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Selecting Bunker Sands: Between a Rock and a Hard Place?

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Bottom line: Selecting a bunker sand sometimes seems like a no-win situation. This is partly because some of the features that must be taken into account -- such as color or playability – are a matter of opinion, and cannot be determined using technical data. And for those features such as particle size and particle shape that can be evaluated objectively using lab data, the science isn't exact enough to allow us to predict bunker sand performance, and particularly firmness, based solely on the data. Based on previously generated summaries, as well as ongoing research at the PACE Turfgrass Research Institute, we have developed a procedure that can help you to narrow down your choices to several technically suitable sands. These sands can then be evaluated by your golfers to obtain the subjective, yet absolutely critical, information that will allow you to select a bunker sand that gets you out from between a rock and a hard place by meeting golfer preferences as well as your maintenance needs.

What features does the ideal bunker sand possess? If golf course maintenance was your only priority, most superintendents would come up with a similar list: a good draining sand that is compatible with USGA specifications for putting green root zone mixes, that doesn't require excessive raking, that is firm enough to provide a stable footing, and that is dark enough in color to mask small accumulations of organic matter and algae. However, when it comes to golfers, the situation gets much more complex. This is because different golfers have different preferences – some prefer light colored sand because it is pleasing to the eye, while others prefer tan or light brown sands because of the reduced reflection and glare (Figure 1). Some golfers prefer extremely firm sands, while others prefer slightly softer sands that permit the ball to sink about half way down.

Figure 1. Range in appearance of six different bunker sands. Top row, left to right: August white (ground marble, or calcium carbonate); Gail; PWG. Bottom row, left to right: Sand collected from a bunker that has been in play; Caltega VII; pure, sieved 0.25mm silica sand.

In this issue of *PACE Insights,* we will focus on one feature of bunker sand – it's firmness – that is one of the most difficult characteristics to measure and to predict. Given the large array of technical and personal preferences involved, the process of selecting a bunker sand that meets everyone's needs can be challenging. But not impossible, as you will see.

The role of particle size in performance

The size of bunker sand particles can range anywhere from the very small (0.002 millimeters [mm] diameter) grains of clay and silt that contribute to crust formation, to the very large (greater than 2 mm) particles of gravel that can contribute to mower damage, poor putting quality and slow play. In between these extremes lies a range, or distribution, of different sand particle sizes (Table 1). The quantity of each different size class, and their proportion to one another has a very important effect on bunker performance -- playing quality, crust formation, firmness of footing, ball lie, and drainage. In addition, because some bunker sand inevitably ends up on putting greens, bunker sand particles must be compatible with putting green root zone mixes. This means that the particles must be small enough to penetrate the turf, but not so small (or fine) that they interfere with putting green drainage. This complex set of requirements is summarized in Table 1 below.

The role of particle shape in performance

A bunker sand with the ideal particle size distribution may still result in bunkers that are too soft or too hard. This is because of the important role that sand particle shape plays in bunker sand performance.

Sand particle shape is generally broken down into two different measurements. **Angularity** refers to how sharp the edges and corners of each sand particle are. For example, a sand classified as "very angular" has many sharp and well-defined edges, while a sand classified as "rounded" has very few sharp edges. **Sphericity** refers to the actual particle shape, with measurements that range from "high sphericity" (a round, ball shaped particle) to "low sphericity" (an elongated particle). Particles of sand that are classified as angular and low in sphericity will lock together more firmly. For this reason, angular sands do not move as easily when impacted by foot traffic or golf balls, thus resulting in firmer bunkers, fewer buried balls, and less movement of sand off the bunker face.

If this is the case, why doesn't everyone use high angularity, low sphericity bunker sands? First of all, it is possible for a bunker to be too firm to please golfers. Secondly, and even more importantly, not all sand types are available in a given region at a given time. For this reason, our choices are limited by the sands offered by the local supplier.

Predicting bunker sand performance: a case study from Los Angeles Country Club

We recently had the opportunity to delve into the issue of bunker sand performance with the assistance of Bruce Williams, CGCS, of the Los Angeles Country Club (LACC). The golf course has two 18-hole courses, with bunkers at both courses constructed with bunker sand that met the particle size recommendations in Table 1. Yet on one golf course (the North Course), golfers complained that the bunkers were too soft, while at the other course (the South Course), golfers were satisfied with bunker performance.

With bunkers at both courses maintained identically, it became possible to isolate the differences between the bunkers at each course, and therefore to better understand the factors contributing to bunker sand performance. An ideal experimental set-up!

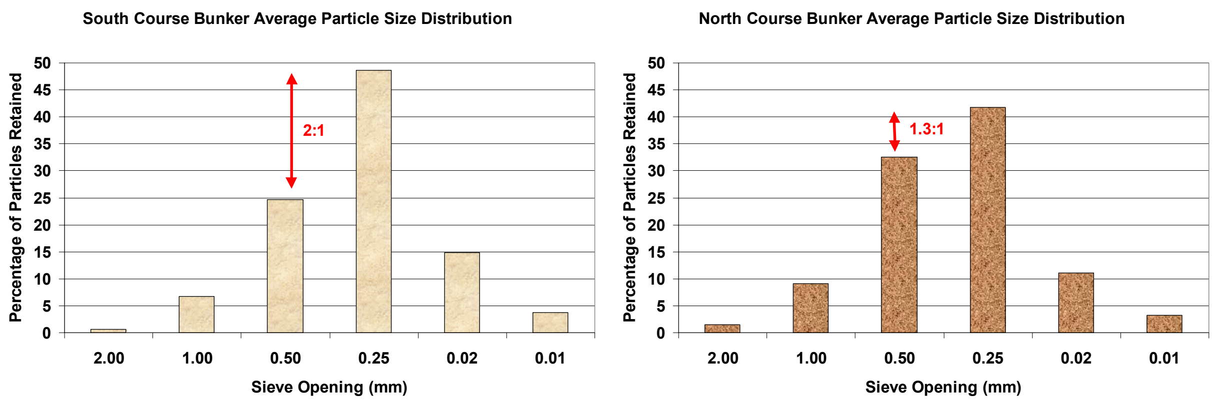
When the sands from both courses were analyzed for particle size distribution and particle shape, we found that most features were similar (Table 1) and that both sands met the current particle size guidelines. The one feature that distinguished the good performing bunkers was a large ratio (greater than two to one) of medium sand (0.25 mm) to coarse sand (0.5 mm). In other words, the good performing bunkers had twice as many 0.25 mm particles as 0.5 mm particles (Figure 2) (a 2 to 1 ratio), while the poor performing bunkers had only 1.3 times as many 0.25 mm particles as 0.5 mm particles (a 1.3 to 1 ratio).

Based on this information, there appears to be some value in listing the percentages of medium and coarse sand particles separately, rather than combining them, as is currently practiced. A separate listing would allow us to calculate the ratio between medium and coarse particles by dividing the percentage of medium particles by the percentage of coarse particles.

Table 1. Bunker sand case study, Los Angeles Country Club. Bruce Williams, superintendent. The ratio between 0.25 mm (medium) and 0.50 mm (coarse) particle size percentages listed in red has been proposed to insure firm sand. Percent values in for the North and South bunkers followed by the same letter are not significantly different (LSD, P<0.10). Values printed in **red type** are proposed for use with rounded sands, based on PTRI preliminary data.

		USGA Recommendations		LACC	LACC
Sand Fraction	**Particle size retained on sieve**	**Root Zone Mix**	**Bunker Sand**	**North Course: poor bunkers**	**South Course: good bunkers**
Gravel	2.0 mm	<3%	<3%	1.5% a	0.5% b
Very-coarse	1.0 mm	<10% (gravel + very coarse)	<7%	9.1% a	6.7% a
Coarse	0.50 mm	>60%	>65%	32.5% a	24.7% b
Medium	0.25 mm			41.8% a	48.6% b
Medium to coarse ratio			**≥2 : 1**	**1.3 : 1**	**2.0 : 1**
Fine	0.15 mm	<20%	<25%	11.1% a	14.9% a
Very-fine	0.05 mm	<5%		3.2% a	3.8% a
Silt	0.002 mm	<5%	<3%		
Clay	<0.002 mm	<3%			
Sphericity				Medium	Medium
Angularity				Angular	Angular

Figure 2. Bunker sand case study, Los Angeles Country Club. The data presented in Table 1 is graphed here. Each graph represents the average values obtained when sand from 3 separate bunkers from either the South Course (left graph) or the North Course (right graph) was analyzed. Note the large ratio of 0.25 mm to 0.5 mm particles in the South course (there were twice as many 0.25 mm particles), which was judged to be a good performing bunker by golfers. Particle size distribution for the poor performing North course bunker sand shows a smaller difference (1.3 times as many 0.25 mm particles) between the percentage of 0.25 mm and 0.5 mm particles.



The importance of the 2 : 1 ratio

To evaluate the theory that the ratio of medium to coarse particles was the primary cause of firmness of the LACC bunker sand, a simple experiment was designed. Twelve different sand mixtures were prepared by blending medium (0.25 mm) and coarse (0.5 mm) sand particles together in the ratios listed below. Seven of the 12 mixtures were composed of sand that was rated "angular" and "medium sphericity" (A + MS), the same as the LACC bunker sands. The remaining 5 mixtures were composed of a much more angular sand that was rated "very angular" and "low sphericity" (VA + LS)

medium sand	coarse sand	Medium to coarse ratio	Sand shapes tested
0	400	0 : 100	A+MS, VA+LS
200	200	1 : 1	A+MS, VA+LS
300	100	3 : 1	A+MS, VA+LS
350	50	7 : 1	A+MS, VA+LS
375	25	15 : 1	A+MS
387.5	12.5	31 : 1	A+MS
400	0	100 : 0	A+MS, VA+LS

Each of the 12 mixtures listed above was then evaluated for firmness using the penetrometer method described below. The results are illustrated in Figure 3 . This data suggests that for sands that are on the rounded side, striving for greater than a 2 : 1 ratio of medium to coarse sand particles may help insure firmer bunkers. However, when sands are very angular and non-spherical in shape, bunkers will be very firm – regardless of the proportion of medium and coarse sands. In this case, striving for a 2 : 1 ratio is unimportant. From these results, we can therefore conclude that there is no one combination of features that defines a "perfect" bunker sand. Instead, the interaction between particle size distribution and particle shape can produce many different winning combinations.

Going beyond the case study

Can the conclusions drawn from the LACC case study be applied to other golf courses? At this point, we don't have enough data to answer these questions, but we are continuing to look at the question and will keep you updated. In addition, the USGA is conducting research towards developing better ways to measure and select bunker sands. Until then, your selection process will necessarily rely on a variety of parameters, as outlined below.

Making the final decision

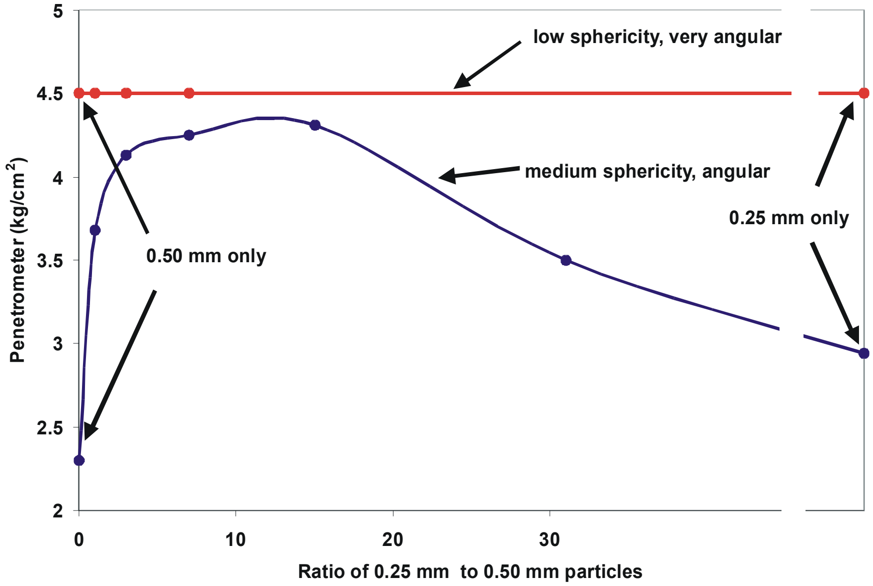
Selecting a bunker sand will always rely on both objective (technical) data, as well as subjective input from golfers. To deal with this, many superintendents have adopted a two-stage decision making process that relies on a technical assessment to narrow down the number of candidate sands to roughly three choices, followed by golfer evaluation of the selected sands.

You can carry out initial technical evaluations yourself, using methods such as the penetrometer test described below. However, you'll want to confirm any technical testing you do with a final assessment from a certified A2LA laboratory. A listing of accredited labs can be obtained from the website: http://www.usga.org/green/coned/greens/physical_soil_testing.html. Recommendations for optimum particle size, shape, chemical composition and other features are outlined in the references that appear at the end of this article.

To gain the highest quality input from golfers, they should ideally be able to play at nearby courses where the top three sands that you've selected are in play.

However, if that's not possible, you may want to consider renovating a few existing bunkers with the candidate sands to allow members to experience each before arriving at a decision.

Figure 3. Penetrometer readings on relatively rounded sand (blue line) and angular sand (red line). The results indicate that for more rounded sands, a ratio of greater than 2 : 1 for medium to coarse sand particles will result in significantly firmer bunkers with penetrometer readings of greater than 3.5 kg/cm^2. However, the results for angular sand were quite different. In this case, all five sand mixtures were extremely firm, with penetrometer readings of 4.5 kg/cm^2 (the highest reading possible on the penetrometer).



Determining bunker sand firmness on site

We have modified a method developed by Thomas Turf Services so that you can conduct your own tests for bunker sands for firmness. This test can help you narrow down the number of samples that you submit to an analytical lab for further testing. Because our method is a modified version of the procedure used in analytical labs, the values you obtain may not correspond exactly to those you would obtain from a professional lab. However, you can be assured that the firmest bunkers will result from the highest penetrometer readings, whichever method is used.

To conduct your own tests, you will need: 1) a pocket penetrometer (catalogue number 221565) available for approximately $60 from Ben Meadows Co. (phone 800-241-6401); 2) a golf ball; and 3) a 705 ml (3 cup) Rubbermaid container.

To make your very own bunker sand pocket penetrometer, drill a hole into the golf ball that is about ¼" in depth and about the same width as the penetrometer. Once you insert the penetrometer into the golf ball, you are ready to begin testing.

1. Fill the Rubbermaid container to the protruding lip near the top, with the sand that is to be tested. Tamp the filled container firmly onto a hard surface ten times to settle the sand.
2. Holding the penetrometer by the handle, use a firm and even pressure to press the ball until half of the ball is buried in the sand.
3. Record the penetrometer reading (kilograms per square centimeter [kg/cm^2]) that appears below the black ring.
4. Repeat steps 1 – 3, three times for each sand. To obtain a final penetrometer value for each sand, average the three values.

References

J.F. Moore. How to select the best sand for your bunkers. Green Section Record, Jan – Feb, 1998.

J.C. Thomas. Grains of truth: selecting sand for greens and bunkers. Golf Course Management, July, 1997.