

Molly Ann's Brook Channel Protection System

Condensed form of the paper presented at the 31st Annual International Erosion Control Association conference in Palm Springs, California, February 21-25, 2000.

Presenter:

Anthony J. DePasquale

Phone: 215-656-6669 Email: anthony.j.depasquale@usace.army.mil

Geocell Wall and Channel Protection for US Army Corps Flood Control Project

Paper by

Anthony J.
DePasquale
P.E. and
Douglas
Leatherman
P.E., U.S. Army
Corps of
Engineers,
Philadelphia
District, Randy
Thomas P.E.,
ACF
Environmental



INTRODUCTION

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, New Jersey. 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 even more critical in an urban setting due to the limited space and 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 over 3000 lineal feet of precast concrete retaining walls were used to protect the banks of the brook and contain the floods on adjacent areas of Molly Ann's Brook. Given the savings and ease of construction, the Corps of Engineers decided to take an innovative approach at two difficult locations.

THE 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 (geocell). Cellular confinement was developed in the late 1970's as a cooperative research effort between the Corps and Presto Products. Although the system has been around for almost 20 years, its use in the Corps' flood protection projects was miniscule. In fact, using geocells for the construction of earth retention walls along streambanks for Corps projects was nonexistent.

The first alternative applied the unprecedented use of geocells in the construction of an earth retention structure. Perforated 8-inch depth geocell layers, filled with compacted soil or aggregate, was utilized to construct a 400 foot 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 feet to 14 feet, the wall is protected from scour by a 4-inch concrete filled geocell layer along its base as the structure will be subject to flash flooding and high velocities during its 50-year design life.

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

Channel Lining

As the design parameters were established, it was clear that the velocities in the first channel bend were excessive, requiring substantial reinforcement. Traditional 54-inch riprap could be implemented, 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 would be more economical. The final design integrated a perforated 4-inch depth geocell filled with concrete and underlain with a non-woven geotextile to protect the bend.

Polymeric tendons and ½ inch 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 anchor system. The tendons were spaced every 19 inches or every third cell, running perpendicular to the brook. Varying lengths of ½ inch diameter rebar, spaced between eight to 48 inches, were used to anchor 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 to 1) allow the concrete within the 4-inch depth to adequately bond between the cells and 2) 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. The perforations were also 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 the geocell material strength and the concrete infill/cell wall interaction is based on a geocell product with ISO 9002 quality-controlled perforations, use of a non-perforated product manually drilled with holes, is not recommended.

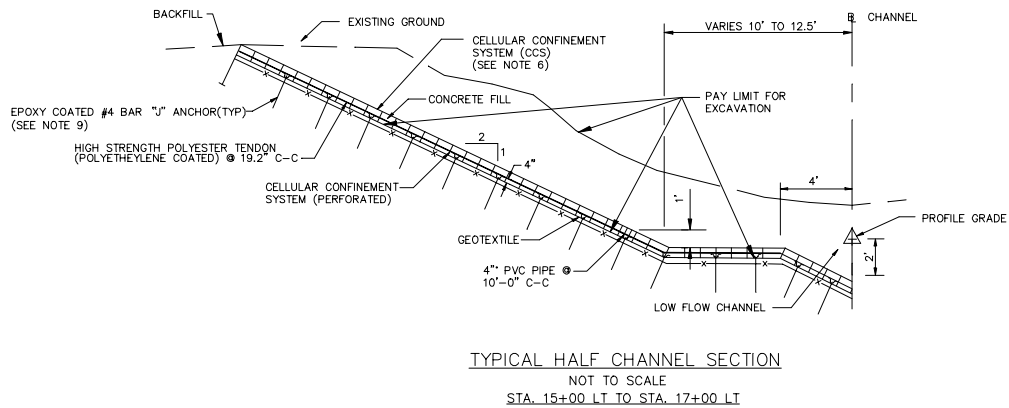


FIGURE 1: Cross section of geocell channel lining taken from actual construction plans.

Since bedrock was anticipated, it was determined that any outcropping would be left in place and the geocell system would be formed around the outcrop. Weep holes were placed on 8-foot 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 was known to vary greatly was optimal. Essentially, a gravity wall had to be designed for the greatest anticipated height, and then modified in the field according to conditions.

The design of the wall was accomplished through an iterative process between the Corps and InterSol Engineering, Inc., consultants for Presto Products Company. Utilizing a maximum height of 14 feet, the geocell wall was designed as a conventional gravity wall comprised of eight-inch depth layers of geocell. The resultant design was geocell layers extending from the face into the bank a distance of three feet to 7.5 feet. Each layer of geocell was setback two inches from the face of the underlying layer. The slope of the front face of the wall was 1H:4V. The design called for filling the cells with the 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 ¾ inch stone. The concern was that the exposure to constant flows could cause loss of material in the wall. The final stream grade was established and the drawings reflected only the one visible rock outcrop along the 400-foot length.



Since it was 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-inch depth layer of geocell (same as used for channel lining), 8 feet wide, was included at the base of the wall and filled with concrete. The final design typical section 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.

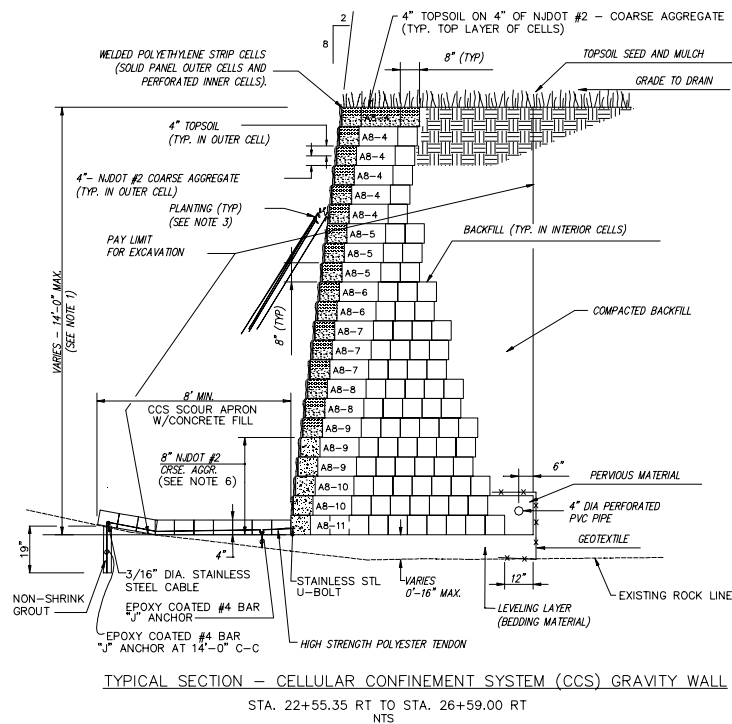


FIGURE 2: Design cross section for geocell wall taken from actual construction plans.

On the face of the exterior walls, a solid tan geocell material was utilized for aesthetic purposes. In addition, the two-inch 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 a vegetated appearance.

THE INSTALLATION

Channel Lining- The construction of the channel lining was accomplished with a high degree of success. The 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. Although the contractor had never worked with the product before, and was skeptical of its success, he quickly became an advocate for use of the system.

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. Students from an adjacent high school who cut across the channel could potentially 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 and not be concerned with cold 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; the material had to be flexible enough to cover the 8-foot wide x 2-foot deep trapezoidal channel and maintain the integrity of the cells. The 300 linear feet of channel lining was completed in less time than it would have taken an equal length of 21-inch 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 many large rocks, and the need to overfill the cells for compaction, the geocell infill was changed to ¾ inch stone. Inclusion of stone infill alleviated the need for meticulous compaction and removal of excess materials, as well as rendering 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-inch horizontal cell depth, a breach of an outer cell exposed the next cell completely intact. Multiple cell breaches would be unlikely under even the worst conditions.

CONCLUSIONS

Although the Molly Ann's Brook project required only 300 lineal feet of concrete-filled geocell channel lining and 400 lineal feet of geocell gravity walls, the project should be a springboard to future use of geocells in flood protection and streambank erosion projects. It is estimated that the U.S. Army Corps of Engineers, Philadelphia District designed and constructed the geocell wall for less than one-half the cost of an equal length of reinforced concrete retaining wall. The channel lining was completed at about 25 percent of the cost of a 54-inch riprap section of equal length.

ACKNOWLEDGMENTS

The authors would like to thank Dan Senf of Presto Products - Geosystems and Andy Lister of InterSol Engineering Inc. for their review and contributions to this paper.

For more information, contact:

Anthony J. DePasquale, PE, US Army Corps of Engineers – Philadelphia District Ph: 215-656-6669

Email: anthony.j.depasquale@usace.army.mil

Daniel F Senf, PE, Chief Engineer, Presto Products Co. Ph: (920) 738-1118 Email: dfsenf@prestogeo.com

Randy Thomas, PE, Engineer, ACF Environmental Ph: (215) 368-1848 Email: Rthomasacf@aol.com