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Stabilization Techniques

Safety First: Slope Stabilization Techniques

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CALTRANS

Professionals who work with soil erosion control are accustomed to using the Revised Universal Soil Loss Equation (RUSTLE2) to determine erosivity, erodibility, and land use. What began as an equation method became an enhanced database for scientists that includes the results of those equations to help determine soil loss and techniques for soil conservation.

Engineers who work in the field of slope and rockfall management use potential energy equations to calculate how much energy might result from rocks and debris falling from hillsides. From that, they can calculate the strength of the materials to be installed to protect the public from the rockfalls.

The potential energy equation is P.E. = mgh (where m = mass of rock, g = gravitation acceleration, and h = vertical height of rock).

To use this information to provide a design height recommendation for a protective fence, the Rockfall Catchment Area Design Guideline (RCADG) and the Ritchie Criteria are then used.

Engineers at Yeh and Associates used these equations to help the California Department of Transportation (Caltrans) design a suitable rockfall safety fence. The Marina Lake Fire had pressed Caltrans into an emergency situation. Geobrugg was able to modify fence elements and deliver them in a timely manner to keep Highway 395 in southern California open to motorists.

Working Together to Provide Road Safety

When Caltrans proposed two phases of a motorist safety project along a 1-mile section of Highway 395, agreement required more than three years of meetings, in-depth analysis and testing, and collaborations with the Mono Lake Committee. In the 2015 remedy, Caltrans planned to use an anchored mesh to help prevent falling rock from landing in the traffic corridor.

"This was a traffic safety project by Caltrans," explains Joe Blommer, resident engineer with Caltrans. "The wind just blew everything down onto the road. But as we were gearing up for 2016—one week before work was to begin—the fire came up. The fire burned up to the 10,000-foot elevation, and then the rocks really fell. We had a 10-ton boulder come down."

Caltrans monitors Highway 395 at Mono Lake north of Lee Vining in Mono County, CA. Mono Lake is considered to be one of the oldest lakes in North America. Blommer describes the route as a critical north-south corridor for tourists, commuters, and property owners traveling between San

Bernardino and northern California. The transportation corridor on the east side of the Sierra Nevada mountains affords access to Yosemite National Park, Mammoth Mountain ski area, and southern California vicinities.

Near Mono Lake, the highway narrows to two lanes, making safety projects of paramount importance. For Caltrans, these safety projects had no alternative. The $5.8 million project was funded through the State Highway Operation and Protection Program. The majority of transportation funding for Caltrans is provided by federal and state fuel taxes.

A raging fire that began June 24, 2016, started near an old marina on Mono Lake and became known as the Marina Lake Fire. Before its containment July 7, it devastated 654 acres, mostly steep hillsides. Along Highway 395 from mile posts 53.2 to 53.7, six cut slopes were the focus of the Caltrans two-phased rockfall mitigation project. Phase 1 had been completed before the fire, but post-fire stripping of vegetation at the higher elevations, outside the Caltrans right of way, produced rockfall events that led to the need for emergency rapid mitigation of increased rockfall threats. Needless to say, phase 2 was temporarily suspended.

"The contractors [Geobrugg] were already mobilizing, and we just kept them," says Blommer.

Yeh and Associates, an engineering firm in Grover Beach, did an onsite field investigation on July 19 and 20, 2016. Evaluating the site for rockfall conditions included the geologists interviewing construction and maintenance personnel along the roadway to obtain their verbal eyewitness accounts of rockfall activity post-fire. Walking the site, the engineers documented conditions and measured slope angles and catchment widths.

Caltrans had installed K-rails, the white concrete barriers, to keep cars from veering into the previously installed mesh wire fence from phase 1, says Blommer. K-rails are usually installed as an immediate response to a rockfall event.

Engineering geologists from Yeh observed rockfall impact to the K-rails along the fog line and to the pavement in the roadway. Caltrans reported that a rockfall had spalled concrete from the upper part of the rails and moved over into the highway lanes.

Yeh and Associates recommended that Geobrugg modify and install its GBE-500 A-R system in two areas along 3,500 linear feet of the highway to mitigate any increased risk of rockfall. However, a challenge arose that complicated typical installation of the temporary flexible rockfall fence: fiber-optic cable was located in the area of the installation.

Geobrugg's regional manager, Saleh Feidi, explains why a typical installation was not possible. "The GBE-500 is an all-encompassing system, with posts, cables, anchors, and the mesh fence. But we couldn't pour any concrete foundation because the fiber optic runs all under the area. Depths were anywhere from 5 feet to 15 feet, so we had no way of knowing where it was."

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Highway 395 in California

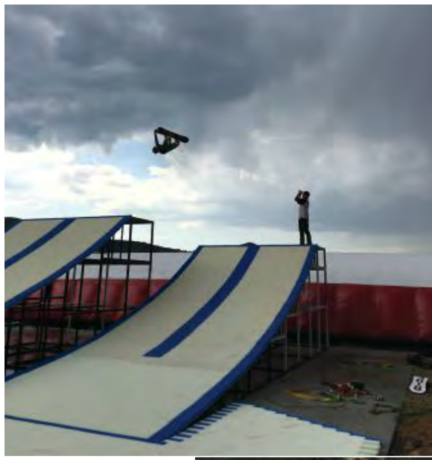
The answer, he said was a "floating" one-of-a-kind foundation.

Geobrugg's focus is on high-tensile steel wire systems used for rockfall mitigation, landslides, and avalanche and debris flow. The global company, based in Switzerland, has branches and partners in over 50 countries.

The Forest Service had requested that any temporary mitigation have a five-year service life and that efforts include revegetation. In making their recommendations, Yeh engineers used the potential energy equations to determine the flexible rockfall fence's energy rating and height. After studying the natural slopes above the highway, they used slope heights and geometries to determine maximum vertical height for the potential rockfall to hit the road. The vertical height was estimated at 200 feet. Using that, they calculated maximum potential energy of rockfall from the 200-foot vertical height impacting the flexible rockfall fencing.

Olympic Park training facility in Utah

UTAH OLYMPIC SKI AND SNOWBOARD PARK



Using data collected about the size of boulders observed in the most recent rockfall, the weight of the boulders that could potentially hit the fence was estimated to be 1,500 pounds. Although the maximum potential energy was calculated for a 500-kJ rockfall fence, the maximum kinetic energy actually hitting the fence would be much less. Blommer explains that the soils in the slopes are very soft, and in some places the slopes level off. In addition, taking into account the trees in the area, the rocks would lose energy when traveling down the soft embankments; rolling along flat surfaces and hitting trees and vegetation slows their velocity.

Geobrugg installed 2,000 linear feet of 10-foot fence at the southern end of the project. In the steeper northern areas, 13-foot-high fencing was installed along 1,500 linear feet of the highway.

Working around the two constraints of the project—emergency time factors and the buried fiber optic cable—the engineers collaborated with Geobrugg to help modify the GBE-series rockfall fence to optimize its functionality and ensure installation in a timely manner at the site.

To modify the rockfall fence, the Geobrugg engineers took the GBE A, with its basic hinged post and a base plate supported by upslope and lateral wire ropes, and the GBE A-R, with a braced post design but no support ropes, and came up with the A-R Modified. The GBE A-R Modified uses a global support to accommodate the post base support (from the original A-R) with wire ropes and upslope and lateral support wire ropes (from A). Because the purpose of the new design was to prevent the post from "kicking out" upon impact from the rockfall, the post's wire rope is attached to the base of the post and attached to a ground anchor located at the base of the slope.

Air rotary drilling methods using an excavator-mounted drill were used to drill the anchor holes into the subgrade. Geobrugg contractors were onsite in July 2016 for layout and post hole markings. Within that first week they began delivering posts to the site. By August 5, 2016, the posts had been installed. 57 posts, spaced 30 feet apart, were put in and more than 700 linear feet of #3 TECCO mesh fence was hung. The $2.2 million Marina Lake Fire Emergency Project also included repairing guardrails.

Blommer says that in May, the area had experienced rockfall that originated from as far as the top of the hillside. "In 2016, they put up the 500-kJ 10-foot and 13-foot fences. In 2018, we had another rockfall event; a 300-foot section got destroyed. So under another emergency contract, that was removed, and we put in a 1,000-kJ fence," he explains.

"The Forest Service study said it was a five-year plan to stabilize that area, and we're three years into it now. We'll be having an evaluation again. Caltrans geotechnical personnel and the Forest Service will come together on that one."

The ultimate goal is to stabilize and revegetate the six eroded slopes. The anchored mesh is only one component. Vegetation in the area has been specifically chosen to the Mono Basin's ecosystem and soil characteristics.

Training Winter Athletes—Throughout the Summer

As millions around the globe watched the 2002 Winter Olympic Games, ski and snowboarding teams took their talents to the slopes. Many of the events were hosted at the US Olympic Park training facility in Park City, UT. The 400-acre winter sports venue houses one of only four sliding tracks in North America, as well as facilities for bobsled and luge, ski jumping, six Nordic combined jumps, and skeleton events.

In an effort to help professional and aspiring winter athletes train during summer months, Olympic Park manager Jamie Kimball and US Ski and Snowboard began looking at options that the Olympic Park could offer. The winter athletes had previously trained by performing their jumps and landing on snow slopes, by doing flat airbag-style landings, or by landing in million-gallon water pools. Other parks featured the airbag-style training, but the snowboarders had to train to land on top of the airbag resting on their backs. Some complained this was not a good option. The idea was to design a 160-foot-long ski jump that replicated the winter snow jumps and that athletes could land on—safely.

The design Kimball wanted would provide the same slope with artificial snow and a landing similar to those on slopes that replicated the true conditions of the sport. The US ski and snowboarding team consulted with Snow Park Technologies as they designed the new summer-use training airbag slope. With his son, Chandler, on the snowboard team, financial executive Brandon Hunt led a successful fundraising campaign to help with the costs of new equipment for conditioning the winter Olympic athletes.

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"The options we looked at ran the gamut. We had a steep slope, greater than a 2:1 slope," says Kimball. "We needed something to retain the slope and at the same time provide the structure we needed. You had to be able to put a ski surface on it and have it stand up to the winters here. We literally looked at several things like a wood deck, concrete beams, steel beams, and concrete pillars. Some geoengineering options sounded okay until after digging into the ground. We found it was all a sandy slope."

Kimball then came across the idea of using a 3D geocell system as a base. He had seen it used as pond liner and on roads and knew it remained flexible as the ground moved. He thought the concept seemed sound, but wondered whether it would it provide the precise slope retention he knew was absolutely necessary.

He called Joe Kaul, a Colorado-based contractor with Kaul Corporation and distributor for Presto Geosystems. Kaul became the project support for Kimball and his construction crew. Presto's Geoweb system was ultimately chosen to use in the project because of its ability to withstand subgrade movement. Equally important to Kimball was that it allowed reduction of the 6-inch reinforced concrete depth to 4 inches. Still, given the 150-pound-per-cubic-foot unit weight of concrete, the 4-inch slab would weigh approximately 250,000 pounds; that's a lot of concrete to stabilize on a 2:1 hillside slope.