Foster Geotechnical Retained Earth™
Mechanically Stabilized Earth Abutment Walls
Initial Report 2004-1
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Reporting on Work Plan 1999-S-13
Category II Experimental Project

State of Vermont
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16. Abstract

In 2002 the Vermont Agency of Transportation constructed its first Foster Geotechnical Retained Earth™ mechanically stabilized earth wall (MSEW) as part of the Bennington-Hoosick project. The wall was constructed as the west abutment over the Airport Brook West as part of the Bennington Bypass, along Vermont Route 9, 2.00 kilometers east of the Vermont-New York border. The wall will be supporting one end of a 55 meter simple span steel girder bridge.

The product under study is a proprietary system of Foster Geotechnical, A Divison of L.B. Foster Company. The system is composed of concrete facing panels which are attached to layers of steel reinforcing mats in compacted select material.

The project site has been continuously monitored since before construction with inclinometers and settlement platforms. Data collected from this project will provide a valuable reference for future use of MSE technology by VAOT.

If a future evaluation of the wall alters the conclusions in this report, follow up reports will be issued.

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Introduction

In 2002 the Vermont Agency of Transportation constructed its first Foster Geotechnical Retained Earth™ mechanically stabilized earth wall (MSEW) as part of the Bennington-Hoosick project. The wall was constructed as the west abutment over the Airport Brook West as part of the Bennington Bypass, along Vermont Route 9, 2.00 kilometers east of the Vermont-New York border. The wall will be supporting one end of a 55 meter simple span steel girder bridge.

Foster Geotechnical provided the shop drawings for the project, based upon design criteria provided in the contract plans. Since this was the State of Vermont's first time using this particular type of MSE wall, it was designated a Category II Experimental Feature and incorporated extensive geotechnical instrumentation.

Foster Geotechnical Retained Earth™ mechanically stabilized earth wall is an economical and aesthetically customizable product that worked very well for this project. The wall is approximately 10 meters high and 50 meters long, including both wing walls, for a total wall area of approximately 450 square meters (4844 square feet).

The Foster Geotechnical Retained Earth™ system was determined to be beneficial for several reasons:

- Complete details of the wall system would be solicited in advance and incorporated into the contract documents. This would allow contractors in this area not familiar with this type of construction to become better acquainted with the construction requirements.

- The design could be reviewed in advance by the Agency of Transportation. This would allow the Agency to resolve any problems it had with computations, allowable stresses, design loads, construction details and specifications, before bid letting.

- An MSE wall can be constructed to greater heights compared to a conventionally reinforced concrete abutment. For this project the MSE wall allowed for a reduction in the span length. The preliminary estimates were for a savings of $67,000 in foundation costs and $120,000 in superstructure costs as a result of the decreased span length.

- In accordance with the Agency's "Policy on Earth Retaining Structures" dated November 1995, successful completion and satisfactory performance of this wall in the field would allow the addition of another MSE system to the Agency's Approved Product List and more competitive bidding of future projects.

- An MSE wall would be more tolerant of differential settlement than a conventional reinforced concrete wall.

Product Description

The mechanically stabilized earth wall supplied by Foster Geotechnical achieves its structural integrity through the use of steel wire mesh (Figure 1), placed within layers of compacted fill material, which are attached to vertical concrete panels to form a reinforced earthen embankment, wall or abutment. The precast concrete panels are interlocked and erected in lifts. The panels have clevis loops placed in them during casting to provide a means of securing the wire mesh to the wall during construction. The wire mesh is laid out horizontally behind the panels and is then secured to the panels as shown in Figure 2, and covered with compacted select backfill. The layered system of wire mesh forms a mass which is sufficiently stable to provide structural support without the use of piles.

Figure 1: Steel Mesh being placed in layers of compacted fill.

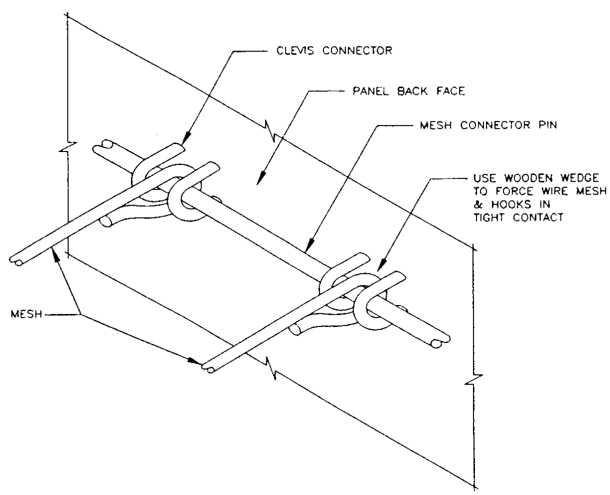

Figure 2: Steel Mesh Connection to Concrete Panels

Reinforcement Mesh

The reinforcing mesh is made up of a grid of galvanized steel. The length and spacing of the steel grids would be project specific, based upon the design requirements. An unavoidable weakness in the system is the eventual corrosion of the steel mats. Several precautions were taken in order to prolong the structure life and ensure that the 100 year design life would be attained. Limits were placed on the electrochemical properties of the select backfill used in the reinforcement zone of the structure. Backfill was tested to ensure that allowable levels of chloride content, sulfate content, pH and resistivity were not exceeded. The reinforcing mats were galvanized and sized such that sufficient steel would remain to resist tensile loads at the end of the design life. The final precaution taken was the installation of a membrane and drainage system to collect salt laden runoff from snow removal operations.

Wall Units

Each unit has a face dimension of 1505 mm (5 feet) high and 1505 mm (5 feet) wide with a minimum thickness of 140 mm (5.5 inches). There is an additional 32 mm (1.25 inches) of thickness due to the ashlar stone finish. Each unit weighs approximately 770 kilograms (1700 pounds). The ashlar panel face can be seen in Figure 3.

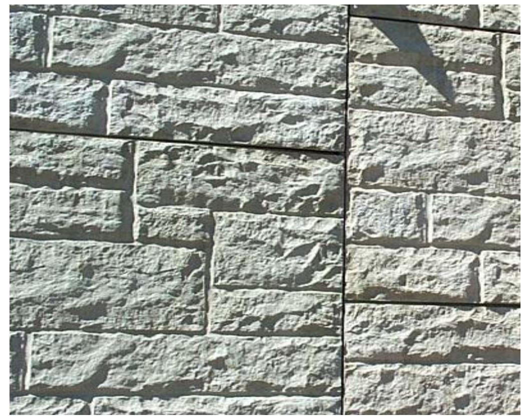

Figure 3: Ashlar Panel Face

Leveling Pad

The leveling pad is the base for the Foster Geotechnical Retained Earth™ mechanically stabilized earth wall. It is constructed of unreinforced concrete with a minimum 28 day strength of 13.8MPa (2000 psi). The leveling pad had nominal dimensions of 150-mm (6 inches) thickness and 300-mm width (12 inches). If the wall is designed to have a batter, then the leveling pad is finished with the same batter.

Design Considerations

Early designs of this structure included a traditional reinforced concrete abutment and wing walls. As the span became larger due to environmental concerns, the size of the abutment grew taller and the cost escalated significantly. An MSE wall was proposed as a means of decreasing the cost of the structure. The initial estimate for savings due to the MSE wall was $67,000 in foundation costs and $120,000 in super structure costs, due to the ability to reduce the span length with an MSE wall.

Construction

The Foster Geotechnical Retained Earth™ mechanically stabilized earth wall was designed by Foster Geotechnical Retained Earth of Woodbridge, Virginia. The precast sections were made by Faddis Concrete Products in Dowingtown, Pennsylvania and the wall was assembled by Kubricky Construction from Glens Falls, New York.

The first stage of construction involved placing the 300mm by 150mm non-reinforced concrete leveling pad on which the panels rest. Alternating half sized panels were placed and shored on the leveling pad (Figure 4). This was followed by placing the backfill in maximum lifts of 250mm up to the level of the first reinforcement mesh. The mesh is laid out and attached to the panel (Figure 5). After securing the reinforcement mesh to the panels, the backfill material was dumped on the reinforcement mesh and spread out with CAT 325 Track Hoe. The backfill material was compacted with a 2002 DVNAPAL Roller CA-250 and a Plate Tamper. Rubber tire vehicles were permitted to drive over the reinforcement mesh as per authorization from the manufacturer's representative. The contract specifications did not specifically permit driving on the mesh, nor did it prohibit it. This should be considered in any future use of this product. Although the manufacturer's representative authorized it, there could be possible damage to the galvanization of the reinforcing mats.

Figure 4: Placement of first row of panels

The project plans specified a precast coping along the top of the wall. The precast coping proved difficult to fit due to compound angles. Additionally, no filler material was specified to fill the joints between the pieces of the coping.

Figure 5: Reinforcement Mesh Attachment to Panel

Geotechnical Instrumentation

Concerns for differential and total settlements of the structure and a desire to monitor the performance of the wall as a Category II Experimental Feature resulted in the use of the following types of instrumentation:

- Two inclinometers were placed behind the face of the wall to monitor any deflection that occurs in the wall face.

- Two types of settlement platforms were installed to monitor the differential and total settlements within the structure and to give the Resident Engineer the flexibility to advance the construction sequence if settlement occurred more rapidly than predicted. A total of 5 settlement platforms were used.

Settlement Platforms

Two types of settlement platforms were used to monitor the vertical displacements anticipated due to the addition of the MSE walls, approach embankments and the bridge. Three Type I standpipe settlement platforms and two vibrating wire settlement platforms were placed at the locations given in Table 1 and shown in Figure 6. Type I platforms consist of a 76 mm (3 inch) diameter galvanized steel stand pipe attached to 1.3 meter by 1.3 meter (4 foot by 4 foot) piece of pressure treated plywood placed on existing ground prior to fill placement. As the embankments and wall sections were constructed, additional riser pipe sections were added and the elevation changes were recorded using traditional optical survey equipment.

Settlement Platform Type	Number	Location		Measured Settlement* (mm)
		Station	Offset	
Stand Pipe	SP-1	14+110	8m RT	0
Stand Pipe	SP-2	14+122	8m LT	0
Stand Pipe	SP-3	14+130	8m RT	0
Vibrating Wire	SP-8	14+130	5m RT	0
Vibrating Wire	SP-9	14+130	5m LT	0

Table 1: Settlement platform Results

* As of 11/26/03

Slope Inclinometers

Two slope inclinometers were located in the reinforced fill to monitor lateral movement in the ground during the construction of the MSE wall and embankments. The inclinometers were installed to the depths, stations and offsets indicated in Table 2 and shown in Figure 6 to help ensure roadway slope stability and a plumb wall were being maintained during and after construction.

Inclinometer Number	Station	Offset	Depth (meters)
IM-1	14+129	11m RT	13.5m
IM-2	14+129	11m LT	13.5m

Table 2: Slope Inclinometer Locations

Boreholes were advanced 1.5 meters into bedrock at each location and self aligning 85mm O.D., 73mm I.D. inclinometer casing was lowered into the boreholes and then grouted into place. The inclinometer casing was manufactured with four internal longitudinal grooves precisely made to fit the dimensions of the inclinometer wheels. The grooves control the orientation of the sensor which was lowered through the casing to obtain initial readings at 0.6 meters depths. The inclinometer probe has two servo-accelerometers in a waterproof housing. One accelerometer has its sensing axis in the plane of the spring-loaded wheels which ride in the casing grooves. The second accelerometer has its sensors at 90 degrees, so that the angle of the sensor and casing is measured in two orthogonal directions. Periodic reading throughout the casing provided data on the location, magnitude, direction and rate of movement of the casing. Figures 7A & 7B show the inclinometer readings through April 28th, 2003. Although minor movements were registered, they are within acceptable limits.

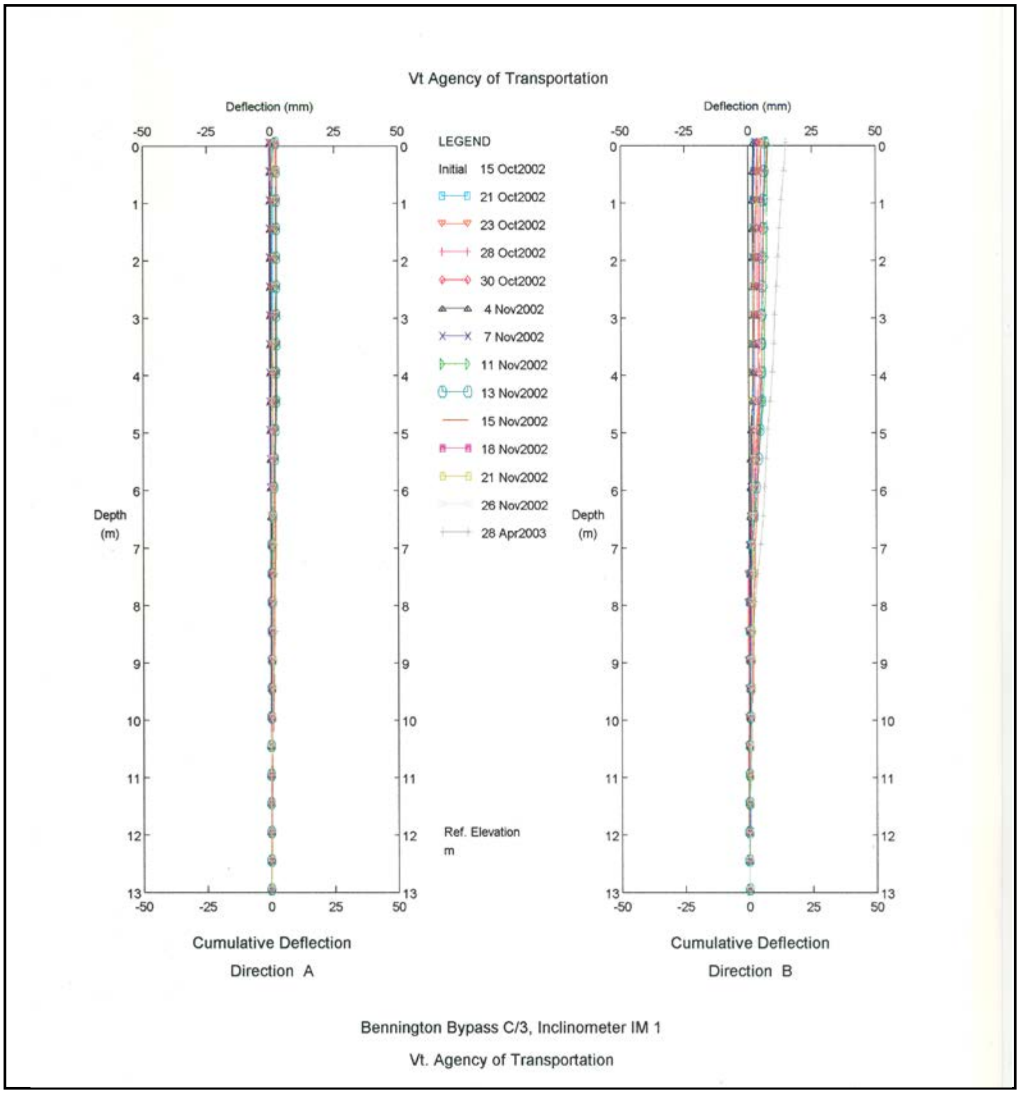

Figure 7A: Inclinometer 1 Readings.

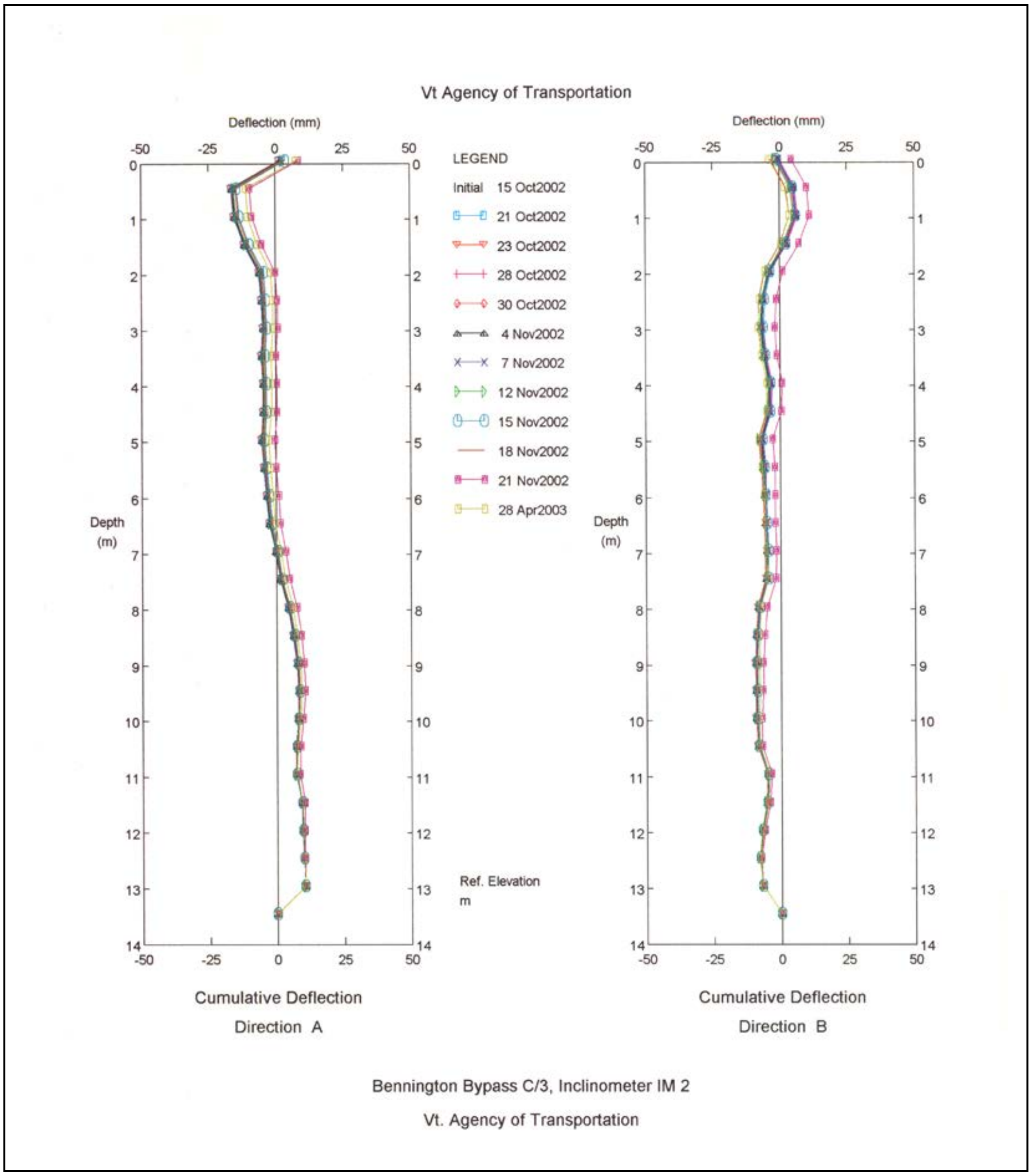

Figure 7B: Inclinometer 2 Readings.

Summary

Figure 8: Completed Wall

The mechanically stabilized earth wall provided by Foster Geotechnical Retained Earth™ for Abutment 1 of the bridge over Airport Brook West as part of the Bennington Bypass has shown to be an economical and viable option as a retaining wall for the State of Vermont. The use of an MSE wall provided the ability to reduce the overall span length of the superstructure as well as reduce the abutment costs. The final construction costs of the MSE wall were $620 per square meter in place including panels, reinforcing grid and reinforced backfill.

The steel reinforcement used in the design of this wall has shown that it is capable of providing the lateral load capacities necessary to withstand the earth pressures generated by the soil mass and structure weight. At present, the MSE abutment wall is performing as expected. The structure (Figure 8) has been stable and no adverse distress has been found. If subsequent inspections show any significant changes, an updated report will be issued.

The only problems encountered during the construction of the MSE wall, was quality control from the plant fabricating the Ashlar concrete panels. Panels were delivered with the stone facing alignment in the wrong direction and some panels were delivered missing the clevis pin connections. The panels with the stone facing in the wrong direction were used in areas where they would be below the finished ground surface. The panels missing the clevis pins had them grouted in after delivery based upon specifications provided by the manufacturer.

Recommendations

- The contract specifications for any future MSE wall should specify that a State of Vermont inspector be present during the manufacture of the face panels as well as for testing of the concrete used in the construction of the panels. This would reduce the number of panels delivered to the site that are unacceptable. It would be beneficial if the panels could be produced at a facility closer to Vermont than Pennsylvania.

- The coping should be specified to be cast-in-place as is expected that it would provide a better fit to the structure in the field.

- The specification should address the issue of driving over the reinforcement grids with rubber tire vehicles.

In conclusion, it is recommended that the MSE retaining wall system supplied by Foster Geotechnical Retained Earth™ to the Bennington Bypass be approved for use on Agency projects and be added to the Vermont Agency of Transportation Earth Retaining System Selection Chart.

It is also recommended that this project be monitored into the future for any adverse changes and the changes be reported in future updates.