By John Heap, Samuel Randolph, Patricia Stelter

The Mud Lake Dam project

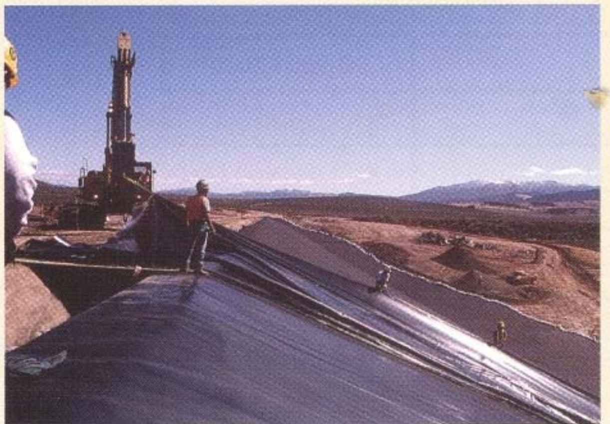

Photo 1: The protective geomembrane layer was placed over a geotextile on the dam face and the vertical seams were field-welded.

Situated at the base of the United States' picturesque Sierra Nevada range, the reservoir at Mud Lake Dam, Gardnerville, Nev., was built using horse-drawn scrapers and steam shovels more than 100 years ago as an earthen dam. No longer meeting the safety standards established by the Dam Safety agency of the State of Nevada, rehabilitation was deemed necessary, A cost-effective alternative to the traditional reinforced-concrete face dam was proposed by Colorado Lining International. The proposed geosynthetic solution incorporated a geomembrane with geotextile protective layers and a concrete-filled geocell armor cover.

This paper focuses on a specific geomembrane face/geosynthetic composite rehabilitation to the rockfill dam built early in the year 2000.

Design considerations

The geosynthetic design included the following components installed on the prepared dam face, as detailed by geotechnical engineer Norm Bishop of Stone & Webster:

- a nonwoven geotextile protective underlayer (16 oz./yd²);
- a 45-mil reinforced poly-propylene geomembrane;
- a nonwoven geotextile protective over-layer (16 oz./yd.²);
- a 75-mm (3-in.) tendoned, perforated Geoweb® cellular confinement system;
- a 75-mm (3-in.) poured-in-place concrete veneer facing element protecting the underlying geomembrane.

The geosynthetic solution was chosen for three reasons, according to John Heap, President of Colorado Lining International. "First, it saved cost. The client saved between $600,000-$700,000 over conventional reinforced-concrete methods. Second, it provided a waterproof protection to the dam face, the client has a system that will conserve more water and will function for a long, long time." The third reason, added Heap, was constructability. "Custom-made geomembrane panels were precut and welded offsite, significantly reducing construction time, as well as limiting exposure to natural degradation elements and eliminating the need for special construction equipment."

The geocell slope-protection system with integral tendons and ATRA® clips was specified as the geomembrane-protection system. The tendons allowed the geocell sections to be anchored at the crest of the slope, secured to a deadman anchor system and suspended over the geomembrane. "When anchoring with traditional stakes is not possible, as in this case, integral tendons and load-transfer clips allow the geocell system to be suspended over the geomembrane without jeopardizing its integrity," Samuel Randolph of Soil Stabilization Products Co. notes. "This method enables a system that directly protects the geomembrane from accidental puncturing and natural degradation."

Photo 2: The tendons and restraint clips were integrated in the geocell panels at a fabrication area and carried to the slope for deployment.

Installation

The installation of the geosynthetic components was performed in layers.

Layer 1

A 16-oz. (435-gm) nonwoven geotextile underlayer was first installed over the entire 2h:lv dam face. Rolls measuring 4.6 m x 91.4 m (15 ft. x 300 ft.) were pulled in place from the top of the dam and heat-welded together. Despite winds up to 48 kph (30 mph) slowing construction, the entire face was covered and ballasted at the top and bottom with sandbags in one 10-hour work shift. The geotextile layer provided protection to the geomembrane, adding puncture resistance and supporting strength across the face of the dam. In addition, this layer allows for drainage along the face by providing a path for water to flow under the lining.

Layer 2

The second layer was a 45-mil reinforced polypropylene geomembrane. Custom panels were fabricated to size with staggered panels to account for length differential along the face of the dam.

A total of nine panels were custom fabricated and tested prior to shipping to the site. On the second day of the geosynthetic installation, deployment of the custom geomembrane panels began on the west side of the dam abutment.

A total of 8,360 m² (90,000 ft²) of material was deployed and tested in a 12-hour workday. By utilizing deployment equipment on the crest and toe of the dam face, materials were placed quickly and efficiently. As deployment progressed, the geomembrane welding crew began field-welding the eight vertical field seams with a hot wedge welder and flat roller assembly **(Photo 1)**. Field QA/QC consisted of trial weld samples prior to field welding to verify machine settings and non-destructive testing utilizing the air lance test method ASTM D 4437. All welds were nondestructively and visually inspected by the geosynthetic installer and QA/QC inspector.

Layer 3

A 16-oz. (453-gm) nonwoven geotextile layer was installed as a protective layer over the geomembrane lining. Providing an additional protective and supporting layer between the geomembrane and the cellular confinement system, this layer was also installed and welded in place in one 10-hour workday.

Preplanning and resourcefulness by contractor Kiewit Pacific Construction helped facilitate the placing of the tendons and clips within the geocell sections. As the geotextile/geomembrane layers were being installed, a separate crew joined geocell sections for the final layer of the dam facing. Crews prefabricated geocell panels to specified lengths up to 34.7 m (114 ft.) using assembly beds constructed for threading and securing tendons and the load-transfer restraint clips **(Photo 2).**

Kevlar® (aramid) tendons with a minimum break strength of 13.34 kN (3,000 lbf.) were threaded through predrilled holes in the geocell sections. Restraint clips were attached to the tendons in designated cells according to the design. To ensure the preassembled panels would match the required length when deployed on the slope, the sections' outer edges were stretched and placed over perimeter stakes.

Photo 3: *With the high-strength tendons secured to a crest anchor pipe, the trench is filled with concrete prior to securing the geocell sections to the trailing tendon ends.*

Pre-assembling the geocell sections with the tendons and restraint clips in a controlled, flat environment precluded the need for construction crews to work on the steep dam face. With the bulk of the labor expended in this safer setting, the installation time of the pre-assembled sections was significantly less than the contractor's expectations.

Layer 4

After the geotextile/geomembrane layers were installed, a Schedule 80 steel pipe deadman anchor was placed the full length of the crest anchor trench in preparation of the geocell system. The pre-assembled geocell sections were carried from stockpiles in the prefabrication area and positioned on the slope according to the correlating slope length. The tendon ends on the up-slope end of each section were secured to the deadman anchor.

Once secured, the trench was filled with concrete **(Photo 3)**. The geocell sections were then expanded down the slope to their proper length and secured at the toe. To maintain the sections' proper dimension and to facilitate infilling, adjacent sections were interleaved and connected with staples using a pneumatic stapler.

After installation of the 75-mm (3-in.)-deep geocell layer, concrete was placed in the geocell layer to protect the membrane/fabric layer over the dam face. A concrete mix with a 10-mm (3/8-in.) pea gravel aggregate was used to infill the geocell sections **(Photo 4)**.

On day one, the concrete infill was placed in the geocell sections on the slope's upper area using the chutes of the concrete trucks. On day two, a concrete pump was used to place concrete on the remaining length of the slope face **(Photo 5)**. This method allowed over 382 m³ (500 yd.³) of concrete in-fill to be expediently placed in just two days while cutting pumping expenses in half.

The flexibility of the geocell sections also allowed construction workers to walk within the cells and easily maneuver on the slope face while raking concrete infill.

The results

The geomembrane provides a waterproof barrier that will prevent water loss through the dam face. The concrete-infilled geocellular structure suspended over the liner offers stability and protection to the liner without endangering the liner's integrity. This type of dam rehabilitation can be installed on a relatively short schedule (six months at this site for design, construction and reservoir filling).

Photo 4: Concrete with a 3/8-in. pea gravel aggregate mix was placed in the open cells of the geocell sections and distributed evenly by workers positioned on the face of the slope.

In total, 8,360 m² (90,000 ft.²) of liner material and more than 100 sections, or 5,574 m² (60,000 ft.²), of geocell material and more than 382 m³ (500 yd³) of concrete were used to protect the dam face at Mud Lake Dam.

The design-build team for this project included: Kiewit Pacific, Stone & Webster, Colorado Lining International, and Soil Stabilization Products Co. associated manufacturers. GFR

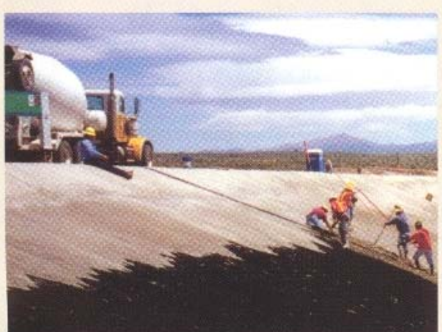

Photo 5: Working from the slope top to bottom, concrete was placed in the expanded lower geocell sections using a concrete pump.

This project received Outstanding Achievement Award recognition for outstanding and innovative work with industrial/technical fabrics at the Industrial Fabrics Association International's Expo 2001. The International Achievement Awards recognize the latest advancements in industrial technical fabric design and manufacture in 24 categories.

A different version of this article appeared previously in Land and Water.

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