile system could come to the surface of the green at the lowest point, which is usually the front. On the other hand, if the parent soil takes water at 1/4 to 1/2 inch an hour, a tile system may not be necessary if heavy rain and excessive jrrigation are not a problem.

A rock blanket 2 to 6 inches deep does not make the surface mix drain more rapidly nor does it increase the amount of water that will be removed from the overlying surface sand or special mix. In the case of the U.S.G.A. greens construction method, the rock and/or sized coarse sand is designed to make sure the surface mix retains more water than it might otherwise.

In the construction of a fine sand green, we have found that there is no advantage to having a rock, gravel, or coarse sand blanket. A simple trench with a minimum of pea gravel surrounding the tile functions as well and as fast in removing excess water below the surface fine sand as any other system tried.

It is important that a tile system be closely spaced at the front or low point of the green (10-foot centers). However, there is some question as to whether any water enters the upper tile line (back one-third of the green) where there is a uniform slope from the front to the back of the green. (This problem is currently being studied.) If the tile lines are spaced too far apart, the slower lateral movement of the water could create a mounded water table between the tile lines, which could saturate the fine sand to the surface for a long period of time.

The cost of construction of any green involves a number of factors. We can assume the cost of forming the parent soil for a green is the same, irrespective of the tile system or mix. Unless we can demonstrate the need and function for special gravel blankets-wide trenches with expensive tile covering the entire green-considerable money can be saved.

Since sand is the primary ingredient of any green surface its cost is important. Most fine sands are no more costly than coarse non-uniform sand and, in many cases, are relatively cheap at their source. But it is the on-site delivery price per ton that is your real cost, and hauling from some distance increases the price. In the case of a fine sand, the delivery price of the sand is your total cost of the mix.

Although plaster and other types of sand, which may be located closer to you, can usually be delivered on-site at a lower cost, this is not the cost of your mix. Most coarser sands must be amended with 20 to 50 percent organic mater to improve their physical characteristics. Amendments have a price and proper mixing requires considerable labor and/or specialized equipment. Therefore, it is not the price of sand that must be determined, but the cost of the mix in place.

If it were not for the concentrated traffic on our golf greens, the best growing medium for grass might well be a sandy loam to clay soil. However, these soils are highly compactible when moist to wet and so require a high cost, skillful management program to keep them in good condition for the golfers. Regardless of budget and the skill of the superintendent, they will still be unplayable if there is a good rain just before or during a tournament. Such is not the case with a fine sand green, when properly installed and managed. But, alas, the fine sand green is just another method, although it may be the best and/or most economical green for your course.

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