MSE submerged walls assist waterfront development, Chestermere, Alberta

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ABSTRACT
As part of the Waterfront Development in the town of Chestermere, east of Calgary, a Reinforced Earth® Wall was used to define approximately 200 metres of shoreline for a small lake.
Although the retaining wall structure was constructed in the dry, since it was put into service in 2004 it has been continuously exposed to fluctuating water levels and ice conditions.
This paper will provide a case study of this interesting project with references to a similar application in the same local area at the Westmere Commercial Development.
In addition, the internal design aspects of submerged MSE walls will be discussed including backfill gradation, drawdown conditions and hydrostatic forces. The importance of scour protection will also be discussed.
Panel joint design is reviewed with regards to allowing easy drainage of water from the backfill behind the panels while at the same time offering protection against loss of fill.

RÉSUMÉ
Dans la ville de Chestermere, a l'est de Calgary, un mur de "Reinforced Earth®" etait utilisé a établir à-peu-près, 200 m de rivage d'un petit lac.
Construis au sec en 2004, ses murs expérience les changements de niveau d'eau et les glace d'hivre.
Ce papier etudira ce projet intéressant, avec allusion d'un autre application semblable, à "Westmere Commercial Development", qui est dans les environs du lac.
De plus des conception interne des murs immerger (MSE), nous discuteron de la gradation du remplissage, et des condition "drawdown" et les forces hydrostatique. Et en plus nous descuteron l'importance de la protection contre le récurage.
La conception des joints des panneaux seronsaussi discuter en qui se concern l'écoulment d'eau en main temp la conservation du remplissage

1 INTRODUCTION

The purpose of this paper is to demonstrate the use of Reinforced Earth style Mechanically Stabilized Earth (MSE) walls in situations where significant portions of the walls are below the level of adjacent open water.

This paper will focus on the waterfront wall built at Chestermere Lake and will also include aspects of another wall built as part of the storm water retention pond at the adjacent Westmere Commercial site.

1.1 Project Overview

Rich Bassett of Bassett Associates Landscape Architecture Inc. carried out the overall project design for both the Chestermere waterfront wall and the Westmere storm pond. Henry Crawford of Thurber Engineering assisted him with the geotechnical Engineering of the sites and Paul Boos and Bill Brockbank of Reinforced Earth provided the design for the MSE walls.

1.1.1 Chestermere Waterfront Wall

The Chestermere Waterfront Wall is part of the redevelopment of John Peake Park by the Town of Chestermere (located just east of Calgary, AB). This redevelopment is being spread over several years and is still ongoing. Among its many components it included the replacement of pre-existing wooden boardwalk along the edge of Chestermere Lake with a new Retaining Wall, Sidewalk and boat launch along approximately 200m of the lakeside. This construction was the first stage of the project and took place in 2004.

The new retaining wall is located approximately 20m further out into the lake compared to the old wooden boardwalk. As a result the retaining wall is almost completely submerged for much of the year (this is discussed more further on).

The construction of the MSE structure and other aspects of the project were undertaken by John Conolly of Graham Construction & Engineering Inc.

1.1.2 Westmere Storm Pond

The Westmere storm water pond is part of a commercial development by Melcor Developments Ltd on the property

Figure 1. Chestermere Lake and Westmere Pond

adjacent to the John Peake Park. The retaining wall portion of this project was designed to turn the pond into an architectural feature.

The construction of this MSE structure was undertaken by Ed Gramlich of Volker-Stevin Contracting. Volker retained McIntosh Lalani Engineering to carry out a geotechnical review and global stability analysis of the wall structure.

2 RETAINING WALL SELECTION

Chestermere Lake is part of the Western Irrigation District's canal irrigation network. The lakes water level is raised in late spring and this water level is maintained through the summer into the fall to act as part of the irrigation network. During this time the lake also serves as a recreational facility. In the late fall the water level is drained down and remains low through the winter months.

The design for the retaining wall structure needed to accommodate three specific conditions:

- First, the condition of low winter water level – during which time the retaining wall stands dry from toe to top of wall.
- Second, the condition of high summer water level - during which time the wall is submerged almost in its entirety.
- Finally the wall must withstand the transition from one state to the other – particularly the drawdown of water levels in the fall of each year.

The geotechnical report for this site looked at two possibilities for the construction of the retaining wall along the waters edge. The first being a traditional concrete retaining wall (either cast-in-place or pre-cast) and the second being an MSE wall.

The report pointed out that during the winter the water level will be below the base of the wall, therefore, unlike most shoreline structures, there would be no ice forces to contend with. However, the report also noted that the old wooden boardwalk that predated this project was significantly distorted both laterally and longitudinally and it was suggested that this should be attributed to frost action during the winter season with its low water level.

Due to this concern with frost action and its potential affect on a cast-in-place or precast concrete retaining wall the geotechnical report recommended that any such wall be founded on cast-in-place concrete piles at least five meters in depth. This requirement greatly increased the cost of this option for the project.

The geotechnical report went on to examine the use of a mechanically stabilized earth wall for this project. The report pointed out that the flexibility of mechanically stabilized earth walls would allow the wall to adapt to minor soil movements that may occur due to frost action in the foundation or due to the change in water levels. The only concern brought forward was that the architectural design of the project included extensive curvilinear features that would challenge the design of an MSE system with concrete facing panels.

Storm water retention ponds, such as the Westmere pond, are now a common requirement for new developments and can have a significant geographic footprint - affecting the amount of space available to the development. The use of retaining walls around a portion of the retention pond perimeter can reduce this footprint, while at the same time providing a desirable architectural detail. This can increase the space available for development while also increasing the value of that property.

The retaining wall system selected for both projects is known as a Reinforced Earth with TerraClass facing. The major components of the system are cruciform shaped precast facing panels with shiplap joints and galvanized steel soil reinforcement strips 4mm thick X 50mm wide and of varying lengths to match the design requirements of the project.

3 DESIGN CONSIDERATIONS

3.1 Geotechnical Design Input

As for any MSE structure it is important to have a good geotechnical analysis of the site prior to starting the design process for the MSE structure. This analysis will provide information on the soils present and often relates these to the various design alternatives under construction.

In the case of MSE walls it is important that this analysis examines the overall stability of the site with the retaining wall in place. This would include the global stability analysis, the bearing capacity of soils under the reinforced volume, and settlement under the new structure. This report can also provide the opportunity to provide observations and directions relevant to the implementations of various alternatives.

The observations made in the report prepared for the Chestermere wall were discussed under the section on retaining wall selection.

Settlement can be significant for a wall built on soils that either have or soon could have high moisture content and may require an increase in the initial wall height in order to insure that the desired top elevation is maintained over the structure's life. The MSE wall constructed at Chestermere was fairly low – only about 1.8m from levelling pads to top of coping. This limited the potential for settlement.

The global stability for MSE walls traditionally assumes that the critical failure surface will not pass through the reinforced volume due to its increased strength. A preliminary estimate of the width of the reinforced volume is generally 0.7 times the height of the structure. In some cases the analysis may indicate that it is desirable to increase the width of the reinforced volume to intercept critical failure circles. If so this should be conveyed in the report.

In the case of Chestermere the width of the reinforced volume was defined by a further factor. The minimum length of soil reinforcement that is used by Reinforced Earth is 2.5m - which is considerably larger than seventy percent of the height. This provided a higher stability for the structure. In order to improve global stability a gravel keyway 1500mm wide was recommended under the front of the MSE structure.

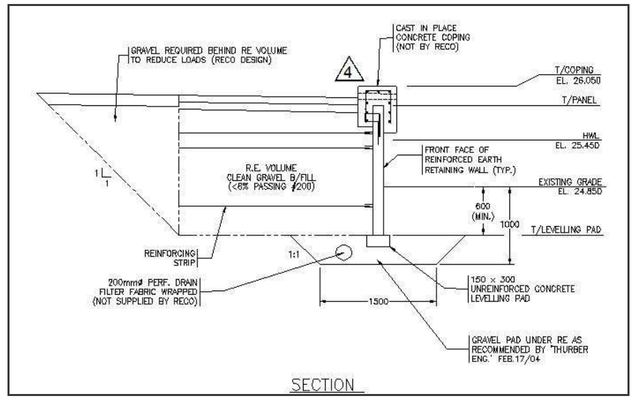

Figure 2. Design Section for Chestermere Wall

Of course there are other methods that can be used to increase global stability. In their report on the Westmere wall McIntosh Lalani recommended using additional geofabric at the bottom of the wall and the provision of an impermeable liner to separate the reinforced volume from the backfill below and behind it.

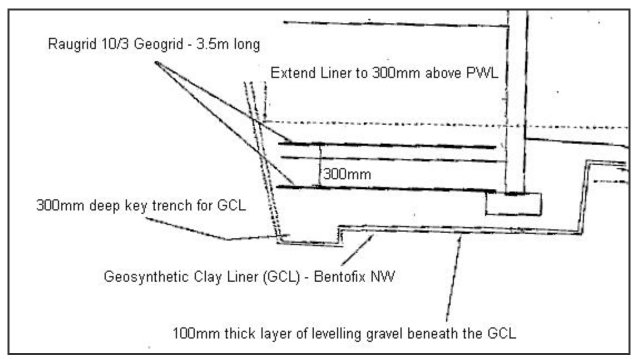

Figure 3. Geotechnical Provisions Westmere Wall

3.2 Hydrological Considerations

For a MSE structure where a significant portion of the structure will be submerged, the effects of the water in the backfill must be considered in the design of the structure. The relevant effects of the water on the structure relate to the effect of the water on the backfill material and the forces that can result from the presence of the water.

The effect of the presence of water in the backfill relates directly to the characteristics of the backfill that are relevant to the design of MSE structures. The amount of force that the soil reinforcement can potentially resist is related to the friction forces that can be generated so that the reinforcement can resist movement. The potential force is a combination of the weight of the backfill material and the friction angle along the failure plane. Both of these factors can be affected by the presence of water. The weight can be effectively reduced by the buoyant force introduced by the water and the friction can be reduced by the lubrication introduced to the system. These effects can apply to both the reinforced volume of the MSE structure and the backfill behind. The effect of saturation on the friction angle may be negligible if the backfill used is a free draining granular material.

Another possible effect of water in the backfill depends on the chemical composition of the backfill and/or the water. This is the possibility of a change in the electro-chemical properties of the backfill. The importance of these properties lies in the expected life span of the structure. In order to determine the expected life span of the structure it is necessary to make assumptions on the rate at which corrosion of the (in this case steel) soil reinforcement. These assumptions are only valid if the characteristics of the backfill are within certain bounds. If the characteristics range outside of these bounds the terms of the design will need to be adjusted. An example of this is the construction of an under-water wall in a salt water environment. This would obviously have the affect of increasing the corrosion rate for steel soil reinforcement. This usually would necessitate a change in the design to a system less prone to that type of corrosion.

The other effect that came into play for these walls was that of drawdown of the water level. For Chestermere one of the design conditions is that the water level would be reduced each fall from near the top of wall to below the bottom of the wall. For Westmere the frequency of the drawdown conditions is less certain. For a storm water retention pond we know the design high water and low water levels, but, the occasions on which the high water level will occur are subject to the seasonal precipitation rates.

At Chestermere the length of the soil reinforcing was in excess of the normal 70% thus providing additional reserve strength. In addition a wedge of granular backfill was placed behind the reinforced volume to reduce the loading against the back of the reinforced volume and a gravel keyway was run under the wall facing. Together these compensated for the reduction in capacity due to the buoyancy effect and friction reduction from the saturation of the backfill and improved the global stability of the MSE wall during all of the loading conditions.

For Westmere the wall extended significantly above the high water level and the weight of the granular material above the high water level mark made the effects of the water in the reinforced volume less significant. However, the effect of the high water level on the native backfill behind the reinforced volume was of more concern. Therefore, an impermeable liner was extended under the reinforced volume and up the backside (and ends) of the reinforced volume past the high water mark to keep the water out of the native fill.

In both of these walls the water adjacent to the wall was fresh and the backfill met the guidelines for corrosion so that no special corrosion allowance was required in the design.

3.3 Architectural Challenges

The design for the Chestermere retaining wall along the water front had to include allowance for architectural features that provided challenges in the design of this project.

First, the geotechnical report for this project identified as a concern the curvilinear geometry of the wall design. In order to provide a pleasing architectural layout the front of the structure included a number of curves with radii below what is normally incorporated into a mechanically stabilized earth wall with concrete facing.

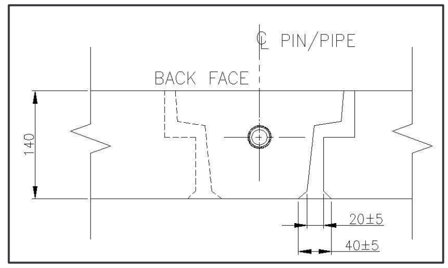

Figure 4. Shiplap Joint with Pin & Pipe Connection

In this case of the selected design the facing panels are 140mm thick and are set with a space of 20mm between panels. In order to protect the geosynthetic fabric used behind the facing panels and provide a second defence against the loss of backfill through the wall facing, the facing panels are provided with shiplap jointing around the entire periphery of the facing panels.

The panels rotate around the pin and pipe connection that is located at about the mid-thickness of the panel. This means that at a radius of 12m the back corners of the panel would just touch and the gap between front corners would be approximately 40mm. In order to accommodate the tighter radii for this project (as tight as six meters) it was necessary to design a bevel along the back edges of the facing panels to allow the corners to effectively overlap and allow the front corners to separate even further. This was possible for two reasons: the shiplap joint of the panels insured that the facing would still properly retain the backfill and second the as the wall is submerged the wider seams would not detract from its appearance.

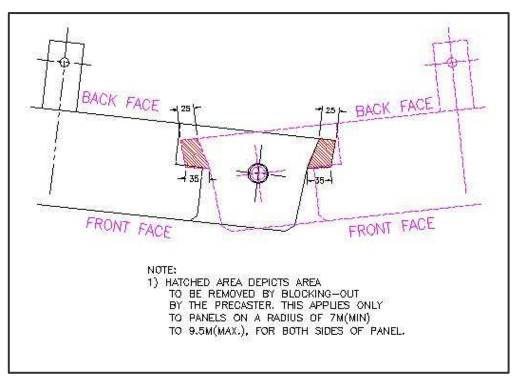

Figure 5. Blocking out of Corners for Tight Radii

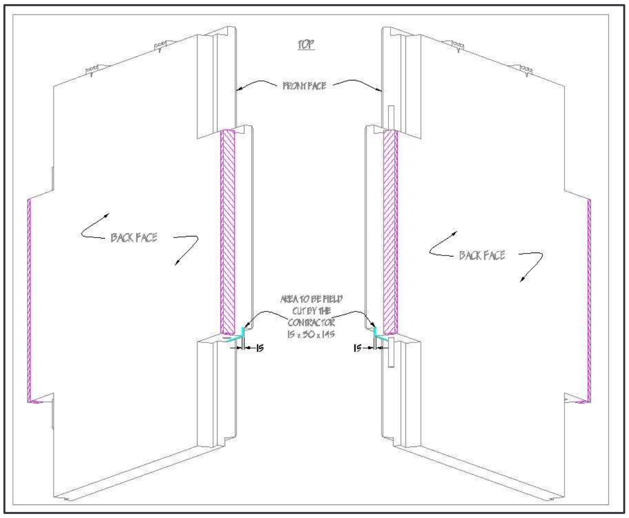

Figure 6. Bevelling of Panel Corners

Another challenge was the provision of a protective curb along the top of the wall while still allowing for drainage from the walkway behind the wall. This was accomplished by adjusting the top of the MSE wall down slightly in some areas and the provision of a thicker than normal coping cap with (scuppers) drain holes set at elevations to match the top of the walkway (which was constructed later).

Figure 7. Chestermere Walkway at High Water (Note: Scupper Drains through Coping)

The final challenge at Chestermere was the necessity to allow a large drainage pipe (from the Westmere pond) through the wall face to allow for storm water runoff. This pipe was so large relative to the height of the Chestermere wall that it was necessary to leave out a section of MSE wall to allow a cast-in-place collar around the storm water drain.

Figure 8. Chestermere Wall at Low Water (Note: Storm Water Drain through Wall)

For Westmere the architectural challenges were more typically architectural and involved the inclusion of a number of corner elements and the allowance for an elaborate coping and fence detail along the top of the wall.

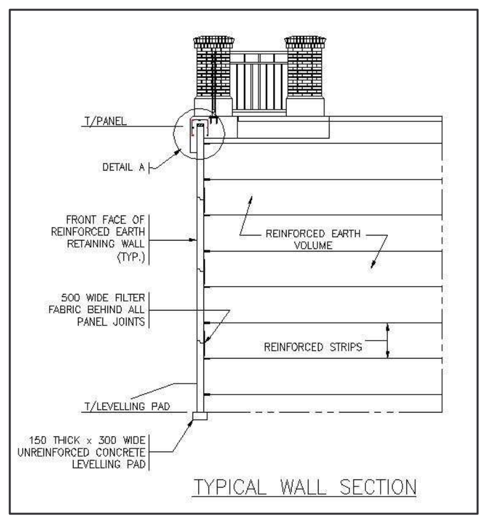

Figure 9. Design Section for Westmere Pond

4 CONSTRUCTION

As is always the case the construction of the Chestermere Lake wall presented a few challenges not anticipated during the design phase.

The first was timing. The design and preparation phases of the work took a bit longer than anticipated to complete and by the time the actual wall construction commenced the irrigation authority was already preparing to raise the water level in the lake. It was necessary for the contractor to push up temporary beams along the wall face to let the wall construction proceed in the dry as planned.

The second challenge was layout. The inclusion of many complex curves in the alignment meant that careful attention had to be paid to the layout of the wall. It was important to know where the layout referred to the front, back or midpoint of the facing panels in order to have the wall follow the elegant curves planned for it.

Similarly the Westmere wall had a number of corner details to be laid out.

In both cases the contractors paid close attention to the layout and successfully translated the layout into reality.

The third concern was specific to Chestermere. The MSE wall was constructed in the spring of 2004 but the cast-in-place coping was not constructed until late summer of 2004. At the time the coping was to be constructed the water level was at its high water level – only about two inches below the bottom of the coping. The coping had to be formed and cast with the water at that level.

5 SUMMARY

There are challenges involved in the design and construction of MSE walls that are partially or even totally submerged by adjacent water but these are engineering challenges to which there are ready solutions and it is hoped that with the example provided here that it can be seen that these challenges can be easily and reliably overcome and need not be avoided.

These projects provide unique opportunities to provide attractive and cost effective solutions to enrich our communities.

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- The Town of Chestermere
- Melcor Developments Ltd (Westmere Pond)

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