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CONSTRUCTION STAGING AND TRAFFIC DEVIATION USING REINFORCED EARTH WALLS IN TURCOT INTERCHANGE PROJECT

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Abstract: Work phasing and traffic flow maintenance are major components of certain civil engineering projects, particularly in densely populated cities. These items can be more critical when project involves the reconstruction of a main inner-city highway where traffic cannot be stopped, and diversion is limited. Those challenges were present in the reconstruction project of Turcot Interchange in Montreal, Quebec. In this project of Ministère des Transports du Québec, large structures must have remained in service while some parts of it were being dismantled and reconstructed. Reinforced Earth walls were used in all phases of the project to accommodate that need. The temporary and permanent structures were built in complementarity to allow the movement of thousands of vehicles a day during the dismantling of existing structures. Adding to the complexity, the space was limited for construction of MSE retaining walls within the perimeter of existing structures. In some occasions, the MSE walls were built directly on the edge or under the bridge decks, while settlements of existing structures had to stay within the allowable limits under the new loading configurations. Although the use of MSE walls in construction phasing is not uncommon, the complexity of Turcot Project makes it a unique example. This paper discusses the design and construction challenges of temporary walls in the project and presents different solutions. For illustration, the paper presents specific cases such as temporary structure supporting 83 m span modular steel bridge, or a 15 m high temporary wall utilized as a true bridge abutment for construction staging.

1. INTRODUCTION

Turcot Interchange in Montreal, Quebec, connects highways 15, 20 and 720 – the main roads to go north-south and east-west out of the city. It is the largest interchange of Québec province, with a traffic volume of three hundred thousand vehicles per day. It was originally built to open in time for Montreal Expo in 1967. Before reconstruction works started it was in service for nearly 50 years. Existing structures, mostly high elevated bridges on big columns, needed to be dismantled and replaced with new structures. However, to maintain the traffic flow, those works had to be carefully orchestrated and happen gradually.
New structures being build – retaining walls and ramps leading to bridges - are in a large portion Mechanically Stabilized Earth (MSE) retaining walls. For technical and compatibility reasons, the temporary structures used for staging and traffic diversion would also needed to have the same soil reinforcements. Using same supplier to provide both types of structures made the design and later construction faster, smoother and well-coordinated, with a quick response to unanticipated changes.

2. MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALLS

Retaining structures used in Turcot reconstruction project are coherent gravity retaining walls consisting of alternating layers of backfill soil and high adherence steel reinforcement, as shown on Figure 1, forming a composite material. The walls are protected from erosion by a facing of two types – precast rectangular concrete panels (semi-rigid) for permanent wall application and wire mesh (flexible) facing for temporary structures.

Figure 1: Typical cross section - flexible facing MSE retaining wall

2.1. SOIL REINFORCEMENT

Reinforcements used for the structures are high adherence, ribbed, galvanized steel strips, 4mm thick and 50mm wide. The design life for permanent and temporary structures is respectively 75 years and 5 years. The reinforcement used for both are the same steel strips, despite the design life difference. Because of the project's complexity in the geometry, the strips from both types of walls are often overlapping. Once the project is fully completed, the temporary walls would stay buried inside the permanent structures. The use of one type of inclusions made the construction easier.

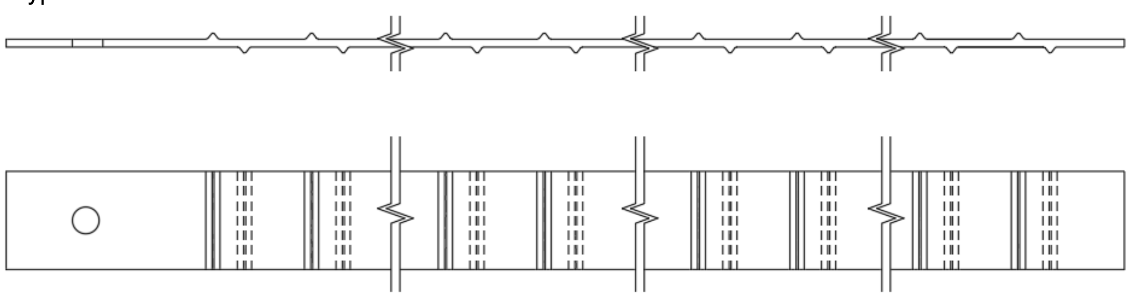

Figure 2: High Adherence ribbed steel strips

2.2. BACKFILL

By the end of the project, the dismantling of the Turcot Interchange structures is estimated to produce more than 800 000 tons of recycled material on the job site, usually containing large amount of crushed concrete and a small proportion of asphalt. The use of recycled concrete material is generally limited for permanent walls using steel reinforcements, given the high pH accelerating corrosion. The reuse of this material was however possible for temporary walls which reinforcement did not overlap with the permanent wall soil reinforcements. The construction of temporary ramps made the use of tons of recycled material possible. For temporary walls with reinforcement overlapping with permanent strips the backfill used was a crushed stone MTQ MG-20 type as request by the owner. In those cases, elevation of strips for temporary and permanent walls needed to be designed on specific levels in order to avoid having extra layers of backfill.

2.3. FACING

There are 2 types of facing used for this project: semi-rigid and flexible. The latter one is a wire mesh steel "cage" facing. It consists of C-shape cage units 3000 mm long by 500 mm high, stack up one on top of

another. Black steel was used in majority of the cases, where the application was temporary; although some galvanized cages for permanent, supporting structures were used in this project as well.
The facing is held in place and connected to reinforcing strips through C-shaped tie strips wrapping cages around in at least 3 points along typical 3 m long cage (see Figure 3). Before the backfilling, cages are lined with geotextile.
Facing of this type is lighter, easy to handle and adjust on site (cutting, bending) and significantly decreases the cost of MSE wall while providing a reliable and high-performance structure.

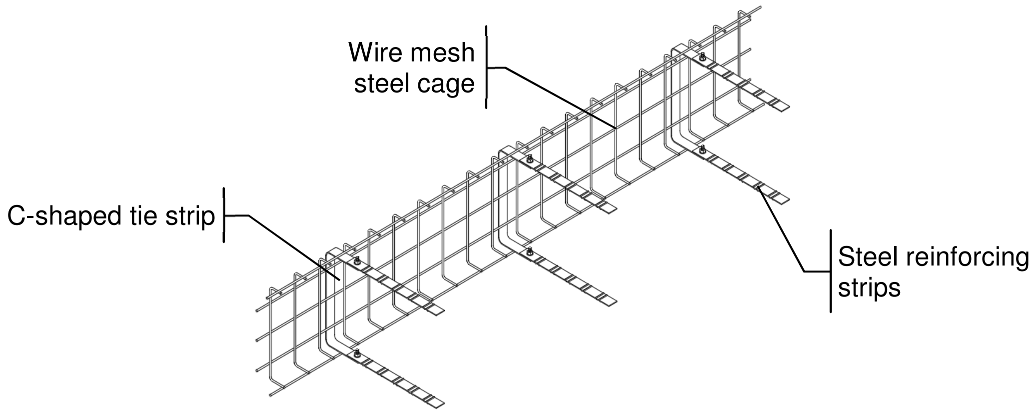

Figure 3: Wire mesh cage, tie strips and strips for Flexible Facing MSE wall

3. APPLICATION FOR WIREMESH FACING MSE RETAINING WALLS

Wire mesh facing MSE retaining walls on Turcot project can be categorized based on main application for:

- Construction staging
- Temporary access/ traffic diversion
- Surcharge walls for preloading

3.1. CONSTRUCTION STAGING

The most common and simplest staging application in the project was in a situation where a single permanent wall connects multiple abutments as a front wall, but not all the abutments were built in the same time and some had to be opened for traffic before others. In those cases, temporary wall perpendicular to the abutment was built together with the front precast facing wall at the staging section, allowing for future continuation of the concrete panel facing. The construction of the permanent wall generally stopped when reaching the boundary of the adjacent existing structure to allow its dismantling while the traffic was diverted on the new structure.
Most abutments on the project were so called “false abutments” – bridge footing supported by concrete piles of ±1.2 m hidden inside MSE volume. Then even those simplest cases became challenging. Strips from the front permanent walls had to be skewed to avoid obstructions (abutment piles, existing piles of in-service structures, new water and sewage system structures etc.) and the temporary wall would conflict with those skewed strips. It required coordination in design between permanent and temporary structures.
Reconstruction of the new Autoroute 720 was a good example of this type of phasing. The construction consisted of multiple phases of traffic diversion on a new permanent route during the dismantling of the existing adjacent highway. It is interesting to note that the construction of MSE walls was carried out during the spring, summer and fall while most of the disassembly work was done during the winter, as construction is very difficult during winter months in Quebec. The continuation of the subsequent phases could therefore continue following spring, once the dismantling has been completed.

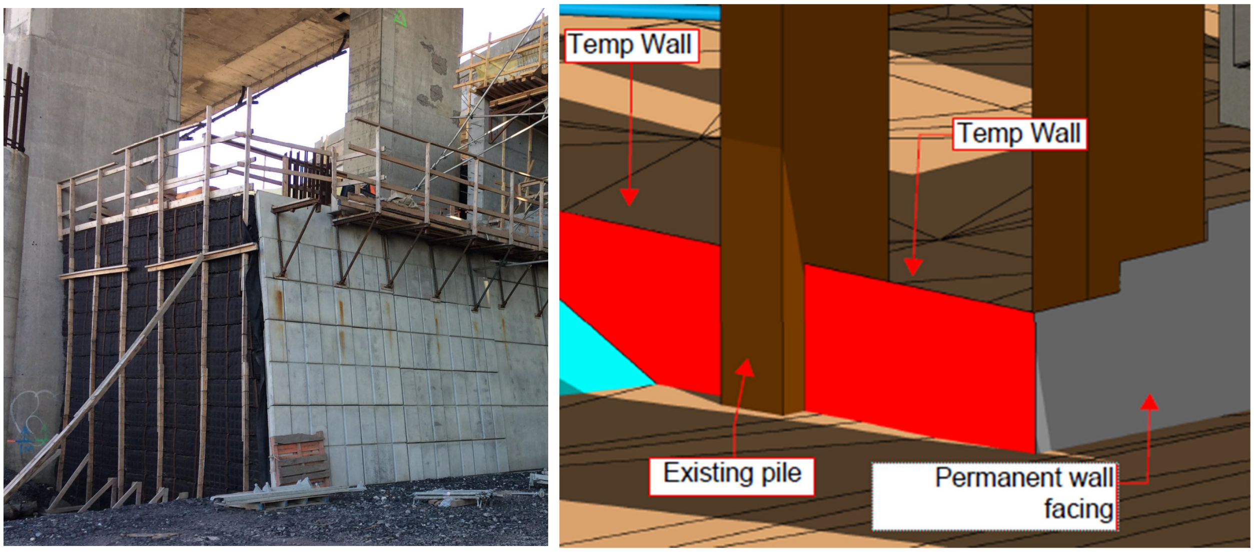

Figure 4: Temporary MSE wall used for construction staging.

In more complicated cases the temporary wall had to be designed according to existing and future obstructions. In one such case a large diameter pipe was going along the planned temporary wall, not leaving enough space between the front face of that wall and the pipe for laying the strips. In the same time the wall could not have been moved away from the pipe as a whole, so the future structure could be built alongside its top part. The solution used was a tiered wall, where bottom part of the facing was protruding, leaving enough space to avoid the pipe, and top section was left in the original location, allowing future wall to be built (see Figure 5). In that case not only the design was challenging, but also was the construction itself. Due to limited head space below the old structure (still in-service), no heavy equipment could have been used in constructing the top layers of the MSE wall.

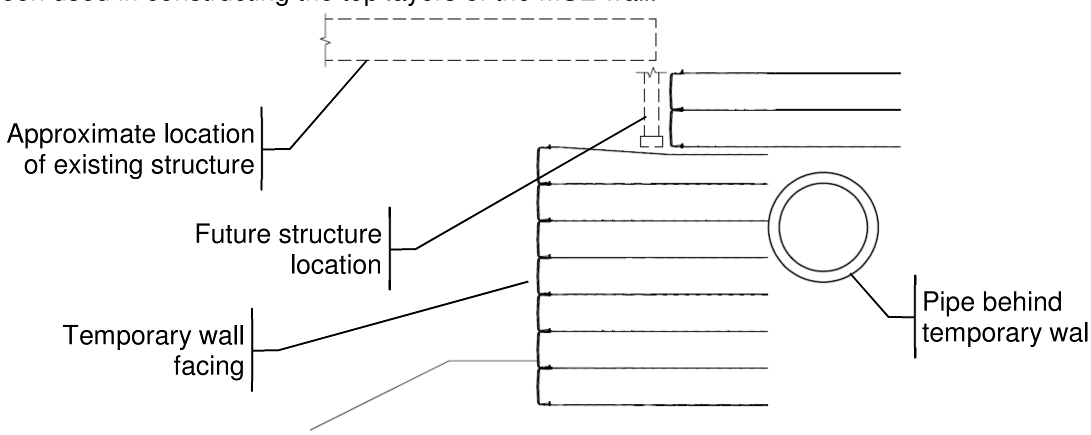

Figure 5: Tiered Wire Mesh Facing MSE wall used for staging.

In this project, conflicts with water and sewage system structures were common and construction in different phases were a challenge for the drainage installation. Particularly it was impossible to avoid MSE volume. Thus, several pipes were running through the wire mesh facing during the construction phasing and left cantilevered until the next stage. Opening was made in the wire mesh facing, number of reinforcements increased in the area and everything sealed around the pipe after its installation.

3.2. TEMPORARY ACCESS ROADS AND TRAFFIC DIVERSION

In most cases, new structures must be built underneath or adjacent to the old ones and after completion and diverting the traffic on the new structure, dismantling of old structure could start. However, in some cases the old structure had to be disassembled before construction of the new road and therefore, the traffic had to be diverted to a temporary bypassing ramp.

The biggest challenge in one case, was that the height of the temporary ramp was 15 m and it had to fit in between dense grid of the old structures' piles. Limited space required many bends and alignment modifications to shape the wall around the piles. To achieve the desired elevation at top of the wall, prediction of settlement and backfill compression was an important part of the design. The wall was designed as a back-to-back structure, connecting the existing elevated structures at both ends. That required a shallow foundation placed directly on the top of the temporary ramp at one end to support the loads of jumping slab. Holding the alignment and verticality of the temporary wall was essential since a distance of a few centimeters separated these two structures connected by a jumping slab at the top, approximately at 15 m elevation.

The importance of temporary structures diverting the traffic is perfectly demonstrated by the fact that the construction of this wall took more than 8 months while its service life was about 1 year.

Figure 6: Temporary ramp fit in between existing structures' piles.

Figure 7: Tall temporary access road.

3.3. SURCHARGE WALLS FOR PRELOADING

The project in some areas required preloading. To meet the schedule, the construction of abutments had to be planned simultaneously with preloading. The situation was even more complicated because reinforcing strips had to be installed at the back of the pile cap and backfilled immediately after its completion (see Figure 8). For that reason, wire mesh facing MSE walls were used as preloading surcharge on top of finished permanent MSE walls. They allowed to achieve final settlements on permanent MSE walls faster in the same time leaving sufficient space for construction of bridge pile cap with reinforcement at the back.

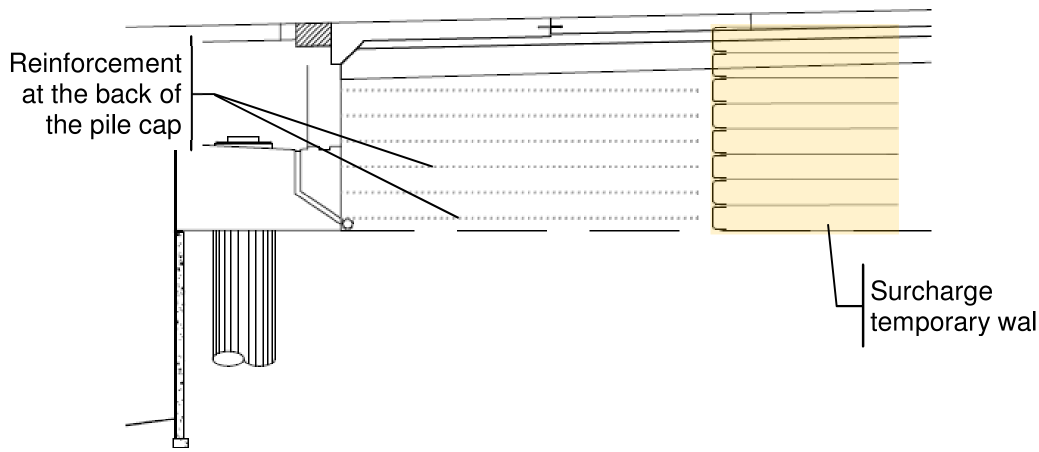

Figure 8: Surcharge wall behind the pile cap

4. SPECIAL CASES AND DESIGN CHALLENGES

4.1. EXISTING PILES CONFLICTING WITH A WALL FACING

In many cases on the project new structures were built below the existing ones still in service, accommodating structure's piles in MSE volume. In more complicated cases the piles were conflicting not only with the strips but with the facing as well and a solution was needed to continue the construction despite the conflict. That was the case on a construction of the wall supporting Autoroute 720 leading north-east of the city. At the conflicting locations the designed height of permanent wall was close to 14 m. Construction staging plan suggested building precast facing panel wall to the height of about 7 m, from the top of existing structure, before dismantling it.

The design of permanent and temporary wall had to be closely coordinated. The temporary wire mesh facing wall was designed around the piles, connecting to the precast panel portion at both ends. Sufficient space was left allowing the dismantling of the columns in the next stage. Permanent part had to be designed to allow future completion of the wall without noticeable difference at the finished wall facing.

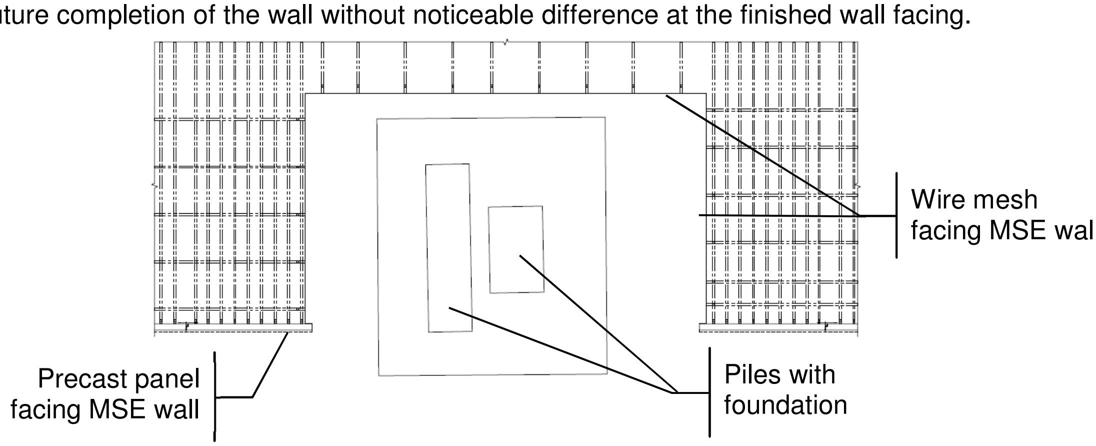

Figure 9: C-shaped temporary wall – plan

4.2. TRUE BRIDGE ABUTMENT

True abutments are MSE walls directly supporting bridge footings. The stresses are then distributed into the reinforced soil designed for restricted settlements and high loads. This technology was used on this project for temporary diversion roads.
Out of the two bridges with true abutments built, one that was at the east end of the project for a bridge on Autoroute 720 overpassing Greene Avenue had very limited space available between the wall face and the beam seat. Therefore, concrete precast panels were utilized at the abutment section to allow construction of the true abutment at the edge of the wall facing.

Figure 10: Temporary “true” bridge abutment with concrete panel facing

Second bridge with true abutments has been built over an existing railway on the west section of the project to serve as a bypass for Autoroute 20 West. In this case, the distance between the bridge seat and the front of the wall was sufficient to allow the use of a wire-mesh facing.

Figure 11: Temporary “true” bridge abutment with wire mesh facing

4.3. MODULAR STEEL BRIDGE

Another case of traffic diversion was necessary at south of the interchange. The final alignment of the permanent wall would cross through a railway that had to remain in service at that stage of construction. The deflection road had to pass over the tracks through a temporary bridge. Temporary abutments on piles were installed on either side of the tracks to support the modular steel bridge with a span of 83 m. The bridge was assembled and launched from the top of temporary and permanent MSE walls and the design of them had to consider the loads generated by this operation. A jumping slab connected the bridge abutment to the temporary walls.

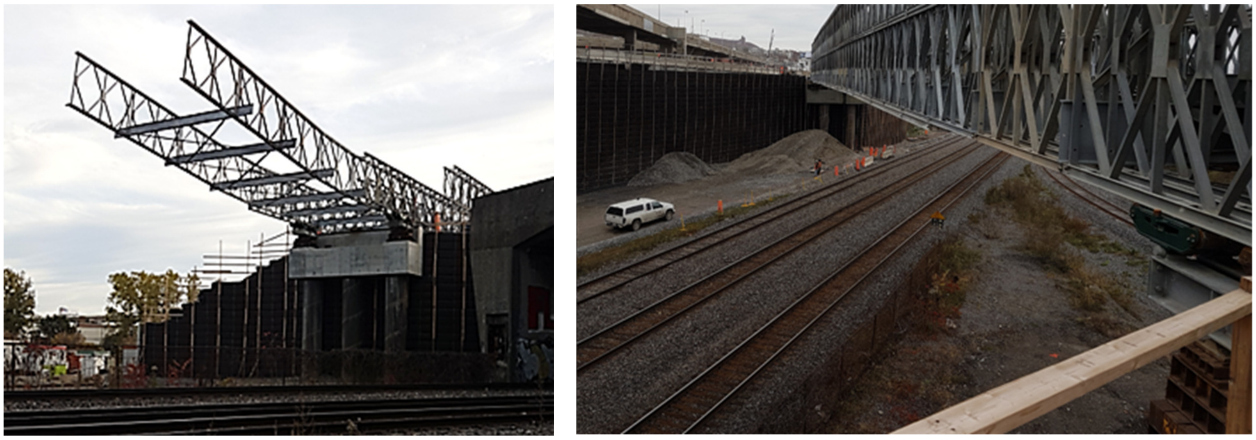

Figure 12: Modular steel bridge pushed onto piles from temporary MSE wall

4.4. CRASH WALL

Temporary MSE walls have not only been used for traffic diversion or staging. The temporary re-aligned railway tracks were in close proximity of existing bridge columns carrying road traffic. This proximity required impact protection for columns in the event of a derailment. The solution was a combination of a trench box directly around the column and a closed wire mesh MSE wall forming an enclosure around the column. With a very limited distance between the wall and the railway there was not enough space to place reinforcement. Direct connection between the temporary wall and the trench boxes for this part was designed and implemented.

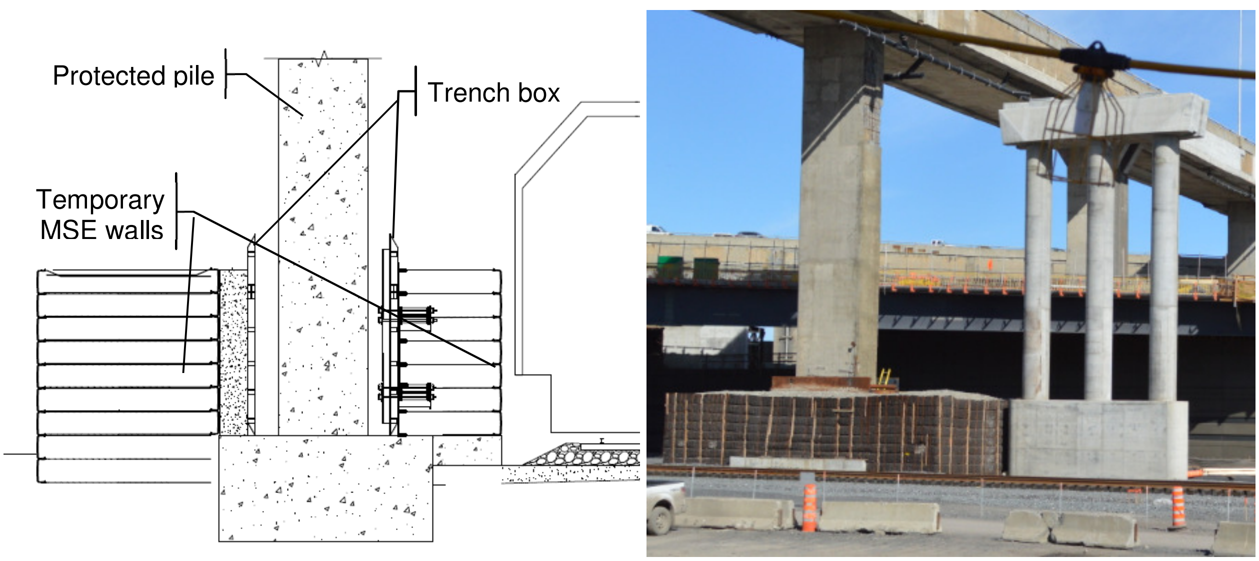

Figure 13: Crash wall protecting the pile

5. CONSTRUCTION CHALLENGES AND SPECIAL CONSIDERATIONS

5.1. WIRE MESH WALL PROTECTION

Wire mesh facing walls were built in the proximity of existing structures that needed to be dismantled. There was an increased risk of damaging the geotextile behind the wire mesh panels due to inevitable impacts from dismantling operations. Breakage of the geotextile can result in loss of granular fill, which is a structural component of MSE walls. The contractor used a freezing technique to protect the temporary walls during the dismantling.

Some surficial repair was also necessary following damages due to impacts on unprotected facings. Repair techniques varied according to the extent of the damage, that included placement of a wire mesh and geotextile over the damaged part and grout or expandable foam injection when a loss of material was observed.

Figure 14: Icing protection of temporary MSE wall facing

5.2. CLOSED RAMP

The construction of a ramp mentioned in section 3.2 of this paper came with its own challenges. The supply of a granular material to the higher parts of a back-to-back ramp with closed ends without access to the top turned out difficult; considering the wall would reach 15 m in height. Two methods were used to provide the aggregates for the construction of the wall. First, the access was situated near the center of the ramp and construction started by keeping the wall height low at the center and raising the wall in steps toward ends of the ramp. The construction of the wall continued to the full height at both ends. The second method was utilizing conveyor belts to carry granular materials when the access in the middle of the ramp was no longer possible.

5.3. DISMANTLING

Some temporary structures were buried in the permanent body of structures and some were disassembled when no longer needed. The dismantling was carried out in a safe way and repetitive steps of backfill and reinforcement removal. The demo operation begun from the top and at a certain height, the dismantling was carried out from the outside, in front of the wall.


Figure 15: Dismantling of temporary MSE ramp

6. CONCLUSION

Densely populated, high traffic areas with limited space come with many challenges for construction and Turcot project is a prime example. Reinforced Earth walls are great solution for works requiring staging and traffic diversion. Permanent and temporary structures supplied together provides an advantage and offer wide variety of solutions and proved to be an economical and easily adaptable option.

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REFERENCES

American Association of State Highway & Transportation Officials (AASHTO). 2017. *AASHTO LRFD Bridge Design Specifications*. 8th ed., Washington, DC, USA.

Brockbank, B. and Wu, P. 2011. Reinforced Earth Solutions for Rail Application in Canada. *GEORAIL 2011 International Symposium.* Paris, France.

Guide Pour la Surveillance Specialisee et le Reinforcement. 1994. *Les ouvrages en Terre Armée.* Service d'Etudes Techniques des Routes et Autoroutes (SETRA), France.

Owies, I. and Mirmirani, S. 2013. MSE False Abutment Walls for Rodick Road Extension. *CSCE 2013 General Conference*, Montréal, Québec, Canada.

Reinforced Earth Canada Ltd., *Reinforced Earth Construction Manual.*

Wandschneider, H. and Wu, P. 1985. Reinforced Earth Bridge Supporting Structures. *Canadian Transportation Research Forum,* Ottawa, Ontario, Canada.

Vidal, H. 1969. *The Principle of Reinforced Earth.* Highway Research Record No. 282, Highway Research Board, USA.