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Living noise barrier by geosynthetics reinforced soil wall

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ABSTRACT: The need for noise and environmental-protection measures has greatly increased in recent years. Conventional noise barriers are made of concrete, aluminium, wood or steel are almost exclusively used. An attractive alternative to the conventional noise barriers is the vegetated earth wall reinforced with geosynthetics. However, vegetated steep earth walls are scarcely used due to the lack of design guide and experience. In this paper, a research project for geosynthetics reinforced soil walls is presented. A test wall with a total length of about 70 m, which is divided into seven test sections of 10 m each, has been constructed. Analysis of different construction systems, installation methods, fill and reinforcement materials and vegetation are being carried out. The test wall is extensively instrumented by extensometers, horizontal inclinometers and geodetic survey. The instrumentation and first results are described.

1 INTRODUCTION

In recent years, traffic noise on highways and railways has been an increasing concern both to the public and to the authorities. Noise barriers are traditionally built by vertical structural members of wood, concrete, aluminium or steel. However, such conventional noise barrier walls appear as obtrusive objects in otherwise harmonious landscape. Recent practice of noise control shows that ecology and aesthetics are becoming increasingly important. An alternative to the conventional noise barrier are earth embankments. Vegetated embankments have a natural appearance and are usually more attractive. In order to reduce the land use the earth embankment can be made steeper by geosynthetics reinforcement. In noise control practice, however, it is often difficult to get permission for this innovative noise barrier because of the rare reference projects and lacking technical specifications and regulations.

In view of this situation a cooperative research effort on geosynthetics reinforced soil walls has just been initiated financial support from the Austrian Research Agency. The consortium partners include university, geosynthetics manufacturer, highway contractor and special contractor in soil bioengineering. The present paper will report the results of this research project. The project deals with two major aspects of this noise barrier, namely geotechnical and bioengineering aspects. Both aspects are being investigated in a test site near Vienna.

The test wall (Figure 1) with a total length of about 70 m is divided into seven test sections of 10 m each. Different wall systems are being investigated in these sections. The walls are about 4.5 m high. The wall width varies from 2.6 m to 4.9 m at the base and 0.5 m to 2.5 m at the crown. The slope inclination ranges from 70° to 85°.

Figure 1. Test wall before vegetation.

2 PRELIMINARY DESIGN

The geosythetics reinforced soil walls are dimensioned by the method of limit state equilibrium. The external stability was examined by the conventional method with the reinforced structure regarded as a monolithic body. The design of the internal stability was carried out based on the method of local strength mobilisation (Shaigani et al. 2005). The input parameters for a typical cross section are given below (see Figure 2).

wall height	4.5 m
slope inclination	70°
crown width	1.5 m
fill material:	
$\gamma = 16.1\ kN/m^3$	$\gamma_\gamma = 1.3$ (safety factor)
$\varphi = 33°$ (assumed)	$\gamma_\varphi = 1.3$ (safety factor)

With the above parameters, the required tension force of the geogrid was found to be 35 kN/m. Nevertheless, the design tension force of 20 kN/m was used in order to optimise the design.

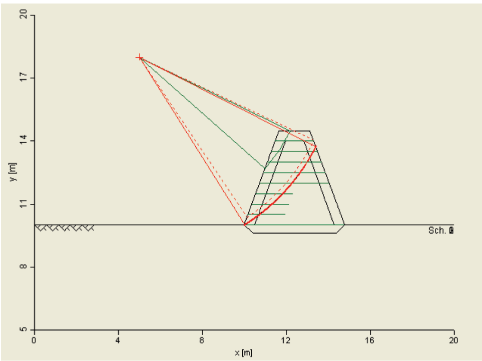

Figure 2. Critical failure mechanism.

3 CONSTRUCTION DETAILS

A test wall with a total length of about 70 m was constructed between May 2005 and August 2005. The construction is divided into 7 sections of 10 m each with crown width between 0.5 m and 2.5 m. Different shuttering systems with permanent (construction steel meshes, pre-bent construction steel meshes and stone filled gabions) and reusable framework (combined steel-wood-shuttering) were used. Each section is reinforced by high strength geogrid made from high-tenacity polyester with a polymeric coating, high stiffness, high friction and low creep. The mechanical properties of the geogrid are provided by the manufacturer: $t_1 = 20$ kN/m, $t_2 = 20$ kN/m, $\varepsilon_1 = 12\%$, $\varepsilon_2 = 11.5\%$, $m_1 = 20$ mm, $m_2 = 35$ mm, where t_1 and t_2 are the tensile strength, ε_1 and ε_2 the corresponding strain and m_1 and m_2 the mesh size along the two principal directions of geogrid.

The viability of a wall system in the practice depends strongly on the cost compared to conventional noise barriers. Both the construction time and the material cost are documented during construction to find out the performance efficient and cost effective shuttering system. Currently, extensive economic analyses are being carried out.

3.1 *Fill material*

In six sections recycled ballast (low-quality brick recycling material, RMH 0-45) was used. For comparison one section was constructed using coarse gravel. Prior to filling, the recycling material was subjected to various chemical analyses in order to characterize the current contamination potential. This recycling material was chosen because the present regulation does not allow the use of such recycling materials in road construction. The chemical tests shall provide evidence that such materials can be used for the construction of the noise barrier. This will also save the cost for deposition.

Similar to dam construction, the fill material was spread in layers of 0.5 m thickness and compacted conventionally. Between the layers geogrids were placed.

3.2 *Potting soil*

The earth walls are covered by a 0.5 m thick potting soil, which provides the nutrition base for vegetation. Thereby the contact between the contaminated recycling material and rain water shall be minimized in order to reduce the transport of toxic substances into the ground. Several substrate mixtures (crushed bricks with 10%, 20% and 50% topsoil) were used to study their influence on plant growth.

3.3 *Impermeabilisation measures*

The individual wall sections incorporate an impermeable PEHD geomembrane (about 2 mm thick) to study the storage capacity of the individual substrate mixtures. The seepage water is collected in a drainage blanket (see Figure 3) and analysed in a chemical laboratory from time to time.

3.4 *Vegetation*

Combining a geosynthetic reinforced slope with adapted vegetation represents an innovative, efficient and also optically appealing solution for noise barriers compared to conventional means. The steep earth walls with their limited water storage capacity and

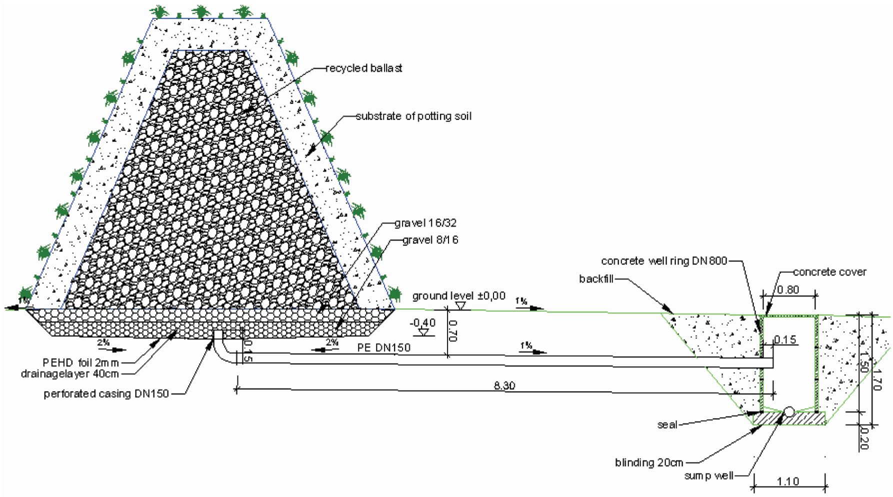

Figure 3. Typical wall cross section with substrate for vegetation and drainage blanket at the base.

extreme conditions (moisture and temperature) present some challenges for the vegetation technique. The vegetation must live with the limited amount of water provided in the substrate through rainfall.

The plants are selected in consultation with colleagues from the Institute of Soil Bioengineering and Landscape Construction of our university. Different plants are being investigated to find out the most suitable species for the noise barrier.

The structure is constructed in an L-shape to enable at least a qualitative assessment of the relationship between exposition and the growth of the selected plant. The investigated plants include twigs, branches and fascines of some rooting plants, shrubs and herbs.

The observation on plant growth combined with the meteorological data will help to select suitable plants not only for aesthetic reason but also to reduce maintenance cost.

Figure 4. Inserting of willow branches.

4 GEOTECHNICAL INSTRUMENTATION

The testing wall is accompanied by an extensive geotechnical instrumentation programme, which comprises mainly of compaction control, extensometers and geodetic survey. As the construction was designed with low safety factors, the survey will be continued after completion of the construction work.

4.1 *Compaction control*

Simultaniously with the construction progress the compaction in each section has been controlled using the dynamic plate loading test and the nuclear density gauge. In the fill area, the dynamic deformation modulus E_{vd} between 10 MPa and 25 MPa were measured. The lower values were obtained in the substrate area, because the compaction near the slope edge is very difficult. Additional Proctor tests and grain-size distribution measurements were carried out in the laboratory. The Procter density amounts to 1.40 g/cm^3 with the water content of about 14.7%.

4.2 *Geotechnical measurements*

A total of four multiple extensometers are installed. The length extension of the geogrid is controlled by rod extensometers. The extensometers allow for a spatial resolution of 0.5 m for strain measurements. The extensometer measurements are compared with the strain measurements using the newly developed system Geotetect based on integrated optical fibre. Both systems yield maximal strains of about 0.6%.

Two different areas are chosen, where two horizontal inclinometer pipes are installed. In one of the sections, a permanent framework made of construction steel mesh is used. In the other section, a reusable framework is used. In the latter case, higher deformation is observed.

4.3 *Geodetic survey*

Some geodetic survey is performed in order to measure the deformation of the front wall. Measuring points are placed at the centre of each layer as well as at the heads of the extensometer and horizontal inclinometer rods. The spatial coordinates are obtained via the intersections from fixed positions. The geodetic measurements allow the survey of every measuring point from three different positions. From each position two vertical fix points can be sighted (Figure 5). For increasing the vertical accuracy of the measurements a total of five vertical fix points are placed.

In addition, moisture measurements are carried out for characterizing the relationship between moisture evolution and rainfall. Furthermore, the amount and spatial distribution of possible contamination of the seepage water is measured. Finally, some acoustic measurements of noise absorption complete the measurement program.

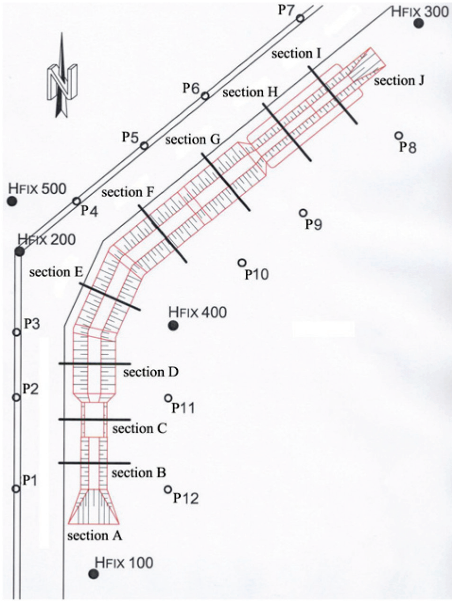

Figure 5. Principle sketch for geodetic survey.

5 CONCLUSIONS

The present design methods for reinforced soil structures use high safety factors, which are largely based on experience and strong simplifications. This practice often gives rise to rather conservative design. This is particularly true for the design of steep earth walls.

Base on the large scale testing walls, our project aims at providing some basic data on the behaviour of reinforced steep vegetated noise barriers. A better understanding of the behaviour of the system consisting of reinforcement – recycling material – shuttering – substrate – vegetation, will help to use this kind of noise barriers in the practice.

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