

After the Landslide

High-strength geosynthetics save a prestigious golf club's oceanside 18th hole

By Rich Sack, P.E.

Trump National Golf Club, an 18-hole oceanfront public course in Los Angeles County, Calif., sits high atop jagged cliffs, with the waves of the Pacific Ocean crashing below. Having cost more than \$250 million, it is noted as the most expensive golf course ever constructed.

When the approximately 17-acre area of an ancient landslide reactivated in a single rapid event on site, it resulted in downward movement of almost 10 ft and a horizontal/seaward translation of about 50 ft. At the base of the slide was a thin

(0.125 to 3 in.), nearly horizontal layer of bentonite, which becomes extremely slippery when exposed to water.

The slide mass had a 1,700-ft length, 400-ft width and 70-ft depth. It took with it most of the 18th hole; bluff edge; pedestrian trails; a bike path; and part of a major Los Angeles County Sanitation District sewer line.

The Design

Three repair options were considered for the design:

- 1) Complete landslide removal and replacement;





Of three possible repair approaches, project leaders opted to partially remove and rebuild the landward portion of the landslide.



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- 2) Partial removal and rebuilding of the seaward portion of the landslide; and
- 3) Partial removal and rebuilding of the landward portion of the landslide.

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

Various earth retention options were analyzed for implementing the repair strategy. The mechanically stabilized earth (MSE) wall option was deemed the best solution, favorably meeting all parameters: construction time, expense, reliability, fill settlement, height and landform change.

The design required high-strength fabrics—more than 40,000-lb/ft tensile strength—combined with high soil interaction coefficients. Layers of geosynthetic reinforcement were to be placed at approximately 5-ft vertical intervals, with embedment lengths as great as 95 ft.

Geolon PET600, PET300, PET200 and HS4200 solutions were used as the primary reinforcement to create a 100-ft-high, fabric-wrapped MSE wall/buttress. The face of the wall was designed with 18-in.-high welded wire forms and a nearly vertical batter of 4.6 degrees.

As secondary reinforcement, workers used Mirafi Filterweave 404 to line the interior of the welded forms, containing soil at the face, which was to be butted up against another reinforced triangular backfill. This second reinforcement fill mass was butted up against existing

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To save its 18th hole, Trump National invested \$61 million in landslide repair.



slide material of the seaward portion of the landslide; the native soils were left in place to maintain the natural environment, hide the face of the wall and protect the MSE structures from the Pacific Ocean.

This composite of soil and high-strength fabric serves as a giant, stable soil block that will stop any future movement and keep the rest of the golf course from falling into the ocean.

Construction

Construction had to occur in environmentally sensitive habitat areas along steep bluffs, often with unstable soils and deep excavations. Furthermore, workers had to take care not to disturb golfers, as the course remained open during construction.

The first step in repairing the slide area was to stabilize the main slide block with 116 shear pins. Each steel pin, filled with high-density concrete, measured 20 ft long and 36 in. wide. Once installed at 25-ft intervals, construction of the MSE wall began.

First, more than 1.5 million cu yd of slide-area soil was excavated in sections to a depth of 100 to 150 ft below the failure plane. The ninth 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.

Next, workers placed the first row of welded wire forms at the bottom of the excavation. Filterweave 404 was placed up the back of the steel forms, with a 5-ft-long flap of reinforcement draped over the face. Geolon PET high-strength fabric was then placed up to the face of the basket. Onsite fill materials were compacted into place over the reinforcement lengths, and the

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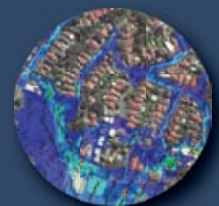
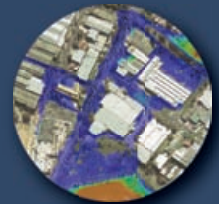
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flap was wrapped back over the top of the soil. This process was repeated for each lift—every 18 in.—until the wall reached its full required design height.

A clay cap was placed over the entire filled area to keep water out. A layer of topsoil over the clay cap allowed for the planting of vegetation and landscaping. Today, a grass fairway, putting green and sand traps cover the entire reinforced fill structure.

Performance

The cost of the landslide reconstruction totaled \$61 million. As golfers take in the stunning view from the 18th hole nearly 10 years after the fact, few realize that they are standing on an exceptionally safe coastal site—the result of many layers of high-strength geosynthetics at work below their feet.

“If I’m ever in California for an earthquake,” said course owner Donald Trump, “this is where I want to be standing.” **[SWS]**

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