A Precast Faced Mechanical Stabilized Earth Solution for a 20 Metre High Mining Crusher Wall with Various Technical and Site Challenges.

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ABSTRACT
This paper presents a case study of the design and construction of a MSE wall at a remote mining site at Bloom Lake near Fermont, Quebec, Canada. The project at the time of completion in 2009 represented the highest precast load-supporting MSE structure by Reinforced Earth Company Ltd. Canada in mining application. The project faced several challenges. The steel strip reinforced earth wall was built straddling a cast-in-place reinforced concrete foundation and partially bears on re-compacted fill and bedrock. This required differential settlement design consideration. Design of the crusher wall also necessitated a load distribution concrete slab on the top to accommodate the significant surcharge and horizontal impact load from the 380 ton payload CAT797B haul trucks. Other constraints of the project were its remote location, wall geometry, cold weather backfilling operation and 24 hour installation.

RÉSUMÉ
Cet article présente une étude de cas de la conception et la construction d’un mur TMS dans une mine retirée au Lac Bloom à côté de Fermont, Québec, Canada. A l’achèvement des travaux en 2009, ce projet représentait le plus haut mur préfabriqué TMS de la Société Terre Armée Ltée Canada dans une mine. Le projet se trouvait confronté à plusieurs défis. Le mur renforcé par des inclusions métalliques, a été construit en partie sur une fondation en béton armée coulée en place et se portait partiellement sur du remblai re-compacté et sur le roc. Cela nécessitait de prendre en considération le tassement différential durant la conception. La conception du mur du concasseur nécessita une dalle en béton en haut du mur pour distribuer les charges et contenir les surchages considérables et l’impact horizontal du camion CAT797B de 380 tonnes. Les autres contraintes du projet étaient : l’endroit retiré, la géométrie du mur, le remblayage à temps froid et le montage du mur 24h/24.

1 BACKGROUND

The Bloom Lake Iron Ore Deposit is a 640 million tonne ore body grading approximately 30% Fe. Bloom Lake is a world class development stage iron ore project, with a high recovery and 30 year mine life based on a Feasibility Study completed in April 2007. Bloom Lake is expected to be producing 8 million tonnes of 66.5% iron ore concentrate per year starting Q1 2010.

The Bloom Lake deposits are iron formations related to the Lake Superior-type. Lake Superior--type iron formation consists of banded sedimentary rocks of proterozoic age composed mainly of bands of iron oxides, magnetite and hematite within quartz (chert)-rich rock, with variable amounts of silicate, carbonate and sulphide lithofacies. Such iron formations are a major source of iron throughout the world.

1.1 The Project

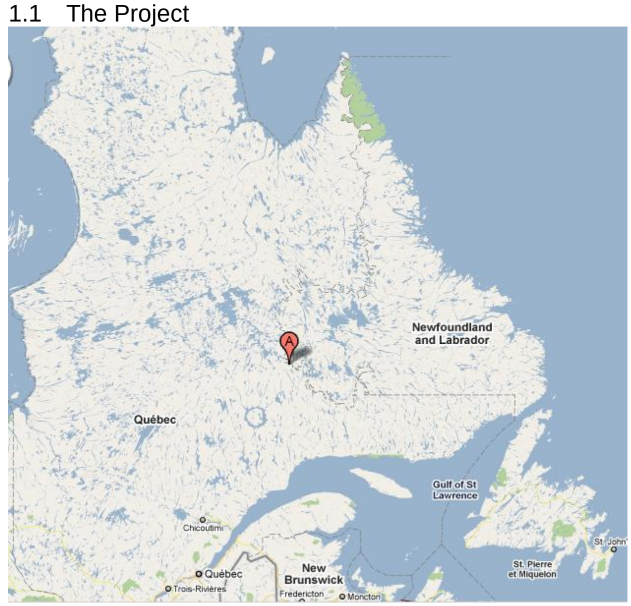


Figure 1. Site Location in Northern Quebec

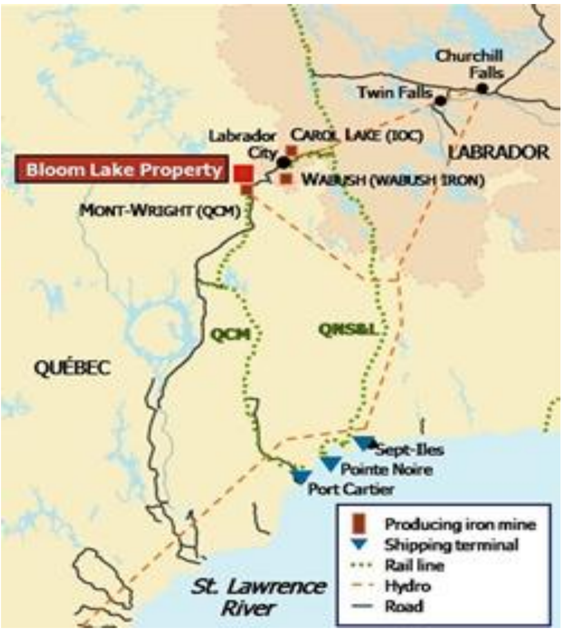


Figure 2. Site Location showing proximity to a number of producing mines.

The Bloom Lake property forms part of the south western corner of the Labrador Trough iron range and is located in close proximity to a number of producing mines. The site is approximately 940 km northeast of Montreal and is serviced by road, rail and air. The terrain may be described as low lying with boreal forest, muskeg, some exposed bedrock and several small water bodies, lakes and rivers. Ground elevation near the Bloom Lake project is about 700 m (2,300 feet) and it descends to about elevation 540 m (1,800 feet) near Wabush, NL.

Following drilling and blasting, run-of-mine (ROM) ore is delivered to a primary crusher located approximately 1000 m to the north-east of pit edge at about 680 m elevation. This is where the MSE crusher wall in located.

Ore from the mine is crushed, stockpiled then fed to a single wet autogenous grinding mill operated in closed circuit with vibrating screens. The liberated hematite minerals are recovered using three stages of spirals. Concentrates from the spiral are filtered and dried and then loaded into railcars for transportation to the port. The tailings are pumped to a disposal area located a few kilometres from the plant.

Figure 3. Crusher, Concentrator structure, and loadout Silo overview.

1.2 PROJECT TEAM

Consolidated Thompson Iron Mine Limited (owner)
Cima+ (Engineering Consultant)
Reinforced Earth Company Ltd. (MSE wall supplier)
Equipements Nordiques Ltée (General Contractor)
Les Entreprises P.N.P (installing company)

2 MSE WALLS

The wall system used is a composite material of compacted granular soil and linear soil reinforcements. The generic name for these types of structures is commonly known as MSE, or Mechanically Stabilized Earth. MSE is designed as a coherent gravity structure made of this composite material with a facing system. It is proportioned and designed internally to resist the applied loads in accordance with well established standards. The inherent compressive and shear strength properties of the soil are improved by the tensile strength of the soil reinforcements in these structures. A positive connection design of the reinforcement with the facing of the MSE is required to prevent overstressing at the connection and to minimize post construction movement.

The author's company provided the design and layout, budget and scheduling, and pre-manufactured materials supplies pertaining to the Mechanical Stabilized Earth (MSE) retaining wall requirements.

The total surface area of the MSE structure was about 1500 m^2, ranging from heights of 5 to 20 metres. Galvanized steel strips were used for soil reinforcement due to the heavy loads of the trucks. The lengths for the steel strips ranged between 4.5 m to 14 m.

2.1 Galvanized Steel Strips Reinforcement

The preferred soil reinforcement of this project's designer has been galvanized steel strips for many years. Along with steels high modulus of elasticity, calculated using Young’s Modulus ($E=FLo/Ao\Delta L$), this inextensible soil reinforcement has several construction advantages over other materials and allows construction of walls with negligible post construction movements and does not require any pre-tensioning techniques. The galvanized steel has proven to offer excellent durability confirmed by the low corrosion observed on samples of strips extracted from existing structures over the past 40 years. High adherence with the soil is achieved by means of shallow ribs on the surface of the strip. Extraction tests conducted on these strips shows high pull-out resistance since the ribs force the shear surface away from the strip and into the soil thus mobilizing the full internal shear resistance of the soil.

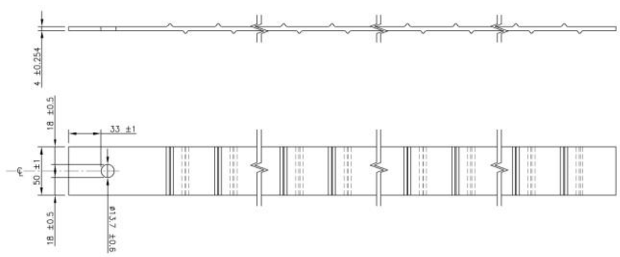


Figure 4. Galvanized Steel Strip

2.1.1 The Panel Connection

The panel connection has changed over the years. The original design of tie-strip and reinforcing strip connection was an embedded U shaped tie strip. The connection was made with two high strength bolts in single shear. Today’s connection is now a “bulb shaped” tie strip, which is still embedded within the concrete panel, but has only one high strength bolt in double shear. This tie strip and reinforcing strip connection is shown in figure 5. Further research was conducted to enhance the strength and resistance of the tie strip and reinforcing strip connection. Photoelastic load analysis was performed using a homogeneous urethane material to construct the panel which was coated with a photoelastically sensitive plastic. When deformed under a load the test panel would reveal a pattern showing the distribution of shear stresses and strains. Upon review of these tests it was determined that internal reinforcing bars were to be placed immediately adjacent to the tie strips. The panel connection is positive which assures a full load transfer from the panel facing to the reinforcing strips during predictable post construction movement.

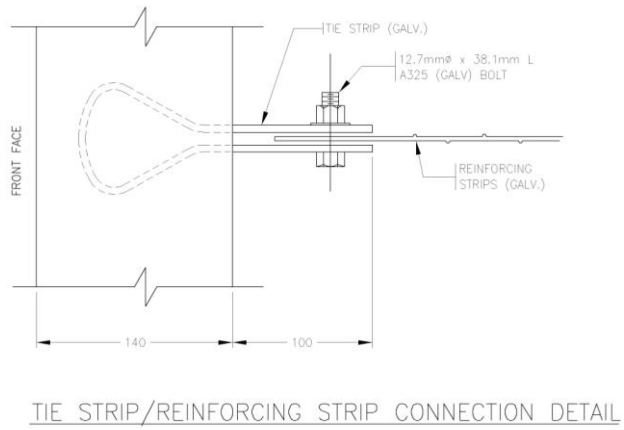


Figure 5. Connection

2.2 Design

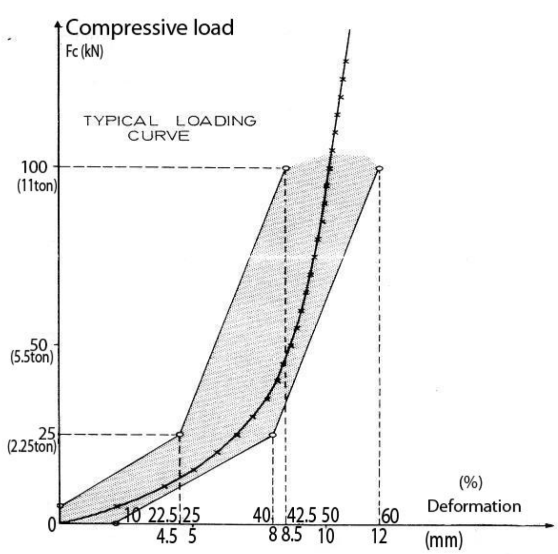
For MSE walls with precast facing exposed to high loads, such as was the case here, it is necessary to have compressible pads in the horizontal joints between modular precast panels. Since the precast panels themselves can obviously not compress, it is essential to have highly compressible pads in the horizontal joints so that the overall vertical consolidation of the facing can match that of the backfill behind the facing (strain compatibility). If this is not done and the backfill can settle to a greater degree than the facing, overstressing of the soil reinforcement connection can occur.

In this particular case the rubber pads were increased in depth, instead of the typical 20mm rubber bearing pads 25mm rubber pads were utilised. This was due to the high loading from the CAT 797B haul truck and the overall height of the MSE retaining wall It was a concern that the height of retaining wall in combination with the high loading from the CAT 797B would have deformed the standard 20mm rubber pad so much as to render them useless. Therefore precaution was taken and the 25mm rubber pad was utilized. Non-standard pads should be carefully designed and tested to accommodate higher than normal backfill compressions

It has been confirmed that the compressible pads in the horizontal joints compress more under higher loads. This was shown in a test that was performed in March 2007. The compression of rubber pads was measured at 35 different locations under various loading conditions simplified here as low, medium and high vertical load. The corresponding compression of the rubber ribs averaged out to be respectively 30%, 65% and 80%. The geometry of the standard pads and the pads used for this case are shown in Figure 6. The top section of the bearing pads are in the form of 4 nibs to allow easier initial compression. A main solid portion of the rubber pad near the bottom of the pad compresses less easily and prevents the pads from completely being squashed, ensuring the panels will not contact each other. Figure 7 shows the compression characteristics of the rubber pads as tested in the laboratory, showing stiffness increasing as a function of increased deformation.

Differential settlement was a design consideration for this project. Having this occur can cause a range of problems for MSE walls. Differential settlement can occur between adjacent panels which can cause panels to crack and break. This was a concern for this project as the facing bears on a concrete footing and immediately adjacent to that the facing bears on a compacted granular material, an obvious potential for settlement differences. Due to this potential problem, the granular material that was to be placed and used as a foundation for the panel facing was to be compacted to a minimum of 98% modified proctor to reduce the amount of settlement that would occur at these locations therefore reducing the differential settlement within the facing. Another possibility for differential settlement was between the facing as an entity and the internal settlement of the granular material within the reinforced area. With the concrete panels bearing on a concrete foundation the overall consolidation for the facing was minimal as stated above. This was a potential problem due to the fact that a high surcharge would be placed on the granular backfill from the CAT797B haul trucks as well as the earth pressures itself. Thicker than normal highly compressible bearing pads were used to counteract the high wall and high loading, but were also integral in reducing the differential settlement between the facing and the reinforced area and reducing the overstressing of the tie strips/panel connection.

The wall's intricate geometry posed several logistical, technical and site challenges. Design of the crusher wall necessitated a load distribution concrete slab on the top to accommodate the significant surcharge and horizontal impact load from the CAT 797B haul trucks which have a payload of 345 tonnes (380 tons) shown in figure 8. Backfill for the wall was supplied from crushed rock available at the iron ore mine site. Due to the existence of iron in the native rock that was crushed there was a higher than normal unit weight which had to be factored into the design due to the higher earth pressure that was exerted on the wall as a direct result of this increased unit weight.



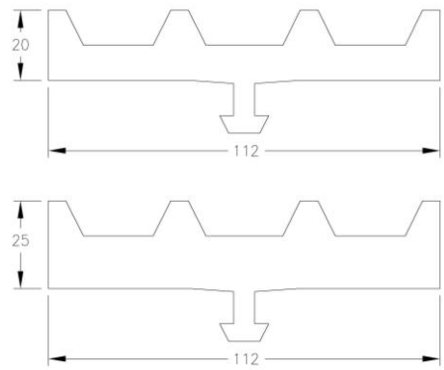


Figure 6. Geometry of a standard compressible joint pad (20mm) and compressible joint pad used for Bloom Lake (25mm)

Figure 7. Laboratory results plotted as load versus deformation for 20mm thick compressible joint pads.

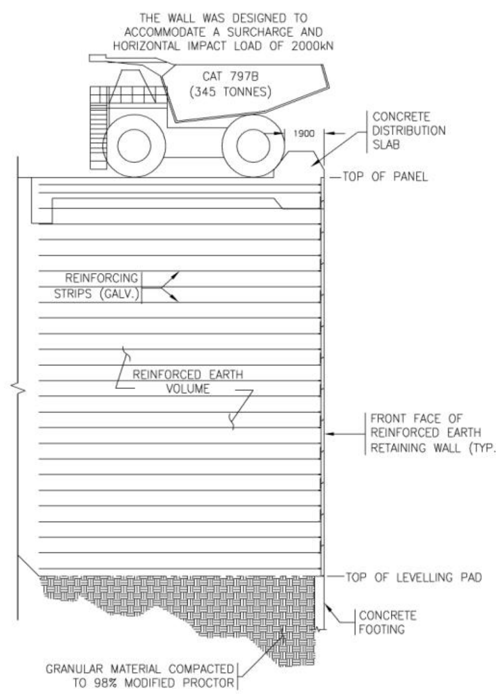


Figure 8. Section shown at concrete distribution slab

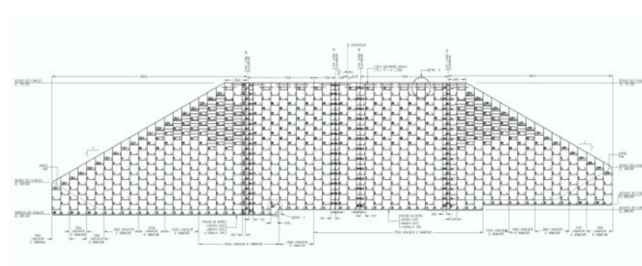


Figure 9. Typical Elevation Drawing from this Project

3 CONSTRUCTION

The basic erection sequence for an MSE structure installation are as follows:

- Prepare the site including excavation and installation of drainage systems per design elevations and grades,
- Form and pour unreinforced concrete leveling pad,
- Install, align and secure precast facing panels, both vertically and horizontally, (Higher vertical batters may be required due to extensible reinforcement),
- Connect steel strips to tie strips.
- Spread and compact backfill in lifts of 25 cm.
- Monitor the actual movement of panels during the placement and compaction of each lift of backfill; adjust the amount of batter according to field conditions.

The project crew consisted of two inexperienced local teams, working in 2 shifts 24 hours a day, under the part-time guidance of the MSE company advisor.

Materials had to be delivered quickly to the remote location of Bloom Lake due to the non-stop erection schedule.

Construction was interrupted several times by heavy rains and hail. The backfill material had to be continually improved to reach the desired compaction. The length of the strips also dictated the amount of time for backfilling and compaction. The crew was successful in completing the MSE structure satisfactorily following the above procedures.

Figure 11. During construction of this Project (long strips and wide area of compaction)

Figure 12. Overnight construction.

Figure 10. Storage of delivered materials.

Figure 13. Backfill improvement.

Figure 14. During construction of this Project

Figure 15. MSE Wall installation complete

4 CONCLUSION

After encountering all of the onsite challenges that were associated with this project, such as, remote location, weather and certain design constraints it is evident that an MSE wall with precast concrete modular panels was a viable option when all the proper measures outlined in this paper were used to counteract all the challenges that were presented on this project.

5 ACKNOWLEDGEMENT

The writers would like to acknowledge the contribution of a number of individuals to the paper.

Consolidated Thompson Iron Mines Limited, Bloom Lake team, QC, Canada

Design team at Cima+, Montreal, QC, Canada

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