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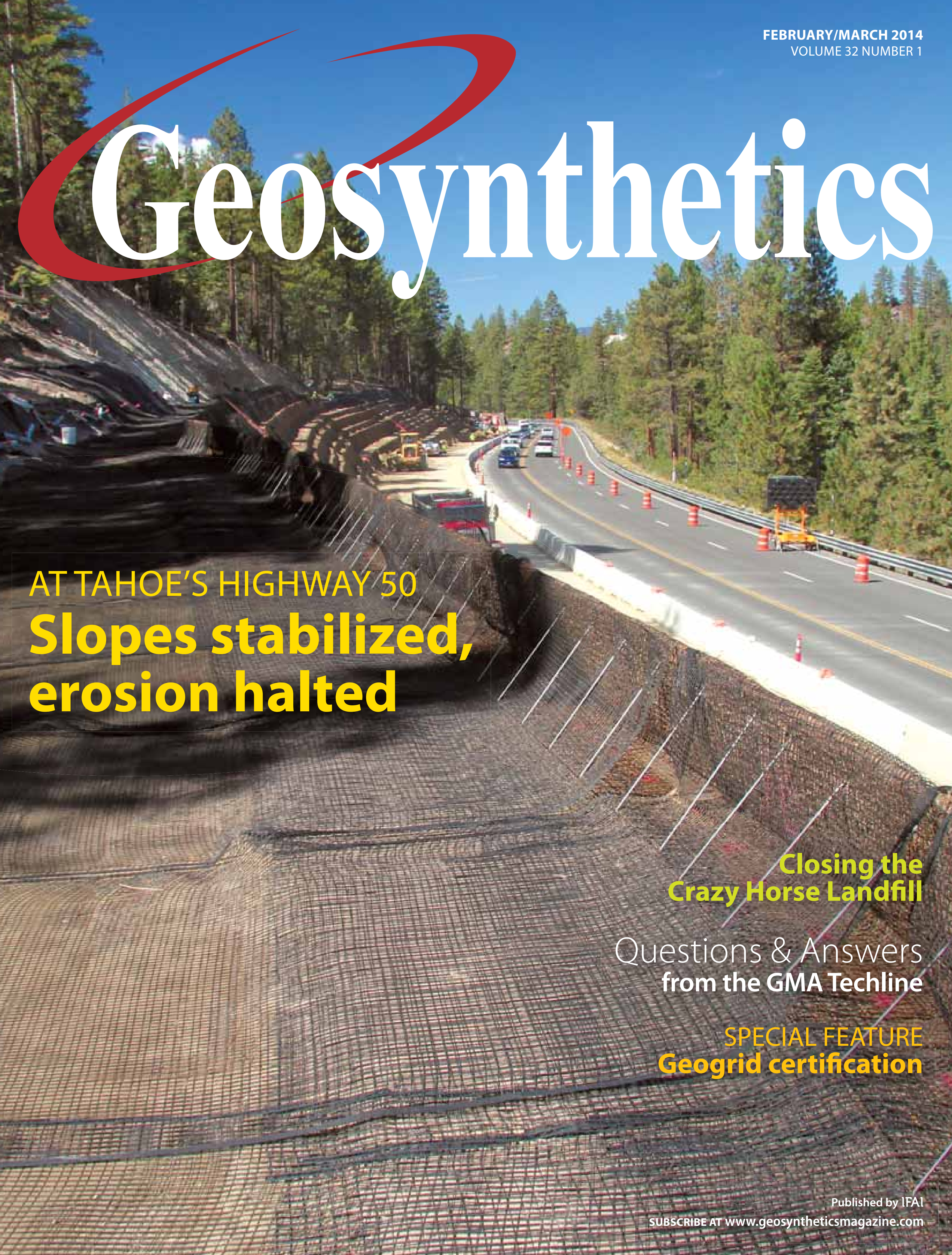

AT TAHOE'S HIGHWAY 50

Slopes stabilized, erosion halted

Closing the Crazy Horse Landfill

Questions & Answers
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Geosynthetic reinforcement solutions for Lake Tahoe highway

By Katie Westfall

The slope along U.S. 50 near Lake Tahoe is now secure and stable. The project's life is expected to be in excess of 70 years.

Introduction

U.S. Highway 50 crosses the central portion of Nevada through several large desert valleys, basins, and mountain passes. The road climbs steep 8% grades and carries travelers around hairpin turns and through pine forests. In some places, erosion of the slopes adjacent to the highway is a problem for motorists who encounter rock and soil in the road. Also of concern is the possibility of runoff from eroded slopes entering the local water system, including the legendary cobalt-blue waters of nearby Lake Tahoe.

These concerns were at play for a section of U.S. 50 near Lake Tahoe between Cave Rock Tunnel and State Road 28 in Douglas County, Nev. The north-facing slope started sloughing, and small rocks and soil began sliding into the road. Closer investigation indicated a large area of the pine-covered hill, which plunges toward the busy highway, was failing. Repair of the slope was a top priority for the Nevada Department of Transportation (NDOT).

A variety of reinforcement solutions were proposed through the NDOT public bid process. One aspect of the project that made choosing a solution challenging for NDOT was that a bed of granite lay directly beneath the slope surface, making anchoring and reinforcement particularly difficult. NDOT considered not only the cost and effectiveness of the proposed methods to secure the slope long term, but also its ability to satisfy the environmental and aesthetic concerns of the Tahoe Regional Planning Agency (TRPA).

TRPA is a bi-state agency created to establish a balance between the natural and human-made environments. NDOT was concerned that this particular slope's erosion was impacting Lake Tahoe, and the slope reinforcement solution would have to satisfy TRPA's requirements. The agency insisted that construction, such as slope reinforcement, blend with the environment and would not detract from the natural beauty of the area.

The general contractor for the project was eager to find a new solution after an initial design was considered too complex and costly. A revised turnkey material/design package was developed that adhered to basic engineering and aesthetic requirements. The design was presented to NDOT and, once NDOT approved the design concept, it took nine months to finalize the plans as the firms involved undertook

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Photos courtesy of Strata
Figures courtesy Terracon

PHOTO 1 Rock anchor drilling commenced in the spring of 2012. Rock anchors were the linchpins of the project and their design was carefully considered to withstand the loads on the veneer soil slope.

a redesign to create an easier-to-install, less expensive solution.

Essential to the final approved design was the use of geosynthetic materials that worked to stop erosion and reinforce the slopes. Welded wire baskets, lined with coconut blankets and hand-seeded, created a series of micro-terraces ready for vegetation. And structural geogrid reinforced the soil veneer placed against the granite rock slope.

Although the proposal ultimately accepted by NDOT was not significantly different from the initial proposal considered, it reduced material costs by approximately $80,000, and installation was simplified for the contractor, although it wasn't without its challenges.

Sizing up the slope

The final design would reinforce approximately 80,000ft^2 of slopes with a vertical rise up to 90ft above the road elevation.

Underground utilities construction began in spring 2011, but it wasn't until spring 2012 that slope construction got under way **(Photo 1)**. Completion of the U.S. 50 slope reinforcement project was hampered by problematic soil conditions in one area of the slope and work slowed during the summer tourist season

PROJECT HIGHLIGHTS

HIGHWAY 50 SLOPE STABILIZATION
DOUGLAS COUNTY, NEVADA

GENERAL CONTRACTOR
Granite Construction Inc.
Watsonville, Calif.

ON-SITE CONSTRUCTION
Sparks, Nev.,
division of Granite

ENGINEERING
Terracon Consulting
Engineers and Scientists
Tempe, Ariz.

Wood Rogers Inc.
Oakland, Calif.

GEOGRIDS
Stratagrid SG150
(secondary geogrid face wrap)

Stratagrid SG350
(primary geogrid reinforcement)

Stratagrid SG600
(primary geogrid reinforcement)

Strata Systems Inc.
Cumming, Ga.

GEOSYNTHETIC MATERIALS
Hanes Geo Components
Winston-Salem, N.C.

PHOTO 2 At each anchor location, a 6-foot-wide layer of geogrid was attached using a simple wrap connection around 3-inch diameter pipe.

and during special events, such as the Ironman Lake Tahoe Triathlon.

The slope was divided into three surfaces: Slope 21 was the longest at 1,300ft; Slope 27 East and Slope 27 West were shorter. A roadway was cut into the side of the mountain, and one lane of U.S. 50 was blocked with concrete barriers to allow access to the site. Another concrete barrier was slightly elevated near the slope and temporary fencing was deployed hillside to protect motorists from flying dirt and debris.

Excavation was completed to a maximum limit line established by the design engineers to support the volume of backfill required at each terrace.

Rocking the anchors

The main challenge for this project was designing and installing a rock anchor-to-geogrid connection. Lab testing was performed on the anchor-geogrid connection to determine the load capacity and pipe size. Field testing backed up these conclusions.

Drilling the holes for each rock anchor began after site preparation. The rock anchors were the linchpins of the project and their design was carefully considered to withstand the anchor loads and the forces of gravity at play on the slope face.

One issue that slowed progress was a site condition problem discovered on Slope 27 West in June 2012. Loose rock made it impossible to continue drilling for the rock anchors in that area. It had to be excavated. Pneumatically applied concrete was used to stabilize the area before commencing with anchor drilling. This situation slowed progress and set back the project by two months.

To build slopes 27 East and 27 West, excavated dirt from Slope 21 was moved to the top of 27 East and 27 West to make a bench for drilling equipment. Starting from the top of Slope 27, the drill rig began

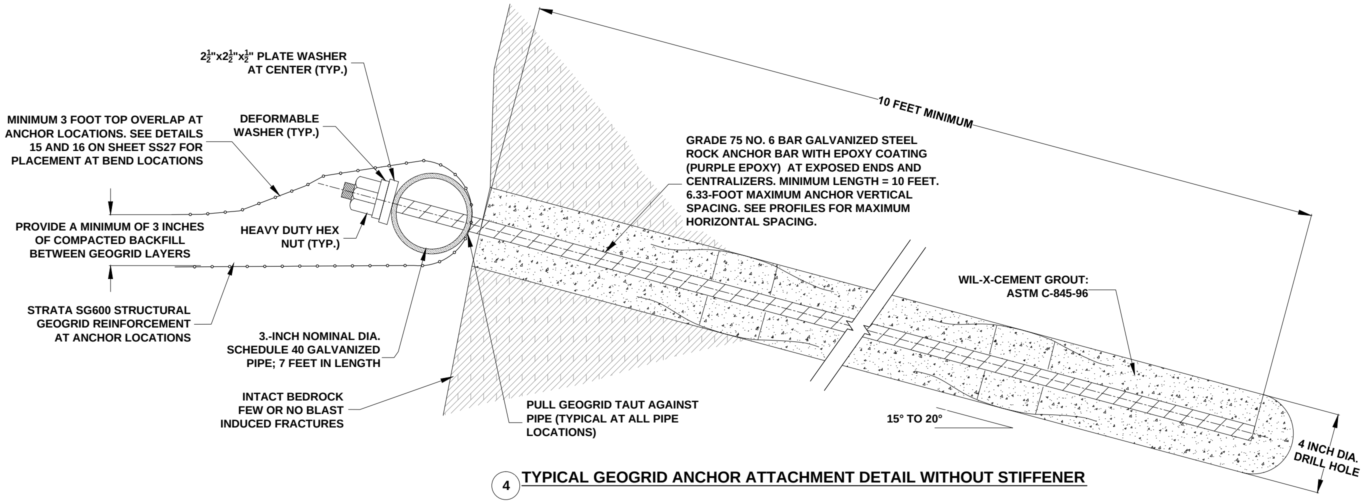

FIGURE 1

boring anchor holes, and three rows of anchor holes could be reached from the drill's position on each bench. As dirt was excavated, it was moved to the top of another slope to create another bench.

The anchor hole drilling process continued in this way from top to bottom of each slope. The location of each anchor was individually analyzed and chosen based on its position in the slope's geometry and the loading conditions of the stabilization system.

Testing of the anchor system determined that, at minimum, anchors should extend 10ft into the bedrock. Each connection was designed to the geogrid's long-term design strength capacity. The connection system incorporated a grade 75, No. 6 bar rock anchor, 3in.-diameter schedule 40 galvanized pipe section, C-channel stiffeners—4in. × 7.2 lb/ft (if required)—plate washers and hardware. Structural analysis of the connection and bending moments along the length of the galvanized pipe resulted in the need for C-channel stiffeners at various locations to prevent excessive deformation (bending) of the pipe sections.

Anchors were placed at an 8-ft horizontal spacing and 6.33-ft vertical spacing. Where the bar exited the bedrock it was fastened to the center of a 7-ft galvanized steel pipe positioned horizontal against the granite face. At each anchor location, a 6ft-wide layer of geogrid was attached using a simple geogrid wrap connection **(Photo 2)**. The geogrid extended to the welded wire form facing (approximately 9ft or more from the anchor) where it was also placed in wrap configuration behind the wire forms. The geogrid wrap and rock anchor T-bar system provided a stable connection between the welded wire form facing and excavated slope face. (**Figure 1** illustrates a typical geogrid rock anchor.)

Static and seismic stability of the 9- to 10-ft reinforced soil slope veneer for the 90ft-tall structure was evaluated using the general limit equilibrium method: Mohr-Coulomb model.

The reinforced slope facing stability (surficial stability) analysis was evaluated in accordance with Federal Highway Administration (FHWA)/National Highway Institute (NHI)-10-025 and as documented in the Proceedings from the Geosynthetics 1993 conference in Vancouver, B.C., Canada, in the paper

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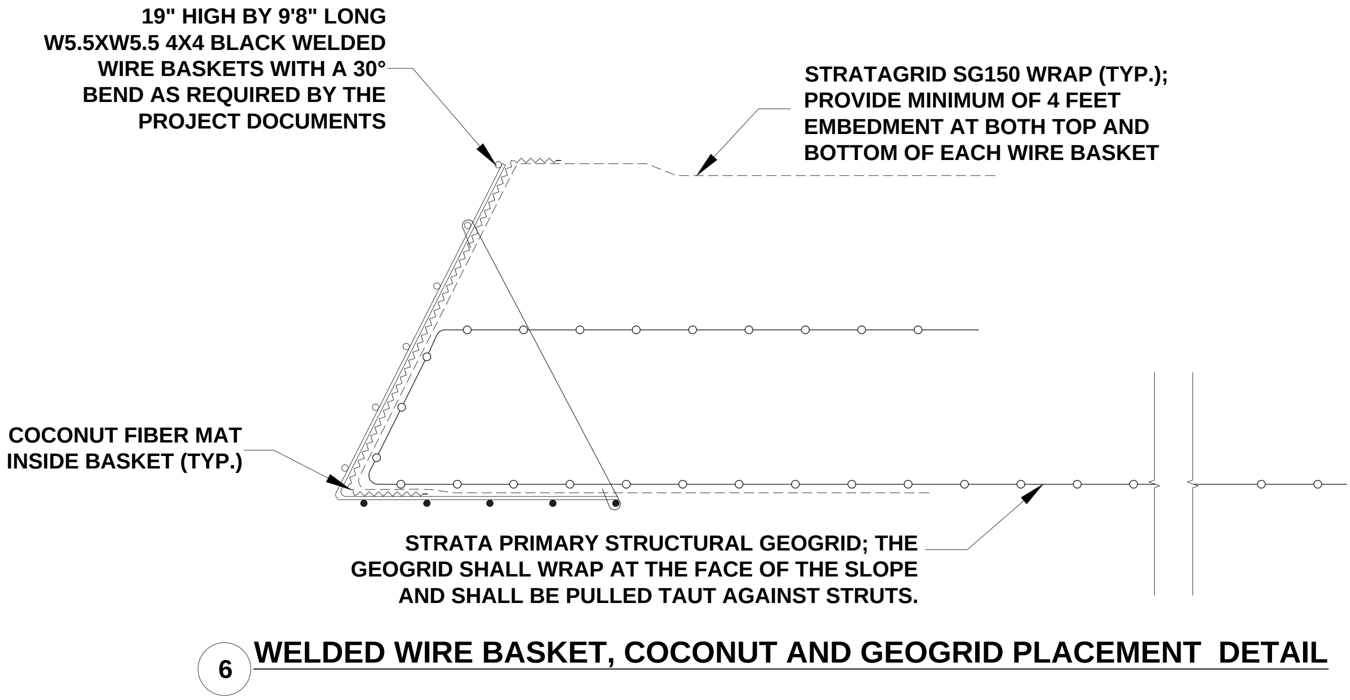

FIGURE 2

"Geogrid Reinforcement for Surficial Stability of Slopes" by J.G. Collin and D.L. Thielen. The surficial stability analysis considered the primary geogrid reinforcement and secondary geogrid face wrap.

For the purposes of this project, the surficial stability model presented by Collin and Thielen was modified to incorporate a horizotal seismic acceleration (kh) of 0.25g. The designed horizontal seismic acceleration was taken as one-half the peak ground acceleration for the project site.

Welded wire forms

The TRPA did not allow the use of shiny galvanized metal because it would clash with the natural environment, so non-galvanized baskets were fabricated. As a result, the welded wire forms (WWFs), or baskets, selected were fabricated from larger diameter steel than typically used for vegetated, reinforced soil slopes. (Typically, forms of this type are fabricated from w4.0 wire to meet ASTM A82 standards. For this project, forms were fabricated in conformance with ASTM A185 with w5.5 steel wire meeting ASTM A82.) The resulting welded wire forms measured about 10ft long and 22in. x 18 in. with a 4in. x 4in. aperture. The welded wire forms were constructed off-site by cold bending wire fabric to a 60-degree batter (from horizontal) with a vertical face height of 19in. (**Figure 2** illustrates typical facing detail.)

Backfill was placed and compacted at the toe of the slope prior to construction of the first micro-terrace, which began at the bottom of Slope 21 and continued upward. The WWFs were placed along the horizontal length of the slope and vertical joints were staggered **(Photo 3).** Adjacent WWFs were tied together using hog rings. This strong yet flexible system allows for some movement and can tolerate a certain amount of settlement.

The baskets were easy to install and were adjustable, enabling the design to follow the slope topography with cutbacks and steps that blended naturally with

PHOTO 3 The welded wire forms were fabricated in conformance with ASTM A185 with w5.5 steel wire meeting ASTM A82 and measured about 10 feet long with a 22-inch front face (19-inch vertical rise) and an 18-inch base.

PHOTO 4 As baskets were placed, each was wrapped in a biodegradable coconut blanket to control erosion and stabilize the soil while local vegetation was established on the micro-terraces. The blankets were seeded by hand on the slope-facing side of the blanket.

PHOTO 5 The primary geogrid reinforcement was installed after the coconut blanket. The geogrid extended from the backcut and wrapped inside the baskets.

PHOTO 6 Backfill was placed using a portable conveyer to reach the higher elevations of the slope.

PHOTO 7 Each micro-terrace was compacted upon completion to create a solid base for the next terrace.

the environment—an aspect of utmost importance to TRPA.

Basket placement was methodical. The construction crews had to learn new techniques for this project, and crews were divided into specific tasks. For instance, some installed fabric or wrapped the baskets with the coconut blanket or cut the blankets to specific lengths. Others pinned baskets to the ground prior to anchoring.

Select granular backfill was used to accommodate the high, steep micro-terraces, and topsoil filled the basket faces to encourage growth of vegetation.

Geogrid and coconut blanket placement

NDOT specifications required the erosion protection to consist of a heavyweight, ultraviolet (UV)-stabilized polypropylene netting with coconut fiber inclusion that exhibited a 960 lb/ft tensile strength. The mat chosen, a 100% coconut fiber turf reinforcement mat, was bonded to biaxial geogrid reinforcement. The mat exceeded NDOT specifications and was incorporated into the final facing reinforcement solution.

As baskets were placed, each was wrapped in a biodegradable coconut blanket to control erosion and stabilize the soil while vegetation was established on the micro-terraces. Four stakes per square yard in an offset square pattern held the coconut blanket in place.

The secondary reinforcement face wrap had a minimum embedment of 4ft at the top and bottom of each basket **(Photo 4).** Micro-terraces were backfilled as they were built from the ground up **(Photos 5, 6,** and **7).**

Seed was applied by hand to the hill-facing side of the coconut blanket, compared to the common practice of spraying the seed onto an erosion control mat. This was to help ensure that vegetation would take hold. Vegetation

PHOTO 8 A wide-view lens captures the entire slope near project completion. This reinforced soil slope meets requirements for beauty and strength: Motorists are protected from rocks and soil in the road, and runoff has been stopped from crossing under the roadway and emptying into a nearby stream system that flows into Lake Tahoe.

type and placement were defined by NDOT specifications and TRPA requirements, which called for only indigenous plantings.

TRPA required the contractor to commit to a three-year maintenance period of the slope. Currently, vegetation is established and has not required much upkeep **(see page 20)**, although during construction the slope was watered daily. Because the slope faces north and doesn't get much sun, it retains moisture more easily.

Safe, stable, secure

The contractor for the U.S. 50 NDOT slope reinforcement project stored all of the excavated material and monitored its stockpiles for runoff. Its best management practices methods convinced the TRPA to allow work beyond the Oct. 15 construction moratorium in the area so the slope was not unprotected during the winter. From October to mid-December 2012, the crews worked on slopes 27 East and 27 West, finishing the construction in mid-December **(Photo 8).**

Travelers along this scenic stretch of U.S. 50 can rest assured that the slope above them is secure and stable, and the beauty of the mountainside has been preserved. While the erosion and runoff at slopes 21 and 27 is now stopped from crossing under the roadway and emptying into a nearby stream system that flows into Lake Tahoe, neighboring slopes are experiencing erosion and runoff.

This reinforced soil slope meets TRPA requirements for beauty and NDOT requirements for strength, stability, and durability. By rethinking the original proposal, NDOT benefited from a stronger, easy-to-install reinforcement on the slopes, and all those who venture to Lake Tahoe on this stretch of U.S. 50 can enjoy a safe, serene ride.