greens are built with the same soil and have been managed similarly in the past, most often the putting green located among the trees will show problems.

If trees cause a green to be difficult to maintain, root prune the trees by digging a trench two-and-a-half feet deep around the perimeter of the greens. Trenching between the green and the surrounding trees will sever the invasive tree roots, and allow the turf to absorb water and nutrients without competition. After reviewing the irrigation system layout, the trench should be established as close to the greens as possible. Then thin out and prune the surrounding trees to improve air circulation and sunlight penetration. As a guideline, continue to prune and remove trees until the problem green receives the same amount of sunlight as greens located in open areas.

After these important steps have been taken, it's time to wait. If the trees were indeed the primary problem source, some improvement should be noted during the next several weeks or months. If the green does not show signs of recovery, then other problems need to be addressed, and reconstruction may have to be considered.

Putting Green Contours — In the race to achieve faster putting green speeds, the slopes on many older greens are becoming unplayable. Not only do severe slopes frustrate the average player, but they also limit the number of good hole locations available on each green. Concentrating the hole locations in the same areas over an extended period of time inevitably leads to a thin turf canopy and soil compaction.

The alternatives for dealing with severely sloped greens are very much limited. One choice would be to reduce the speed of the greens to allow for more hole locations. The other would be to restrict the number of rounds so the few available hole locations would not suffer excessive compaction and wear injury. If these solutions are impossible or unacceptable to the golfers, then it is probably time to approach a golf course architect and construct a larger green with a less severe slope.

Membership Demographics — There is no doubt that the passion for golf is growing throughout the country. The result is that some golf courses designed for 15,000 to 20,000 rounds annually are now entertaining from 70,000 to 120,000 rounds. Despite great advances in equipment technology and significantly greater understanding of the principles of turfgrass science, discrepancies such as this are more than can be dealt with. In such instances, rebuilding greens may be the best solution.

If all your detective work reveals that reconstruction is necessary, it would be wise to employ a golf course architect. He can be given the task of preserving the architectural theme of the original design, and he can be held responsible for the finished product. Furthermore, the architect can provide accurate blueprints to work from during construction, and he can help ensure a successful renovation program.

The USGA Specifications for Putting Green Construction are certainly not the only construction specifications available, but they do have a successful record in all geographic locations. These specifications are the result of years of scientific investigation and field experience, and are highly recommended. Simply mixing sand and soil together based on intuitive feel often leads to disastrous results.

In summary, deciding whether or not to rebuild problem greens can be a very complex business. Each case must be considered individually, and all the potential causes of failure must be given due consideration. This includes studying what makes each course unique by looking at soil and water test reports, surrounding vegetation, putting green contours, and membership demographics. After this information has been carefully evaluated, it might well be the right time to approach the Board of Directors with a greens reconstruction proposal. Sometimes successful agronomy means starting over.

Putting Green Construction: Interpreting Physical Soil Test Data

by JAMES M. LATHAM
Director, Great Lakes Region, USGA Green Section

THE LABORATORY procedures followed for establishing the physical characteristics of mixtures used in putting green construction haven't changed much since the USGA Green Section Specifications were introduced some 30 years ago. The specific recommendations based on the results, however, have evolved through the years to correspond to continuing research and experiences in the field. The agronomic success of greens built with mixtures of sand and peat, with little or no soil, has led not only to a critical evaluation of all the types of components, but also to the laboratory data the mixtures are based on.

In earlier days, when soil was considered to be a mandatory part of topmixes, concrete-grade sand was used to create resistance to compaction and to furnish large, non-capillary pores for drainage. Greens built with concrete sand during the late 1950s and early 1960s, however, were hard, because of the gravel content, and they required more time to mature than many people thought necessary. To compensate for the hardness, many superintendents used softer topdressing materials, which often turned out to be incompatible with the gravely topmix.

The evolution of component specifications began in the early 1970s, and favored greater sand uniformity and a trend to medium-sized, round particles. Articles published by Madison[1] and Spomer[2] furthered the movement to near soil-less greens and topdressing. Some researchers promoted the use of fine and very fine sands in topmixes, but experiences in the field have not supported this.

The upshot of these evolutionary advances is the present set of specifications

Determining sand particle size range is one part of a complete soil analysis.

(Table 1), which should be with us for some time. The changes since the last publication appear to be small, but their application in future construction will result in better playing conditions and a prolonged life expectancy for the greens. Shortcuts in construction or failure to follow laboratory recommendations will significantly increase the potential for failure.

Data produced by a laboratory physical analysis of test mixtures tell a great deal about the construction components and their future performance. Laboratory reports include sieve test results on the sands, showing the percentages of different size particles and how well they fit the basic recommendations.

Organic components are also tested to expose the amount of mineral matter present, since some apparently good peats can contain surprisingly high percentages of silt, clay, and very fine sand, which can be detrimental to a green's long-term performance. These very small particles can migrate downward with the flow of drainage water, and eventually accumulate at some point in the profile to the degree that drainage will be restricted or blocked.

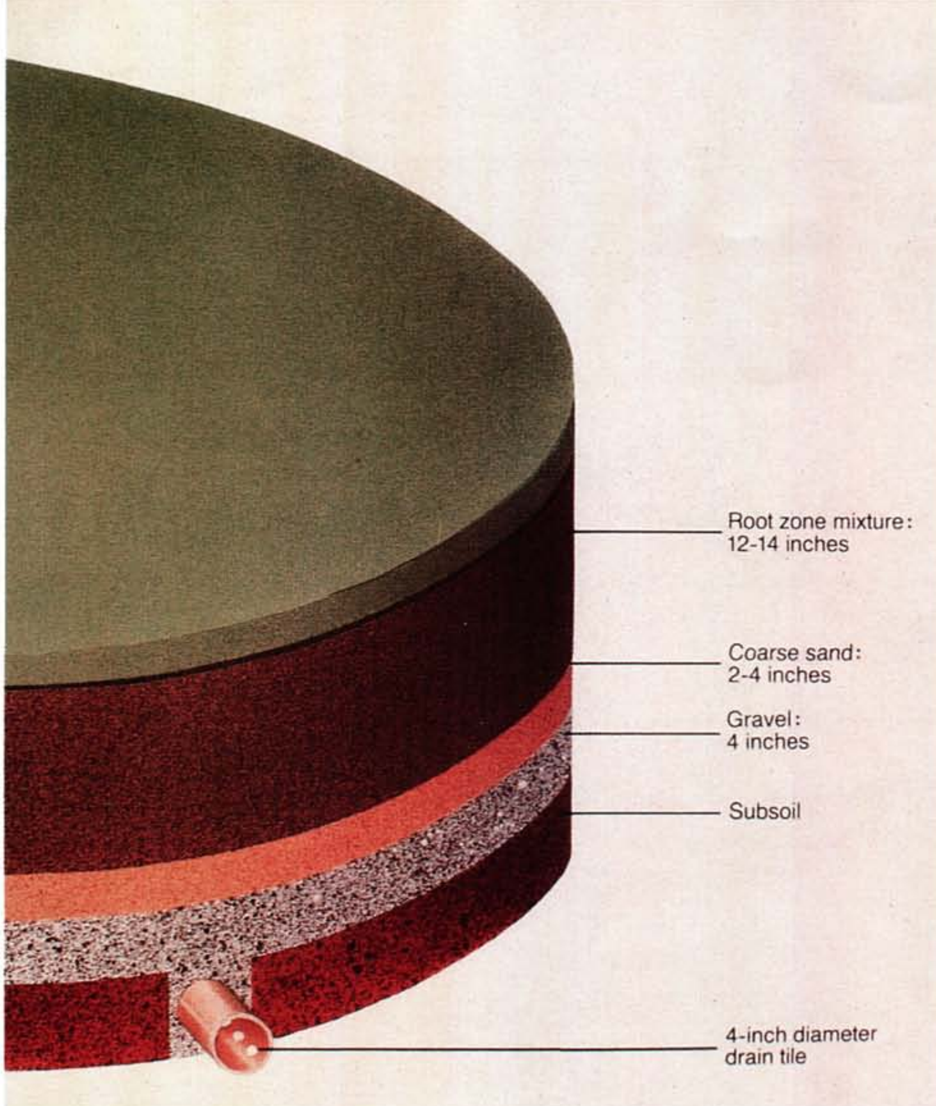
Physical performance data are developed from specific tests on trial mixtures of components that are submitted to the laboratory.

The data collected correspond to several factors considered to be essential to the performance of putting green turf. Among these factors is **porosity** (pore space), the volume of empty space in a dry sample. The recommended total pore space now ranges from 35% to 50%, up from the 33% in earlier publications. The amount of that space that retains water against the pull of gravity is called **capillary pore space**, and the water that drains freely is called **non-capillary pore space**. These numbers vary with the quantity and the quality of the various components.

The current specifications call for 12% to 18% capillary pores (down from 15% to 21%) and a minimum of 15% non-capillary pores, compared to the earlier 12% to 18%. These changes may seem minor, but they can greatly influence the drainage capability of the profile and the oxygen supply for the turfgrass roots in the years to come. They reflect a concern for the status of the root systems of turfgrasses subjected to extreme traffic and environmental stresses.

Table 2 compares a recommended mixture composed of concrete sand, a sandy loam soil, and a peat (7-2-1), circa 1958, with a recent mixture consisting of medium sand and peat (85-0-15). Note that the bulk densities and porosities are not very far apart.

The difference in non-capillary pore space is only 4%, but there is a tenfold difference in permeability. It is interesting to note that the low permeability of the 1958 sample was acceptable at the time, since the rates were set relative to the permeability of good-quality soil greens of that era.



Profile of a green built to USGA Specifications.

TABLE 1

Summary of Acceptable Physical Analysis Data for Root Zone Mixtures in "USGA Greens"

Characteristic	*Range*
Porosity (Pore Space)	
Total	35% to 50% (by volume)
Capillary	15% to 25%
Non-Capillary	15% to 25%
Water Retention	12% to 18% (by weight)
Bulk Density	1.25 to 1.45 g/cc (ideal)
Permeability (H_2O infiltration)	A lab decision
Sand Particle Size Ranges	
> 2mm	None
0.25mm to 0.75mm	Maximum 100% (optimal)
0.10mm to 0.25mm	Minimum
< 0.10mm*	Maximum 10%
Silt	Maximum 5%
Clay	Maximum 3%

*In some cases, particles < 0.25mm should be limited to 10%

The influence of peat selection is illustrated in Table 3.

The reed-sedge peat produces more capillary pores and greater water retention than the sphagnum peat when mixed with the same sand. Sphagnum, on the other hand, produces more non-capillary pores and a much higher permeability. (The data apply only to these particular samples, and do not necessarily reflect test results using other sources of peat or sand.)

The only factor in the current recommendations for which an accepted value range is not set is **permeability**. Experience has shown that this factor may have exerted undue influence on recommendations in the past, because the water infiltration data generated in the laboratory is usually much higher than that of mature greens in play. In addition, permeability needs can vary from location to location. For example, the use of saline irrigation water requires better drainage capability for leaching purposes than where higher quality water is available. Greater permeability is also desirable in high-rainfall areas and/or where heat stress is a major concern. Greens located in milder or drier climates may not need such high infiltration rates. An experienced laboratory may well set its own parameters, based on the grass species to be used and specific knowledge of the region involved.

Water retention is the percentage by weight of water in the compacted test sample at field capacity (held against gravity) compared to an oven-dried sample. (Porosity, on the other hand, is a measure of volume.) This value is considered to be a measure of the amount of water available for plant use after drainage by gravity and before wilt becomes permanent. It should be between 12% and 18%.

Laboratory analysis also includes a report on **bulk density**. It is the weight of a specific volume of the mixtures, reported in grams per cubic centimeter. The acceptable range is from 1.20 to 1.60 grams per cubic centimeter, which is broader than before.

To summarize, the parameters used to evaluate mixtures for putting green construction have changed as our understanding of the performance of topmixes has grown. In turn, better *playing* and *staying* quality has been achieved in greens constructed by those who have followed USGA Specifications to the letter.

When testing components for putting green construction, it is very important

TABLE 2

The Relationship of Components to Topmix Permeability

	Sample 1 (1958)	Sample 2 (1988)
% Sand-Soil-Peat	70-20-10	85-0-15
Bulk Density	1.49 g/cc	1.41 g/cc
Total Pore Space	39%	44%
Capillary	18%	19%
Non-Capillary	21%	25%
Permeability	1.4 in./hr.	14 in./hr.

TABLE 3

Differences in Physical Characteristics Between Mixtures Using Different Peat Sources with the Same Sand*

Characteristics	Sphagnum	Reed-Sedge
Bulk Density	1.39 g/cc	1.40 g/cc
Total Porosity	42%	41%
Capillary	23%	28%
Non-Capillary	19%	13%
Water Retention	17%	20%
Permeability	17 in./hr.	5 in./hr.
Compression Factor (shrinkage)	9%	18%

*Data courtesy Agri-Systems of Texas

to provide the laboratory with as much up-front information as possible. The decision by the laboratory to recommend a particular mixture over another may hinge upon such factors as anticipated play, unusual local conditions, quirky weather, irrigation water sources, and other concerns. The physical ayalysis of a mixture to be used in green construction should not be just a sterile compilation of numbers. Rather, it should be part of a dialogue with the laboratory director that results in a clear understanding of all of the factors that influence the outcome of such a major undertaking. And don't forget, there is no such thing as a dumb question when it comes to building greens the right way.

References

[1]Madison, John H., J. L. Paul and W. B. Davis. 1974. Consider — A New Management Program for Greens. USGA Green Section Record. 12(3): 16-18.

[2]Spomer, L. Art. 1977. Principles of Soil Preparation for Drained Golf Greens. USGA Green Section Record. 15(4): 9-12.

Editor's Note: A copy of the recently published (1989) version of the USGA's Specifications for a Method of Putting Green Construction can be purchased through the United States Golf Association, P.O. Box 708, Far Hills, NJ 07931-0708.

New Zealand . . . The Grass Capital

by **DR. JEFFREY V. KRANS**
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DURING a six-month period in 1989 I had the opportunity to study turfgrass science and tissue culture technology in New Zealand. I was granted a sabbatical leave from my present position at Mississippi State University, and I worked at the Division of Scientific and Industrial Research (DSIR), Grasslands, in Palmerston North, New Zealand. The trip was supported in part by the USGA, and included laboratory research as well as on-site visits to golf courses, sports fields, and general-use turf areas. In my study and research I collaborated with Peter Evans, an agronomist, and Derek White, a molecular geneticist.

Research work dealt with the development of protocol for the *in vitro* manipulation of colonial bentgrass (brown top) *Agrostis tenuis*. The on-site visits to turf areas were arranged by David Howard, an agronomist with the New Zealand Turf Culture Institute, who also accompanied me on many of these visits.

New Zealand consists of two islands located in the South Pacific Ocean approximately 1,200 miles southeast of Australia. Its land mass is comparable to that of Montana, and it has a climate similar to coastal Washington and Oregon. If you went to Cairo, Illinois, and dug a deep enough hole, it would eventually come out in the center of New Zealand. Because it is in the southern hemisphere, its seasons are the opposite of ours.

With a population of about three million people, New Zealand has a low population density, which makes the country pleasing and unspoiled. Visitors are overpowered by another statistic that adds to New Zealand's flavor and appeal — it is home to over 65 million sheep. As this figure implies, the country's economy is based heavily on agriculture. In addition to its sheep and low population density, New Zealand possesses some of the most beautiful landscapes and scenic countryside in the world.

Of special interest to me was New Zealand's ability to grow grass. This alone was one of the most impressive parts of my six-month study. For example, at the turfgrass research plots in Palmerston North, perennial ryegrass (a cool-season species) and bermudagrass (a warm-season species) were maintained side by side as perennial