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Highway three-tier surface geogrid reinforced wall

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ABSTRACT: On the D1 highway section Ladce-Sverepec in Slovakia, probably a highest three-stage reinforced full-height panel walls were constructed. These vertical walls are constructed of precast concrete facing to full height manufactured by casting in short starter lengths of stiff punched/ stretched uniaxial HDPE geogrids at the rear. The paper describes design of reinforced wall and selected results from monitoring program. The long-term measurement and monitoring of construction and post-construction horizontal deformations of geogrids provide considerably valuable information on performance of that original structure.

1 INTRODUCTION

A section Ladce – Sverepec (highway D1 – western Slovakia) is constructed on a high embankment. The highway embankment is separated from the road by designed reinforced retaining walls. This particularly important road is situated on an embankment toe. It had to operate without stopping. Presented walls connect two bridges as one, two and three-tier retaining structures. The berm between particular walls has a width from 0.8 m to 2.4 m. A total length of the walls is 500 m, and a maximum height is 16 m. A total surface area of facing panels is 4 000 m^2. Reinforcement of walls consists of stiff punched/ stretched uniaxial HDPE geogrid of various types from 40 RE to 120 RE in the total quantity of approximately 70 000 m^2.

Because reinforced retaining walls are unique, we decided to monitor them with focus on horizontal deformations of geogrids.

2 DESIGN OF THE THREE-TIER GEOGRID REINFORCED WALL

We used several programs to analyse reinforced retaining walls:

- horizontal deformation and panel displacement - software Plaxis;
- vertical deformations – calculations according to Slovak standard STN 73 1001(1988) and Plaxis;
- design of geogrids & internal stability – Tensar software Winwall;
- external stability – Winslope and Plaxis.

Design parameters are as follows: foundation ground 0-2,6 m, $\gamma = 20$ kN/m^3, $c' = 10$ kPa, $\phi' = 20°$, 2,6–7,6 m, $\gamma = 19,5$ kN/m^3, $c' = 10$ kPa, $\phi' = 26°$, reinforced fill $\gamma = 19,5$ kN/m^3, $c' = 0$ kPa, $\phi' = 35°$. Water pressure 30-60 kPa at level about 6 m under terrain.

During Plaxis computations, we used two computation models: Mohr–Coulomb model (MC) and Hardening–Soil model (HS). The computations were made without and with updated mesh for 8 cross-sections. Comparison of results for static most unfavourable cross-section is in Table 1.

Table 1. Plaxis results for wall of high 16.0 m.

Model	Max. horizontal deformation (mm)	Max. geogrid load (kN/m)	Max. bending moment in panel (kNm)	Stability M_{sf}
MC model	59.18	30.02	33.96	1.66
MC + updated mesh	57.63	29.26	36.34	1.66
HS model	61.77	29.98	33.66	1.66
HS + updated mesh	61.68	30.11	39.53	1.75

The determining criteria for initial lateral panel movement were anticipated horizontal deformations. Maximum horizontal deformations were computed on the top edge of the bottom grade. Deformations were substantially eliminated by temporary props.

The props were removed just after depositing about 2/3 of the fill.

Figure 1 shows a horizontal deformations that were computed by using Plaxis. The values are greater than values computed by Winwall. Because of that, the initial lateral panel movement was determined on the basis of values that were computed by using Plaxis.

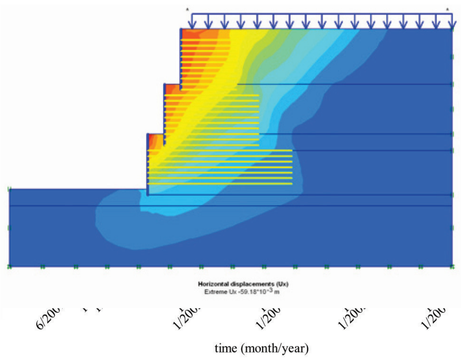

Figure 1. Horizontal deformation (Plaxis).

Figure 2 represents safety analyses and indicates failure mechanism of reinforced walls in the final stage.

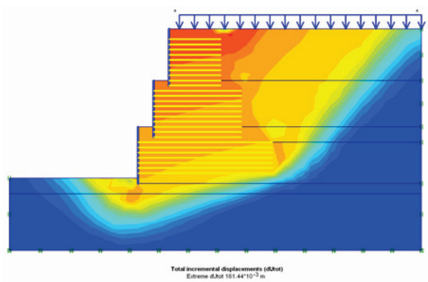

Figure 2. Total displacement increments (Plaxis).

A maximal tensile strength in geogrids that was determined by using Plaxis was in accordance with long-term geogrid design strength from Winwall.

Geogrid length of lower stage (1st tier) was computed on a basis of results of total stability evaluation (deep seated failure surface).

3 INSTRUMENTATION

The monitoring program was focused more on displacement measurements. To measure a geogrid displacement, rod-line extensometers were used. Each single-point extensometer was comprised of fiberglass rod attached to a geogrid junction. Rods were encased into individual stiff plastic sleeves to minimize frictional effects from the surrounding soil. The distance from the face of the collar anchor to the end of the rod was measured by a mechanical transducer. Figure 3 shows extensometers as measuring points placed at different locations of the geogrids.

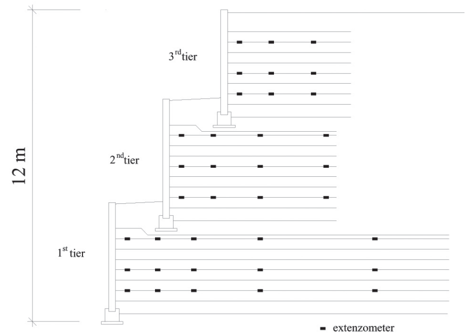

Figure 3. The 1st monitoring section.

Two measuring sections were established. The first measuring section (MP1) (Figure 3) is in the south structure and the second measuring section (MP2) is in the north structure, where the total height is 16 m.

4 CONSTRUCTION

Figure 4 shows the construction rate for the first monitoring section. Time equaling zero in the plot corresponds to the time when the second layer of geogrid in the first tier was placed and covered by the fill material.

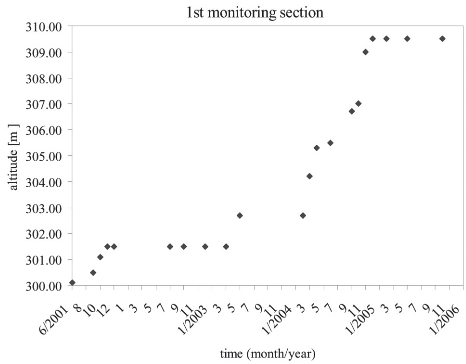

Figure 4. Construction history for 1st monitoring section.

Construction of the reinforced wall began with placing a geoplate on the top of the soil bed. Geoplate consisted of two layers of stiff punched/stretched biaxial PP geogrids and crushed stone. A simple foundation was constructed under the concrete panels. After doing that, the first layer of stiff punched/stretched uniaxial HDPE geogrid was connected to monolithic concrete strip foundation by casting a short starter geogrid length into the foundation. Another geogrids were used in conjunction with segmental precast panels and connecting to the full length of geogrid with a bodkin joint. The panels were erected vertically on the foundation. The fill was placed layer by layer, and the thickness of compacted layer between two horizontal geogrids was 400 mm. A walk-behind vibrating roller was used to compact the backfill material located within 2 m of the back of the facing column while a 12-ton drum roller was used elsewhere.

Construction of the wall did not follow the original time schedule. The periods of time with very intensive construction activities were interchanged by inactivity. The reason was a change of a contractor and a new design of the bridge structure.

The Figure 5 shows completed south three-tier geogrid reinforced wall with the bridge beams. The 1st monitoring section is 35 m away from the beginning of the lower tier. The Figure 6 shows completed north three-tier geogrid reinforced wall with connection to another bridge. The 2nd monitoring section is 15 m away from the end of the lower tier.

Figure 5. Completed south three-tier structure.

5 REINFORCEMENT DISPLACEMENTS AND STRAINS

We focused on the 1st measurement profile in this article, where we have the most measurement results available.

Figure 7 shows the displacement of the measuring points onto 1st layer in first measuring profile on 1st tier measured during the construction and three month before the construction of 3rd tier in MP1. At the end of one-year break and during the construction of the 2nd tier, the maximum horizontal displacements were recorded generally. After that construction stage, the geogrid's deformation slowed down. The similar results were recorded on other layers of 1st tier. At the completion of construction, the maximum displacement in MP1 was 10,6 mm (point 2-5, the 5th measuring point on 2nd layer).

Deformations both during and after construction were analyzed separately. Figure 8 shows the

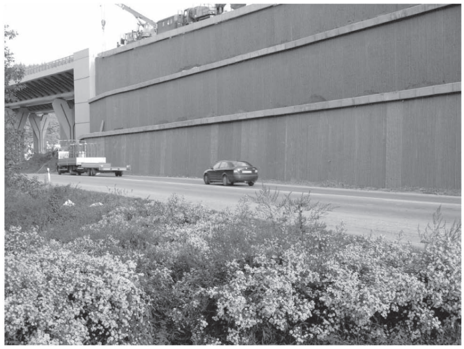

Figure 6. Completed north three-tier structure.

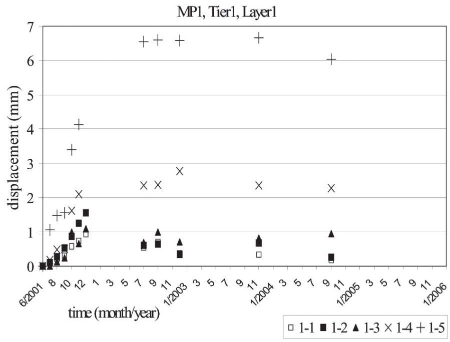

Figure 7. Horizontal displacement of geogrids (MP1, Tier 1, Layer 1 on third geogrid).

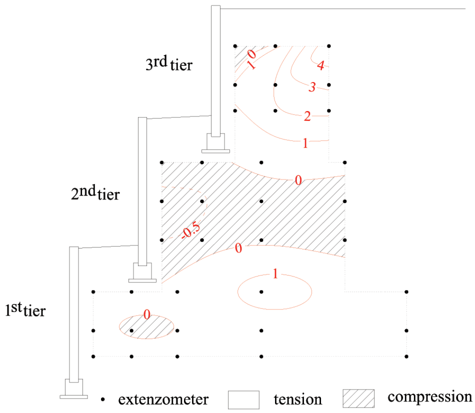

Figure 8. Horizontal displacement of geogrids a $^1/_2$ year after construction (MP1).

horizontal displacement approximately a half year after construction only. You can see that the horizontal displacements in both the lower and medium tiers are very small and the values are around zero. The tension and compression zones are there as well. During the construction phase the displacements in the medium tier were from 4 to 6 mm. After that the geogrids are practically without the displacements and so the medium tier is without horizontal deformations. Considering that the reinforced zone contains very high quality crushed stone material this block performs like stiff one. The conclusion is valid for measuring period of $^1/_2$ year after construction only.

The displacements on 3rd tier are affected by greater values on the geogrid ends on the top part.

The displacements were then converted to average horizontal strains of geogrid between the measuring points.

Figure 9 shows the distribution of the strains in selected geogrids in 1st tier in MP1 three months before the construction of 3rd tier. The maximum strain in layer 3 and layer 2 was located in the front part of the tier but not immediately vicinity of the facing panel.

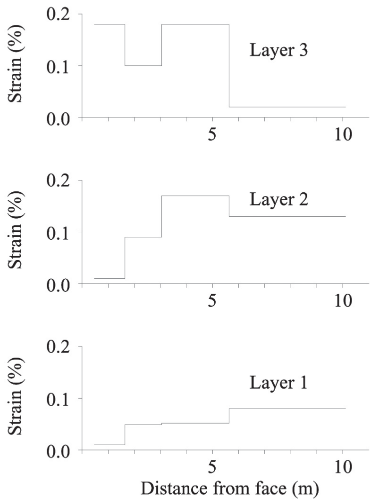

Figure 9. Distribution of strains for 1st tier in MP1.

6 CONCLUSIONS

The three-tier geogrid reinforced retaining walls (on a highway D1), with a maximum height of 16 m, were used to overcome problems with construction of high embankment, that is close to existing road in narrow valley. The other obstacle was unstable subsoil under embankment. Due to the importance of the project, a two instrumented sections were provided with horizontal extensometers.

The long-term measurement and monitoring of construction and post-construction horizontal deformations of geogrids provide considerably valuable information on performance of that original structure. Field measurements showed small post-construction horizontal movements of geogrids. There has been no sign of any instability in the reinforced walls.

Particularly interesting are the results of horizontal deformations in full measuring section that inform us about how the particular tiers affect each other.

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