Mechanically Stabilized Earth Retaining Walls, Overlander Bridge Access Improvements, Kamloops



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ABSTRACT

The "City of Kamloops" selected an optimized ARES MSE system comprised of Full Height Panels coupled with HDPE Geogrid Soil Reinforcement. This paper will discuss the innovative use of geogrid soil reinforcement for what is commonly referred to as "true abutment support", whereby the bridge seat is cast directly upon the compacted MSE mass. The project was challenging from the settlement perspective as founding materials quickly transitioned from bedrock to fills. This paper will focus on the key aspects associated with extensible geogrid design for true abutment support. In addition, it will emphasize the efficiencies associated with full height panel construction in comparison to other alternatives.

RÉSUMÉ

La ville de Kamloops a choisi un système optimisé ARES MSE consistant de panneaux de pleine hauteur accompagnée de géogrille de renforcement de PEHD. Ce document discutera l'utilisation innovatrice du renforcement de sol avec les géogrilles pour ce qui est généralement conçu sous le nom de "véritable appui de butée", par lequel le siège du pont soit coulé directement sur la masse MSE compactée. Le défi de ce projet relevait des affaisements possible car il y avait une transition rapide des matériaux d'infrastructure de roc en place au remblai. Ce document se concentrera sur les aspects clé liés à la conception des géogrilles extensibles pour les véritables appuis de butée. En outre, il soulignera les efficacités liées à la pleine construction de panneaux de pleine hauteur comparativement à d'autres techniques.

1 INTRODUCTION

This true bridge abutment project is located within the City of Kamloops, just northwest of the downtown core. In 1998 the City opted to tender this project as bridge access improvements at the Overlander Bridge.

The original tender condition allowed the use of conventional MSE modular panels complete with extensible reinforcement. During the tender period the successful contractor (BA Blacktop) opted to employ Tensar's Full Height ARES concrete wall system. This wall system utilizes extensible High Density Polyethylene HDPE geogrid mechanically attached to the back of the precast concrete facing.

This project was innovative as it was one of the first Geogrid HDPE MSE Abutment supporting walls whereby the bridge seat footing is supported on the top of MSE backfill (without any piles). The project was tendered by the City of Kamloops in 1998 and construction proceeded during the summer of 1999. This structure has now been in service for 10 years, and this paper will discuss the technical highlights.



Figure 1. Looking West along approach ramp



Figure 2. Looking Southeast beneath the bridge deck.

2 GEOTECHNICAL ASPECTS

The original geotechnical investigation was completed for the owner by Amec Earth and Environmental of Kamloops, BC.

2.1 Stratigraphy

In summary their findings revealed bedrock and shallow bedrock at the western extent of the project. Along the northeastern part of the site the presence of fills in the range of one metre deep were noted at some locations during initial geotechnical investigation. These fills were underlain by varying sands/gravels, silts/clays, in turn underlain by bedrock.

It was suggested that surficial organic materials be removed, and the native soils be compacted to 98% standard proctor density. Any further soft zones delineated during compaction would then be excavated and replaced with granular material. Deeper excavations were not possible along this corridor due to the presence of the existing road network connecting North and South Kamloops, as well as the adjacent rail line.

For both abutment walls it was anticipated that the abutment supporting structure would be founded upon bedrock on the west and shallow bedrock on the east. Estimated settlements were anticipated to be in the range of approximately 15 mm beneath the abutment zone.

The underlying bedrock surface was anticipated to dip down toward the north and east direction (towards the long approach wall seen in Figure 1). Settlement along the North approach wall was anticipated to be upwards of 90 to 150 mm.

2.2 West Abutment Proximal to Bedrock

The west abutment (Figure 3) was located at an existing bedrock outcrop at its southern extremity.



Figure 3. Precast panel c/w C.I.P. transition panel

2.3 Special measures at base of wall panel

For the approach ramps, when not directly bearing on rock, a frost-trench was over excavated and replaced with non frost susceptible aggregate. Refer to Figure 4 below for the sketch of the frost trench beneath level pad.



Figure 4. Frost trench with 1:1 sideslopes

3 DESIGN APPROACH WITH HDPE GEOGRID

A 100 year service life was specified by the Owner's Engineer, Stanley Consulting Group Ltd, of Kamloops. Design codes at that time consisted of the following:

CAN/CSA-S6 AASHTO where CSA-S6 did not govern ATC-6 Seismic design guidelines.

3.1 HDPE Geogrid Types Utilized

For the purpose of this project the following geogrid types manufactured by Tensar were employed as follows: Table 1. Geogrid Properties

Grid Designation	T ult kN/m	
UX 1400HS	64.1	
UX 1500HS	100.6	
UX 1600HS	131.3	
UX 1700HS	157.3	

T ultimate is the ultimate strength of the geogrid before applying reduction factors. The load is measured in accordance with ASTM D6637.

3.2 HDPE Vertical Geogrid Spacing

Geogrid soil reinforcement was designed at vertical spacing increments of 0.5 m to 1.0 m.

The closer spacing of 0.5 m attributed to the abutment walls, where the tallest panels were located. The wider spacing of geogrid was often employed on the low panel heights such as the approach ramps for example.

On the panel noted in Figure 5 both grid spacing's are evident. Closer grid spacing at the top of panel was also required to allow for impact loads from traffic barriers at top of wall.



Figure 5. Geogrid Tabs at 0.5 and 1.0 m intervals

3.3 Reduction Factors on HDPE Design

This proprietary Tensar design implemented the following reduction parameters.

Durability reduction factors RFd = 1.1 based on clean granular structural backfill within the (reinforced zone).

Installation damage factors ranging from 1.10 to 1.20 were applied dependant on specific grid type. Creep reduction factors ranging from 2.33 to 2.48 were applied.

3.4 Owners Geotechnical Design Inputs

The soil parameters for design inputs were provided by the owner's geotechnical engineer as follows:

Reinforced backfill ϕ = 35° and 19.5 kN/m³ Reinforced backfill ϕ = 30° and 19.5 kN/m³ Reinforced backfill ϕ = 30° and 19.5 kN/m³

Seismic acceleration of 0.05g Max. applied bearing pressures of 250 kPa. Traffic surcharge of 12 kPa

3.5 Internal Design

Within the MSE mass, stability is achieved using the strength of the soil being reinforced in conjunction with the tensile force of the Tensar Geogrid.

Design methods ensured that the geogrid were long enough to avoid pull out of the fill behind the Rankine failure plane, and that geogrid was well distributed within the reinforced mass, with sufficient tensile stress to preclude rupture (either short or long term).

Grid lengths on the abutment faces ranged from 75% to 95% of the total height (as measured from base of wall to top of road surface). Shorter grid lengths were evident on the West Abutment adjacent to rock. Grid lengths were maintained at 2.5 m or greater as per the owner's requirements, and AASHTO guidelines.

3.6 External Design

The following minimum factors of safety were maintained as follows:

Table 2. External Factors of Safety.

Condition Checked	Static	Seismic
Sliding on Base	1.5	1.1
Overturning	2.0	1.5

3.7 External Design Rock Cut Considerations

Due to the presence of bedrock at the West Abutment, an additional analysis of the external stability for rock failure along the critical slip plane was completed.

It was determined the critical slip plane was oriented at 42.5 ° from horizontal for the sliding condition. For this condition a Factor of Safety for sliding of 5.46 was calculated. During the assessment of the overturning condition a critical slip plane of 46.4 ° was determined, and yielded a 3.5 Factor of Safety.

4 MANUFACTURE WITH HDPE GEORID

4.1 Precast Panel Geometry

Panels were cast to full wall height with a nominal 20 mm joint between adjacent precast elements. This joint width is typical of the MSE precast industry.

Panels shown in Figure 7 were of standard size of 2765 mm wide and 170 mm thick.

4.2 HDPE Geogrid Tabs in Precast Placement

Grid tabs are simply set within the back face of precast panel at time of casting. The tab is embedded a minimum of 100 mm as shown in Figure 6.



Figure 6. Grid tab embedment of 100 mm



Figure 7. Transition Panels Abutment to Wingwall

4.3 Concrete Panel Specifications

Panels were cast with the following specifications.

Type 10 Cement Air Content of 5 to 8% Strength @ stripping of 20 MPa Strength @ 28 days of 35 MPa Precasting was completed by a CSA certified precaster at that time formerly known as Western Concrete Products.

4.4 Special Precast and Joint Detail for Settlement

The owner's geotechnical report had cited the possibility of settlement of up to 150 mm of total settlement. Since settlement could not be entirely ruled out, a special precast joint needed to be implemented to mitigate the settlement of adjacent panels.

After extensive review of this potential settlement concern it was determined the best solution from a precast point of view was to place a settlement joint at a midway location on the long approach wall. If the reader recalls earlier in this report this was the area where the previous fills had been predominantly noted. In reference to Figure 8 the special joint has been flagged with the arrow pointer. This allowed for a joint width at this location larger than the standard 20mm joint width.

The "backup panel" as it was referred to is noted proud of the front face of precast, allowing the designer to aesthetically hide an imperfect joint as settlement progressed during the short-term.

In the photo below one will also note that a larger joint was also required at the corresponding coping location.



Figure 8. Precast settlement joint shown above

This wall settled up to 150 mm over this 10.9 meter long section, in the range of 1.4% settlement.

4.5 HDPE Grid for Corner Elements

For standard 90 ° corner elements small width geogrid was cast in the backside of the corner elements. The design methodology for the corner element is identical to that of the larger panels. This ensures that the corner elements are not just aesthetically pleasing, but more importantly; structural load carrying precast elements.



Figure 9. Special precast corner c/w geogrid tab

4.6 Initial Panel Placement

In Figure 11. full height panels are in the process of being rotated to a near vertical position. The panel is lifted by four pick- points on the back surface of panel.

In the lower portion of this photo (Figure 11) Richard Lockwood of Western Concrete Products has carefully planned and prepared the site by pre-positioning Lock Blocks to facilitate the efficient erection of panels as later described in this paper.

In Figure 12 the reader can see the precast panels securely braced with steel support struts at the 2/3 rd panel height location. The panels at this stage are placed and secured with a pre-defined batter in readiness for backfilling.



Figure 11. Panel lift from 4 pick points



Figure 12. Placement of Approach ramp panels

4.7 Bridge Seat Supported Directly On HDPE Geogrid

In an identical fashion to the more traditional method of MSE design, the bridge seat is cast directly atop the HDPE geogrid mass.

Figure 13. illustrates the seat cast directly atop the geogrid mass with no need for piling.



Figure 13. Abutment Seat is cast directly on HDPE Mass

4.8 Bridge Seat atop HDPE Tensar Geogrid

Figure 14 shows the concrete pour in progress at the West Abutment. The rock outcrop is noted immediately in the background.



Figure 14. Casting of Bridge Seat atop HDPE Mass

5 INSTALLING HDPE REINFORCEMENT

5.1 Quick Connect Bodkin Bar

The attachment of panel grid-tabs to engage the primary soil reinforcement grid is easily accomplished with no special tools required. As illustrated in Figure 15. the bodkin bar is simply slipped through both ends of geogrid to make a positive connection.

5.2 Tensioning of Geogrid

Figure 16. illustrates how the geogrid is pulled taut at the tail-end to remove the slack over the geogrid length. This tensions the bodkin connection to ensure a positive connection and load transfer. This positive connection coupled with the inherent junction strength of the HDPE geogrid within a compacted engineered mass enables the load transfer mechanism to take effect.

Tension on the grid is applied manually with a gridrake. The excavator end-dumps granular backfill onto the grid, so tension in the grid is maintained while compaction proceeds. This procedure is repeated from bottom to top of wall until the engineered mass is completed.

5.3 Compaction of the Geogrid Mass

As evidenced in Figure 17 compaction is achieved through the use of a vibratory roller compactor, excavator, and smaller plate tamper immediately behind the wall.

Backfill was placed in maximum lift thicknesses of 250 mm where compacted by riding roller. For fills placed within 1 metre of the back of wall and compacted by plate tamper the lift thickness was reduced to 150 mm.



Figure 15. Grid Tab Connection to Primary Soil Reinforcement Grid



Figure 16. Use of a grid rake for tensioning of geogrid

The minimum compactive effort required was 95% of standard proctor dry density. Full height panel construction with HDPE geogrid allows the contractor to have un-impeded access to his entire backfill operation. This allows the backfill operation to be entirely independent of panel placement.



Figure 17. Vibratory riding roller for compaction

6 HDPE AND FULL HEIGHT ADVANTAGES

6.1 HDPE Geogrid where De-icing Salts are present

As cited in AASHTO, impermeable liners are often suggested where conventional steel soil reinforcement is utilized and de-icing salts are present, as are used in many Canadian cities. For this reason backfill used in the presence of steel reinforcement should be tested for pH, Resistivity, Chlorides, and Sulphates.

By comparison backfill used in the presence of HDPE soil reinforcements requires testing of pH alone, and does not require testing of Resistivity, Chlorides, or Sulphates.

The choice of HDPE geogrid allows the client to source a wider range of backfill options, since the backfill parameters for HDPE geogrid are less restrictive as cited above.

6.2 High Panel Erection Rates

Figure 18 illustrates the East Abutment and associated wing walls being erected as noted below:

1 panel set every 12 to 18 minutes. 32 panels set in 10 hours or 445 m2 of facing.

7 CONCLUSION

The Full Height ARES system provided by Tensar and its distributor, Nilex Inc., has been successfully in service for 10 years at the time of this paper.

It has demonstrated excellent performance for a true abutment supporting application on HDPE geogrid. With varying foundation conditions and settlements up to 1.4% ARES has performed exceedingly well, and consistent with the performance of any other modular precast system on the marketplace today



Figure 18. East Abutment & Wings Erected in 10 hours

At the time of this paper the writer Mr. Dan MacDonald, contacted the owner's yearly bridge inspection engineer, Watson Engineering of Kamloops. Andrew Watson indicated to the writer that they have not observed any maintenance concerns with respect to this structure over its current 10 year service life to date.

Interestingly it was pointed out to the writer that this structure is also known locally as "Mission Flats Road Overpass" by the local community in Kamloops.

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