NICKLAUS DESIGN

GOLF DATA

SOIL STABILIZATION • DUST CONTROL • EROSION CONTROL

SOIL & DUST SOLUTIONS

Case Study and Observations of the integration Of Bunkertac and Hydrotac on Golf Course bunkers for stabilisation, hydro-seeding, erosion control and prevention of sand contamination using different application rates and methods

November 2007-December 2007
January 2008-April 2008

This report was compiled by
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Contents

Nicklaus Design

Nicklaus Design, long associated with superior golf course design and the industry leader, once again has demonstrated their ingenuity and ability to consistently improve and advance new techniques of course design. Nicklaus Design recognized that the traditional methods of stabilisation and hydro seeding could be improved through the use of environmentally safe and technologically advanced products, Bunkertac and Hydrotac and thus became the first designer to investigate, encourage and support a case study using these highly advanced and newly developed products for bunker lining, hydro seeding, erosion control and sand contamination prevention.

Golf Data

Golf Data is a premier force in the South African golf, construction and services industry and is the construction partner of Nicklaus Design in South Africa. Golf Data is dedicated to providing hands on service combined with the innovated use of modern technology. As Golf Data continually strives to raise the standards of all aspects of golf course construction and maintenance they were eager to participate in these case studies, which stand to revolutionize the methodology of golf course construction, in terms of cost effectiveness, environmental footprint, and maintenance.

Soil & Dust Solutions

Soil & Dust Solutions (Pty) Limited and Soil Solutions Limited are the authorized and exclusive distributors for Bunkertac and Hydrotac, throughout Africa and a number of countries in Europe and the Middle East. From Mine haul roads to golf course bunkers, Soil & Dust Solutions has earned a reputation for providing engineered solutions specifically designed to meet the clients needs, and as a *on the spot* solutions provider.

The coming together of Nicklaus Design, Golf Data and Soil & Dust Solutions, all of whom are innovative leaders in their industries proved to be the perfect combination of expertise to conduct the on site case studies using Bunkertac and Hydrotac for the stabilisation and hydro seeding of bunkers.

We extend our special thanks to Nicklaus Design for affording us the opportunity to prove the performance levels and capability of Bunkertac and Hydrotac on the Serengeti Golf Estate Development in Johannesburg, South Africa, as well as to Sean Quinn, as without their cooperation, on site assistance and willingness to experiment with various mix designs and methods, the extensive information and results which were documented would not have been possible.

We also would like to specifically thank Andrew Mills of Golf Data whose support and continual assistance during the testing period was greatly appreciated.

In addition we would like to thank Dave McIntosh of Turfgrass Consulting, a professional agronomist for his expert advice and assistance, which proved to be invaluable in the development of the case studies.

Introduction

Bunkertac and Hydrotac can be used in a number of applications on any golf course development which include:

- Bunker lining
- Sand Contamination Prevention
- Wetting and Compaction of Bunker Sand
- Erosion control
- Hydro seeding
- Dust control
- Base stabilisation for cart paths, parking lots, roads, access roads
- Helipads
- Airstrips

Bunkertac and Hydrotac are completely environmentally friendly, safe for animals, wildlife and vegetation. As the products dry clear and transparent, they leave the environment in its natural state.

Bunkertac and Hydrotac offer a number of advantages, which include:

- A significant reduction in the amount of water required
- A reduction (or elimination) of the need for harmful chemicals in the hydro seeding process
- A reduction in the number of times hydro-seeding applications must be applied

As a result the use of Bunkertac and Hydrotac will significantly decrease the environmental footprint of golf course developments, while at the same time allowing for superior treatment of several areas and significant cost reductions.

At the request of Nicklaus Design, Soil & Dust Solutions (working with Andrew Mills of Golf Data), specifically developed various processes, mix designs, and methods for the most effective application of Bunkertac for bunker stabilisation and Hydrotac for hydro seeding in order to yield optimal results. These methods take into account the factors of the locality and soil type of the course as well as the various factors and requirements of Golf Course bunkers and their design. Working together with Golf Data a number of different application rates and mix design were utilized in order to determine the most effective use of Bunkertac for stabilisation and Hydrotac for hydro seeding which meet the strict requirements of Nicklaus Design for bunkers.

Tests

A number of specific tests were conducted on the Serengeti Golf Course development in Johannesburg, South Africa for the application of Bunkertac and Hydrotac for:

- Hydro seeding
- Bunker lining and stabilization
- Erosion control
- Stabilisation of vertical faces and various edge designs

This report outlines the different observations, application rates, and process and methods implemented and the respective results. The various weather conditions, site conditions and soil properties, which were prevailing at the time of application and after have also been documented.

It is important to note that Bunkertac has been proven and well documented in terms of its superior performance as a soil stabilizer.

The applications which are being outlined and tested in this report are specialized in terms of stabilisation, as it is not only focusing on stabilising the internal bunker lining, but also:

- **stabilising specially designed "rough edges" of the bunkers which will maintain their design and shape against normal playing conditions, weather, maintenance, etc.**
- **Stabilizing an internal sand layer against (and covering) the soil, which remains permanently in order to create the important aesthetics feature of the bunker being completely filled with sand up to the top edge. The challenge being the vertical angles at which the sand needs to be "permanently in place" ....which defies gravity.**
- **With reference to Serengeti specifically, the in-situ soil is clay, the most difficult soil type to work.**

These specific objectives are outside the typical applications and uses of Bunkertac, which is why a number of different trial sections were conducted in order to develop the best method to obtain results for the specific requirements of golf courses.

As all golf course bunkers are different in terms of style; edges; slopes; in-situ soil; and are affected by different weather and watering patterns, the information contained herein is a general guideline as to the product application rates and methods to be used. The different mixes and rates used will demonstrate the different results and can then be adapted to meet the specific objectives and soil on other curses. In terms of a general application specification we have developed one for bunker stabilisation and hydro seeding which can be found at the end of the report.

Soil & Dust Solutions recommended application rates and methods of application with the objective of yielding the most effective mix designs while simultaneously streamlining the application process, the results of which are documented in this Report.

For a video of the product applications, please contact us tel: +27 11 460-0981 info@soilanddust.com

Objectives of the Trials:

The properties of Bunkertac and Hydrotac allow them to be effective for a wide variety of applications. The objective of conducting numerous tests was to develop a successful, standardized (and proven) process for hydro seeding and bunker lining and stabilization.

We tested different methodologies in order to develop a set standardized method of application procedures, the specific performance objectives of the various tests and application methods conducted included:

1. The introduction and discussion of the properties and application methods and equipment that would be used for bunker preparation and treatment using Bunkertac for stabilisation of the base and edges of bunkers.

2. Demonstrate that the performance level of Bunkertac as a soil stabiliser will meet the requirements of a flexible bound surface with a high load bearing and shear strength capacity while allowing for drainage; prevent distortion and disfiguration of the bunker's shape; prevent contamination of the sand contained in the bunker and most importantly reduce initial application, repair and maintenance costs.

3. Utilizing the performance characteristics and advantages of Hydrotac as an additional component in the hydro seeding process, as a tackifier, to assist the seed and mulch to stick to the bunker surrounds, the steep bunker edges and on the Nicklaus Design "rough edge" bunker design allowing germination of grass on the bunker edges and particularly on the top of the vertical "rough edge". This is important as weather conditions and watering have a tendency to wash away the hydro seeded areas causing the contractor to have to completely re-apply the hydro seed again at a significant cost.

4. Refine the bunker preparation process and streamline the Bunkertac application methodology and application rates to be easily transferable skills; cost effective; simple to maintain and efficient to apply on a large scale basis for golf courses currently under construction and those undergoing rehabilitation.

5. Test various types of application equipment and ascertain which equipment is the most effective; economical; locally available and easy to clean and maintain.

Bunkers (stabilisation)

Sand bunkers on golf courses are, in general, pits designed to have specific peripheral configurations and contour, a specific depth and sides at a predetermined angle. Bunkers typically have 100-150mm (4-6 inches) of sand on the bottom of the pit which then tapers off to 30-40 mm (2 inches) on the sides and are surrounded by grass/sod which extends very slightly over the edges.

Generally the drainage is created in trenches lined with gravel and perforated pipe in the sub-grade layer underneath bunker base and the sand.

Bunkertac is unique in its ability to form strong yet flexible matrix of three-dimensional bonds between soil and aggregate particles. Bunkertac will allow for a stronger in situ base layer, while eliminating contamination, overlaid by the softer sand on top of this which allows for the preferred playing environment, which is an important factor to be considered at all times.

Normal usage, weather conditions and watering tend to cause the sand to retreat from the sidewalls of the bunkers and mixing with the in situ soil contaminating and discoloring the bunker sand. This is particularly common in instances where the bunker sidewalls are steep.

In addition, erosion may in some instances disfigure the specific contours or break the edges of the bunkers and will decrease the angles of the sidewalls.

This change in angle will affect the difficulty factor of the bunker. Exposure of the top angle of the bunker by maintenance workers trimming grass, etc., also allows for erosion to take place. The contamination of the sand in a bunker causes a number of problems including aesthetics, exposure for the effects of erosion, and negatively affecting the consistency of play.

The type of contamination is also important if rocks and sizable gravel are introduced, this allows for possible injury to golfers and or golf equipment and adverse playing conditions. In addition, silt and clay contaminates will not only discolor the sand but could also cause the drainage system to become clogged or blocked, requiring increased maintenance costs.

Other attempts have been made to prevent erosion, which include the use of clay, cement, bitumen and geotextiles, all of which have critical shortcomings in terms of effectiveness in performance and cost.

Bunkertac when used for stabilisation of the bunker inside and edges as well as being sprayed with a hydro-seeding application on the outside perimeter of the bunker will effectively prevent erosion, runoff; the effects of contamination; and prevent any disfigurement of the bunker design.

In order to demonstrate the spectrum of performance levels of Bunkertac, increase load bearing capacity; retention of sand and shape; prevention of erosion when using Bunkertac for bunker stabilisation, and how this relates to the method of application, different methods were used to apply Bunkertac.

1. Bunkertac being sprayed on to an un-compacted surface
2. Bunkertac being sprayed on to a compacted surface
3. Bunkertac being sprayed on a compacted and spiked surface
4. Bunkertac being sprayed on an un-compacted spiked surface
5. Varying times between compacting and spraying of Bunkertac
6. Dusting of bunkers with sand after initial application

An additional method which was discussed initially, being Bunkertac mixed in, plastered and compacted along the bunker base and edge was later determined to be unnecessary and not as effective as the results of the spray-on applications were seen to be sufficient, especially when considering the higher construction cost associated with this mix-in method.

The most suitable method for application of Bunkertac was determined to be a topical application spray achieving the desired rate with several coats, it was noted that application on a compacted and spiked surfaced yielded the best results. Spiking the surface, not the edges, as the debris from spiking the edges was not desirable, is an optional method depending on soil conditions.

The particle size of the in-situ soil being stabilised is another important factor – as particle sizes should be 2 mm or less to allow for bonding of the particles and the maximum increase in load bearing strength.

As noted by the USPGA, an ideal aggregate mix is comprised of 1-3% gravel (2mm); 30-45% coarse sand; 25-45% fine sand and 15-30% silt and clay. This will allow for maximum increase in CBR and tensile strength, remembering that the sub grade surface must be strong enough to accommodate human traffic and the equipment typically used when stabilising a bunker. *(These tests were conducted on a soil with 95+ % clay content)*

Hydro Seeding

The hydro seeding of a golf course is an important, time consuming and costly component of golf course development.

Typically hydro seeding will comprise of a number of different components including:

- Tackifier
- Soil binder
- Water retention additive
- Fertilizer
- Mulch
- Cotton
- Wood fiber
- High quality grass seed

Hydrotac is an environmentally safe, co-polymer emulsion liquid, which is diluted with water, which serves as the carrier agent and when applied to the ground, air and sunlight become the curing agents. Hydrotac is a tackifier and soil binder, which in effect "glues" the hydro seed mixture to the surface of the ground until the germination and root growth occurs.

The adhesive properties of Hydrotac allow it to glue the grass seed to the surface of the soil while allowing air and water to pass through it into the ground facilitating the germination of the seed without any negative hydrophobic impact. Bunkertac® has the ability to penetrate the soil by holding the seed in place for germination. The application rate for hydro seeding is very light (.03-.010 l/m²), and will provide for a very light flexible crust which will allow the seed, mulch, fibre and cottons to be "tacked" to the soil.

Hydrotac is completely environmentally safe (non-toxic, non-hazardous, safe and easy to apply) and will result in a decrease of the environmental impact of golf course development as Hydrotac eliminates the need to use other products which according to Audubon International have the following ecological effects: -

- Pollution of ground water and surface water caused by the use of pesticides, fertilizers, and other contaminants
- Poor stream water quality due to eroding shorelines
- Withdrawal of large quantities of water for irrigation
- Degradation or loss of natural areas
- Health hazards from chemical handling and applications
- Negative impacts of chemical use on "non-target" wildlife
- Unsound turf management driven by increasing and unrealistic golfer expectations and demands

Hydrotac dries odorless and completely transparent leaving the soil in its natural state; it is safe for vegetation and wildlife and is non-leaching with no plastic coverings or linings necessary.

Commencement of Test Section Applications

Serengeti Golf Estate Bunkertac and Hydrotac applications commenced on November 21, 2007 and documentation thereof is as follows: -

NOTE: 1 US Gallon = 3.784 litres 1 inch = 25.4 millimeters (mm)

See Soil Indicators contained herein

Test Bunkers:

For Hydro seeding & Stabilisation 11A & 11 B

For Hydro seeding only – 11 C, 11D,

Date: 21 November 2007

Soil Description: High Clay content, sandy, silty with a low bearing capacity

Application: Hydro seeding of Bunkers 11 A, B, C, D,
Stabilisation of Bunkers 11 A, B and C.

Hydro seed curing should be 24 hrs; however it rained the same day of application

Stabilisation curing should be 24 hours; however there was rain within 3 hours of application

Weather Note: 9mm of rain within 24 hours / Total of 19mm of rain over the next 48 hours

Preparation of Bunkers

Measure area to be hydro seeded

Chalk lines applied to establish areas to be hydro seeded and stabilized

Area to be stabilised, seeded & spiked

Inside of bunker raked and cleaned

Area to be stabilised is measured and recorded

Compact inside area of bunker prior to stabilisation with Bunkertac

After compaction:

(1) Sweep away all loose material inside bunker
(2) Re-chalk inside line
(3) Collect any loose large material
(4) Spike inside area
(5) Pre-wet both areas to be treated

Hydro Seeding Application of Bunkers 11 A, B, C, D,

Application Date: November 21, 2007

Bunker 11A
Hydro seeded area 90 m² x .10 liters/m² = 9 liters of Hydrotac
Weather: experienced rain within 12 hours of Application

Bunker 11B
Hydro seeded area 105 m² x .10 liters/m² = 10.5 liters of Hydrotac
Weather: experienced rain within 12 hours of Application

Bunker 11C
Hydro seeded area 75 m² x .10 liters/m² = 7.5 liters of Hydrotac
Weather: experienced rain within 12 hours of Application

Bunker 11D
Hydro seeded area 91 m² x .10 liters/m² = 9.1 liters of Hydrotac
Weather: experienced rain within 12 hours of Application

BUNKER FACES

Description	Application rate per 1000m2 Kg	Cost per kg	Total
Organic supplement	120	R 0.87	**R 104.40**
Wood fibre mulch	128.5	R 10.68	**R 1,372.38**
Cotton Mulch	43	R 1.42	**R 61.06**
Hydro Pam	1	R 69.00	**R 69.00**
Stock absorb	5	R 55.77	**R 278.85**
Seed (Rgh Mix)	34	R 66.64	**R 2,265.76**
			R 4,151.45
		Material cost per m2	**R 4.15**
		Hydro seeding cost per m2	**R 1.50**
			R 5.65

Note: One tank of "hydro mix" will theoretically cover approximately 1000m2.

Note: The above costs are representative of materials cost in South Africa in ZAR –Rand and were provided by Golf Data.

When 40 Liters of Hydrotac was added to the mix of 3,784 litres in a Finn T120 hydro seeder the total hydro seed application with stood over 150mm (6 inches) of rain as well as additional watering by grounds staff *(which was in conflict with the after treatment instructions)*.

Traditional hydro seeding methods would have required 3-4 additional applications of the hydro mix after such rains, in order to allow for germination. In this case, due to the addition of Hydrotac, **No additional applications were required and thus eliminated the cost of re-application this represents a savings of R5.65 per square meter per additional application**

At the time of Application the rate of exchange was 7.00 Rand to 1.00 US Dollar.

At the time this report was written the Rand / USD rate fell to 8.10 Rand to 1.00 US Dollar.

The amount of savings realized will vary from location to location and will be dependent on the local cost of materials used. **In addition to the cost savings of the materials used in the mix itself is also the savings realized from a decrease in labour, equipment and water.**

Hydro Seed Mix Preparation using a Finn T120 Hydro Seeder

Hydro Seeding Application

Hydro seeding application

STABILISATION

Stabilisation of Bunkers 11 A, B

Application Date: November 22nd 2007

Bunker 11 A no drainage/no compaction/no spiking

Total Stabilised Area: 60m²

Note: Drains not yet installed

Application rate used: 60 m² @ .81 liters per square meter equaled 49 liters of Bunkertac plus 7 parts or 400 liters of water.

Bunker 11 B no compaction / spiking

Total stabilised area: 90m²

No compaction or sweeping

Spiking immediately after cleaning and raking

Application rate used .81 L/m² x 90m²= 73 L of Bunkertac

Weather Report: Heavy rain started within 10 minutes after the completion of the Bunkertac Application on these two bunkers.

Stabilisation Application Process

November 29, 2007 -- Seven days after initial application

Hydro Seeded Bunkers 11A, 11B, 11C and 11D

Stabilised Bunkers 11A, 11B

The most suitable method for application of Bunkertac was determined to be a topical application spray achieving the desired rate with several coats, it was noted that application on a compacted and spiked surfaced yielded the best results.

Bunkers 11 A, B -- 12 days after Hydro seeding, Stabilisation and Rain

No Erosion, Some flooding from rain and watering, Grass Germination

Hydro seeding

Application Date: November 28th 2008

Hydro seeding done on bunkers 11 E, 11 F, 11 G

Hydro seed Mix:

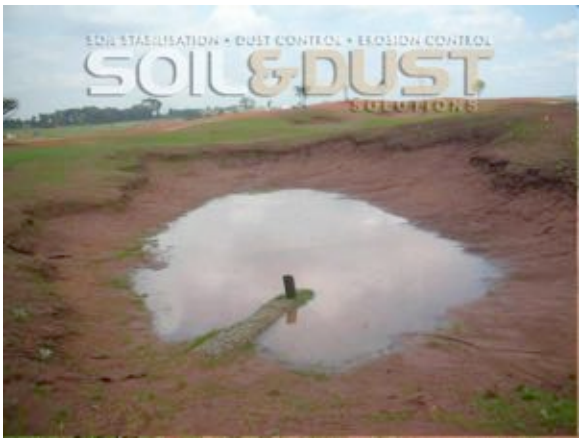
Mulch, 3 Bales of Wood fiber, NO cotton bales used, 50 Liters of Hydrotac

35mm of rainfall during the following week
(Grass germination within 4 days)

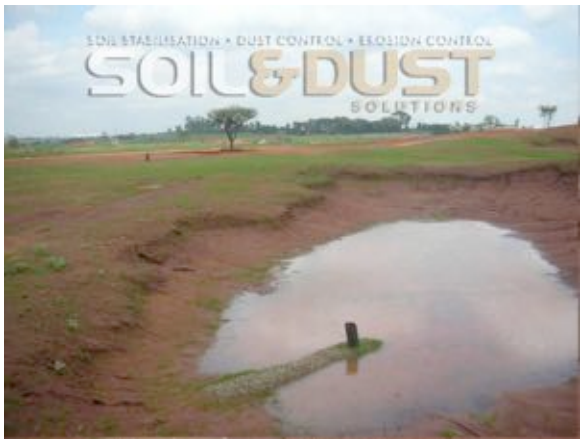
Bunkers 11 E, F, G, 12 Days after Hydro Seeding with Hydrotac

NO Stabilisation had yet been applied

Massive flooding from rain and watering, Erosion and contamination from top of untreated bunker area





These bunkers were hydro seeded only with only a small area around the edge and the bunker wall being treated (the bunker lining itself was not treated) —due to heavy rains the area within 2 metres of the bunker edge literally "washed" down into the treated edge areas and into the bunker itself, had there been sand in the bunker it would have been contaminated. Hence, underscoring that the simple act of treating the surround areas is quite effective when compared to not doing so.

As shown by the pictures, the different applications used in hydro seeding and the stabilisation of the bunkers, it is evidently clear that where Bunkertac or Hydrotac were used there was a substantial difference to those areas as opposed to the untreated areas.

Where Bunkertac was used in the stabilisation of the bunkers:

1. No erosion

2. Grass germination was evident.

3. A solid thick layer was formed around the treated area, which prevented the erosion from the top of the untreated bunker area, flowing down in to the bunker, during the rain.

In comparison, the bunkers that were ***not*** stabilised experienced massive flooding and erosion, after heavy rainfall.

In areas where Bunkertac® was incorporated into the hydro seeding of the 1st series of bunkers (11 A, B, C, D):

1. A hydro seed mix including 2 Bales of wood fibre, 1 Bale cotton, fertilizer and grass seed was used.

2. NO Hydro Pam was used in this mix

3. Hydrotac was just added to the mixture

4. Heavy rainfall followed in the proceeding days with little or no effect on the hydro seeding

5. Grass germination was seen within 7 days after the Hydrotac application. (See April 19, 2008 observations below)

With the hydro seeding of bunkers (11 E, F, G) a different hydro seed mix was used:

1. 3 Bales of wood fibre, fertilizer and grass seed

2. NO cotton was used in this mix

3. NO Hydro Pam was used in this mix

4. Hydrotac was added

5. Heavy rainfall proceeded with no negative effect to the hydro seeding

6. Grass germination was evident within 4 days after the application.

December 13th 2007

Inspection of Bunkers 11 C, D, E, F (Hydro seeded with no stabilisation)

Evidence of excessive rainfall coupled with watering – note the depth of water And actual algae and mould growing

Over watering despite that the clay soil was already over saturated

Flooding and mould

evidence of algae and mould

December 13, 2007
Bunkers 11 A & B

Due to the excessive rainfall and over watering which occurred coupled with the 5 week holiday break from December 10th –January 14th 2008, the hydro seeded (only) bunkers 11 C-G were never completed or installed with sand, as it was intended to stabilise them as well, but as they were oversaturated with water and exposed to excessive weather conditions, this could not be done, and to date is still not complete.

A decision was taken to cancel any further testing or monitoring of the hydro seeding progress and stabilisation of these bunkers and to resume in early 2008 with a selection of new trial bunkers to be prepared and made ready for the addition of sand upon completion of the Bunkertac application.

A decision was also made to abandon bunkers 11A & 11B as it was thought that the excessive rain and water had seriously (negatively) effected the Bunkertac applications.

Observations made on April 19, 2008

Bunkers 11 A and 11B which were hydro seeded and stabilised

Despite the decision which was taken in mid December to abandon these bunkers it was decided to conduct an inspection on April 19, 2008, this being nearly 5 months later and after continuous rain from mid December 2007 to April 7th 2008.

Upon observation Bunkers 11 A & B, which were hydro seeded & stabilised resulted in demonstrating remarkable success in terms of highly effective germination and stabilisation.

The bunkers were simply left – never finished – no weed killer was applied, no sand installation was done.

April 19, 2008 - Bunker 11 A (hydro seeded and stabilised)

April 19, 2008 - Bunkers 11A and 11B (hydro seeded and stabilised)

The bunkers were hydro seeded and stabilized, but never completed with the sand layer, and they were simply left untouched.

An important observation is that in spite of the heavy stabilisation of the bunker lining with Bunkertac, it still allowed the grass to grow through.

As these bunkers were both hydro seeded and stabilised, it is evident from the pictures above that this is precisely where germination took place.

Notice the colour differential in the green colour of the grass, a virtual line indicating positive results in the treated areas.

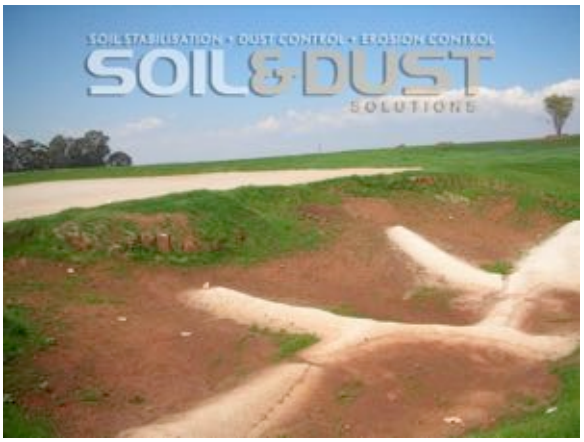
The Hydrotac allowed for successful and plentiful "vertical" seeding, which allowed for thick lush grass to grow on and over the edges, thus demonstrating again that Hydrotac does not have a "hydrophobic impact", and in fact, encourages the germination process. This demonstrates that despite over watering; excessive rain; and possible under dilution of Hydrotac; high performance levels were achieved, including the total prevention of erosion. Hydrotac successfully kept the grass seed in place to allow germination despite excessive levels of water.

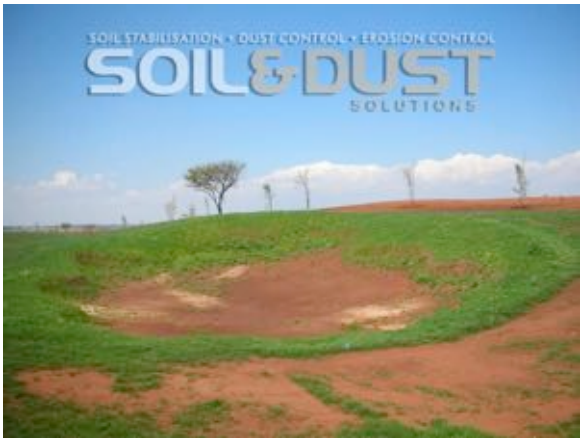
The drainage was never added to these bunkers

These germination results were obtained after ONLY ONE HYDROSEEDING APPLICATION.

Compared to bunkers which were hydro seeded without Hydrotac

Bunkers that were hydro seeded (traditional method) without adding Hydrotac





These bunkers pictured above were already *hydro seeded FOUR Times*, (without any Bunkertac) and still lack the homogenous growth and the fullness of the grass.

A continuation of this report is attached hereto as Part II (January-April 2008)

This Report Part II records the steps which resulted in the most successful Bunkertac application method for hydro seeding and stabilisation, as well as introducing a third step of adding sand and using Bunkertac to effectively line the bunker, the vertical slope of the bunkers and the rugged edges.

Serengeti Golf Course Bunker Case Study
Using Hydrotac for Hydro Seeding & Bunkertac for Stabilization

Part II - January 2008 to April 2008

January-February 15, 2008

During this period general observations of the previously treated areas were made as well as the planning and preparation for the next set of bunkers to be treated. Several site visits were conducted during which it was decided that due to excessive (and unprecedented) rainfall, final preparations and Bunkertac and Hydrotac applications could only commence end of February.

February 25, 2008

Hydro Seeding

Three bunkers were identified for hydro seeding using the Finn T-120 Hydro seeder on site.

These trial bunkers were identified as: **Hole 1 Bunker 1**
Driving Range Bunker 1
Driving Range Bunker 2

Features of the Finn T-120 Hydro Seeder

- 1,000 gallon (3,785 liter) capacity
- Special designed tank to provide a smooth slurry flow pattern from beginning to the end of the load
- Optimum mixing capabilities featuring hydraulically controlled paddle agitation and liquid recirculation
- Individually driven agitator and pump allowing complete mixing of the slurry without pump operation enhancing mechanical longevity and flexibility during operation

The following mix was used in the Finn T-120 Hydro Seeder:

128.5 kg of wood fiber
43 kg of cotton mulch
5 kg of stock absorb
1 kg of hydro pam
34 kg of seed
120 kg of organic supplement
50 liters of Hydrotac (a rate of .05 liters per square meter or 50ml/m²)

This mix was used on the three identified trial bunkers covering a total area of approximately 752 square meters (752m²).

Hole 1 Bunker 1

Preparation of the bunker prior to hydro seeding included compaction of the bunker, cleaning and sweeping of the bunker of any and all loose material using shovels, rakes and brooms and the marking and measurement of the area to be hydro seeded.

Hole 1 Bunker 1 before hydro seeding

Preparation of Hole 1 Bunker 1

Application of hydro seed mix

after application of hydro seed mix

Hole 1 Bunker 1 March 28, 2008

Hole 1 Bunker 1 March 28, 2008

Driving Range Bunker 1

Preparation of the bunker prior to hydro seeding included cleaning and sweeping the bunker of any and all loose material using shovels, rakes and brooms. Then the measurement and marking of the area to be hydro seeded.

Driving Range Bunker 1 prior to hydro seeding

Preparation of Driving Range Bunker 1

Preparation of Driving Range Bunker 1

Measurement of the area to be hydro seeded

HYDROTAC HYDRO SEEDING APPLICATION MIX

Hydro seed application Driving Range Bunker 1

Hydro seed application Driving Range Bunker 1

Driving Range Bunker 1 after Hydro seeding

Driving Range Bunker 1 after Hydro seeding

Driving Range Bunker 1 March 28, 2008

Driving Range Bunker 1 March 28, 200

Driving Range Bunker 1 March 28, 2008

Driving Range Bunker 1 March 28, 2008

Driving Range Bunker 2

Preparation of the bunker prior to hydro seeding included compaction of the bunker, cleaning and sweeping of the bunker of any and all loose material using shovels, rakes and brooms and the marking and measurement of the area to be hydro seeded.

Driving Range Bunker 2 prior to hydro seeding

Compaction of Driving Range Bunker 2

Hydro seed application Driving Range Bunker 2

Hydro seed application Driving Range Bunker 2

Hydro seed application Driving Range Bunker 2

After Hydro seeding Driving Range Bunker 2

Driving Range Bunker 2 March 28, 2008

Driving Range Bunker 2 March 28, 2008

Mixing the Hydrotac with the hydro seed mix proved to be effective and successful on all three trial bunkers. As seen from the pictures, the Hydrotac did not have a hydrophobic effect on the germination process. Germination is evident even on the steep faces thus achieving the original objective.

The same successful results which were realized in the first set of bunker tests was achieved again and proved that the use of the Hydrotac within the hydro seed mix essentially "glues" the hydro seed in place **thus eliminating the need to repeat the hydro seeding process after heavy rains resulting in considerable cost savings as shown in the chart below.**

BUNKER FACES

Description	Application rate per 1000m²	Cost per kg	Total
	Kg		
Organic supplement	120	R 0.87	**R 104.40**
Wood fibre mulch	128.5	R 10.68	**R 1,372.38**
Cotton Mulch	43	R 1.42	**R 61.06**
Hydro Pam	1	R 69.00	**R 69.00**
Stock absorb	5	R 55.77	**R 278.85**
Seed (Rgh Mix)	34	R 66.64	**R 2,265.76**
			R 4,151.45
		Material cost per m²	**R 4.15**
		Hydro seeding cost per m²	**R 1.50**
			R 5.65

***Submitted by Golf Data 31/3/08** **This mixture should cover 1,000 m²**

Note: Additional costs savings in terms of less labour, water and equipment requirements

Bunker Stabilisation using Bunkertac

Driving Range Bunker 2 Stabilisation

February 26th 2008

Preparation of the bunker for the Bunkertac application included compaction, removal of all loose aggregate and soil using rakes, shovels and brooms as well as application of the Enviro Weed Outpace Super herbicide for weed control.

Bunkertac was applied using an application rate of .80 litres per square meter (800ml/m²) and a dilution including 50 litres of Bunkertac and 450 litres of water. (*)

This mix was applied to an area on Driving Range Bunker 2 of 62.5 square meters (62.5m²). A 5.5 horsepower pump with a 1-inch flat hose and spray nozzle attached was used to apply the Bunkertac to the bunker.

Bunkertac was applied evenly over the entire bunker using several coats. Each coat was allowed to penetrate or soak in *before* application of the next coat.

(*) NOTE: After this initial application approximately 150 litres of the mix was left unused the actual quantity used at this stage was approximately 32 litres Bunkertac and 300 litres of water.

For this particular trial, a layer of bunker sand was added to the area after several coats of Bunkertac were applied to the base and Bunkertac was then applied topically to the bunker sand.

Driving Range Bunker 2 before application

Preparation of pump for Bunkertac application

Preparation of Driving Range Bunker 2

Sweeping of steep faces prior to application

Application of herbicide for weed control

Bunkertac application to Driving Range Bunker 2

Adding layer of bunker sand to applied area

Sweeping bunker sand against steep faces

Bunkertac application to bunker sand

Bunkertac application to bunker sand

Driving Range Bunker 2 after Bunkertac application

Driving Range Bunker 2 after Bunkertac application

February 27th 2008

Upon inspection of Driving Range Bunker 2 it was determined that the bunker had been significantly watered (against the after treatment instructions which were given not to water area) and was also subjected to human traffic during the crucial first 24 hours after Bunkertac application.

Significant watering during first 24 hours

Human foot traffic during first 24 hours

March 3rd 2008

We repaired the areas damaged from the watering, rain and human traffic. Using rakes, shovels and brooms, and then applied the remaining balance of the 150 litres of Bunkertac mix to Driving Range Bunker 2.

Driving Range Bunker 2 March 28th 2008

Driving Range Bunker 2 March 28th 2008

Driving Range Bunker 2 March 28th 2008

Driving Range Bunker 2 March 28th 2008

Driving Range Bunker 2 developed a skin layer resulting from being over compacted, under optimum moisture

Note: the soil should be allowed to "relax and recover" from compaction for a few days while being watered prior to Bunkertac application.

NOTE:

An on site inspection was conducted on April 19, 2008, and although the bunker did develop a thin "skin layer", this could easily be pulled away and revealed that the surface below was completely stabilised and hard, as were the bunker walls and edges. This occurring after it had been allowed to dry.

Driving Range Bunker 1 Stabilisation

March 3rd 2008

Preparation of the bunker for the Bunkertac application included compaction, and in one area spiking or aerating using a pitch fork, removal of all loose aggregate and soil using rakes, shovels and brooms as well as application of the Enviro Weed Outpace Super herbicide for weed control.

Bunkertac was applied using an application rate of one litre per square meter (1000ml/m²) and a mix design including two batches of 100 litres of Bunkertac and 800 litres of water for a total dilution of 200 litres of Bunkertac and 1,600 litres of water.

This mix was applied to an area of approximately 200 square meters (200m²).

A 5.5 horsepower pump with a 1-inch flat hose and spray nozzle attached was used to apply the Bunkertac to the bunker.

Bunkertac was applied evenly over the entire bunker using several coats. Each coat was allowed to penetrate or soak in before application of the next coat.

For this particular trial, a layer of bunker sand was added to only half the bunker after the first batch of the mix was applied to the base and Bunkertac was then applied to the entire bunker using the second batch of the mix.

When applying the second batch of the mix a new spray nozzle was used which provided an increased output rate as well as a more even spray coat over the bunker.

Driving Range Bunker 1 is the first trial bunker that was not subject to manual watering, rain or human traffic during the crucial first 24-hour period after Bunkertac application.

Driving Range Bunker 1 before application

Application of herbicide for weed control

Bunkertac application Driving Range Bunker 1

Bunkertac application Driving Range Bunker 1

Bunker sand layer over half of bunker 1

Bunkertac application over the bunker sand

Driving Range Bunker 1 after application

Driving Range Bunker 1 after application

After the Bunkertac application Driving Range Bunker 1 developed a skin layer as a result of being over compacted and under optimum moisture.

Driving Range Bunker 1 March 28th 2008

Driving Range Bunker 1 March 28th 2008

Driving Range Bunker 1 March 28th 2008

Driving Range Bunker 1 March 28th 2008

Hole 4 Bunker 3 Stabilisation

(Determined to be the best application method to date)

March 28th 2008

Preparation of the bunker for the Bunkertac® application included compaction, removal of all loose aggregate and soil using rakes, shovels and brooms as well as application of the Enviro Weed Outpace Super herbicide for weed control, and no spiking.

Andrew Mills and his team did the preparation of this trial bunker several weeks prior to application from Golf Data. This bunker was above optimum moisture on the day of the Bunkertac application.

Bunkertac was applied using an application rate of .70 litres per square meter (700ml/m²) and a dilution including 112 litres of Bunkertac and 672 litres of water.

This mix was applied to an area of approximately 160 square meters (160m²). A 5.5 horsepower pump with a 1-inch flat hose and spray nozzle attached was used to apply the Bunkertac to the bunker.

Bunkertac was applied evenly over the entire bunker using several coats. Each coat was allowed to penetrate or soak in before application of the next coat.

A fire hose spray nozzle was used for this application, which provided a better output rate as well as a more even spray coat.

For this particular trial prior to the Bunkertac application, a very thin layer of bunker sand was placed against one of the steep faces using a whisk corn broom. In addition immediately following the Bunkertac application bunker sand was placed throughout the balance of the entire bunker.

Placement of bunker sand using whisk broom

Hole 4 Bunker 3 Before Bunkertac application

Hole 4 Bunker 3 during Bunkertac application

Hole 4 Bunker 3 during Bunkertac application

Hole 4 Bunker 3 after Bunkertac application

Hole 4 Bunker 3 after Bunkertac application

Placement of bunker sand after application

Sweeping bunker sand into steep faces of bunker

Bunker sand placement along steep face

Hole 4 Bunker 3 after bunker sand placement


Hole 4 Bunker 3 after bunker sand placement


Hole 4 Bunker 3 after bunker sand placement

April 4th 2008

A site inspection was conducted by Gary Waage and Andrew Mills of Golf Data, Dave McIntosh of Turfgrass Consulting and Patrick Schoutens and Brian Killeen of Soil & Dust Solutions whereby it was determined that the Bunkertac application for stabilisation of Hole 4 Bunker 3 yielded the best results of all the trial bunkers and that the method and process of stabilisation used for this bunker has set the precedent for future bunker stabilisation at the Serengeti Golf Estate and more advanced trials and training of Golf Data personnel.


Hole 4 Bunker 3 April 4th 2008 (7 days later)


Hole 4 Bunker 3 April 4th 2008 (7 days later)


Hole 4 Bunker 3 April 4th 2008 (7 days later)


Hole 4 Bunker 3 April 4th 2008 (7 days later)

Hole 4 Bunker 3 April 4th 2008 (7 days later)

Hole 4 Bunker 3 April 4th 2008 (7 days later)

April 19, 2008 – (21 days after sand stabilisation application)
Site inspection – below are close-up pictures of the bunkers vertical edges. The darker sand at the top is the sand which was stabilised with Bunkertac—it was very hard and proved that Bunkertac could actually "glue" the sand to the edges (covering the actual in-situ soil) and have it stabilise and remain in place. Once the bunker is completely filled with sand it will always appear that sand is covering the edges despite weather factors.

Hole 4 Bunker 3 yielded the best results of all trial bunkers using Bunkertac for stabilisation to date.

As seen from the above pictures the placement of a thin layer of bunker sand into the bunker immediately following the Bunkertac application, before the Bunkertac could penetrate or cure resulted in not only better penetration into the base but also absorption into the bunker sand which essentially "glued" itself in place even on the steep faces and edges.

During the first 7 days after the Bunkertac application of Hole 4 Bunker 3 there was 53mm (2.08 inches) of rainfall as well as daily watering which had no harmful effect to the stabilised bunker walls whatsoever.

Case Study Comments & Observations

The remote locations, construction phase environment, weather, type of soil, equipment available and accessible and the understanding of after treatment maintenance instructions are just some of the factors, which affect the results of the tests which were conducted.

Challenges Encountered During Bunker Trials

- For each application a utility trailer was hired to house the Bunkertac mix and pump used to apply the Bunkertac making access to the bunkers more difficult as well as increased costing for the completion of the trial bunkers. *The trailer was necessary, as heavier vehicles are not allowed on the grass.*
- Not having sufficient labour and equipment available prior to arrival on site to begin the trial bunkers resulting in significant time delays.
- Not having a sufficient water source that was readily available and easily accessible resulted in significant time delays.
- Rain, watering and human trafficking during first 24 hours after Bunkertac application causing undesirable results and damage to the trial bunkers.

Hired trailer used for Bunkertac® applications

Fire hose spray nozzle providing better spray

Whisk corn broom being used for sand placement

Whisk corn broom being used for sand placement

Hired Trailer showing tote used for Bunkertac mix and pump set up with T-fitting and return valves

Observations Resulting from Bunker Case Studies

Bunkertac has been tested extensively in a number of large-scale projects in South Africa, some of which included extensive on site MMLS testing (simulation) as well as extensive laboratory tests. Its performance capabilities in terms of increasing load-bearing capacity are confirmed.

Our objective was to ascertain and prove with empirical data of the capability of Bunkertac and Hydrotac to perform to the specific levels relating to hydro seeding and bunker stabilisation, including producing a flexible bound surface which still allows for drainage; grass growth (through stabilised areas); the prevention of distortion and disfigurement of the bunker shape; prevention of contamination of the sand and a methodology which would reduce costs and future maintenance.

With reference to the original objectives of these case studies carried out at Serengeti during which we implemented a variety of different mixes of application rates and methods, several important observations were made, these include: -

- Bunker base must be moist (OMC) prior to Bunkertac application.
- All equipment must be tested (off-site if necessary) prior to Bunkertac application to ensure proper functioning.
- Spray nozzles should be set to provide an even spray coat over the bunker with minimal running or draining of the Bunkertac mix dilution.
- Proper preparation of a bunker for stabilisation includes sufficient compaction (but not over), removal of all loose soil and aggregate, hydro seeding around the outside edges, application of herbicide for weed control and placement of a thin layer of bunker sand to the faces or edges using a whisk corn broom.
- If drains are in place, Bunkertac must not be applied to the marked drainage areas.
- When preparing the mix dilution the Bunkertac is added last, directly into the water and circulated through the return valve of the pump.
- All areas must be measured prior to application to determine proper application rates and mix designs.
- For best application, a firm round hose may be more effective than a flat hose in order to prevent kinking and allow for a smooth continuous flow rate.
- During the Bunkertac application each coat must be allowed to penetrate or "soak in", but not dry, before applying the next coat.
- Compaction of the bunker should be done 2 to 3 days prior to application.
- All equipment used must be rinsed off thoroughly as soon as possible after application before the Bunkertac has a chance to dry or cure.
- After Bunkertac application bunkers must remain free of watering, rain and any human traffic for a minimum of 24 hours.
- The placement of a thin layer of bunker sand into the bunker immediately following the Bunkertac application before the Bunkertac has a chance to dry or cure helps to "glue" the bunker sand in place.

The case studies conducted together with the documented observations and empirical data will allow a general standard streamlined application method to be developed, documented and implemented.

Conclusions Resulting from Bunker Trials

The different mix ratios used in the hydro seeding and stabilisation yielded very useful results in terms of the desired end results, we have referenced these specifically as follows: -

- The Bunkertac treated bunkers remained in tact and unharmed from approximately 205 millimeters of rain between February 25th 2008 and April 4th 2008 plus additional watering.

- Adding Hydrotac to the hydro seed mix and spraying the hydro seed *prior* to stabilisation aids significantly in the prevention of erosion; distortion and disfigurement of the bunker edges or faces; run-off; contamination; and allows for the elimination of repetitive application of the hydro seed mix.

- Using Bunkertac for stabilisation of the bunkers provides a flexible bound surface with high load bearing and shear strength capacity while still allowing for proper drainage and germination.

- Using Hydrotac mixed in the hydro seeding or for stabilisation of the bunkers did not have a hydrophobic impact on the germination process.

- Placement of a thin layer of bunker sand using a whisk corn broom to push the sand against the edges or faces of the bunker immediately following the Bunkertac application will help "glue" the bunker sand in place achieving the original design and appearance of the bunker desired by the course designer.

- The use of Hydrotac for hydro seeding and Bunkertac for stabilization of the bunkers provides the most cost effective solution for the prevention of erosion, run-off, contamination and disfigurement or distortion to the bunker edges and faces.

- Repair and maintenance of damage to the treated areas is simple, efficient and quick (not labour intensive or time consuming)

- Spraying Bunkertac around the perimeter and high sides of the bunkers will assist in the prevention of contamination from fugitive material transported from fairways and landscaped areas nearby.

Final Notes:

1. 8 Additional Bunkers have been treated as well, the results of which will be forthcoming

2. Standardized Application Specifications are being finalized which will set forth the best procedures to follow for stabilisation and hydro seeding

3. After Treatment and Maintenance Instructions are also being finalized, as it will be critical to the success of treated areas that these instructions be followed.

4. These case studies covered a wide range of different types of application methods and shall serve as the general tests for future projects as such extensive testing will not be required on every course in the future.

As a result of the extensive tests carried out and the successful results, which were obtained, we look forward to working with Nicklaus Design and Golf Data on future projects.

For additional copies of this report, please send your details to:
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Signed: