Application of Mechanically Stabilized Earth Wall with Geo-synthetic Strap Soil Reinforcement for False Abutment Structures

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Abstract:

This case study highlights a Light Rail Transit (LRT) structure in Ottawa, ON which has utilized Mechanically Stabilized Earth (MSE) walls in conjunction with a false abutment. While MSE walls are very commonly associated with this type of structure, some unique features have differentiated this project from others of similar scope.

Specifications for this project limited the soil reinforcement strictly to geo-synthetics. In addition, the selected MSE wall system, implements the use of strap elements as soil reinforcement in conjunction with inclusions in the Reinforced Zone, which sets this project apart due to its unique nature. Some of the challenges that were encountered during both the design and construction phases of this structure will be discussed in further details within this paper. One example of the challenges faced during design and construction is the fact that piles for the false abutments are embedded into the Reinforced Earth zone and the soil reinforcement was required to avoid those obstacles while simultaneously resisting the horizontal forces coming from the superstructure.

The conclusions drawn from this particular experience are that with the proper design and understanding of the variables affecting this type of structure, MSE walls are a reliable and efficient solution.

1 Project Overview

The Hurdman East Overpass project is a LRT bridge overpass carrying a light rail vehicle over a pedestrian pathway. This structure is part of a large infrastructure project in Ottawa, Ontario, which involves the construction of an LRT system to span the city (See figure 1). This project will improve congestion on local highways as well as create a more efficient and environmentally friendly transit system. This project is owned by the City of Ottawa, who awarded the package to the Rideau Transit Group (RTGE) consisting of a consortium including Canadian and International entities. The construction of the false abutment with Mechanically Stabilized Earth (MSE) structures was completed in late 2015, with approximately 300 m^2 of MSE walls distributed between the two abutments. The Ottawa Light Rail Transit (OLRT) design build project was awarded to RTGE in February 2013 and shortly thereafter preliminary construction began. In order to accommodate the need for transitioning of the Bus Rapid Transitway system already in place to the future Confederation Line, a major overhaul of Highway 417 took place which saw the highway being expanded to counter the negative impact that construction may have on the existing transit system. The OLRT program will decrease air and noise pollution by emitting minimal sound (as compared to the diesel buses which are now used) and running off of strictly electricity. This project includes a tunnel through downtown Ottawa which is a major infrastructure accomplishment and will be the longest of all the individual projects. The Hurdman East Overpass Bridge (highlighted in this paper) will be supported by 14 H-Piles and Reinforced Earth false abutments. The inclusion of the H-Piles creates the need for a MSE soil reinforcement skew system (See figure 2), which will be described in this paper.

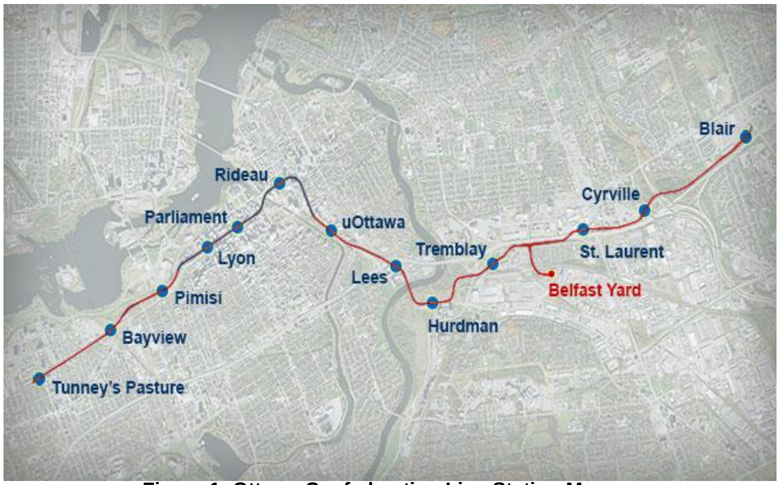

Figure 1: Ottawa Confederation Line Station Map

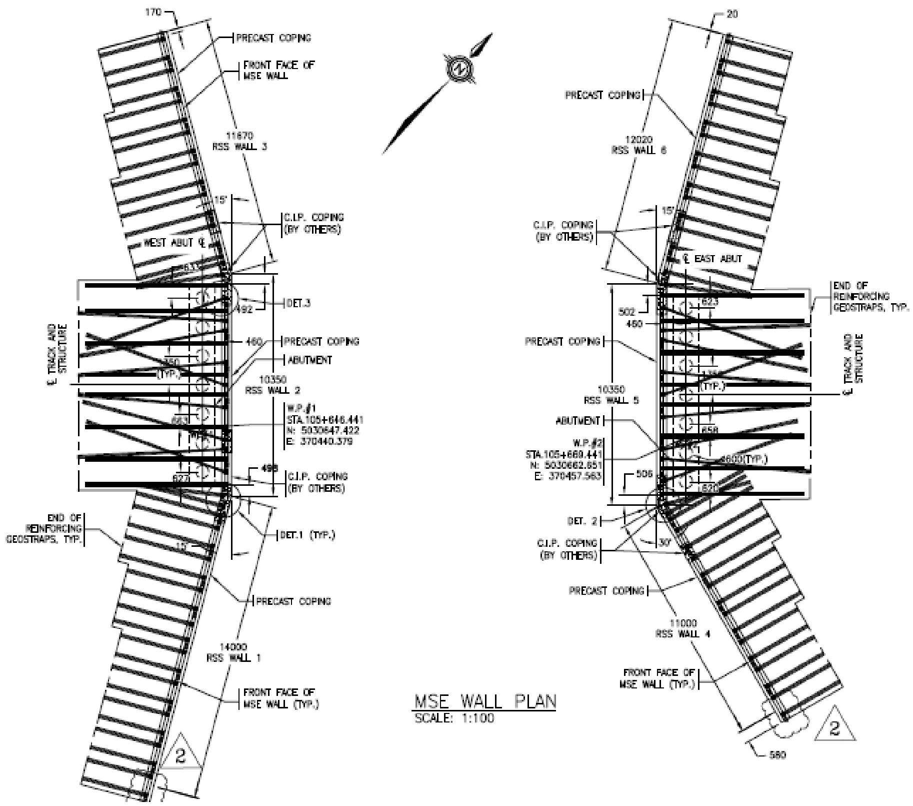

Figure 2: Plan view of Reinforced Earth MSE walls with Skew System

2 Geo-Synthetics

Geo-synthetic soil reinforcements offer some benefits that traditional reinforcements do not. This type of reinforcement is not affected by corrosion and proves beneficial when in contact with soils whose electro-chemical parameters exceed the maximum values for sulfate and chloride concentrations in soil. Nevertheless, special attention must be paid to the pH of soils, since polymers may deteriorate by hydrolysis when the soil in the backfill becomes alkaline. For example, the author's company's GeoStrap reinforcement can withstand a pH range of 3-9 (when tested using AASHTO test method T 289-91 I). Despite the benefit of non-corrosion susceptibility, geo-synthetics present some disadvantages, which need to be evaluated before restrictions are placed on using inextensible reinforcements.

2.1 Extensible vs. Inextensible Reinforcements

While it is understood that geo-synthetics are beneficial in instances where soil parameters may compromise durability of steel, the pros and cons of both the extensible geo-synthetics vs. the inextensible steel type reinforcements needs to be compared. (See table 1)

	Extensible	Inextensible
Electrochemical Parameters	pH limitations	$[Cl]^{-}$, $[SO_4]^{2-}$, Resistivity and pH limitations
Transportation	Compact and light weight	Packed in bundles, heavier
Environmental (Transportation)	Less emissions (idling) by reduced number of trips	More trips required for delivery
Storage	UV ray protection shall be provided (indoor storage)	Outdoor, on skids
Design	Long term deformation under permanent loads (creeping)	No susceptible to reinforcement creep under high stresses
Durability	Maximum size and angularity of backfill is limited to avoid damages to the reinforcement	Vast amount of data on corrosion rates of galvanized steel strips to forecast accurate design life
Construction (connection)	Construction labor/time may increase (dependent on many factors)	Quick and easy connection to façade panel reducing labor costs

Table 1: Comparison of Extensible vs. Inextensible Reinforcement

3 System

3.1 MSE Wall Using GeoMega System with Precast Concrete Facing

Mechanically Stabilized Earth (MSE) walls are used to stabilize what would otherwise be unstable slopes. They are a coherent gravity structure in which reinforcement is placed horizontally in selected locations creating a frictional interaction between reinforcement and soil. Additionally, backfill is placed and compacted in specified lift sizes between the reinforcement; the reinforcement provides enough tensile resistance to stabilize the Reinforced Earth volume. A precast concrete panel, which comes in different geometric variations, is attached to the soil reinforcement and protects the structure from any loss of fill or compaction (See figure 3). Soil reinforcement for these types of structures varies from steel straps, geo-synthetic straps, geo-grid, and high adherence ladders. The soil reinforcement that was selected for this project is a patented system designed by the author's company with some characteristics which differentiate it from other reinforcement types that include:

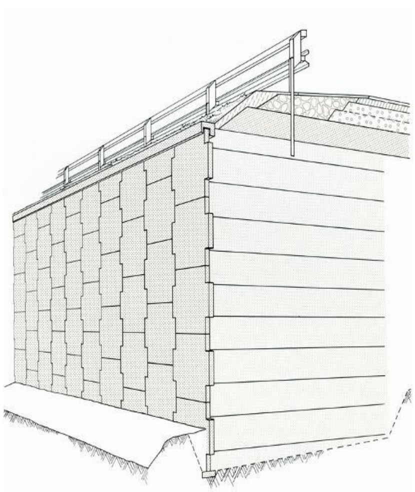

Figure 3: TerraClass Section

- High level of protection against chemical and biological deterioration
- Connection to façade panel is high in strength, reliable and durable
- Vast documentation of reliability throughout the structure's service life at different ambient temperatures
- Various architectural finishes may be applied to the façade increasing the aesthetics of the wall (See Figure 3)

3.1.1 GeoStrap Reinforcement

Geo-synthetic soil reinforcement comes in many forms including geo-synthetic straps, which were selected for the Hurdman East Overpass as soil reinforcement. These are relatively unique in nature and offer design advantages such as skewing past obstructions, which prove difficult for grid reinforcements. Geo-synthetic reinforcement also offers the ability to go beyond the electrochemical parameter limits that may be faced when using steel reinforcement. Considering that these reinforcements are extensible, special care is taken into account when designing and monitoring these structures. The used soil reinforcement consists of high tenacity polyester fibers encased in a polyethylene sheath (See Figure 4) with a tensile strength limit of 50kN.

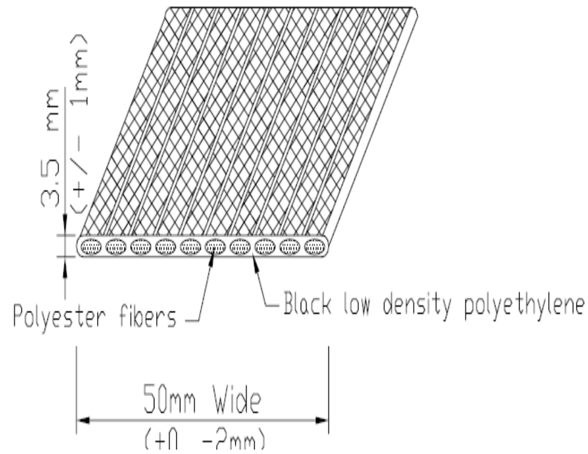

Figure 4: GeoStrap Soil Reinforcement

3.1.2 Connection to Panel

The connection of the GeoStrap to the precast concrete facing is created by inserting the strap through a plastic omega shaped sleeve which is embedded into the panel during casting. This sleeve provides smooth uniform curvature that allows the straps to be fed through the panel without creating any sharp bends or folds in the reinforcement, which can deplete its structural integrity. (See figure 5)


Figure 5: GeoMega Connection

3.1.3 Skew System

During the design of this project the obstruction location was predetermined. Therefore, a skew system was put in place in order to bypass those conflicts. These skew elements give the ability to take the strap reinforcement, which possess no skew capacity, past the piles in the reinforced earth volume. This project was unique as it was the first time in Canada that this skew system was implemented. The geo-synthetic skew system is made from high tenacity polyester fibers (also used for the GeoStraps) wrapped in a polyester sheath, which gives it similar durability and strength to a GeoStrap with a grade of 65kN. This element is threaded through the omega connection in the back face of the panel and connected to the GeoStrap as shown below. (See figure 6) This gives the designer flexibility in the allowable skew angle, up to 30° from true perpendicularity.

Figure 6: Connection between skew system and strap reinforcement

4 Design

The design for this structure was done in accordance with the design specifications of the Canadian Highway Bridge Design CodeCSA-S6/06.

As per the project specifications, a surcharge load equal to an additional of 900mm of earth was taken into consideration, amounting to 20.25kPa. The retaining walls are designed for a service life of 100 years. Factor of Safety considered in the design of this structure met with the specified parameters in the Canadian Foundation Engineering Manual for sliding and overturning, factors equaling 1.50 and 2.00 respectively. A geotechnical consultant was chosen to perform the global stability analysis for this structure. Additionally, this structure was designed with a seismic zonal acceleration ratio of 0.2

5 Construction Features

In general, for critical structures such as bridge overpasses, inextensible reinforcements are generally preferred for utilization as a longer data history exists to more accurately extrapolate the performance level. Since the OLRT restricted the use of steel reinforcement for the MSE structures in their specifications, a limited design approach and particular construction procedures had to be utilized for the structure.

The construction process for building the MSE wall was applied, and is typical to standard MSE construction; which may consist of:

- Excavate/prepare the site and foundation
- Pour unreinforced concrete levelling pad
- Install and brace first course of panels with predetermined vertical batter
- Backfill and compact at lifts specified and by manufacturer's recommendations
- Continue with placement of concrete panels

In addition, to the above standard process, feeding the GeoStrap reinforcement through the connection embedded in concrete façade panel was required. Soil reinforcement straps deliver the highest level of efficiency when placed perpendicular to the facing. If the reinforcement needed to be skewed, an MSE Engineer evaluated what effects were involved in order to design accordingly.

Using an extensible reinforcement, such as grids and GeoStraps, requires care in the construction process. One important construction practice is ensuring that the reinforcement is in tension when backfill and construction operations take place. While there are many ways to put the strap reinforcement in tension, the process used for this project was lay 2"x6" pieces of lumber perpendicular to the extents of the reinforcement and kept in place with rebar pins (See figure 7). With the wood in place, the straps are pulled into tension and stapled to the lumber to ensure a secure connection (See figure 9). If the reinforcements are not in tension, excessive movement may occur during friction mobilization when backfill and compaction takes place. It should be noted that movement in an MSE system is inevitable when pressure from the selected fill material and compaction takes place.

In order to construct a wall which is plumb and falls within any vertical tolerance specified, the panels need to be battered back towards the fill to ensure proper verticality is achieved. The amount of batter used generally depends on the backfill characteristics, for example a fill with a high fine granular content may require more batter than a granular fill of a consistently higher gradation. The batter given to the panels is a function of how inextensible the soil reinforcement is. Using an extensible reinforcement generally more batter will be required, as the wall may be slightly more susceptible to movement. The Hurdman East Overpass is a very good example of a project which used geo-synthetic reinforcements while also using a fill with a high amount of fine granular. The batter was used and adjusted as needed based on monitoring of the walls verticality.

Figure 7: Preparing lumber for tensioning of reinforcement

5.1 Construction of the Hurdman East Overpass MSE Walls

Building the Hurdman East Overpass MSE walls took place in August of 2015. The installer began construction of the walls as described in the previous section, and found that battering the panels at approximately 20mm was sufficient in resisting the movement of the facing as the backfill was loaded and compacted in the reinforced zone. This determination was made solely on gradation of backfill being used, and compaction equipment on site. In some cases +/-5mm alterations were made to the batter, as required.

The walls were 5.42m at the highest point and consisted of reinforcing straps which are 6.5m at the highest section tapering down to 3m at the end of the wing walls. (See figure 8). The GeoMega straps are cut twice the design length specified plus an additional metre which will be inside the connection in the panel. Precast coping with a length of 1.48m was supplied to the project, and placed on the finished wall. At bend lines and transitions into the sloped wing walls, cast in place coping was utilized in order to avoid cutting of the precast coping. Casting these sections in place generally looks better than field cutting precast which can prove difficult depending on bend angle. Corner elements were utilized to offer a more aesthetically pleasing look to the wall, which differs from mitre or butt type corners.

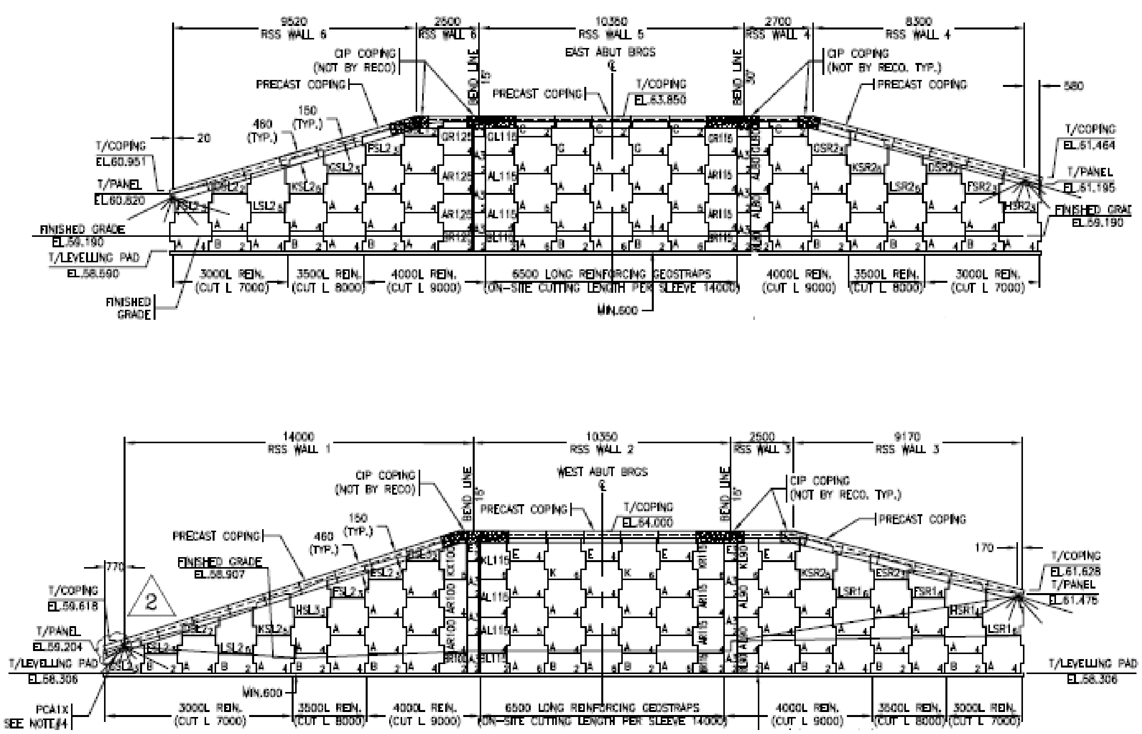

Figure 8: Elevation of Hurdman East Overpass

During construction, it was found that utilizing the GeoLoop skew system, for the Hurdman East Overpass project, made it quite easy to avoid the conflicts in the Reinforced Zone (See figure 10). The maximum skew angle that was required for this project was 20° from a plane perpendicular to the facing. For the height of the wall every layer of soil reinforcement was skewed at the same angle. The backfill was then placed on the tensioned straps, spread and compacted away from the facing in order to ensure the strips would not bulge during fill operations.

Figure 9: Tensioning soil reinforcement

Figure 10: Reinforcement being skewed past obstructions

6 Conclusion

This project is an example of how proper design and construction procedures allow MSE suppliers to design a structure which can withstand high loading and specialized requirements, including the type of reinforcement permitted in the soil. Utilizing strap reinforcements under these conditions with obstructions present in the reinforced soil structure proves to be a unique application which opens the door for potential future projects offering similar limitation as the Hurdman East Overpass. Additionally, Owners of projects with similar scopes could take advantage of more competitive offers by not limiting the soil reinforcement to only one type of material since other options may be feasible.

7 Acknowledgment

The Authors would like to acknowledge the City of Ottawa as the owner of the project, RTGE, along with George W. Drummonds Construction and David Laflamme Construction who helped make this project a success.

Figure 11: Hurdman East Overpass under construction

8 References:

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2) Construction of a MSE Wall Under a 3 Metre Tide in the Gulf of St. Lawrence, GeoManitoba,2012, B.Brockbank, C. Choufani