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Molly Ann's Brook channel protection system

In the summer of 1999, the U.S. Army Corps of Engineers, Philadelphia District, designed and constructed a flood protection project for Molly Ann's Brook, located mainly in Paterson and Haledon, N.J. The brook is a tributary to the Passaic River, which flows through an urban area in New York Harbor. Communities along the 2.5-mile stretch of the brook have been subject to repetitive flooding as a result of inadequate channel capacity.

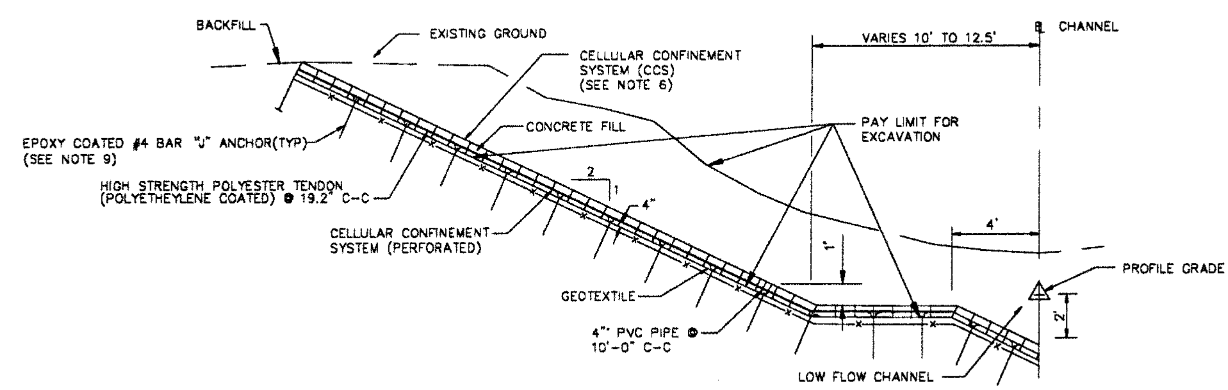
Within this location, there was also limited right of way, undulating and outcropping bedrock, and high stream velocities due to storm-water runoff from the surrounding developed areas. Erosion protection is paramount when designing flood protection projects in any environment, but it's even more critical in an urban setting, due to limited space and the proximity of structures.

In addition to these challenges, the design of the Molly Ann's Brook project varied from a trapezoidal riprap section to a rectangular section formed by precast concrete walls. Conventional solutions such as riprap, wire mesh gabions, cabled concrete mats, and more than 3,000 linear feet of precast concrete retaining walls were used to protect the banks of the brook and contain floods on adjacent areas.

Given the savings and ease of construction of a geocell system, the Corps of Engineers employed this innovative approach at two difficult locations. The geocellular approach in these two channel sections saved the Philadelphia District $395,000 overall. In addition, the District estimates that it designed and constructed the geocell wall for less than half the cost of an equal length of reinforced concrete retaining wall. The channel lining was completed at about 25% of the cost of a 54-in. riprap section of equal length.

Photo 1: Geocell sections underlain with a geotextile are placed on the prepared segment of the channel bend.

Figure 1: Cross section of geocell channel lining taken from construction plans.



Design

Two areas of the channel protection project were chosen to utilize the geocell approach to bank protection. In both areas, the Corps utilized Presto's perforated Geoweb® cellular confinement system.

The first area implemented the geocell system for channel lining protection. Design velocities approaching 20 ft. per second along 300 ft. of a sharp bend in the channel would typically be designed with a 54-in. thick riprap section. As an alternative to the riprap, a 4-in. layer of perforated geocell filled with low-slump concrete was used, to reduce construction time and costs.

The second area applied the unprecendented use of geocells in the construction of an earth retention structure. Perforated 8-in.-deep geocell layers, filled with compacted soil or aggregate, were used to construct a 400-ft.-long gravity wall along the right bank of the brook. The geocell wall was designed to replace reinforced concrete retaining walls. Ranging in height from 9 to 14 ft., the wall is protected from scour by a 4-in. concrete-filled geocell layer along its base, since the structure will be subject to flash flooding and high velocities during its 50-year design life.

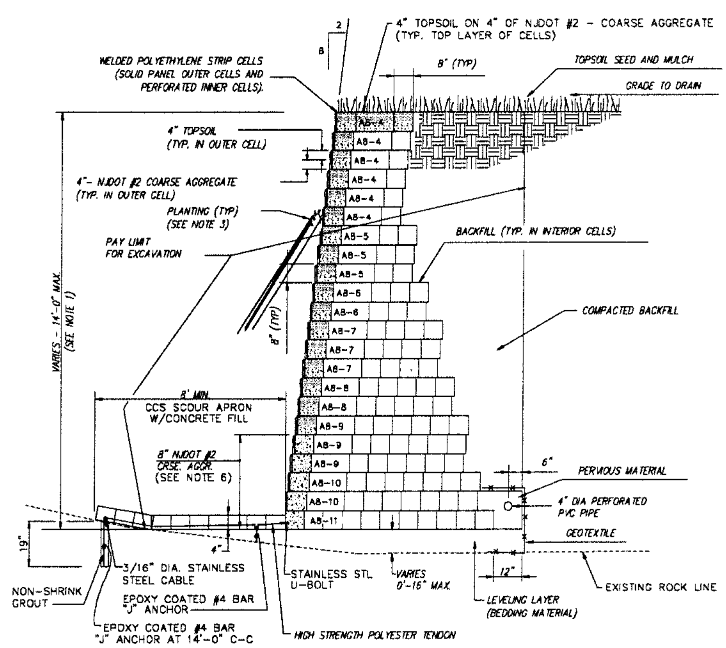
Channel lining

As the design parameters were established, it became clear that the velocities in the first channel bend were excessive, requiring substantial reinforcement. Traditional 54-in. riprap could be used, but a geocell alternative would save time and cost during construction by reducing labor, excavation and materials. Cabled concrete mats, previously used on a separate phase of the project, were also considered to protect this bend, but the geocell solution was more economical. The final design integrated a perforated 4-in.-deep geocell filled with concrete and underlaid with a nonwoven geotextile to protect the bend.

Polymeric tendons and 0.5-in. diameter steel bars were specified to anchor the geocell sections to the 1V:2H channel side slope. The factor of safety for slope stability controlled the spacing of the an-

Photo 2: Concrete infilling of the geocell sections on the 1v:2h channel side slopes.

Figure 2: Design cross section for geocell wall taken from construction plans.



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chor system. The tendons were spaced every 19 in., or every third cell, running perpendicular to the brook. Varying lengths of 0.5-in. diameter rebar, spaced 8 to 48-in., anchored the tendons to the slope, depending on the depth to bedrock. If rock was located within one foot of the final grade, rock anchors were specified. The final design typical section is shown in Figure 1.

Perforations were required in the interior geocell walls in order (1) to allow the concrete within the 4-in. depth to adequately bond between the cells and (2) to increase the frictional resistance between the concrete and the cell walls. By using the perforated cell walls and filling the cells with a reduced-size aggregate in the concrete, this internal bond was established. Perforations also were necessary to achieve a high factor of safety against the dislodging of individual concrete-infilled cells in this channel exposed to freeze-thaw cycles and high-velocity storm events.

Since bedrock was anticipated, we decided that any outcropping would be left in place and the geocell system would be formed around the outcrop. Weep holes were placed on 8-ft. centers near the bottom of the slope to alleviate pore water pressure and uplift.

Geocell gravity wall

Implementing the geocell wall in an area where the elevation of rock surface varied greatly was optimal. Essentially, a gravity wall had to be designed for the greatest anticipated height, then modified in the field according to conditions.

The design of the wall was accomplished through a cooperative process between the Corps and InterSol Engineering. Utilizing a maximum height of 14 ft., the geocell wall was designed as a conventional gravity wall comprised of 8-in.-deep layers of geocell. The resulting design used geocell layers extending from the face into the bank a distance of 3 ft. to 7.5 ft. Each layer of geocell was set back 2 in. from the face of the underlying layer, allowing for future vegetation in the exposed front cells.

The slope of the front face of the wall was 1H:4V. The design called for filling the cells with native silty sand and gravel materials, except for the outer five cells of the first 5 layers of geocell; these cells would be filled with 3/4-in. stone. The concern was that exposure to constant flows could cause loss of material in the wall. When the final stream grade was established, the drawings reflected only one visible rock outcrop along the 400-ft. length.

Since we anticipated that the wall would be subject to high water velocities on a frequent basis, scour along the toe of the wall was a major concern. A 4-in.-deep layer of geocell (the same as used for channel lining), 8 ft. wide, was included at the base of the wall and filled with concrete. A typical section of the final design is shown in Figure 2.

The wall was designed to accommodate several required pipe penetrations for local storm-water outfalls. In addition, a drain was included in the design to collect any groundwater flows from behind the wall.

On the face of the exterior walls, a solid tan geocell material was used for aesthetic purposes. In addition, the 2-in. setback in each layer provided space for the outer cells to be filled with topsoil and planted with Virginia Creeper, a hardy perennial vine. The open front cells of each geocell section form horizontal terraces that capture rainwater while controlling groundwater evaporation, creating a natural environment for vegetation. Eventually, the entire wall face will have vegetation.

Photo 3: Excavator placing backfill material behind the gravity geocell wall.

Installation

Channel Lining: Construction of the channel lining was highly successful. Specifications required that a manufacturer's representative be present during the first week of placement or until the Corps was satisfied that the contractor could competently complete the job.

According to the contractor, the system was easy to install, required a minimal crew of three, and was easily adapted to varying conditions. After grading the slopes, the geocell was laid on the slope from top to bottom, anchored and filled with concrete using a bucket on a tracked backhoe.

The original design called for a trowel finish, but was changed to a rough raked finish due to safety concerns, as students from an adjacent high school who cut across the channel might slip and become injured on a smooth surface. This change in the concrete finish had a negligible impact on the channel capacity and allowed the contractor to complete the job in significantly less time.

Completion of the entire cross-section was accomplished in two phases, due to the need for equipment access along the streambed. The channel side slopes were graded first, followed by the streambed and low-flow channel sections.

The ability to complete the cross-section in phases without concern for cold

Photo 4: Geocell-protected section of the channel suffered minimal damage from Hurricane Floyd.

joints was helpful. The cells act as expansion joints throughout and prevent future uncontrolled cracking. The flexibility of the geocell system was a positive attribute in constructing the low-flow channel, since the material had to be flexible enough to cover a trapezoidal channel 8-ft.-wide-by-2-ft.-deep, while maintaining the integrity of the cells. The 300 linear ft. of channel lining were completed in less time than it would have taken to complete an equal length of 21-in.-thick riprap.

Geocell Gravity Wall: Prior to excavation to the final stream grades, the exact location and elevation of the bedrock was unknown. Once the overburden was removed, the bedrock was exposed under the footprint of the wall in four major areas. Beginning at one end of the wall, layers of geocell were brought up one level at a time. When outcrops protruded in the path of the wall, the geocell was simply cut and the next layer started. As the layers were constructed, the outcrops were eventually encapsulated beneath additional layers of geocell. Outcrops that extended beyond the face were incorporated in the final structure. Due to the width of the channel in this area, impacts to channel capacity due to the rock outcrops were acceptable.

Initially, the design called for filling the cells with native materials. Due to the presence of many large rocks and the need to overfill the cells for compaction, the geocell infill was changed to 3/4-in. stone. Inclusion of stone infill alleviated the need for meticulous compaction and removal of excess materials and made the drain unnecessary. The effect of the free-draining stone, combined with the perforated cells, allowed the entire wall to act as a drain. Previous stability concerns regarding slow draining of the backfill after a flood event were alleviated.

Inadvertent damage to some of the exterior cells during construction demonstrated the redundant nature of geocell wall construction. With the 8-in. horizontal cell depth, the breach of an outer cell exposed the next cell completely intact. Multiple cell breaches would be unlikely under even the worst conditions.

Conclusion

Although the Molly Ann's Brook project required only 300 linear ft. of concrete-filled geocell channel lining and 400 linear ft. of geocell gravity walls, the project may be a springboard to future use of geocells in flood-protection and streambank-erosion projects. GFR

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