Dr Stephen Baker looks at the work that is being carried out to ensure you choose the most suitable sand for your bunkers

True

A frequent source of debate within golf clubs concerns the performance of bunker sands. Regular complaints about bunker sands include excessive crusting, soft and fluffy lies, excessive plugging of the ball on impact and unstable footing. Undoubtedly, some of these comments are influenced by the way in which the sand was installed and its subsequent maintenance. However, the physical composition of the sand also has major effects on the performance of golf bunkers. The objective of this article is to review research studies that have looked in detail on the effects of sand type within bunkers, particularly on playing performance.

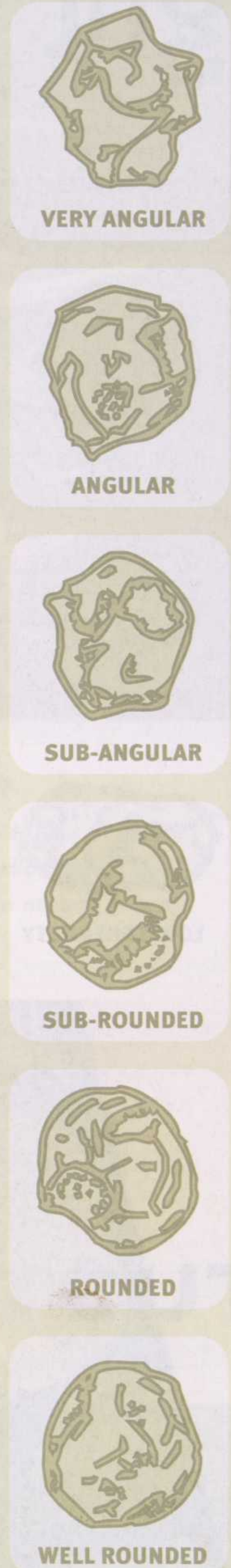
Apart from playing characteristics, many issues need to be taken into account when choosing sands for bunkers. The sand should be free draining and in particular contamination with silt and clay may reduce drainage rates. High silt and clay contents may also contribute to the development of a surface crust following rainfall and subsequent drying. As a guideline, sands with more than 2% silt and clay should be avoided.

Windblow

Windblow is an important consideration. On links courses, most of the local sands used within bunkers fall in the size range of 0.1-0.35 mm diameter. This may be appropriate for the generally deeper and narrow bunkers typical of a links course but this would be a potential disaster on

grit

CLASSIFICATION OF SAND GRAIN SHAPE



many inland courses. The fine sands on links courses are usually a product of transportation by wind before stabilisation by vegetation. Therefore, their use on more open bunkers, particularly on exposed inland courses, would be a recipe for disaster.

In selecting a bunker sand, it must always be remembered that golfers are liable to blast sand out of bunkers while playing from the hazard. If the sand contains a lot of coarse material, greater than about 1.5 mm, this is liable to remain on the surface where it can interfere with putting and may also damage mowers. The localised accumulation of considerable quantities of excessively coarse sand splashed from a bunker may also make the turf more drought susceptible. Similarly, on inland courses, the lime content of the sand is important. If the sand contains appreciable amounts of lime (eg. as shell fragments), this may accelerate the invasion of annual meadow-grass and broad-leafed weeds, encourage earthworm activity and on newer, sand-dominated greens make the turf more susceptible to take-all patch disease.

Sands can stack at different angles. When moisture is present, a sand can easily be raked up and remain against a very steep bunker face. Fine sands retain moisture more readily and they can maintain a steeper angle for longer periods than coarse grained sands, which can quickly dry out. Dry sands have a maximum slope, known as the angle of repose, above which they will not be stable. If the sand has a higher angle of repose, it remains against bunker faces more easily and thus less maintenance is needed.

Colour

The colour of bunker sands can have a major visual impact on a golf course. In general, light coloured sands are preferred (tan, white or occasionally light grey). Light reflection and glare can sometimes be a problem with white sands, although perhaps less so with the British climate than in other parts of the world!

There have been three main studies in which the playing performance of bunker sands has been examined. The first was carried out by Brown and Thomas of the Texas Agricultural Experiment Station and the Texas A&M University and was reported in 1986. The second was a study at the Sports Turf Research Institute reported in 1994. While the most recent was from the now defunct Australian Turfgrass Research Institute that was initially reported in 1994 but which lead to a Bunker Sand Specification for Australian Golf Courses, which was published in conjunction with the Australian Golf Union in 1995.

The Texas study, carried out with the assistance of USGA agronomists, examined 42 sands from all over the United States including materials that were reported to perform well and others that performed very poorly. The size and the shape of the grains were assessed and related to a number of physical properties.

The development of a crust on the sand surface detracts from its quality and this was examined by saturating samples of the sand by sprinkling with tap water, then drying for 24-48 hours until the sand was dry. Crust development was evaluated by sliding a spatula under the sand and lifting it up. Problems of crust development were greatest on sands containing more than 3% silt plus clay.

Penetration

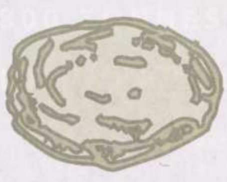
Ball penetration was evaluated by placing a golf ball on the surface of the sand and pressing it into the surface to half the depth of the ball. The force required was recorded using a penetrometer. Angular sands generally required greater pressure to force the ball into the sand and were most resistant to the so-called "fried egg lies", whereby the ball becomes deeply embedded with the sand after impact. Sands with ball penetration values less than 0.18 MPa were particularly susceptible to excessive ball penetration, while sands with values exceeding 0.24 MPa were preferred.

Our study at the STRI extended these principles to assess golf ball impact, surface stability for footing and the angle of repose of bunker sands. For each of the 23 sands studied, we assessed the average grain size, the uniformity of the particle size distribution, the angularity and sphericity of the grains, initial mois-

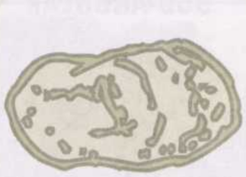
True grit

VARIATIONS IN GRAIN SPHERICITY

HIGH SPHERICITY



MEDIUM SPHERICITY



LOW SPHERICITY

ture content and the packing density of the sands after compaction.

We measured golf ball impact by firing balls using a modified bowling machine into sand prepared under a variety of conditions. The machine had two independently rotating wheels that allowed us to simulate various conditions of ball velocity, backspin and approach angle. For the eventual tests we used an angle of 710, a velocity of 19 in/sec and a backspin of 597 radians/sec. This is equivalent roughly to the impact of an eight iron shot landing on a horizontal surface, although with slightly less backspin than would be achieved by the best players.

Plugging depth (ie the distance between the bottom of the ball and the original sand surface) averaged 31 mm on dry sand, 20 mm on wet unraked sand and 30 mm on wet raked sand. There was a tremendous variation between sands and, for example, on the dry sand, plugging depth varied from 21 mm (approximately half the diameter of a golf ball) to 44 mm, in which case the entire ball was below the surface. For the wet, raked sands the difference was even greater (9-37 mm) because on a number of sands the ball bounced out of the initial impact mark and simply rested elsewhere on the surface.

We examined relationships between plugging depth and sand characteristics and found that plugging depth increased with coarser sands and those with a more uniform spread of particles. Stability of footing was measured as penetration resistance, i.e. the force required to push a 28.7 mm diameter probe into the surface. For dry conditions, results between sands varied by a factor of two and, for wet conditions, there was a fourfold difference in readings. The more unstable sands were those with a very uniform size distribution that lead to a low packing density. Sands with more spherical grains were also more unstable.

We also measured the maximum angle of dry sand. This ranged from 29.50 to 35.60. Rounded sands typically had values around 310 and sub angular sands had values averaging about 340.

This work enabled us to publish guidelines on the selection of bunker sands in my book "Sands for Sports Turf Construction and Maintenance." The preferred particle size distribution for inland golf courses is given in Table 1. Because of possible stability problems, it was also recommended that there should be no more than 60% of particles in the rounded and well-rounded shape categories. Similarly, sands with a very uniform grain size distribution are probably best avoided, especially if there is a high proportion of material above 0.5 mm diameter or the content of rounded grains is high. In case of problems with sand splash, it was also recommended that lime content for bunker sands on inland courses should not exceed 0.5%.

The Australian studies confirmed many of our findings; in particular that the depth of plugging was dependent on the uniformity of sand grains and that the angle of repose was dependent on grain shape. They also found that the angle of repose was higher in bunker sands with increased clay content and the development of a surface crust was influenced by packing density and the presence of more angular grains. On the basis of their results and those of the previous studies, they were able to publish a specification for bunker sands and this is reproduced in Table 2.

The three studies have shown that it is possible to characterise the performance of sands for bunkers to give practical guidelines on how well different sands might perform. However, there have been reported cases of sands being accepted as excellent by members at one golf club while the same sand is considered poor on other courses. This may simply be a result of the fickleness of the golfer, but clearly further work is needed to improve our understanding of the effects of installation methods, sand depth and maintenance.

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Table 1

Recommended particle size distribution for bunker sands on inland golf courses

Sieve size (mm)	*% passed*
8.0	100
4.0	100
2.0	100
1.0	90-100
0.50	35-90
0.25	0-40
0.125	0-2
0.063	0-1

Table 2

Bunker sand specification for Australian Golf Courses

Criteria under test	*Recommended value*
Particle size distribution	Inland courses 0.2mm to 1.0mm Coastal courses 0.1mm to 1.0mm
Particle shape	Angular
Surface crusting	Less than 1.0kg/cm2
Angle of Repose	Greater than 300
Material composition	Silica
Ball Plugging	Greater than 2.5kg/cm2
Hydraulic conductivity	Greater than 25cm/hr
Colour	Light without glare