REINFORCED SLOPE OF ROAD EMBANKMENT WITH LIGHT WEIGHT AGGREGATES

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ABSTRACT: A 200 m long temporary road fill is constructed above a concrete road tunnel. The temporary road is going to be removed after 1.5 years. The upper part of the fill is built with light weight materials with design weight 4-5.5 kN/m^3 to reduce the weight on the concrete tunnel. Approximately 150 m of this fill is built with expanded clay aggregate (LWA) combined with geosynthetic soil reinforcement and approximately 20 m with cellular glass granulate. The light weight fill is 6 m high including pavement. A high strength polyester geotextile is used as reinforcement combined with a wrap-around solution as facing. The slope inclination is up to 1:1 both for the reinforced LWA fill and the undreinforced cellular glass fill.

1 INTRODUCTION

In this project a cut and cover concrete tunnel of some 600 m length joins on to a new rock tunnel for Euroroad E6. In order to keep traffic running on E6 during the construction period a temporary diversion road with an embankment height of more than 15 metre is needed. The upper 6 m is consisting of light weight filling materials to reduce the weight on the culvert and to improve stability and reduce settlement problems. Figure 1 shows a model of the temporary embankment and the tunnel gate. The embankment crosses above the concrete tunnel. Figure 2 shows a map of the situation. As seen in the figures, there is a walkway outside the light embankment.

Initially, the embankment was designed with cellular glass granulate (Hasopor® Light), since cellular glass is stable enough without any abutment at the embankment slopes. However, the contractor suggested the use of expanded clay aggregates (Leca®) stabilized with soil reinforcement towards the sides. The builder, the Public Road Administration, chose to combine these solutions and has supervised the building of the embankments. Among other things, density tests, both in loose and compacted condition has been performed, and the moisture content has also been measured.

The diversion road was opened for traffic in March 2003 and is planned to be in service until the construction of the new road is finished in the summer 2004. The light weight filling materials will then be reused in fills against bridge abutments on other parts of the road project. New sampling and testing will be performed in this part of the project.

This paper mainly describes several issues concerning the building of the reinforced light weight aggregate embankment. However, some comparable information is given for the cellular glass embankment as well. No conclusions have been made concerning which solution is best, except that both embankments function according to the initial predictions.

Figure 1 Model of the embankment

2 THE EMBANKMENT

The embankment is about 200 m long, of which 150 m were built with expanded clay aggregates (9000 m^3) combined with reinforcement and 20 m of cellular glass (1000 m^3). The map in Figure 2 shows where expanded clay aggregates and cellular glass are used in the temporary embankment. Conventional masses are filled in next to the culvert and rounded off to the sides with a steep rock embankment. The light embankment is built up from a new level, slightly above the top of the tunnel (approximately the same level as the walkway).

The lower 4 meters of the light weight embankment has an inclination of 1:1, while the upper 2 meters have an inclination of 1:1.25. Figure 3 shows a cross section of the build-up of the reinforced part of the light embankment. So far, no problems have been registered for any of the solutions.

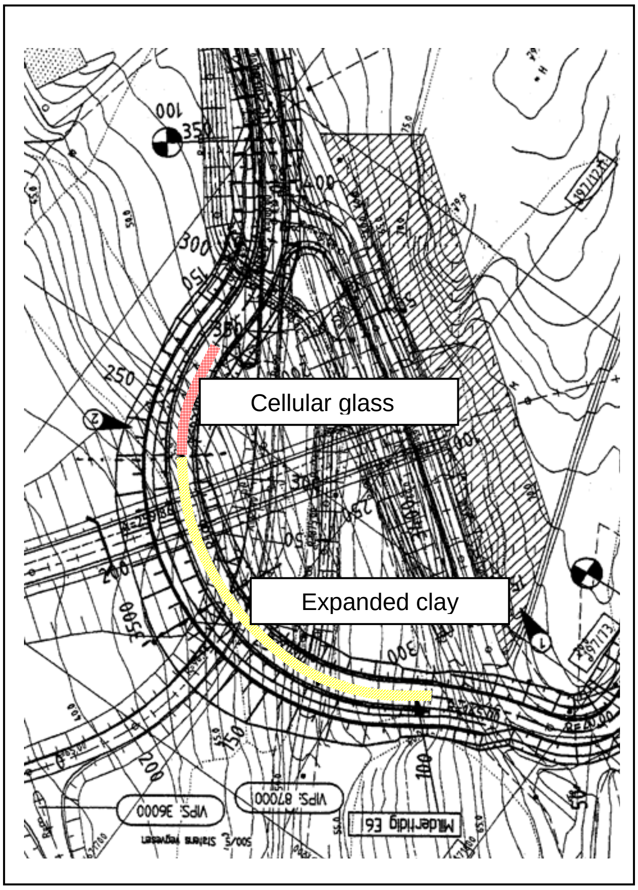

Figure 2 Map and sketch of embankment

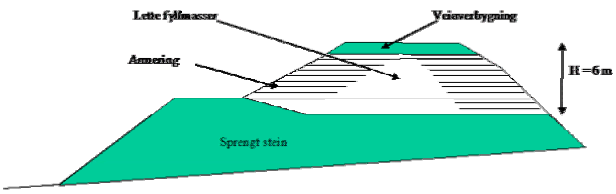

Figure 3 Cross section of reinforced embankment

The facing of the reinforced embankment is a wrap-around solution where the reinforcement is turned up in front and anchored into the layer above (as sketched in Figure 4). To prevent the light weight aggregates to vanish through holes in the reinforcement, it is required to use a high strength geotextile instead of a geogrid. This solution will provide necessary abutment for the expanded clay aggregate (LWA – Light weight clay aggregate). The loose LWA will shape the wraps as tubes along the slope, see Figure 5. Establishing an even shape with such a solution is challenging, but for a temporary construction (such as this) it is satisfactory.

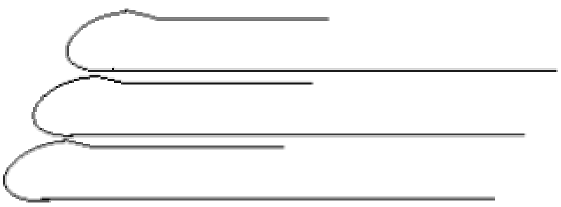

Figure 4 Wrap-around solution

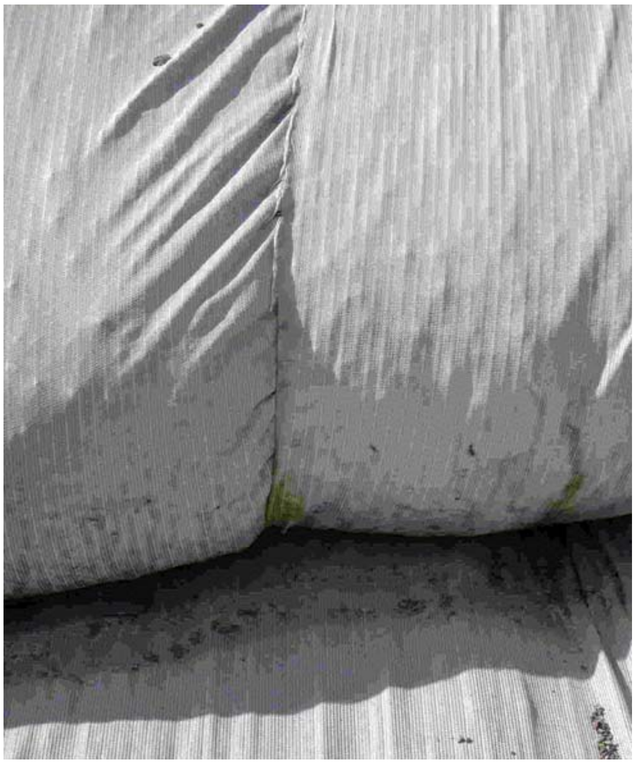

Figure 5 Overlap in joint. Wrap-around solution in front causing a tube shape

To make sure that the LWA cannot slide, it is vital that the overlap in the reinforcement joints (Figure 6). The minimum specified overlap is 30 cm.

Figure 6 Digger laying LWA on the turned-up reinforcement

3 DESIGN OF REINFORCEMENT

Using light filling compounds, there is no need for very strong reinforcement. The reinforcement used has a short time tensile strength of about 70 kPa, both in machine and cross machine direction, corresponding to the lowest quality of knitted or woven high strength geotextiles. It is usually required that such reinforcement, without special treat-

treatment, is covered to prevent decomposing due to sunlight/UV-radiation. Since this is a temporary construction this has not been found necessary.

Figure 7 Compacting

The design length of the reinforcement is slightly longer than what is usual for conventional embankments of this height. This is mainly due to the fact that LWA embankments get very sensitive to loads acting behind the reinforcement. The friction capacity along the reinforcement is lowered because of the low stress level, and this requires increased reinforcement length to achieve sufficient capacity. The required reinforcement length is 6 m for the main part of the fill, and the top layer is prescribed to be continuous through the embankment. It is also prescribed a longer minimum anchoring length for the wrap-around into the layer above than usual for conventional structures. Minimum 1.5 m was prescribed, but to simplify the construction works this was increased even further.

The layer thickness chosen was 0.5 m. It is not recommended to increase the layer thickness when using this construction method combined a wrap-around facing. A thinner layer thickness may give a more even facing. Combined with other facings, e.g. concrete bricks, the layer thickness may be increased.

4 CONSTRUCTION WORKS

Little experience has been made combining light masses and soil reinforcement. The contractor therefore had to acquire experience and find suitable solutions during the construction phase. One challenge was the anchoring of the wrap-ups in front of the slope. The reinforcement has to be tightened until masses are placed on the end for anchoring. That makes some additional length to the theoretical length necessary, to have something to “hold on to”, and also to achieve sufficient anchoring due to relatively little weight on top. An excavator drove along the edge of the surface layer of LWA and placed some LWA on the reinforcement. A slight push in the downwards direction with the shovel filled the wrap-up completely with LWA. This makes the facing more even, and also eliminates any voids the LWA can distribute in later. It can be hard for the driver to realize that it actually may be safer to drive as close to the edge that the machine drives across the reinforcement on the layer below, rather than driving behind this layer. Driving on top of the reinforcement gives the reinforcement increased friction capacity. Driving behind the reinforcement gives a load increase that acts outwards on the reinforced zone, at the same time as the capacity is relatively low due to a low stress level.

The driver managed to do this in a good order and with satisfactorily progress, but the consumption of reinforcement became somewhat higher than initially assumed.

The degree of compaction became higher than presupposed. The material was laid out in layers of 0.5 m between each compaction. Additionally the material was trafficked with truck, bulldozer and digger during the laying of the following layer and reinforcement. This caused a crushing of the material. For later projects it should be considered to perform compaction for every second layer, possible combined with a light compaction in the reinforced zone in every layer. Also, the trafficking causing crushing should be kept at a minimum.

5 DENSITY AND WATER CONTENT

Samples were taken of the embankment for minimum every second layer (every meter), by pushing down a steel pipe and taking up the sample in the pipe. A vacuum cleaner designed for the purpose was used to get up the entire sample (Figure 8).

Figure 8 Sampling of compacted material

The samples show variation in both density and water content. The average loose density for samples taken from the trucks were about 3.3 kN/m^3 (330 kg/m^3) and compacted in embankment about 4.1 kN/m3 (410 kg/m^3). The water content for the delivered LWA showed large variation. Parts of the LWA had a water content between 5 and 10 % (mass). A second part, delivered a few weeks later, had a significant higher water content of about 25 %. This also affected the water content of samples taken from within the embankment. The average water content was 15 % in the compacted embankment.

The embankments were compacted by a belted bulldozer driving on the embankments. Additionally, there was quite a lot of trafficking on the embankment with both trucks and diggers during the building. This caused a higher degree of compaction than when the LWA was filled in one layer only or by blowing, and a significant crushing of the LWA was registered in the surface. The difference in measured density gives a degree of compaction of 1.25 (initial volume/compacted volume), while blowing of LWA usually gives a degree of compaction lower than 1.1.

6 OTHER CONCIDERATIONS

6.1 *Design weight of light masses*

In Handbook 018 Road construction from the Public Road Administration the design density of LWA was at the time of construction said to be 6 kN/m^3 (600 kg/m^3). This is some reduced in the revised version coming up. The measured density for this embankment is 4.1 kN/m^3 (after compaction), significantly lower than recommended by Handbook 018. This is in spite of a significant higher compaction than normal. The deviation is partly caused by a lower water content than assumed for the design density, but also due to the fact that the LWA quality delivered now is lighter than some years ago. The average water content in older embankments that has been investigated is 25 % (mass), but single values of more than 45 % (mass) have been measured.

The fact that the embankment is lighter than presupposed at design is usually not a problem, and will usually give a higher factor of safety and less settlement than assumed. However, when designing with reinforced soil one must be aware that a lighter embankment giving a lower stress level at the reinforcement, will reduce the shear capacity between the reinforcement and LWA. This can cause a need for increased reinforcement lengths, depending on where the loads act. Also, the reinforced structure with light weight materials will be more sensitive to changes in the loading conditions.

Figure 9: Finnished reinforced road embankment of LWA

6.2 *Comparison to cellular glass embankment*

The cellular glass embankment is smaller than the LWA embankment and without geosynthetic reinforcement, but otherwise quite similar. This embankment was built without reinforcement, and the layers were thicker before they were compacted. Compacted density waried between 3,1 – 3,8 sjekk about 3.5 kN/m^3 with a water content between 15 and 20 % (mass). Compared to loose density this gives a degree of compaction of about 1.25. Another 5 % volume reduction was anticipated due to transport on site from local storage areas.

The cellular glass embankment is about 85% of the weight of the LWA embankment per m^3. However, it should be possible to compact the LWA less by reducing the trafficking causing crushing, and perform the prescribed compaction on every second layer only. For permanent embankments the long term water content will have a significant influence on the density.

6.3 *Other facing designs*

Structures combining LWA and reinforcement will probably be simpler to build with other facing solutions were the LWA can be filled towards a steady front. An alternative design with wrap-up solution could be to use a formwork at the facing that is stepwise moved upwards during construction. For permanent structures many of the products on the market must be covered to reduce the degradation caused by UV-radiation.

7 CONCLUSIONS

This project shows that LWA may be combined with reinforcement to design steep slopes and embankments. A wrap-around solution is well suited for temporary structures. For permanent structures other facing solutions may be better. In design it is important to evaluate all possible load conditions. The necessary reinforcement length is more sensitive for changes in load conditions (both the magnitude and the acting points) than for conventional masses.

8 REFERENCES

Handbook 018
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