James River Pulp Mill, Marathon, Ontario Geocell Case History

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Introduction

New provincial and federal guidelines for treatment of industrial waste that take effect in December 1995 mandated the construction of a secondary waste water treatment facility at James River - Marathon Limited's pulp mill in Marathon, Ontario. The mill site is located on the north shore of Lake Superior approximately 300 kilometres west of Thunder Bay, Ontario, Canada.

The new treatment facility includes a large secondary treatment basin which is 375 m long x 278 m wide x 5 m deep. The secondary pond has an outside perimeter length of 1.4 kilometres with 30 m long side slopes at 3.5H:1V.

The side slope of the lagoon is lined with 80 mil high density polyethylene (H.D.P.E.) geomembrane, cushioned with a needle punched nonwoven geotextile. The side slope liner keys into a 300 mm thick sand - bentonite base liner.

A concrete infilled geocell lining system was used to cover the upper zone of the side slopes and protect the geomembrane liner from environmental damage such as ice abrasion, wind and wave action, vandalism and possible damage from aerators if they were to become detached from their moorings. The protection system also had to have sufficient mass to withstand negative pressures from wave action and thus maintain stability in the near surface soil of the earthen slopes. Nonwoven geotextile separates the concrete infilled geocell from the underlying H.D.P.E. liner.

To expedite construction on site, special production length sections of geocell product were provided to minimize the requirement for cutting and stapling during site assembly.

Due to the low coefficient of friction between nonwoven geotextile and H.D.P.E. an anchor system was required to support the concrete infilled geocell in its designed position on the upper portion of the basin side slopes. This requirement was satisfied by use of polyester tendons to connect the installed width of geocell to a dead man anchor system at the crest of the slope. Standard textured geocell material was specified to optimize frictional resistance between the concrete infill and geocell cell walls.

Design Considerations

The design objective was to provide a hard protection system above the geomembrane that would conform to minor deformations (i.e. settlement, frost heave) of the foundation soil. The problem was to develop a system that would not slide downslope over the smooth geomembrane (friction coefficient of 0.14) without the use of ground anchors such as steel stakes or earth anchors. Finally, the protection system itself could not be abrasive or cause damage to the geomembrane.

Protection systems that could have been considered included reinforced concrete, rock riprap and cabled concrete block systems.

A reinforced concrete cover system would require forming on top of the geomembrane which would therefore increase the risk of damage (i.e. puncture) to the liner during construction and increase the cost of construction.

Rock rip rap was rejected since the size of rock required would be too difficult to place without damaging the geomembrane. Unless a wide midslope berm was to be constructed, riprap would also require full, or partial coverage of the bottom of the pond to provide passive resistance to sliding on the side slopes.

A cabled concrete block system was considered since it could be anchored at the crest of the slope and, with proper care, could be placed without damaging the geomembrane. However, concerns about the constructability of a cabled concrete block system on top of the geomembrane outweighed potential cost savings over some of the other alternatives.

Geocell Solution

Geocell confinement of soil, aggregate or concrete infill materials has been used increasingly over the last several years to provide:

- erosion protection of slopes and channels
- confinement of unbound materials as the face component of retaining walls (gravity and reinforced)
- an increase in the shear resistance and bearing capacity of unbound granular soils in load support structures such as unpaved roads and industrial yards.

The system provides full coverage for protection of the geomembrane yet is flexible enough to tolerate deformations in the foundation soil.

For this project, a concrete filled geocell system, with tendon anchorage, was able to satisfy all of the design objectives and requirements. High strength polyester tendons through the geocell system provided continuous reinforcement over the entire length of the slope to be covered and provided a solution to connecting the concrete infilled geocell to a deadman anchor located at the crest

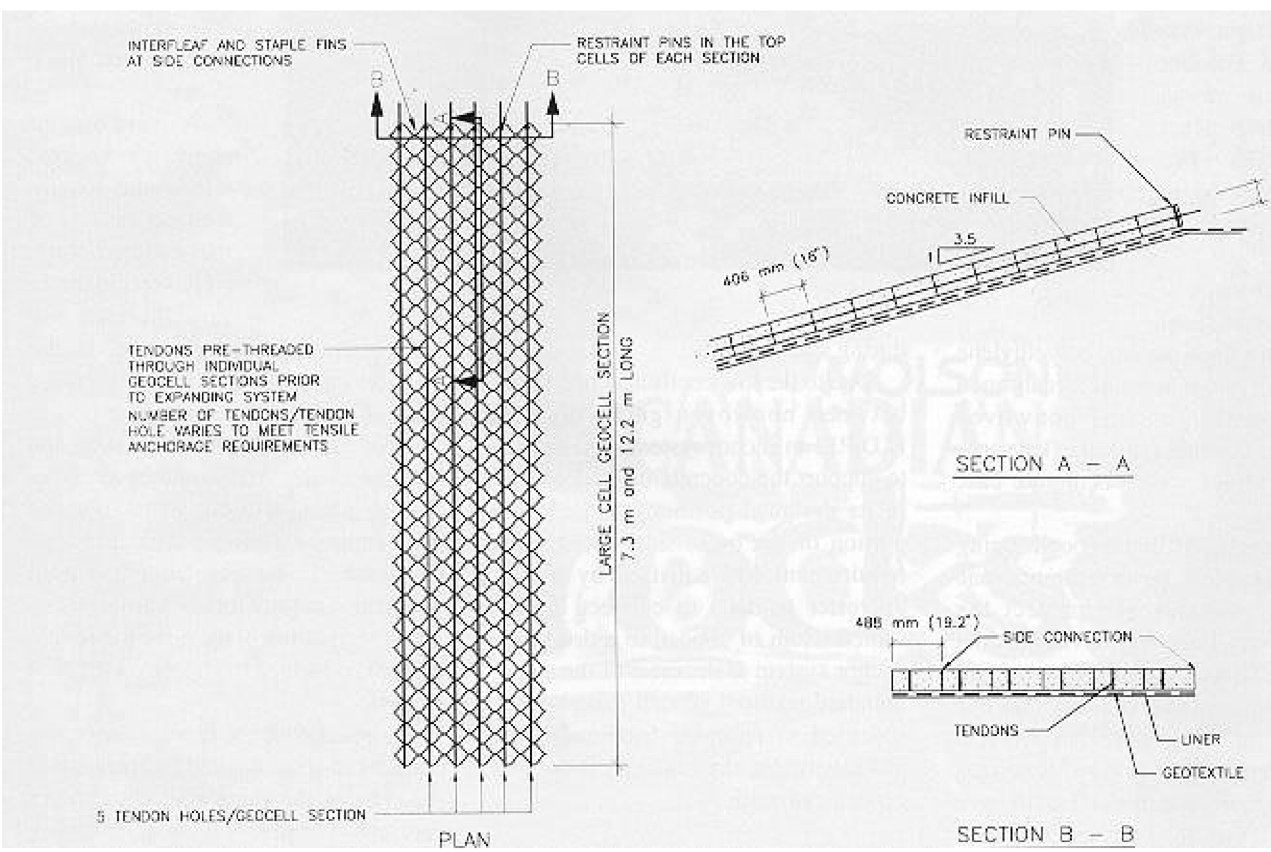

Figure 1 - Geocell and tendon configuration

of the slope. Since geocell material is portable and placed manually before in-filling with ‘ready-mix’ concrete, the system could also be constructed without risk of damage to the geomembrane.

Finally, the geocell protection system was judged to offer a technically superior system at a cost that was within the project budget constraints.

Design

To fully cover the maximum freeboard area of the pond side slopes, the geocell protection system was designed for 7 m and 12 m slope lengths. The slope angle was 16 degrees (3.5H:lV) on all sides of the pond and the coefficient of friction between the nonwoven geotextile and the geomembrane was estimated to be 0.14 (angle of shearing resistance = 8°). The design depth of concrete cover was 100 mm.

Assuming an unit weight of 23.6 kN/m^3 for concrete infill, it was determined that the net downslope driving shear stress would be 0.33 kN/m^2 which equates to destabilizing forces of 4.0 kN/m and 2.3 kN/m on the 12 m and 7 m long slopes respectively. Thus the minimum factored tensile capacities of tendon anchored systems on the 12 m and 7 m long slope sections were required to be equivalent to 4.0 kN/m and 2.3 kN/m, respectively.

The minimum average break strength of the specified tendon was 7.1 kN. A minimum overall design factor of safety of 6.2 was established for the tendons using the following partial factors of safety.

Long term creep (polyester yarn)
2.5[1]
Mechanical damage (e.g. construction)
1.0[1] (applied to knots)
Environmental degradation
1.1[1]
Factor of safety (uncertainties)
1.5[1]
Strength reduction due to knots
1.5[2]
Factored design tensile strength
1.15 kN

1. *after Task Force 27, “Design Guidelines for use of Extensible Reinforcements (Geosynthetic) for Mechanically Stabilized Earth Walls in Permanent Applications*
2. *based on strength tests of knots around a 16 mm diameter; smooth, steel rod using a girth hitch with one extra wrap, and two half hitches. The knot type used was a double anchor bend with two half hitches.*

The geocell material supplied to the site was provided with 5 pre-drilled holes (10mm diameter) per section. Since expanded sections are 2.44 m wide, the required tendon tensile forces per panel width at the crest of the slopes were

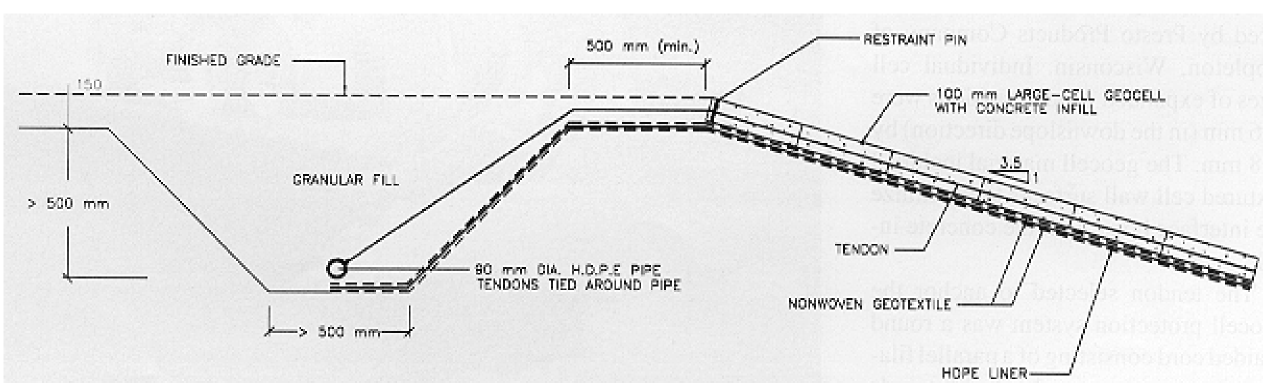

Figure 2 - Pipe Deadman and Anchor Trench Detail

[1] *Ovesen, N.K., 1964, Described in USS Steel Sheet Pile Manual, 1975*

determined to be 9.7 kN (i.e. 3.96 kN/m x 2.44 m) and 5.7 kN. Using the above determined design strength for the tendons, the calculated number of tendons required per panel width were 9 and 5 for the 12 m and 7 m slopes respectively. In the 12m long section of geocell, double tendons were inserted in 4 of the pre-drilled holes in each panel to carry the required tensile loads. The general design configuration of the geocell and tendon anchor system is illustrated in Figure 1.

Detailed analyses of several different anchoring systems determined that the most cost effective method of anchoring the tendons was to tie them to a continuous deadman anchor. A nominal 90 mm diameter polyethylene pipe was selected as the dead man for the anchor system. Ovesen's[1] method for design of deadmen anchor slabs in granular soils was used to determine the required diameter of the anchor pipe and the soil cover to be provided above the anchor to provide the required pullout resistance. Calculations showed that an anchor pipe diameter of 90 mm covered by soil to a depth of 550 mm, provided an adequate factor of safety with respect to pull-out. A high quality aggregate was to be used to backfill the trench over the pipe. The trench details are illustrated in Figure 2.

Material Specifications for the Slope Cover System

The geocell material used was 103 mm (4 in) deep large cell Geoweb manufactured by Presto Products Company of Appleton, Wisconsin. Individual cell sizes of expanded geocell sections were 406 mm (in the downslope direction) by 488 mm. The geocell material included textured cell wall surfaces to maximize the interface bond with the concrete infill.

The tendon selected to anchor the geocell protection system was a round braided cord consisting of a parallel filament inner core covered with 32 strands of braid. The cord material was high tenacity polyester continuous filament yarn which was covered with a protective coating of extruded polyethylene. As noted previously, the minimum average break strength of the tendon material was 7.1 kN and the factored design tensile strength was 1.15 kN.

Specifications for the concrete infill were balanced to facilitate placement in the geocells on the 3.5H: 1V slopes and long term durability under the prevailing climatic conditions. The specifications called for a minimum compressive strength of 20 MPa with 6% air entrainment and a slump of 100 mm ± 25 mm.

The deadman anchoring system for the tendons was 90 mm OD H.D.P.E. pipe

Construction

Installation of the geocell system and concrete infill was completed by a four man crew and one foreman in five weeks. The total surface area covered was 9300 m2 (100,000 ft2).

The general sequence of the construction was to first excavate the anchor trench and place the pipe for the deadman anchor system. Tendons were then cut to measured lengths that included the length of the expanded geocell sections, with a suitable allowance being made for knots and extension to the bottom of the anchor trench. The tendons were inserted through the pre-drilled holes in the geocell sections in sufficient numbers to satisfy the design tensile strength requirements. Knots were tied on short lengths of PVC rod at the downslope end of the geocell sections to hold the tendons in place as the geocells were expanded into position.

Geocell sections were then expanded down the slope and held in position with sand bags, top and bottom. Adjacent sections were mechanically joined by interleaving the ends of outside cells and stapling with a pneumatic stapler. Four 120 mm (4 5/8") long (i.e. total length) by 12 mm (l/2") galvanized staples were used at each cell connection.

Toward the end of each day, the crew would tie all tendons around the pipe, backfill the trench and install the PVC restraint pins in each of the top cells of the geocell sections. The restraint pins were inserted through a double, self knotting, loop in the tendons. Concrete was then placed in the installed geocells using a track backhoe and a concrete skiff and given a float finish.

Conclusions

The ever increasing requirements to place impervious liners and caps on the slopes of waste material treatment ponds, landfill cells, etc. has led to the widespread use of geomembranes. Although more cost effective than conventional clay liners, and caps, geomembrane materials typically have low frictional properties, particularly when used in conjunction with geotextile protection layers, and therefore pose sliding stability problems for the designer

of the cover material (s). As demonstrated on this project Geocells, with tendon anchoring, provide localized confinement (or forming) of concrete cover materials and a means to anchor the system to the crest of the slope. In landfill caps, Geocells can also provide localized confinement and erosion protection of soil infill materials over geomembranes. This system can be anchored by tendons to a suitably designed deadman anchorage at the crest of the slope when stake anchors cannot be used.

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General Contractor: HMCI, Montreal, Quebec

Contractor's Project Manager: Michel Gatien

Earth Works Contractor: Coté and CRT Quebec, Quebec

Earth Works Superintendent : Alain Labonté

Geomembrane and Geocell Installer: Z-Tech Geogard, Boisbriand, Quebec