COXHEATH ROAD BRIDGE RECONSTRUCTION
STAGED CONSTRUCTION USING INNOVATIVE GEOTECHNICAL DESIGNS

Paul Proctor, P.Eng. (Presenter)
Manager Eastern Canada & Caribbean Regions
Reinforced Earth Company Ltd.

Peter Wu, P.Eng.
President and CEO
Reinforced Earth Company Ltd.

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ABSTRACT

With increased traffic volumes and limited space to rebuild ageing bridge structures, engineers look for innovative methods to resolve design challenges. The Nova Scotia Department of Transportation (TPW) needed to reconstruct the Coxheath Road Bridge over Highway #125 in Sydney, Nova Scotia due a combination of repairs and additional exit ramps required near the Sydney River area to relieve traffic congestion at the Kings Road Interchange.

This paper will illustrate the innovative geotechnical design approach the NSDOT incorporated in the reconstruction of the bridge. It will explain and highlight the various aspects the stage construction to allow continuous traffic flow on the Coxheath Road Bridge and Highway #125 with a minimal traffic stoppage.

The application of mechanically stabilized earth (MSE) for retaining structures is ever increasing. In the Coxheath Road Bridge Reconstruction, the contractor chose the material known as Terratrel, designed and manufactured by the Reinforced Earth Company Ltd. (RECO), for temporary abutment walls as a wire-faced MSE system to construct, disassemble and then recycle the internal gravel as the most efficient method. The temporary wire-faced Terratrel system was designed as a true bridge abutment capable of withstanding the launching load of the temporary truss bridge used to re-route the Coxheath Road traffic. Once the detour was in place, the exiting structure was demolished and a new permanent bridge was constructed on a RECO supplied concrete –faced MSE system called Terraclass. The new design allowed for exit ramps to relieve the congestion issues in this area.

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1. INTRODUCTION

In August 2004, the Coxheath Road overpass bridge in Sydney, Nova Scotia was tendered to be demolished and a new structure to be built. The Coxheath Road was to remain open with two lanes of traffic flow at all times. This resulted in a temporary bridge crossing spanning the four-lane Highway #125, which also had to maintain traffic.

J & T Van Zutphen Construction Inc. (VZC) was awarded the contract from Nova Scotia Department of Transportation & Public Works (TPW) to replace the Coxheath Road Overpass along with maintaining all traffic flow. Mechanically Stabilized Earth (MSE) was specified by TPW for the permanent abutment walls. The temporary crossing was to be designed and supplied by the contractor. Atlantic Bridge Systems Inc.(ABS) provided the temporary modular truss bridge (MTB) and Reinforced Earth Company Ltd. (RECO) was awarded the design and supply of the temporary abutment walls and bridge seat design by VZC.

ABS provided the bridge loadings to RECO for design of the abutment walls and bridge seat. Since the bridge structure was a temporary crossing and funded by the contractor, the overall cost was closely monitored by VZC. RECO proposed the use of Terratrel Wire Wall (TTW) to provide optimum design at a lower price. The walls were designed to the current TPW standards and approved as a viable structure.

The construction of the temporary walls began in September 2004, and completed two weeks later. The MTB was erected and cantilevered on one side of Highway #125. VZC had permission from TPW to shutdown Highway #125 for a thirty-minute duration in order to have three cranes position themselves to hoist the temporary structure into place. The procedure proved to be timely and the structure performed flawlessly.

The new permanent Coxheath Road structure, scheduled to be open to traffic by June 2005, at which point the temporary bridge and walls are scheduled to be disassembled, was completed on time without delay. The temporary structure was dismantled in a period of two weeks and sent to TPW yard in Sydney. The Type 2 backfill within the TTW volume of the bridge abutment was recycled and used on another section of the contract. The temporary bridge abutment walls were dismantled and 95% of the TTW components were recovered by VZC.

This paper will describe the various aspects of design concepts, innovation geotechnical approach, choice of materials, construction process and finally some concluding remarks.

2. DESIGN CONCEPT OF MECHANICALLY STABILIZED EARTH

The design of MSE walls to resist earth pressure loads is a well understood and widely accepted practice. Although there are differences between design approaches for different proprietary wall systems, all are generally based on traditional earth pressures theories such as Rankine or Coulomb. Resisting earth pressure is the primary function of any earth retaining wall; however there are several other important loading conditions that MSE design must also consider in order to function in a durable and safe manner for the structure design life both respect to service and ultimate life.

Conventional bridges are commonly supported by rigid substructures. These substructures are usually designed as cast-in-place reinforced concrete supported either on concrete spread footings or on pile foundation. MSE bridge abutments however, support the superstructure directly using a concrete bearing seat which rests on the reinforced earth mass.

The primary technical reason to select MSE for a bridge abutment relates to its ability to withstand post construction settlement without structural distress. There are two major advantages:

-abutments can be built on compressible foundations without resorting to deep foundations

-abutments and approach fills settle together eliminating the characteristic "bump at the end of the bridge".

Types of Bridge Abutments using MSE

False Bridge Abutments

Abutments, where the vertical loads are supported on a piles or pier structures located either in front of or within the MSE mass are known as “false” abutments. The horizontal loads are supported by the MSE structure. (see Figure 1)

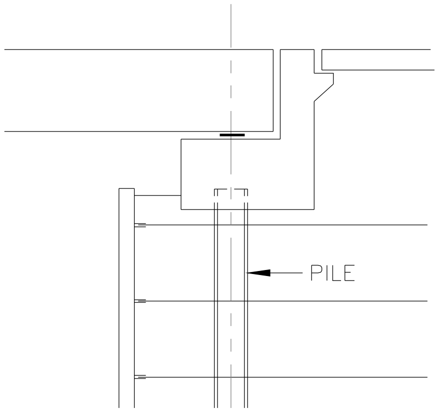


Figure 1 - False Bridge MSE Abutment

True Bridge Abutments

Abutments, where the bearing seats rest directly on the MSE structure are known as "true" abutments. The bridge seat geometry allows for the distribution of vertical stresses to be applied directly to the MSE mass with the aid of a well compacted granular pad. (see Figure 2)

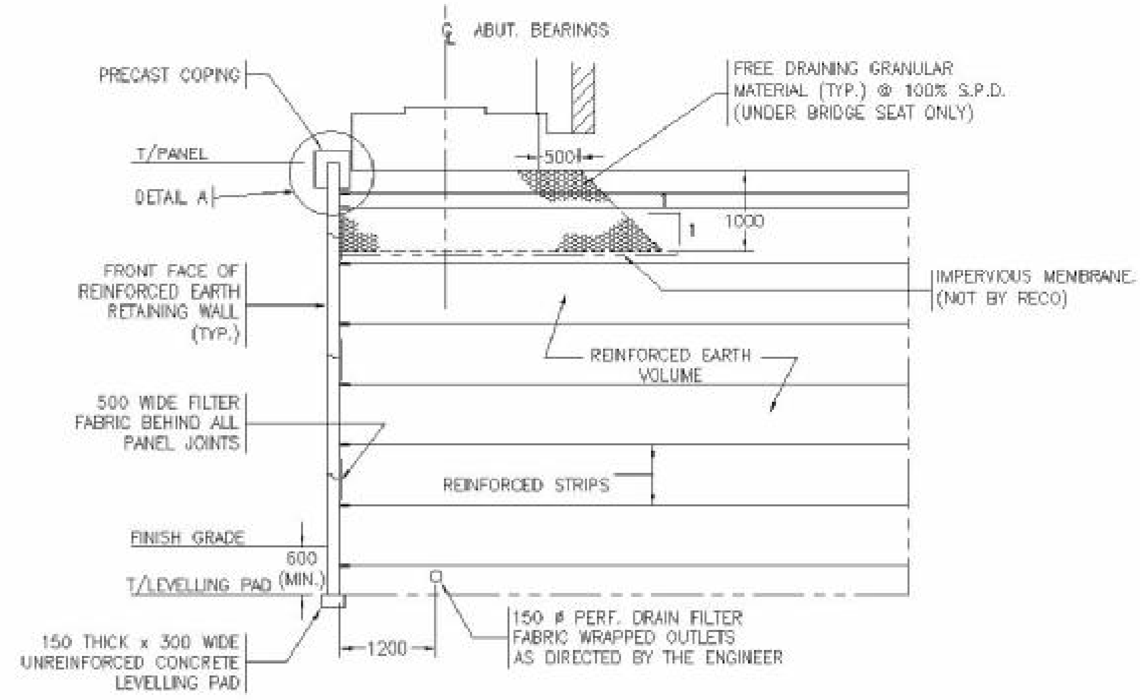


Figure 2 - True Bridge MSE Abutment

This paper focuses on the aspects of using “true” bridge abutments for both the temporary traffic diversion truss bridge crossing and the reconstruction of the permanent bridge at Coxheath Road Bridge Reconstruction Project.

Bridge Loads - True Bridge Abutments

True bridge abutments are MSE walls that support a spread footing which in turn supports the bridge superstructure. The application of bridge loads onto an MSE wall under these circumstances has been presented in many previous publications (Wandschneider & Wu 1985). The basic concept is that of superimposing vertical and horizontal loads through the bridge footing and diffusing them as they pass down and back through the soil mass. The stress at any given point in the soil mass is a sum of the loads due to the retaining wall function earth pressures, plus the loads due to the bridge imposed forces. (see Figure 3)

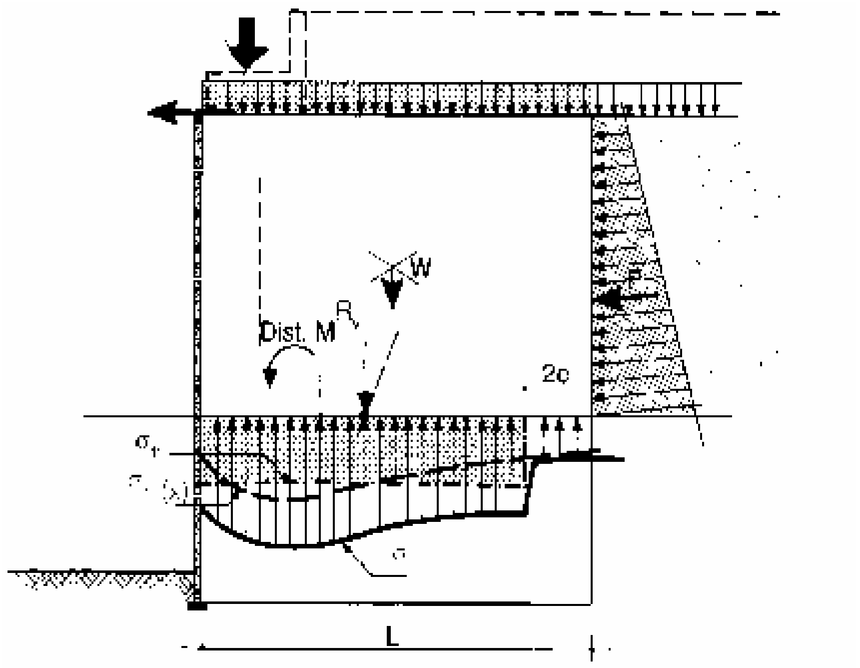


Figure 3 - Superimposed Vertical Stress in a "True Bridge Abutment".

The result of this higher stress is a requirement for a higher density of soil reinforcement and additional facing panel reinforcing steel, particularly in the zone immediately under the spread footing.

Although the majority of the true abutment applications are for single span bridges, there are numerous MSE true abutment applications supporting multi-span continuous bridges. In this case it is important to compare the estimated differential settlement of the spread footings on the MSE wall with the stiffness of the overall structure to limit the negative moment in the superstructure to a tolerable amount. The tolerance to differential settlement of a continuous span structure is a function of the structure type, number and length of spans, girder stiffness, types of bearing, creep, torsional capacity and method of construction. Industry studies have found that superstructures actual performances are generally more tolerant to differential settlement than expected. More information can be found on this in established reports (Moulton 1982 and 1983) and (DiMillio, 1982).

In the case of the Coxheath Road temporary and permanent bridge abutment design using MSE, both structures were analyzed taking all vertical and horizontal loading conditions along with settlement and foundation characteristics into consideration. The quality of backfill within the MSE mass is critical to the overall long term performance of the true bridge abutment wall structures, to perform as designed without deformation beyond tolerable limits set out in the general specifications of TPW.

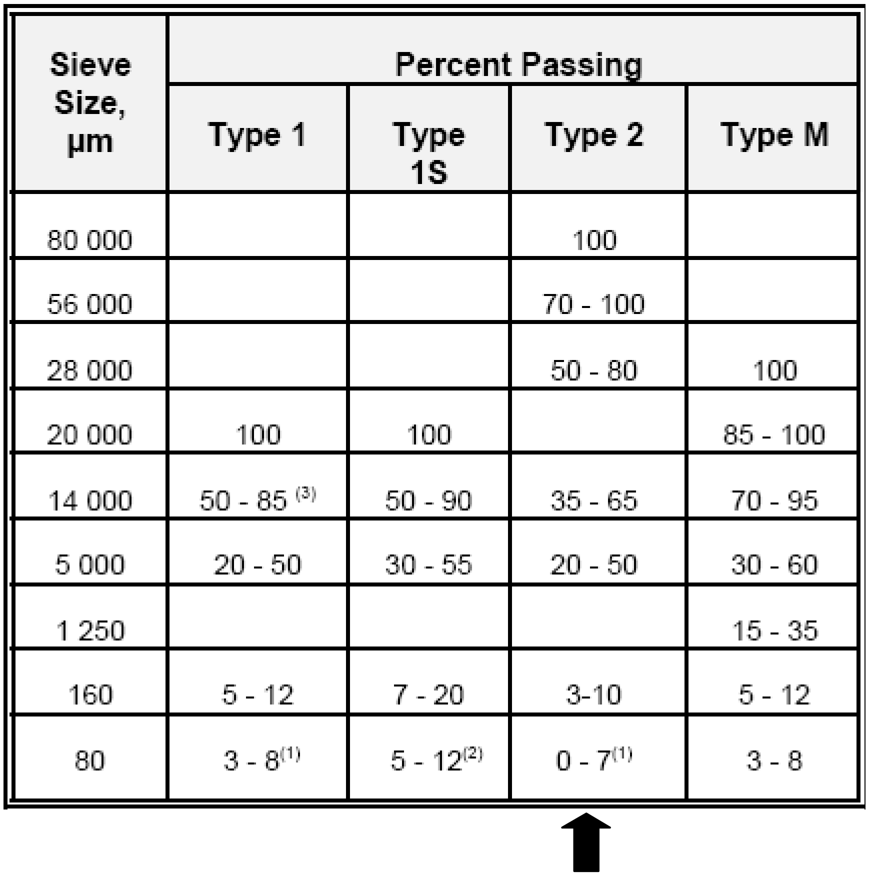
3. INNOVATIVE GEOTECHNICAL APPROACH

The geometric constraints at Coxheath Road and Highway #125 posed challenges to the designers to construct a temporary diversion, demolish the existing structure, to build the new permanent structure with a minimum span dimension to optimize beam depth for vertical road clearance while maintaining traffic flow on both levels. The TPW approved the use of the MSE system for the true bridge abutment wall design for the permanent structure at Coxheath Road. The inherent strength and versatility of the system enables design engineers to provide complicated wall geometry layout within the confines of the right-of-way.

As a part of the contractors’ scope of work for this highway contract, he was responsible for the design and supply of a temporary bridge crossing that would allow for the Coxheath Road two lane traffic to cross over the four lane Highway #125 with a minimum shutdown period acceptable to the TPW. The contractor required a two lane modular truss bridge (MTB) supported on temporary abutments walls designed by professional engineers and approved by the TPW before proceeding with the work. The contractor retained the services of ABS to provide a MTB with the load-carrying capacity to support the TPW live traffic load of CL-625. The MTB would be founded on an abutment system capable of withstanding the live and dead load of the MTB and be versatile enough to be dismantled with relative ease.

The contractor had various options for the design and supply of the abutment walls such as wooden crib, steel sheet piling or bins. He chose the temporary TTW system from Reinforced Earth Company Ltd. based on engineering performance, schedule, versatility and economics. The temporary walls and bridge seat design required the seal of a professional engineer with the experience in designing such structures. The MTB was the first item on the critical path to construct. The project could not move forward without the traffic diversion in place, therefore it was imperative that material supply and construction processes were minimized for the contractors' schedule. Materials that could be designed and assembled quickly for the temporary crossing would rate highly in the contractor choice of building supplies. Finally, economics of the wall system would play the largest role in his decision to choose TTW by Reco and illustrate the innovative geotechnical approach by the contractor.

From recent demonstrated experience RECO had on bridge structures throughout Nova Scotia, the contractor was confident the TTW system could support the MTB loads and could be built in a rapid manner to reduce cost. Using TPW Type 2 backfill within the TTW system was an important choice of materials for several reasons. This backfill specification (see Figure 4) is a granular material that easily spread in compactable layers without excessive time to achieve the required density results by the TTW system. The TTW system had to be dismantled once the new permanent structure was opened to the Coxheath Road traffic. The backfill was removed for the TTW in reverse order it was placed and used elsewhere in the contract. The TTW was systematically dismantled with minimal damage and stored by the contractor for future use.



Sieve Size, µm	Percent Passing			
	Type 1	Type 1S	Type 2	Type M
80 000			100	
56 000			70 - 100	
28 000			50 - 80	100
20 000	100	100		85 - 100
14 000	50 - 85 (3)	50 - 90	35 - 65	70 - 95
5 000	20 - 50	30 - 55	20 - 50	30 - 60
1 250				15 - 35
160	5 - 12	7 - 20	3-10	5 - 12
80	3 - 8(1)	5 - 12(2)	0 - 7(1)	3 - 8

Figure 4 - Type 2 Gradation

4. MATERIALS

The Coxheath Road Bridge Reconstruction Project had two distinct phases of construction, namely the Temporary Bridge Structure - Traffic Diversion and the Permanent Bridge Demolition and Reconstruction. Within each phase, the building materials were similar in nature but different in quality or purpose.

Temporary Bridge Structure - Traffic Diversion

ABS provided a steel modular truss bridge structure capable of handling two lanes of live load rated at CL-625 and one pedestrian walkway that would transverse Highway #125 at Coxheath Road. The MTB was a simply supported bridge 40 m long and 10 m wide with a 1.5 m wide sidewalk attached to one side of the truss structure. The MTB applied a 72kN/m un-factored dead load, a 197kN/m un-factored live load and 21kN/m horizontal (longitudinal) load at the fixed end only. The MTB was supported by cast-in-place bridge seat 2000 mm wide x 1000 mm depth and 400 mm thick designed by RECO based on the applied loads provided by ABS. (see Figures 5a &5 b)

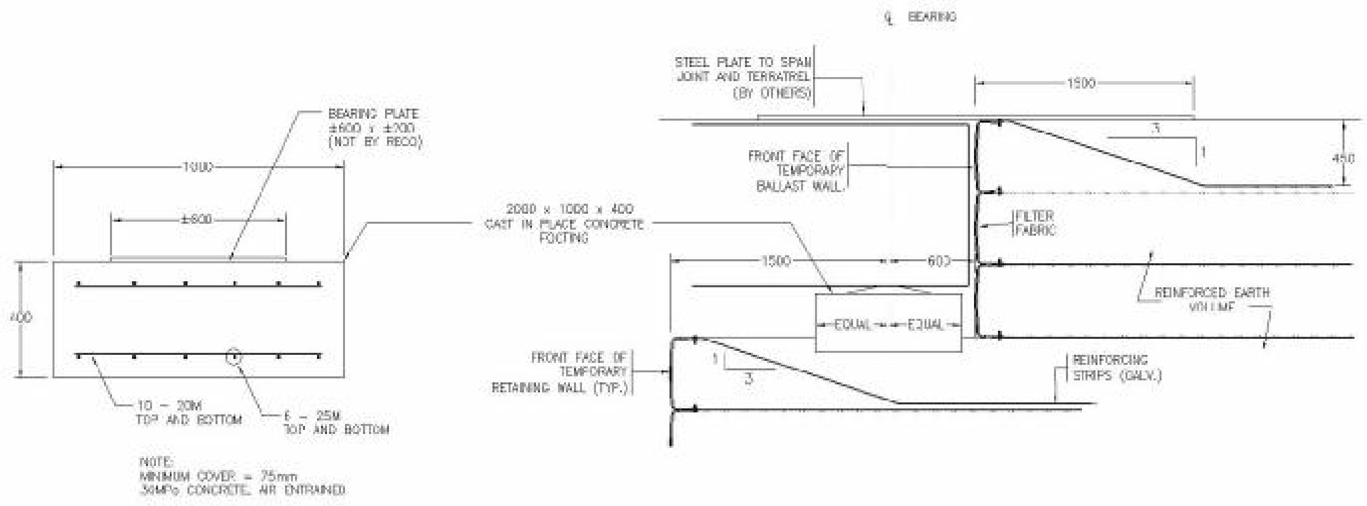


Figure 5a – Bridge Seat Geometry –TTW Layout

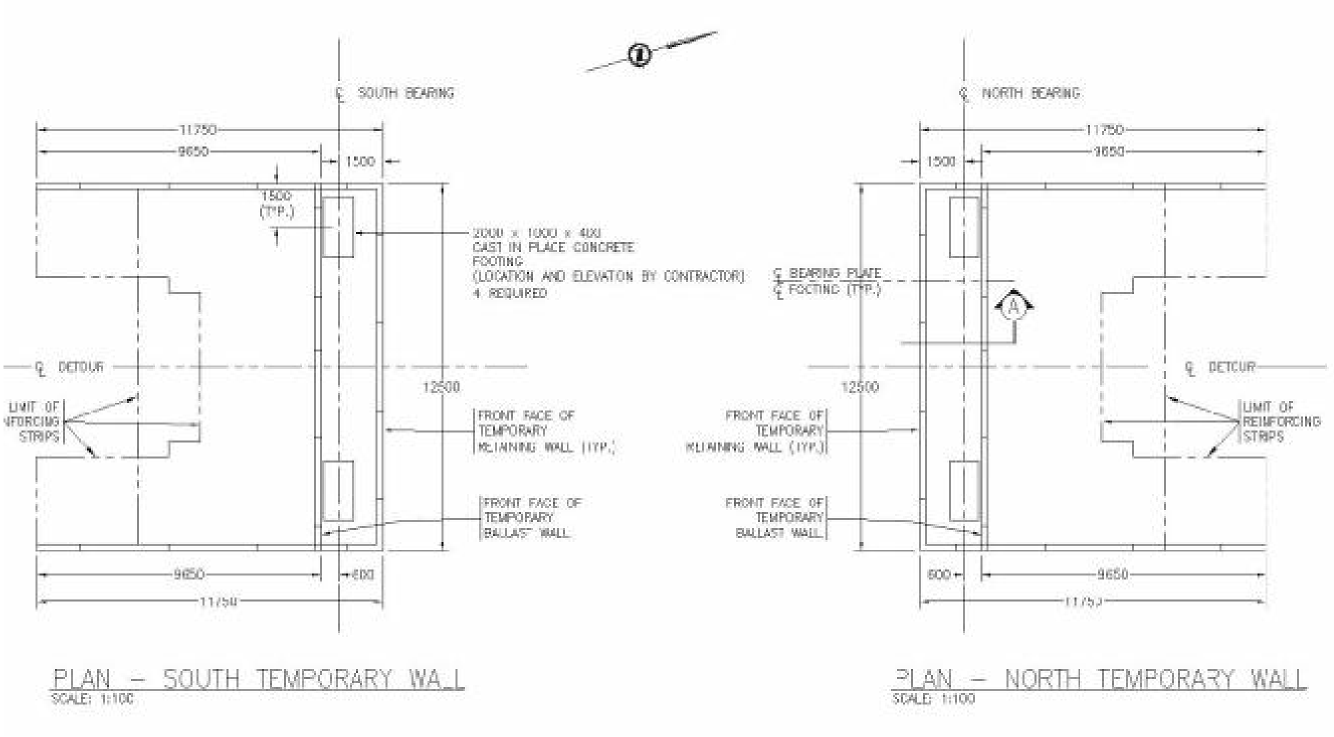


Figure 5b – Bridge Seat Geometry – TTW Layout

The retaining walls were designed as a true bridge abutment with all the vertical and horizontal forces taken by the TTW system. The wall facing is a galvanized welded wire mesh 8.0 mm in diameter. The nominal dimension of each panel is 3.0 m wide x 0.5 m high. (see Figure 6). The overall TTW design is broken up into to various loading zones that require specific steel density (number of strips per panel) and associated strip length based on the amount of earth pressure acting on the particular facing unit. (see Figure 7). A geotexile fabric was used on the back face of the TTW panel to prevent the backfill from escaping through the 100 x 100 mm mesh. Since this was temporary structure, (one-year duration) the ultra violet rays would not be a significant factor to affect the integrity of the wall system. (see Figure 8 & 9)

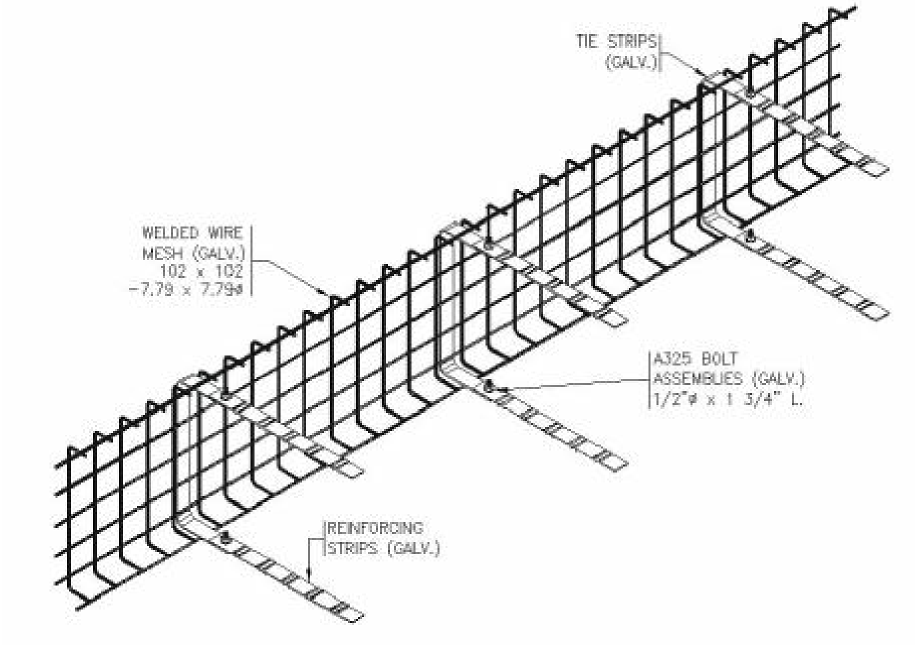


Figure 6 – Typical Terratrel Wall Panel

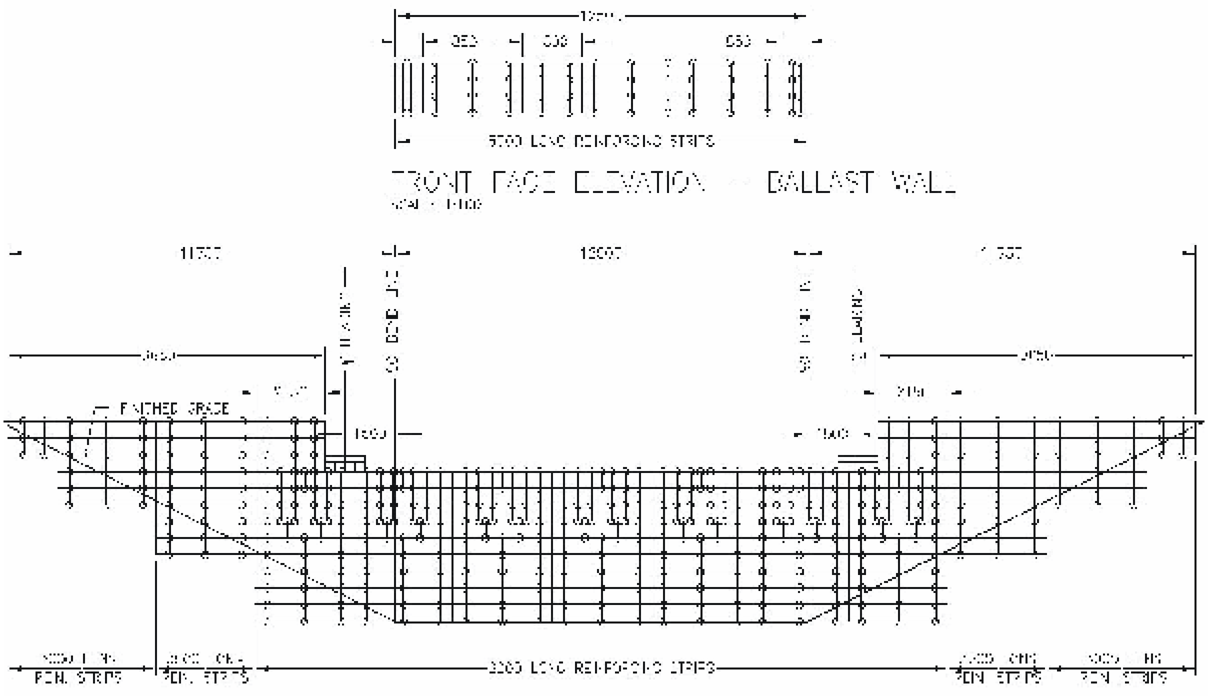


Figure 7 – TTW Zoning

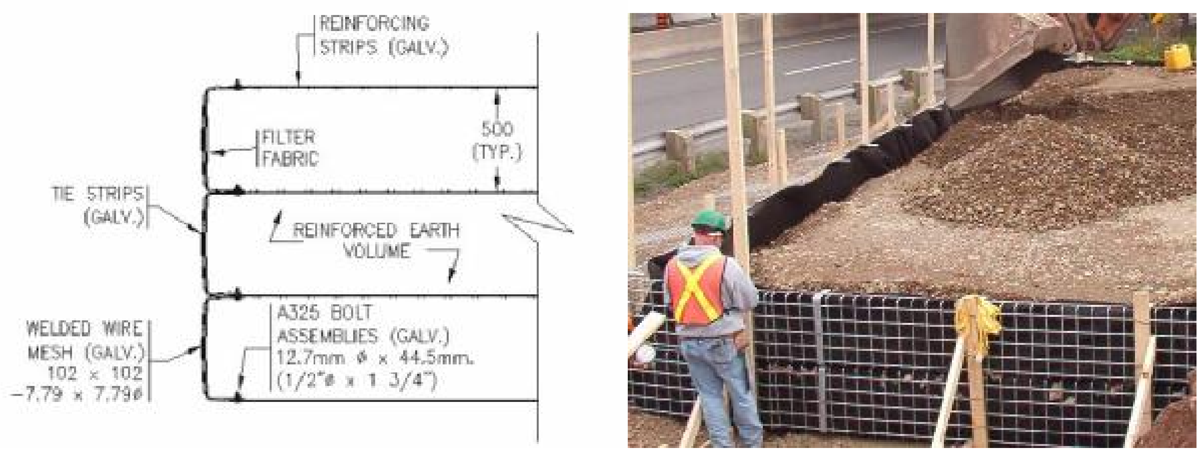


Figure 8 & 9 – General Assembly of TTW

The height and layout of the wall was determined by site conditions at Highway #125 at Coxheath Road. The front face of the wall was 4.5 m to the underside of bridge seat for both north and south abutments. A steel bearing plate 600 mm in depth was placed on top of the CIP bridge seat. The MTB rested on the cast-in-place bridge seat and with a ballast wall that retained the soil that abuts to the end of the bridge. A steel plate spanned the joint between the top of ballast wall elevation and top of roadway elevation. (see Figure 5) Once the temporary structure was in place and the deck installed, pavement was laid up to the bridge joint for a smooth running surface and to cover all plates. The deck of the bridge was a pre-fabricated textured riding surface that did not require any finishing post-installation.

Permanent Bridge Demolition and Reconstruction

The TPW contracted O'Halloran Campbell Consultants Limited to provide a design for the bridge crossing at Coxheath Road and Highway #125 along with the associated ramps for complete access at the intersection. The existing bridge was analyzed for the load-carrying capacity and geometrics for the intersection and was determined to be unsatisfactory for the new intersection. It would have to be demolished. (see Figure 10)

Figure 10 – Existing Coxheath Road Bridge

The new bridge structure would be a single span bridge with steel girders supported by a true abutment design using MSE with concrete facing panels.(see Figure 11)

Figure 11 – New Coxheath Road Bridge

Type 2 granular backfill was used as the material of choice due to the speed of installation and anticipated compaction results expected. The wall panels had geotexile on all rear face joints to prevent fines from migrating to the front. (see Figure 12)

Figure 12 – Geotexile on Rear Face Joint

Similar to the temporary wall design, the permanent wall was divided into various loading zones and the particular density and strip length requirements applied. (see Figure 13)

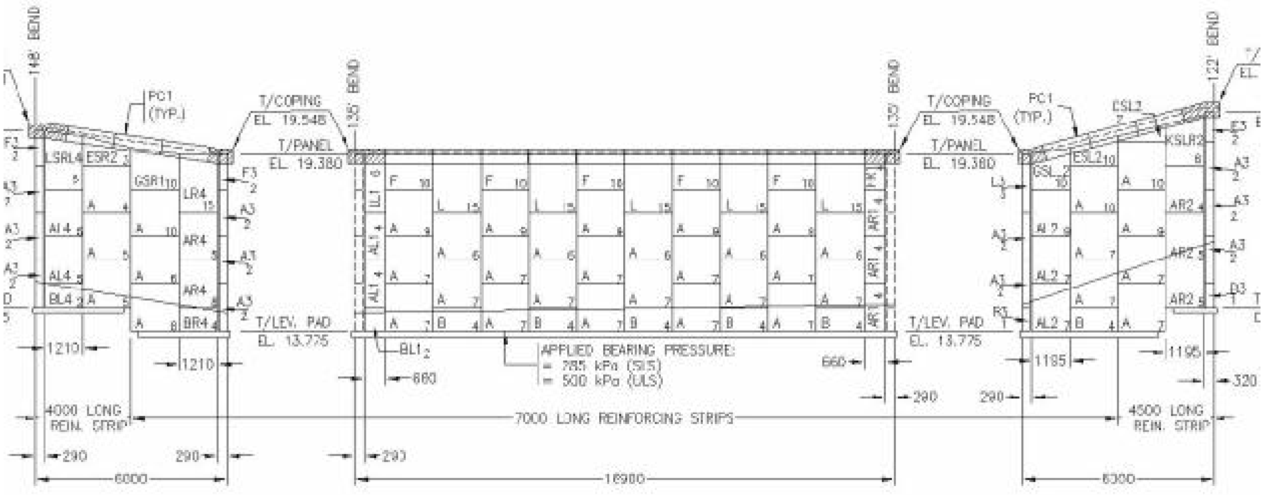


Figure 13 – Permanent Concrete Panel Zoning

The top of wall would be capped with a combination of pre-cast and cast-in-place concrete coping to finish the wall. (see Figure 14 & 15)

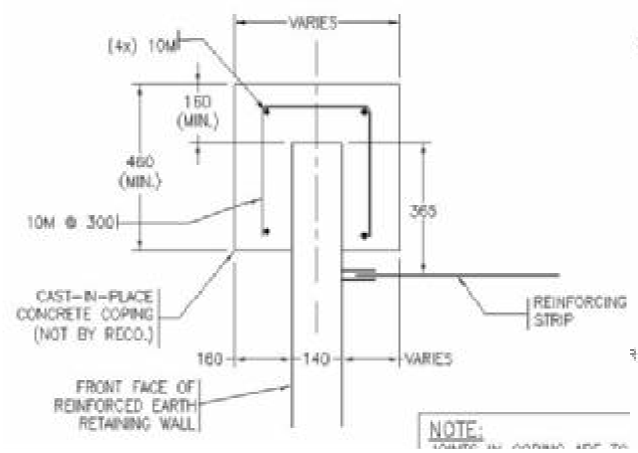


Figure 14 – Cast-in-Place Coping

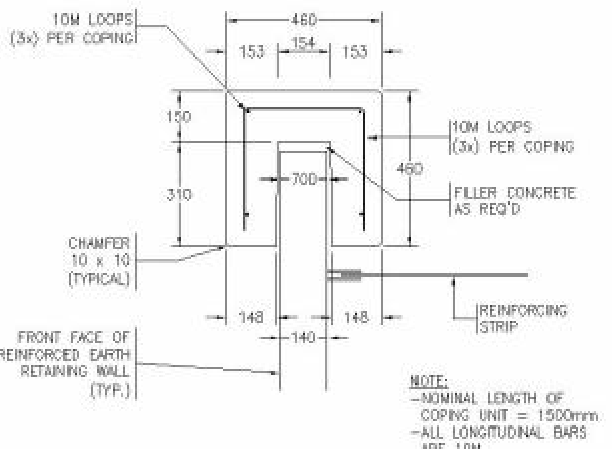


Figure 15 – Pre-cast Coping

5. STAGED CONSTRUCTION PROCESS AND SEQUENCE

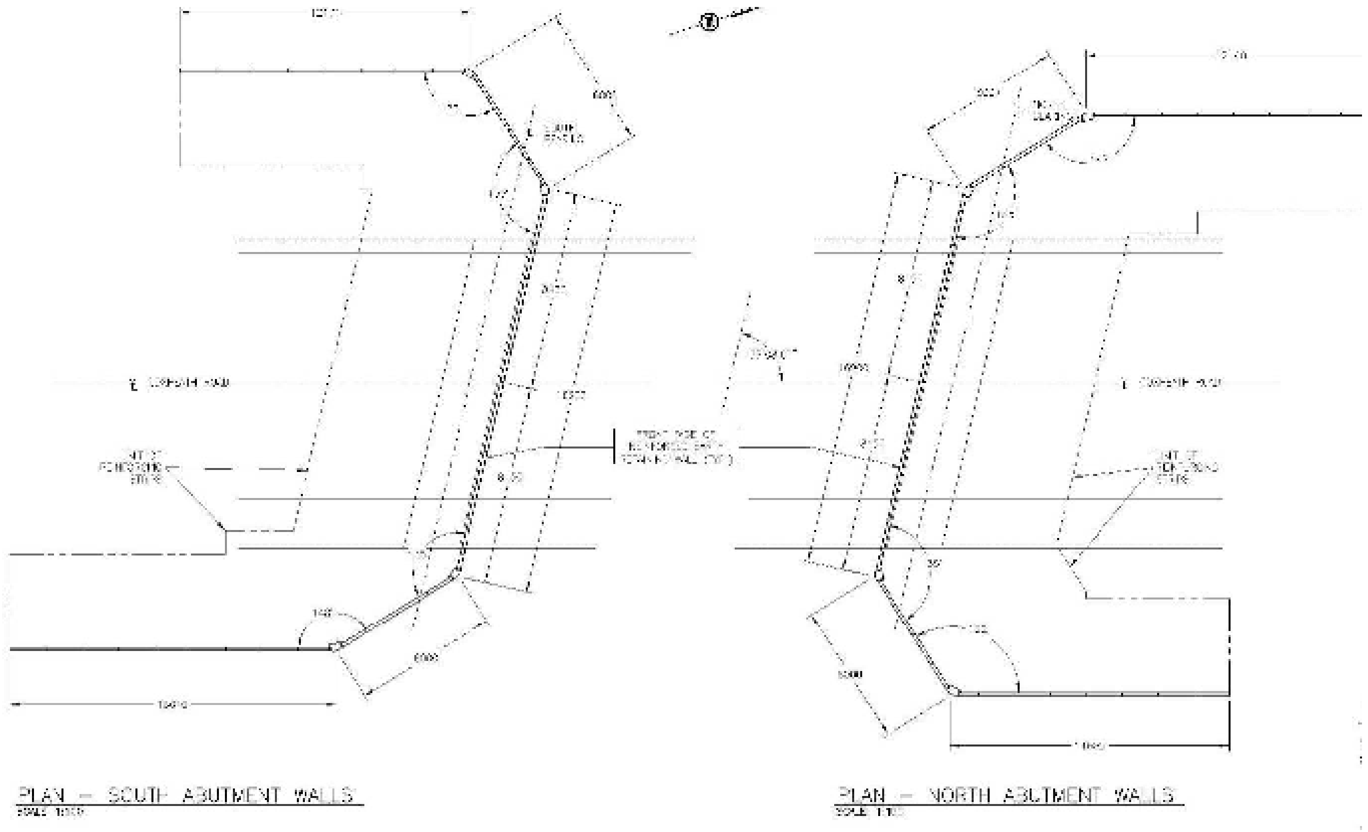
The new intersection at Coxheath Road and Highway #125 required staged construction to complete the work. Initially a temporary bridge structure was required to divert the traffic on Coxheath Road over the Highway #125 so that the existing bridge could be demolished and reconstructed to suit the geometrics of the new intersection. The MTB was assembled on the south side of Highway #125 without the deck in place. The TTW walls were constructed which took one week per abutment. By using three cranes, one 28 ton conventional crawler type crane on the upper section of the TTW abutment wall and two 125 ton hydraulic crane located at the north side of

Highway #125, they simultaneously cantilevered, then lifted the MTB onto the bridge seat.

In the interest of safety, the TPW made special allowance for the contractor to shut down Highway #125 for a thirty-minute period for this stage of the operation to take place. (see Figures 16 to 23) Once the MTB was in place, the modular bridge deck was installed, the pedestrian walk assembled and secured, the roadway and approaches were paved and finally the temporary diversion was opened to traffic Coxheath Road traffic.

Figures 16 to 23 - Modular Truss Bridge Erection Sequence

The focus then turned to the demolition of the existing Coxheath Road Bridge. Initially the approaches and adjacent spans were removed. The demolition of the center span and support piers required the Highway #125 to be shutdown for a day (24 hour period). The next stage required the excavation for the new footing print of the MSE walls to the limited of the reinforcing strips. (see Figure 24)



Figures 24 - Permanent MSE Footprint & Strip Limits

Since the embankment fills of the existing Coxheath Road were somewhat unknown, Jacques Whitford & Associates Ltd. (JWA) was contracted by TPW to evaluate the underlying foundation where the new MSE structures were to be located. The maximum applied bearing pressure for the true bridge abutment MSE wall was provided by RECO to JWA to analyze. Foundation recommendations and approval were provided by JWA prior to this work commencing.

The permanent MSE wall erection started on the south side, then the north. The bridge seats were cast, cured and prepared for the steel girders. With the girders in place, the new deck was formed, rebar installed and cast. The parapets, sidewalks and remaining items applied to the new structure. Final sub-grade to the new structure was completed and then paved. It then re-opened to the Coxheath Road traffic. The ramps at the intersection remained closed as required by TPW. A separate contract for the Highway #125 widening was simultaneously underway and would address the final grading and paving of these intersection ramps.

With the traffic reverted back to the new Coxheath Road Bridge, the temporary MTB structure was dismantled in reverse order. Once again, Highway #125 was only shutdown for a thirty minute period to remove the MTB from its bridge seat. The TTW abutment wall was dismantled with particular care as to minimize any damage to the reusable strips and facing. The embankments slopes were graded, ditches finished, ramps brought to Type 2 gravel elevations and left closed as required by TPW.

6. RECYCLED MATERIALS

The contractor had the insight to see the value in the Type 2 gravel used in the temporary abutment walls to be recycled and placed elsewhere on the project after the MTB was dismantled. Furthermore, the TTW was disassembled with added care, to minimize the damage. The contractor was able to recover 95% of the wall components for future use.

7. CONCLUSIONS

The design of MSE structures should consider comprehensive conditions including advanced loading aspects, site conditions, durability and design life. These are described in order to ensure its intended performance.

The TTW system, which is most suitable for shorter design life, has been used for its load-carrying ability, flexibility to tolerate settlement, ease of installation and economy. Many TTW systems were used in industrial sites for truck dumps, temporary bridge abutment support, grade separation, staging work and avalanche barriers. There are practical design approaches developed and available that should not be overlooked by the designers.

As described herein, TTW system can be designed for various types of advanced loading conditions and combined with innovative approach to non-conventional structural and geotechnical loading applications.

The Coxheath Road Bridge Reconstruction Project had various phases in its construction process which allowed the contractor to benefit from the design-build aspect of the temporary bridge crossing. Decisions were made based on quality assurance of design, materials chosen and delivery sequence to meet his construction schedule. By re-using Type 2 gravel, an added savings was provided to him by choosing the Temporary Terratrel Wire Wall system.

8. ACKNOWLEDGEMENTS

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