Root zone sand survey

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Summary: The objective this study was to determine the range of soil particle sizes found in golf course greens from Southern California and to gain a greater understanding of the nature of Southern California root zone sands.

A particle size distribution measure (PS) was developed to help characterize root zone sands. The PS value provides a single number that describes the range of particle sizes that comprise the root zone sand. A large PS (>1.2) indicates a higher composition of medium sand particles that is desirable. A small PS (<0.6) indicates a higher composition of smaller particles that is undesirable. The PS value was found to be significantly correlated with a number of other soil factors including organic matter content, percolation rate, bulk density, phosphorous, calcium, magnesium, potassium sodium, boron, iron, copper and interestingly, the age of the green. All of the significant correlations with the chemical composition and age of the soil were negative. A negative correlation means a large PS value sand will hold lower levels of nutrients. This relationship is expected and it is well known that higher sand content soils hold less nutrients than finer textured soils. The relationship between PS and age of the greens suggests that the greens are constructed using high sand content materials but the root zone degrades into lower quality finer soils after years of use and management. The reduction in PS may result from decomposition of the materials or addition of fine particles during management or from contaminants in irrigation water.

Based upon these results, some preliminary values have been identified to help understand the aging of greens in Southern California. For example, the correlations suggest that the initial percolation rate of materials used to construct Southern California greens is about 20 inches per hour. The initial PS value for new greens is about 1.6. Several other critical age points were

also estimated using the PS model. For example, accelerated percolation rates, greater than 12 inches per hour, are desired in the intensively irrigated Southern California region. Based upon the PS and age relationship, a green may drop from the initial 20 inches per hour to 12 inches per hour in about 13 years. The critical low limit of 6 inches per hour percolation rate minimum for a USGA specification green will be reached in 23 years and an unacceptable percolation rate of 2 inches per hour will be attained in 30 years. These values suggest that after about 13 years of use, the root zone sand will no longer percolate adequately to satisfy the needs of golf play in Southern California.

The percolation rate information above does not take into consideration infiltration or drainage problems that will greatly influence green performance. Infiltration and drainage will require separate study. The PS values and extrapolated years to reconstruction presented here are used to help superintendents understand the physical changes that take place in the root zone as a green ages. In the future, the PS value may be used to help identify management practices that halt or reverse the drop in PS that normally occurs during the life of a Southern California golf course green.

Background: The physical characteristics of a golf course green root zone sand is determined by the size and shape of the sand particles used to construct the green, the age of the green, and the materials that have been added to the green to improve its physical characteristics or performance. Although the USGA has developed criteria for selecting sands for new construction, we do not have a method of easily evaluating the quality of sands from existing greens and how to manage greens of various sand compositions.

The USGA root zone sand specifications describe the general parameters for a good performing root zone mixture. Those criteria are: Not more than 10% of particles in the very coarse sand and fine gravel categories (retained on 1 and 2 mm sieves). At least 60% of the particles in the coarse sand and medium sand categories (retained on the 0.25 and 0.50 mm sieves). Not more than 20% of the particles fall into the fine sand category (retained on the 0.15 mm sieve), not more than 5% in each of the very fine sand, silt, and clay categories and not more than 10% total for these categories.

In addition, total porosity should be between 30% and 50%. Air-filled porosity should be between 15% and 30% , capillary porosity between 15% and 25% and saturated conductivity of water should be accelerated for our region at 12-24 inches per hour. Organic matter should be between 1% and 5% (for more information see USGA Green Section Record, March/April 1993).

The above parameters are known to produce a good root zone material for golf course greens that are constructed to meet the other USGA specifications. However, these specifications do not help evaluate greens already in use. In this study, a new method of comparing root zone mixtures that are already in the ground was developed to help gain insight into management based upon the root zone physical composition. This is the first step in developing a better understanding of Southern California golf course green physical composition.

Materials and Methods: Two green soil samples were submitted from each of 9 golf courses. Each soil was analyzed for physical composition by sieving. In addition, a full chemical analysis was carried out on the soil in attempt to find correlations between soil physical characteristics and chemical composition. All physical and chemical analyses were conducted by Brookside Laboratories, New Knoxville, Ohio. The parameters measured included: age of the green, area of the green (sq ft), number of rounds, variety of turfgrass, number of aerations per year, % sand, % silt, % clay, Organic matter at 440 C, particulate retention on 2.00, 1.00, 0.50, 0.25, 0.15, 0.106 and 0.053 mm sieves, total exchange capacity calculated by summation, pH, OM by ashing, sulfur, easily extractable phosphorous, Bray II phosphorous estimate by Melich III, calcium, magnesium, potassium, sodium, % calcium, % magnesium, % potassium, % sodium, % other cations, % hydrogen, boron, iron, manganese, copper, zinc, aluminum, and electrical conductivity. All elements were reported in parts per million (ppm). All statistical analyses were carried out using Systat for Windows, Version 5.0.2, SPSS Inc. Chicago, IL.

Full USGA sand analyses data for 32 additional samples were provided by PACE Consulting. These data represented sands from new constructions and from existing greens. USGA sand analysis was conducted by Brookside Laboratories, Turf Diagnostics & Design, Olathe, KA, Agri-Systems of Texas, Tomball, TX, N.W. Hummel & Co., Trumansburg, NY, or Thomas Turf Services, Inc., College Station, TX. In most cases, data included % clay, % silt, % sand, organic matter, percent retained on 2.0, 1.0, 0.5, 0.25, 0.15, 0.106, and 0.053 mm sieves, percolation rate, % moisture retention, % capillary , % non-capillary, and total pore space, bulk density and particle density.

Particle size distribution (PS) is defined as the slope of the regression line fit to the following relationship where **mm** is the sieve size and **cumulative %** is the cumulative percent of particles retained on each of the 0.15, 0.25, 0.5 and 1.0 mm sieves, ***a*** is the slope of the regression line and ***b*** is the intercept.

$$\ln(mm) = a \times \ln\left(\frac{1}{1-\frac{cumulative\%}{100}}\right) + b$$

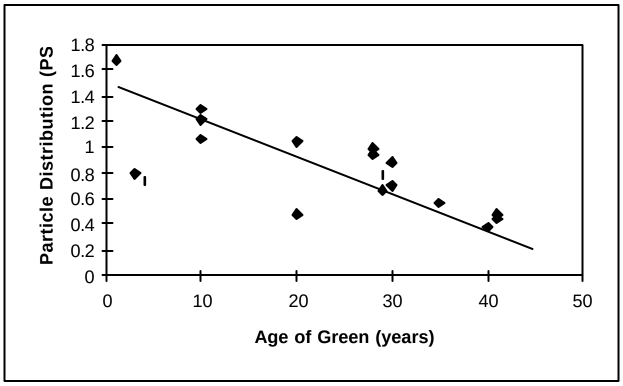
Results and Discussion:
Computation of PS values for the survey sands and the full USGA analysis sands demonstrated a regression coefficients (R^2) greater than 0.96 and the probability that the regression line was due to chance always less than 0.05, or 5%. Two additional sands, #20 and #30 sands that both have very narrow particle size distributions were evaluated with the full USGA sand analyses samples. Neither of these two sands provided significant correlations using the PS transformation equations.

Both of these sands have greater than 90% of the particles captured by either the 0.25 or 0.5 mm sieves. The #20 and #30 sands are widely used in topdressing programs in Southern California.

In order to evaluate the relationship between PS and each of the chemical and physical parameters, a method called regression or correlation analysis was used (Table 1 and Table 2). This process is the statistical equivalent of plotting the values on a graph and then determining whether the relationship is significant or if the relationship is simply due to chance.

For example, Figure 1 illustrates the interaction between the age of a green and the new parameter that describes particle size distribution (PS). A high PS value, approaching 1.6, indicates that the sand may have a good particle size distribution. In the example below, Figure 1, the young green with the PS value of 1.47 meets USGA specification. The negative slope (-28) indicates that the PS values drop when greens age. The slope of the line is a measure of the strength of the interaction. In this example, the slope of the line is -28 and indicates that it takes about 28 years to drop the PS value by a factor of 1. Further research will be needed to determine the value for PS which results in a difficult to manage green, what management factors might be needed for greens that have lower PS values, and if the PS value can be increased by intensive deep tine aeration and backfilling using a high PS value sand.

Figure 1. Relationship between age of a green and the particle size distribution. The probability that the regression line is due to chance is less than one in 1,000 ($P<0.001$).



Development of the proposed PS value followed numerous attempts to remove curvature in the percent particle size distribution results. More common methods were implemented but the model chosen provided the best fit lines. For example, Figure 2 illustrates the relationship between sieve size the cumulative percent of particles that are retained on each sieve. The problem with relationships that curve when plotted is that the slope is always changing. Figure 3, on the other hand, illustrates the results of transforming the data using a mathematical equation to yield a straight line. Straight lines provide many advantages. The example using the age of the green and the PS value illustrated in Figure 1 is a demonstration of how this information might be applied.

Table 1. Sand survey data results. Significant correlations between PS and soil chemical factors. Statistically significant correlations must have a probability that the interaction is due to chance of less than 5% or 0.05. The lower the probability due to chance, the more likely the relationship correctly describes the interaction between PS and the parameter. Y = (a x PS) + b

Parameter (Y)	Slope (a)	Intercept (b)	Regression Coefficient (R)	Probability the interaction is due to chance
Age	-28.0	46.2	0.71	0.000
Sand %	27.5	59.8	0.88	0.000
0.50 mm sieve %	13.8	14.4	0.91	0.000
0.25 mm sieve %	15.1	14.9	0.71	0.001
Silt %	-25.1	35.3	0.87	0.000
Clay %	-2.4	4.9	0.70	0.001
OM 440 C	-3.0	5.2	0.74	0.000
N-release from OM	-27.6	51.8	0.58	0.012
Bray II Phosphorous	-69.4	144.1	0.57	0.013
Calcium (ppm)	-1123.1	2346.9	0.50	0.036
Magnesium (ppm)	-100.5	238.6	0.57	0.014
Potassium (ppm)	-85.6	220.1	0.51	0.014
TEC (meq/100g)	-7.4	16.9	0.48	0.045
Sodium (ppm)	-92.8	189.9	0.68	0.002
Boron (ppm)	-0.6	1.4	0.75	0.000
Iron (ppm)	-252.8	461.5	0.60	0.008
Copper (ppm)	-10.8	15.2	0.58	0.011

Table 2. Full USGA sand analysis results for additional samples provided by PACE Consulting. Significant correlations between PS and soil physical factors. Statistically significant correlations must have a probability that the interaction is due to chance of less than 5% or 0.05. The lower the probability due to chance, the more likely the relationship correctly describes the interaction between PS and the parameter. Y = (a x PS) + b

Parameter (Y)	Slope (a)	Intercept (b)	Regression Coefficient (R)	Probability the interaction is due to chance
Percolation rate (in)	16.3	-7.5	0.66	0.000
2.00 mm sieve %	-4.6	7.4	0.48	0.005
0.50 mm sieve %	13.5	13.4	0.54	0.001
0.25 mm sieve %	23.5	8.3	0.74	0.000
0.106 mm sieve %	-3.6	7.07	0.41	0.027
Sand %	15.5	77.1	0.75	0.000
Silt %	-12.2	17.6	0.68	0.000
Clay %	-3.3	5.3	.55	0.001
OM 440 C	-1.1	3.6	0.46	0.012
Bulk density (g/cm^3)	0.14	1.3	0.36	0.045

Figure 2. Sieve size and cumulative percentage of particles that are retained on sieves. Curves that do not reach 100% indicate that some particles were smaller than the smallest sieve. The lower curve indicates a large proportion of silt and clay particles passed through the small sieve. The upper curve is a USGA specification sand.

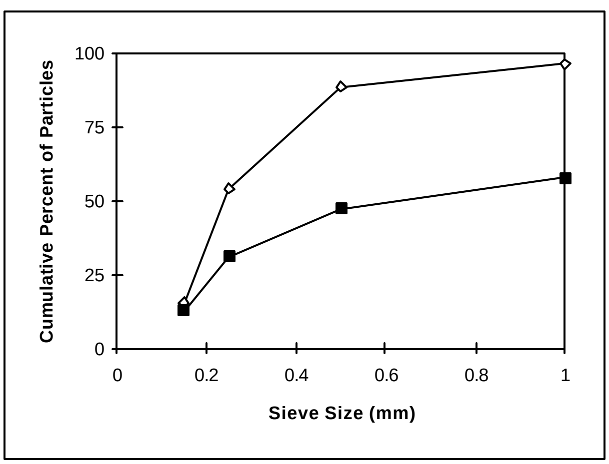
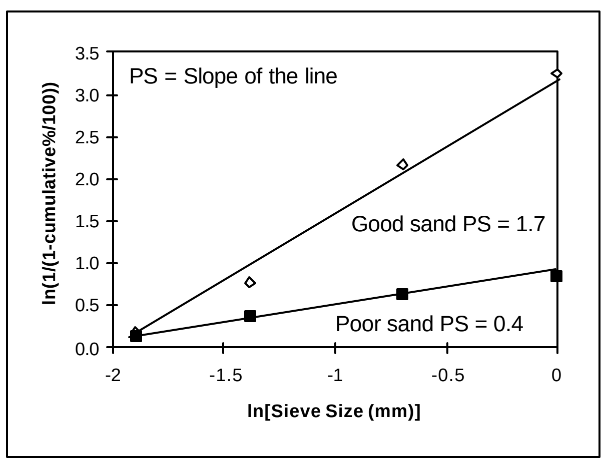


Figure 3. Mathematically "transformed" data that is presented in Figure 2. The advantage of developing linear models is that a slope and intercept defines the entire interaction between sieve size and cumulative percent of particles retained. When the intercepts are similar, as shown below, only the slope of the lines are needed for investigative purposes.



Regression analysis was also used to determine if there were any relationships between the PS value for each sand and the corresponding chemical parameters. Table 1 reports the results of the significant correlations. Some of the more interesting correlations included sodium levels and PS values. In this case, sodium was strongly negatively correlated with PS. If the PS value is high, approaching USGA specifications (about 1.5) the sodium level tended to be low. If the PS value was low, non-USGA specification, the sodium levels were higher. There is an estimated increase of about 90 ppm sodium for a drop in PS value of 1.

Sand %, percent particles retained on the 0.25 and 0.5 mm sieves and bulk density were the only parameters that was positively correlated with PS. The positive correlation with sand % and the negative correlations between silt % and clay % were expected. The positive correlation between bulk density and PS was unexpected and is possibly related to the decrease in organic matter that is observed when the PS value increases. All of the remaining parameters were negatively correlated. When the PS values drop as the green ages, many nutritional factors and organic matter accumulate in the root zone sand. One of the strongest interactions among the minor elements is iron where we see an increase of about 250 ppm when the PS level drops by a factor of one. Although some of these results may appear obvious, the PS relationship provides a mechanism for evaluating management practices that reverse or slow the negative decline in soil quality that is observed as golf course greens age.

Uncertainty: There is currently a great deal of uncertainty in the potential for use of a model as described above. One important factor is the good correlation between PS and age of the green. Upon further investigation, the age of the greens were also found to be strongly correlated with the some of the factors listed below. Does the PS value represent aging of sands and decomposition of sands into smaller particles or were the older greens constructed with sands that had lower PS values initially? Correlations alone should be used with caution and they do not necessarily describe a cause and effect relationship. Additional study will help determine if the proposed PS model is meaningful in practical terms. For example, if the PS value drops below 0.5, will the green need to be aerated more aggressively than a green with a PS value of 1.0?

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