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Photo 1. Infill is sprayed over the cellular-confinement system as installers rake the material into the cells.

Cellular confinement tames near-vertical slope

If you can't move the hill, control it. Stuck with an awkwardly steep shale slope at the Jefferson County, Ala., solid-waste transfer station, engineers selected a cellular-confinement system to mitigate erosion.

By Frank Hogan and William Zeinert

CONSTRUCTING JEFFERSON COUNTY ALA.'S new solid-waste transfer site to fit an existing county lot challenged the project's contractor and engineers to develop a unique solution for a potentially severe erosion-control problem. The county-owned site offered good access for large vehicles and seclusion from residential areas, which made obtaining the proper zoning and permits less complicated. However, the site was not ideal for the intended construction.

Its topography includes a large, shale 1.5H: 1V slope, which ranges in height from 70 to 200 ft and covers nearly 2500 lineal ft. The site's buildable area butts directly against the toe of the slope, leaving only a narrow, 250-ft strip on which to construct the necessary buildings.

Design considerations

Due to budget constraints, the shale slope could not be cut down. Though it was considered self-stable, leaving the surface unprotected would lead to serious erosion problems. Migration of debris and topsoil downslope would clutter the narrow site. An erosion-control solution had to be implemented.

Engineering Service Associates (ESA), Birmingham, Ala., was selected to design the project. Initially, the firm considered a riprap solution. A slope covered in riprap would have provided the needed erosion control while remaining relatively maintenance-free. However, the volume of riprap needed to cover a slope of the Jefferson County site's size would have exceeded budget limits. The county also wanted an appearance that would better blend into the surrounding environment. For these reasons, the riprap option was abandoned.

The next approach to be proposed was the installation of a retaining wall along the toe of the slope. Falling debris would collect behind the wall and be prevented from reaching critical areas. Though this solution had been used in similar projects, the county wanted a long-term solution that would require little maintenance. The retaining-wall solution offered the county a short-term fix, but it would require repeated excavation of the fallen debris, creating a long-term maintenance concern.

The engineers felt that the ideal solution would include geosynthetic technology. They approached Alabama-based Sunshine Supplies to develop a solution that would meet the project's budget requirements while providing a long-term, aesthetically appealing, maintenance-free option.

The geocellular solution

Because of the slope's overall size, make-up and grade, Sunshine owner J. H. "Skip" Ragsdale recommended installing a comprehensive erosion-control system that would provide a vegetative mat over the entire surface. The mat would meet the county's requirements by providing both slope protection and a natural look. The specified system includes a nonwoven geotextile, a 3-in. perforated cellular-confinement system, hydro seeding and erosion-control blankets.

Well-established vegetation is an effective and attractive form of protection for slopes exposed to mild and moderate surface erosion. Cellular confinement provides structural support to the soil veneer, ensuring that a uniform thickness is established and maintained on the slope face. In this case, the geosynthetic system promotes the growth of the slope's vegetative mat, which provides reinforcement. The system's cells increase the vegetation's natural resistance to erosive forces and protect the root zone from soil loss.

The county selected a Geoweb system, manufactured by Presto Products of Appleton, Wis. The product features a three-dimensional, expandable, honeycomb-like structure and a hole pattern that helps increase root lock-up with vegetated systems. The perforations also allows the passage of water, nutrients and soil-organisms from cell to cell, thus creating a healthier soil environment.

At the same time, the cellular-confinement system facilitates parallel-slope drainage of the cell. In saturated conditions, the resulting overall weight reduction of the infill material reduces downslope sliding potential for a more stable system.

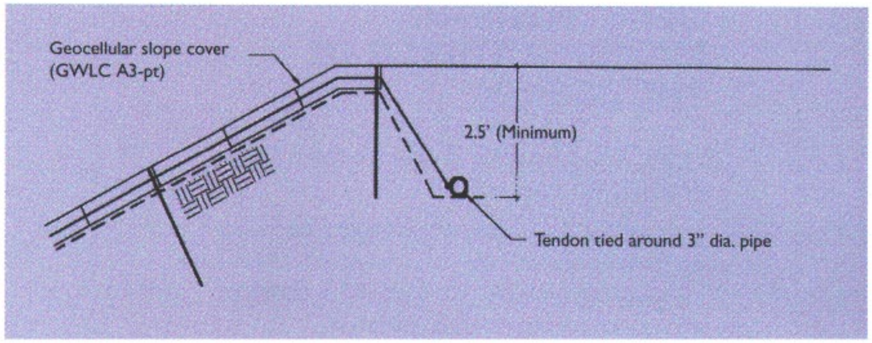

Figure 1. Crest anchor detail

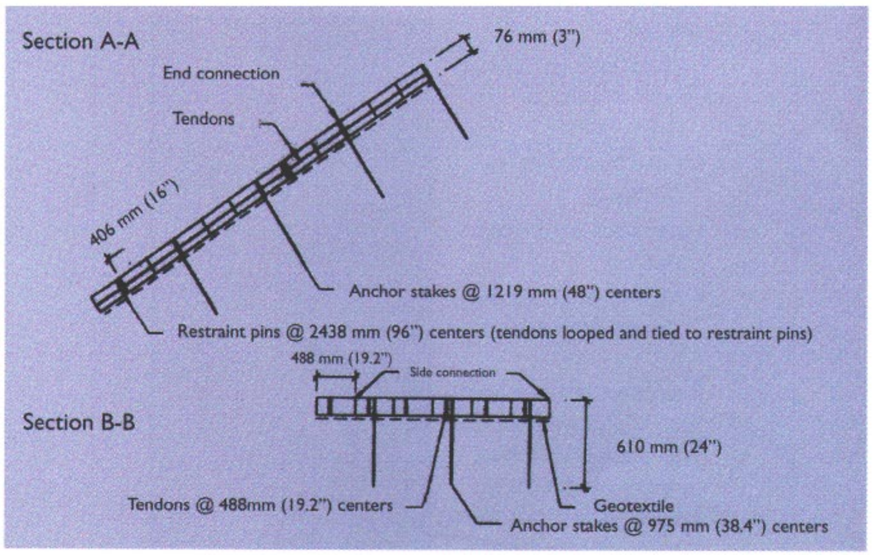

Figure 2. Restraint pins and tendon fasteners add to the cellular system's resistance.

The installation challenge

Installation of the erosion-control system began in April 1997. First, a 4-oz. Mirafi nonwoven geotextile was laid down the slope to serve as a separation layer and to provide in-plane drainage of groundwater seepage from the foundation soil. Because it is anchored at the top of the slope, the geotextile also contributes additional tensile resistance to the soil veneer.

Next, sections of the cellular-confinement system were expanded down the slope. Computer models calculated the total driving shear force (due to gravity) along the geotextile/soil interface to be 2497 lb/ft. For the assumed critical-interface friction of 24°, it was determined that the 3-in. cellular-confinement system slope cover would provide a maximum available shear resistance of 1667 lb/ft. This produced a safety factor against downslope sliding of .67-below the acceptable safety factor of 1.3. The addition of a stake, tendon and crest-anchor configuration increased the total resisting forces and satisfied the design-safety factor.

Number four rebar "J"-hook stakes, each 24-in. long, were installed at 48-in. increments (3 cells) down and 38.4-in. intervals across the slope. Polymeric tendons were incorporated into the system through pre-drilled-holes on 19.2 in. centers. These were anchored to a 3-in. schedule-80 polyvinyl chloride (PVC) pipe, which was buried in a 2.5-ft deep trench at the crest of the slope (**Figure 1**). Four-inch #4 rebar keepers also were installed to act as restraint pins, transferring loads on each tendon to the geocell sections at 96-in. intervals down the slope. The combination of the stakes, tendons and cellular-confinement system produced stability levels that met the project's safety requirements (**Figure 2**).

By the fourth day of installation, the six-man installation crew from Centreville, Ala.-based Forestry Environmental Services was able to place an 8-ft by 70-ft length of cellular-confinement material in less than one hour. This included installation of five tendons and 36 J-hook stakes, plus stapling the sides and ends of each cell with three staples per joint. The rapid installation rate helped keep the project on schedule and on budget.

Once the cellular-confinement system was fully installed, the crews began the tricky process of infilling the slope. They used an unusual approach involving a high-speed conveyor truck positioned on top of the slope. The conveyor sprayed the infill material 50-60 ft out and down the slope as the construction-leveling crew, secured with belaying lines, raked the material into the cells (**Photo 1**).

As work continued farther down the slope, the infilling process became more challenging. According to Ragsdale, ingenuity was required to properly infill the topsoil on a slope of such height and immensity.

To avoid piling up topsoil 50-60 ft downslope, a polyethylene tube was attached to the conveyer truck's discharge, allowing the fill-dirt to be sprayed farther. By sliding the tube from left to right, infill could be placed exactly where it was needed. Varying tube lengths were used to fill different heights down the slope.


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Photo 2. The fully vegetated slope blends well with the site's surroundings.

Shortly after the filling process was completed, a rainstorm provided natural assistance to the compaction process, or "hydrotamping." After the rain, the infill material's degree of compaction was ideal-compacting the infill any further would have hindered root growth and development.

To initiate vegetation, hydroseeding with a mix of hulled Bermuda, weeping love grass, creeping red fescue, and K-31 grasses was performed. Rolls of North American Green S- 150 erosion-control blankets were placed at a rate of 400 yd²/man-hour (2400 yd²/day) to prevent any surface washout before vegetation was established. According to Ragsdale, erosion-control blankets served as the final step toward completing the project to specification by optimizing conditions for the vegetation to germinate and become established.

Vegetated and functional

Since the system was installed, the slope has survived large amounts of rain. During January and February of 1998, rainfalls exceeded the norms by more than 8 in. Despite the very wet winter, the system has had no failures. The vegetation is now fully established, and the project is continuing to perform to specifications (**Photo 2**). GFR

Frank Hogan of Birmingham, Ala.-based Engineering Service Associates Inc. served as project engineer for the Jefferson County solid-waste transfer site.