Application of Soil Reinforced Structures as Urban Transportation System solutions

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ABSTRACT

This paper will outline different applications of Mechanical Stabilized Earth (MSE) walls as infrastructure solutions for Urban Transportation Systems such as Light Rail Transit (LRT), Bus Rapid Transit (BRT) and Subways.

The constant demographic growth in cities has led to serious traffic congestion and pollution issues; this has increasingly lowered the quality of life for citizens. Therefore, city authorities have been implementing the above mentioned Urban Transportation Systems as efficient keys to create more livable communities. Examples of this can be seen in many cities throughout Canada such as Ottawa, Mississauga, Vancouver, Edmonton and Calgary among others.

Adaptability to site conditions, simple and fast construction processes, economy, aesthetic features, excellent performance under seismic and hydraulic situations and durability are some of the advantages that MSE structures offer when implemented as a key part of the Urban Transportation System solutions.

Selection of the proper material and components for this type of retaining structure, including some Canadian examples, are also discussed further in this paper along other challenges in the design and construction.

The main conclusion of this work is the fact that reinforced soil structures with the proper design can be utilized as an excellent and efficient solution for this type of application.

INTRODUCTION

The reinforced earth structure was invented in 1964 by French Architect and Engineer Mr. Henri Vidal. It was only five years later which it was the first technique to be used close to railway line to support high speed and heavy railways as mean of transportation between the cities.

Nowadays, the population have been increasing and with them the needs to improve and expand transportation to facilitate the transfer of the community to their destinations. Therefore, we have implemented the development and utilization of services of high quality capacity urban public-rapid transportation system with its own right of way, electric-powered trains and underground as Bus Rapid Transit (BRT), Light Rail Transit (LRT) and subways system where the transport makes highly efficient use of space and can carry thousands passengers satisfying their necessity.

Reinforced earth structure has been utilized part of the development of these urban services with the passing of the years. Some are the advantages why reinforced earth structures are an option preferred by civil engineering are mentioned as: Flexibility of the wall, very high resistance, ease installation, excellent appearance of the finished structure and considerable saving when comparing with conventional cast-in-place wall due to the high cost of formwork, labor, tool and much faster construction.

With RSS wall the construction time on site is considerably reduced and this may be a fundamental to adopting the system right. The Retaining wall with reinforced earth it is an economic system compared to other containment systems.

Therefore it is appropriate in areas where the work surface is limited and requires a quick implementation where the walls are quick to lift a fairly flexible due to its prefabricated nature as in the case of soil reinforcement structure.

Aesthetically speaking, different types of panels finished can be used in accordance to the project needs.

RSS structures application in urban system

Retaining wall

A retaining wall is a structure designed and constructed to resist the lateral pressure of soil when there is a desired change in ground elevation that exceeds the angle of repose of the soil. Retaining walls are an economical way to meet every-day earth retention needs for highway and bridge grade separations, railroads and mass transit systems. They are also used in response to difficult design conditions such as very high structures, restricted space, where obstructions within the MSE soil mass are present and poor foundation soils. **(See Figure 1)**

Figure 1

Platteview Intersection US 75 & US 34

Head wall for Tunnel and Culvert

Reinforced Earth structures in this type of application absorb the intense vibrations created by passing trains and the sudden massive stresses associated with massive breaking loads. In addition, Reinforced Earth structures have high load bearing capacity, uniform bearing pressure at foundation level and are not adversely affected by stray currents associated with electrified railway lines. **(See Figure 2)**

Figure 2

North Kiama By Pass – New South Wales

Bridge abutment

The bridge abutment is a solution for urban transportation system because this retaining wall is designed to support the earth pressures behind it as well as the heavy concentrated vertical and horizontal surcharge loads imposed by the bridge superstructure and traffic loading. For bridge abutment can be used two types, "True" abutment support the horizontal and vertical loads applied at the bridge seat, directly on the reinforced earth volume and "False" bridge abutments the bridge seat is supported on piles. In this case, when piles are necessary, reinforcing strips can be placed between them as they are easily diverted. **(See Figure 3, 4 & 5)**

Figure 3

Snider Diamond Toronto - Ontario – Canada

Figure 4

Windemere Overpass. Vancouver, BC

The West Corridor "FasTracks Project" is a 12-mile light rail transit (LRT) corridor that will link the Denver city center with nearby Golden. All of the walls directly support the LRT Track System and will have a unique architectural pattern designed for this particular corridor which passes through several neighborhoods and Parks and Recreation areas.

Figure 5

An efficient solution

Urban transportation such as BRT, LRT and subways are very efficient systems that are preferred by users due to their innovative design, high capacity, lower cost, efficiency, predictable journey schedules, reliable (some of these system operates when the snow or ice defeats road vehicles), designated lanes, fully accessible, electrically powered such as LRT system is a clean and green and no emissions at street level. Therefore, the public transit solutions can significantly improve urban mobility and offering the flexibility to meet transit demand.

The simple and fast construction methodology is one of the reasons that make the soils reinforced system eligible as application for railway structures. At the same time, these structures are reliable and trustworthy, making of them a good solution for walls and abutments for BRT, LRT, subways or rail structure. The following reasons, in addition to the already stated, make of the reinforced soil structures the preferred solution.

- Excellent performance with attractive appearance.
- Architectural flexibility.
- Minimal traffic disruption during construction.
- Rapid construction.
- Economy in foundation works.

Figure 6

Charlotte LRT (USA)

Reinforced Earth structure

The a Reinforced Earth wall is a simple structure formed by select backfill, galvanized steel high adherence, reinforcing ladders, Geosyntetic reinforcing straps these reinforcement to use to generate friction on the soil. Moreover, the facing of the RSS wall which help to prevent the erosion of the backfill and give the attractive appearance which can be used the concrete or wire mesh facing. Other components that formed the reinforced earth structure is the levelling pad serves as a flat starting surface for placing panels at the first course and the precast copings which is placed at the end of the construction and the top of the precast concrete panel if it is required by the project. The connection of Reinforced Earth facing panels and reinforcements is made by tie strip and structural galvanized high strength nut, bolt and washer.

Components:

A. **Backfill:** a select granular backfill have to be used as a reinforced volume structure. As a one of the most principal component of RSS wall, the backfill has to meet with some mechanic and (Gradation hasn't more than 8% passing the 0.0075mm size sieve, well graded, free draining, non-frost susceptible, friction and unit weight have to meet the specification requirements) electrochemical properties (non- aggressive soils and free of organic substances has to considered).

B. **Reinforcing Strips:**

B.1 ***Galvanized Steel reinforcement:***

- ***HA steel strip:*** is a perfect solution for high static and dynamic design load, high walls, bridge abutments, heavy duty mining, and industrial retaining wall railway. The strips may be galvanized or black and are designed to be bolted to the tie strips at the back of each facing panel. These are ribbed strip was designed to create friction with the soil mas, are typically supplied in 50mm width and varying lengths according to the design of the structure.
- ***HA Ladder:*** have extremely pullout and is advantageous in structural up to 6m.

B.2 Geosyntetic Reinforcement: The reinforcing geosynthetics can be made of high density polyethylene, polyester, and polypropylene which become efficient solution when the chemical characteristic of the backfill are not suitable to the utilization of galvanized steel.

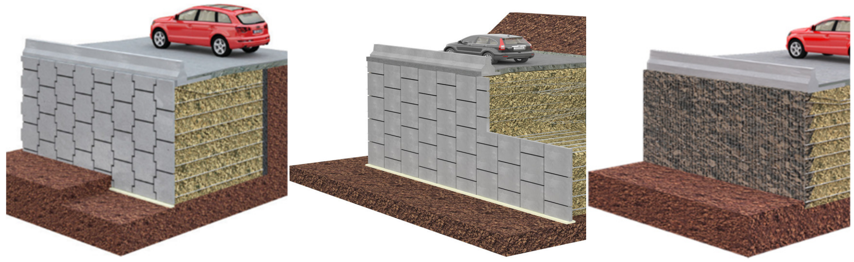
- **Geomega:** this system allows to be constructed in chemically aggressive environments such as marine environments, corrosive backfilling materials, recycled aggregates, pollutions risks, infiltration of de-icing salts, etc. This system used a ***Geostrap*** type of reinforcement made of polyester tendons (poluethylene sheet) and used when the reinforced earth structure is affected by chloride or suphates and low ph (acid environment).
- **Ecostrap:** A Polyvinil alcohol PVA tendon is used when the backfill has high ph and this geosyntetic has the capacity to support higher temperature.
- **HA EcoStrap:** is used by finer grained backfill materials.

C. **Facing:**

- **Concrete prefer for appearance (performance) and durability:** Pre-cast Concrete facing panels is produce with standard sizes in order to meet the elevation of the structure and standardized the construction procedure. Depending on the height and geometric requirement for specific project the reinforced earth structure can be fabricated with some customize panels. **(See Figure 7a)**

- **Wire mesh facing:** is lightweight very flexible, able to accommodate large settlements and very effective wall to be used for remote sites where access is a problem and it can be erected by hand eliminating the need for heavy lifting equipment. The wire facing can be providing with fabric or rock facing according to the service life of the project requirements. **(See Figure 7b)**

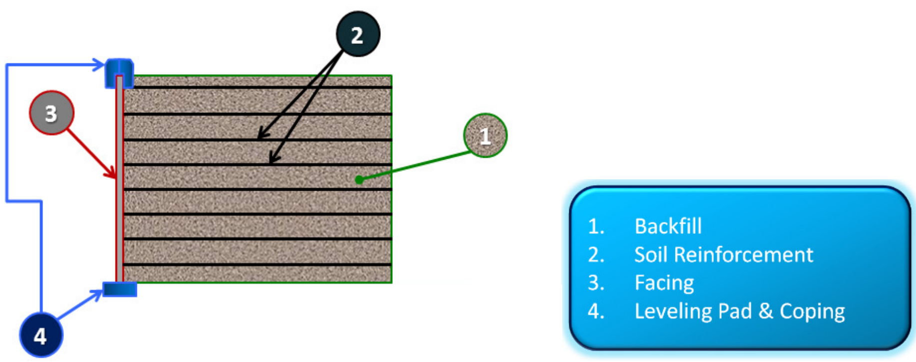
Figure 7a **Figure 7b**



D. Fastener: are galvanized structural bolts, nuts and washers elements to make connections between the facing panel and the galvanized steel reinforcement. The sizes of these fasteners are 13 mm or ½" of diameter.

E. Concrete Leveling Pad: is an un-reinforced concrete not structural element 150mm-deep by 300mm wide pad of serves as a flat starting surface for placing panels.

Figure 8



Design consideration

- **Earth (soil):** a selected backfill which meets the minimum requirement for mechanical and electrochemical parameters allows to fulfilling the required service life of the structure and adds resistance to the flow of stray current. This is particularly important when the steel strips are used.
- **Soil Reinforcement:** according to the selected backfill and the structure service life different types of reinforcements can be used in order to meet the specification require in the project. Extensible or inextensible reinforcements are available in the market.
- **Facing:** service life should be considered for the facing selection of the structures (permanent or temporary). Flexibility and appearance are other important factors for the facing selection.
- **Vibration:** studies have confirmed that "vibrations slightly increase the surcharge forces in the upper strips, but their initial effect is to release the stresses induced by construction and compaction. With respect to the friction between the backfill and reinforcing strips, tests in the laboratory and on experimental structures have shown that although the force required to pull out a strips seems to diminish somewhat during a vibration phase, this is due solely to the fact that vibrations also cause variations in the weight of the soil in contact with that reinforcement.

The friction coefficient itself does not change."…reference Reinforced Earth Structures for Railway Applications, Technical Document, Terre Armée International.

- **Stray Current:** studies have proved that the corrosion due to the stray current from direct current traction power railways is minimal on the reinforced earth structures. Some are the reasons which there are negligible effects of corrosion on buried reinforced structures as is shown below:
    - High insulation (e.g. rails support on ballast) in a railway system.
    - The linear resistance of the rails is relatively low (e.g. electrical insulation of the rails)
    - Distance between substations which means when the distances are close together the effect of stray current tends to be a minimum.
    - Select backfill which conform to mechanical and electrochemical requirements for reinforced earth structures provides additional resistance to the flow of stray currents.
    - The galvanized steel is a predominant choice to be used in the reinforced earth structures due to has stronger properties than other kind of metal. (High resistance and low conductivity)

All the features above made reinforced earth structures ideally suited for support track bed, bridge abutments, earth retention structure adjacent to rights of way and for deflection walls to protect bridge piers from impact in the event of derailment.

2. Canadian Applications

In Canada the first structure built for an LRT system was completed in 1982 in the City of Calgary. Since then many structures has designed and built for Urban transportation system. The following projects have been selected in order to illustrate the use of MSE structures for these transportation systems

- **Mississauga BRT**

The Mississauga Transitway is a bus rapid transit system (BRT) under construction in Mississauga, Ontario, Canada, spanning most of the city from Winston Churchill Boulevard to the junction of Highways 401 and 427 in the city of Toronto.

Figure 9

- **Ottawa LRT**

The Confederation Line is a transportation system 12.5 kilometre line from Blair Station to Tunney's Pasture includes a 2.5 kilometre tunnel through the downtown core, 13 stations. This project have been used the retaining wall along their path building 290 square meter of permanent structure and 100 square meter of temporary.

Figure 10

- **Calgary LRT**

The NW LRT Extension to Rocky Ridge / Tuscany at Calgary, AB it was buit with retaining wall and pedestrian bridge abutment with around 825 square metres.

Figure 11

- **Evergreen LRT – Vancouver**

The Evergreen Extension is a 10.9-kilometre long extension of the SkyTrain rapid transit Millennium Line being built for the South Coast British Columbia Transportation Authority (TransLink) in Metro Vancouver, British Columbia, Canada. For this project was built 491.14 square metres of reinforced earth structure.

Figure 12

CONCLUSION

Mechanical Stabilized Earth Structures with the proper design are excellent solutions for Urban Transportation Systems.

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