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Golfing atop a landslide

A signature hole is born at Trump National Golf Course

By Rich Sack

Trump National Golf Course, formerly named Ocean Trails Golf Course, is an incredible course for many reasons. It is the first and only ocean-front golf course in Los Angeles County, and it received national attention when it was showcased in the final episode of NBC's *The Apprentice* (Season 1). The public course sits high atop jagged cliffs with the waves of the Pacific Ocean crashing below, offering spectacular ocean views from all 18 of its fairways. The course is the host of the 2005 LPGA Office Depot Championship (September 30–October 2). Also, the course has one other very interesting feature: It is the most expensive golf course ever built, costing over $250 million. The largest portion of this money went into just one hole, which is the focus of this article.

Photo 1. A landslide took out most of the 18th hole. The rebuild created a signature hole and a signature geotechnical design.

Landslide

Development of an ocean-front upscale public golf course had been in the planning and permitting stages for nearly 10 years. The permitting process for any coastal development in Southern California is difficult, and was especially difficult for the Trump National Golf Course. The course is located within a known ancient landslide area (known to geologists as landslide "C") and an environmentally sensitive coastal bluff reserve that is home to the endangered California Gnatcatcher bird. This latter point places the site under the jurisdiction of the Coastal Commission.

Through May 1999, the course developed smoothly. It was almost complete, including the now-costly 18th hole. Its green and about one-half of its associated fairway rested atop the area of ancient Landslide C.

Photo 2. Initial stabilization work involved extensive earthworks.

In early June 1999, the 17-acre area of Landslide C re-activated in a single rapid event. The result was the movement of a large "translational block," which occupies the central portion of the slide mass. The slide saw downward movement of almost 10 ft. and horizontal (seaward) translation of about 50 ft. At the base of the slide was an almost horizontal thin layer of bentonite, only 0.12–3 in. thick, that when exposed to water becomes extremely slippery (low friction). The slide mass had a maximum length of 1700 ft., a width over 400 ft. and depth of about 70 ft. The slide took with it most of the 18th hole (fairway and green), bluff edge, pedestrian trails, bikepath, and a portion of a major Los Angeles County Sanitation District sewer line. Many believe that fluid from a leak in this sewer line may have flowed along and saturated the thin layer of betonite, triggering the massive slide.

Repair alternatives

Converse Consultants, a large geotechnical engineering firm located in Southern California was given the task of designing a way to fix this giant slide. Three repair alternatives were considered by Converse Consultants:

1. Complete landslide removal and replacement.
2. Partial removal and rebuilding of the seaward portion of the landslide.
3. Partial removal and rebuilding of the landward portion of the landslide.

Complete removal and replacement and partial removal/replacement for the seaward landslide area were quickly ruled out due to factors such as difficulties from dewatering excavations that are more than 30 ft. or more below sea level; extremely high cost; destruction of any remaining habitat; reactivation of the landslide; and significant landform alteration, including the destruction of natural sea cliff and bluff slopes.

Partial removal and rebuilding of the landward portion of the landslide was found to be the best alternative. This option would achieve the intended purposes, have the least alteration of landforms, and be the most feasible from a geotechnical engineering viewpoint.

Once a repair scenario was decided on, it was necessary to analyze various earth retention options which could be utilized for implementing the repair strategy. The options and a general assessment of each is provided in **Table 1**.

Based on the analysis of the five different options in the table, the mechanically stabilized earth (MSE) wall option was considered the best solution. The MSE wall option was the only alternative that best met the parameters noted in **Table 1**.

Option	Construction Time	Expense	Reliability	Fill Settlement	Height	Landform Change
MSE Wall	**Medium**	**Medium**	**High**	**None**	**Most Suitable**	**Minimal**
Concrete Wall	Longest	Most Expensive	**High**	Some	Less Suitable	Extensive
Tangent/secant Walls	**Medium**	Expensive	Medium	Some	Not Suitable	Extensive
Tie-back pile Walls	**Medium**	**Medium**	Low	Severe	Less Suitable	Extensive
Prefabricated Gravity Walls	**Medium**	**Medium**	Low	Some	Not Suitable	Extensive

Table 1. Project considerations that led to the final design.

Photo 3. Numerous geotextiles and soil baskets provided vital internal support for the refilled hole.

Design

The actual wall design was performed by Bill Lu at Converse Consultants. The design required interface friction testing for both secondary and primary reinforcement layers for use in global and surficial stability design calculations. Extremely high strength fabrics (over 40,000 lbs/ft. tensile strength) combined with high soil interaction coefficients were essential to the design. Layers of geosynthetic reinforcement were to be placed at approximately 5 ft. vertical intervals with embedment lengths as much as 95 ft. in length (using the higher strength fabrics allowed for larger vertical spacing—resulting in lower installation costs). Mirafi® Geolon® PET600, PET300, PET200 and HS4200 were used as the primary reinforcement to create a massive fabric-wrapped MSE wall buttress (100 ft.+ high). The face of the wall was designed with 18 in. high welded wire forms. The forms were designed to be manufactured with a batter of 4.6° (almost vertical) to match the final design batter of the wall. Mirafi® Filterweave® 404 was designed as secondary reinforcement that would line the interior of the welded forms to contain soil at the face. The face of this massive MSE wall was to abut another reinforced triangular backfill. This second reinforced fill mass abutted existing slide material/native soils of the seaward portion of the landslide, which was left in place to maintain the natural environment, hide the face of the wall, and protect the wall structures from the Pacific Ocean's rage. This composite of soil and high-strength fabric serves as a giant stable soil block that will stop any future movement and protect he rest of the golf course from falling into the ocean.

Construction

The final repair plan consisted of four primary steps:

1. Improving the stability of the main slide block with shear pins.
2. Opening a slot by excavating and removing the upper bentonite layer and stockpiling the excavated materials in a stable area.
3. Simultaneously constructing the geosynthetic-reinforced MSE wall buttress and backfilling the areas behind and in front of the buttress in the open slot using the materials excavated from the adjacent slot.
4. Constructing a low permeability clay cap and top soil to final grade.

Construction had to performed in environmentally sensitive habitat areas along steep bluffs with often unstable soils and deep excavations while not disturbing any golfers. (The golf course was actually open for business during construction.)

Photo 4. Constructing the geosynthetic-reinforced MSE wall buttress.

The first step in repairing the slide area was to stabilize the main slide block with 116 shear pins. Each steel pin was 20 ft. long, 3 ft. wide, and filled with high-density concrete. Shear pins were installed at 25 ft. intervals. Once the shear pins were installed the construction of the MSE wall began by first excavating the slide area (over 1.5 million cubic yards of soil) in sections (6 sections total) to a depth below the failure plane (approximately 100–150 ft.). The 9th and 12th fairways were used for stockpiling the soil from the first section, so that no impact would be made on the sensitive habitat adjacent to the site. Construction of the MSE wall began with placement of the first row of welded wire forms at the bottom of the excavation. Once the first course of forms were placed, the Filterweave 404 was placed up the back of the steel forms, with a 5 ft. long flap of reinforcement draped over the face. Geolon high strength fabric was next placed up to the face of the basket. (The fabric was pre-cut and brought down into the excavation for placement.) On-site fill materials were compacted in place over the reinforcement lengths, and the flap was wrapped back over the top of the soil. The construction process was repeated for each lift (every 18 in.), until the wall reached its full required design height. Total cost: $61 million.

A clay cap was placed over the entire filled area to keep water out. A layer of topsoil was placed over the clay cap so vegetation and landscaping could be planted. The entire reinforced fill structure is now covered by a beautiful grass fairway, putting green and sand traps.

As golfers take in the breathtaking view from the 18th hole, few will ever know that they are playing on the most expensive hole ever built. Even fewer golfers will realize that this hole is one of the safest coastal places to be standing as a result of the many layers of high strength geosynthetics sitting below their feet. When asked about this reinforced hole by a reporter, course owner Donald Trump remarked, "If I'm ever in California for an earthquake, this is where I want to be standing." GFR

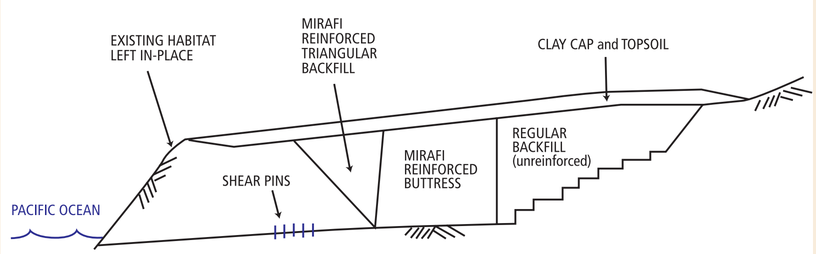

Figure 1. Cross-sectional drawing of the reinforcement strategy.

Rich Sack works for Mirafi Construction Products, www.mirafi.com.

Project information

Design Engineer: Bill Lu, Converse Consultants

Geotextiles: Geolon PET600, PET300, PET200, HS4200 and Filterweave 404 from Mirafi Construction Products