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Vegetated retaining walls using concrete units and geogrids along the A8 motorway in Austria

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ABSTRACT: Using the NEW-wall system of geogrid-reinforced soil, vegetated retaining walls with a total facing area of approx. 17,000 m^2 were constructed along the new A8 motorway between Wels and Sattledt in Upper Austria.

This retaining-wall system was specially designed and constructed to meet the requirements of the original design in regard to function and appearance in an optimum manner, and the technical and economic advantages of the system enabled significant cost savings opposite the anchored retaining wall which was originally foreseen.

The precast units were designed specially for this project and are significantly larger than the elements used to date. The outward curving front face of the element gives an impression of space and depth hitherto unknown in such retaining walls.

Individual elements are anchored with geogrids. The visible front wall-units hide a reinforced wrap-around soil mass which was designed to support the backslope on its own. It is therefore possible, should the necessity arise, to remove and replace individual units without any slope excavation – a requirement of the client. The apparently simple task – the planning and design of a retaining construction of concrete elements and a geogrid-reinforced soil mass (composite body) – soon proved to be a complex problem which could only be economically solved with specially developed computer software.

Earth pressure: using a modified slip-circle program, the earth pressure according to Culmann is calculated for a soil mass of any shape and layer configuration (including anisotropic soils), and the earth-pressure distribution along the rear face of a retaining system is determined.

Slope failure: using the same program, lines of constant slope safety-factor are derived as a tool for the planning and the design of the retaining structure. These enable an examination of slip surfaces through the composite body consisting of soil and geogrids, to ascertain which of these potential slip surfaces have acceptable safety factors.

1 INTRODUCTION

The A 8 motorway forms part of the European E56 freeway. It connects Sattledt in Upper Austria with Suben, near the German border, via Wels (where the A 25 joins it) – a distance of some 79 km. In the area where the retaining walls were planned, the motorway passes through ecologically sensitive countryside.

The design and placement of the walls contribute to a hitherto unknown impression of space and depth.

2 PROBLEM

The two main problems in the construction of these walls were, on the one hand, the desired surface shape and structure, and on the other hand, the requirement that the concrete units be able to be dismantled, should an accident necessitate repairs to the wall. A tailor-made solution was thus required.

The concrete elements had to be designed especially for this project, resulting in individual elements which were considerably larger than those used in previous such walls.

3 SOLUTION

Many years of experience in the design of vegetated retaining walls, and the use of specially developed or modified software, were the key to the successful and economic solution of the design problems associated with this wall.

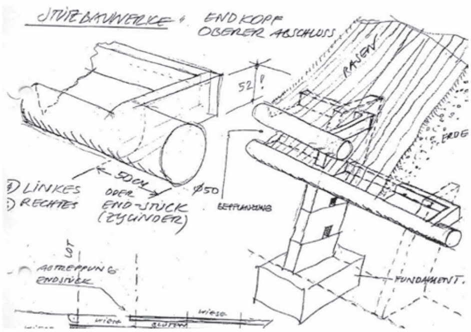

Figure 1. Architectural concept for precast elements.

Major challenges were posed by difficult soil conditions and the depth of the cutting – up to 14.5 m.

3.1 *Wall system*

Using the design principles of reinforced soil, a wall was designed based on a grid 5.4 m long and a height of 1.427 m. In effect, a layered soil body, reinforced with high-strength geotextiles or geogrids, supports the face of the cutting.

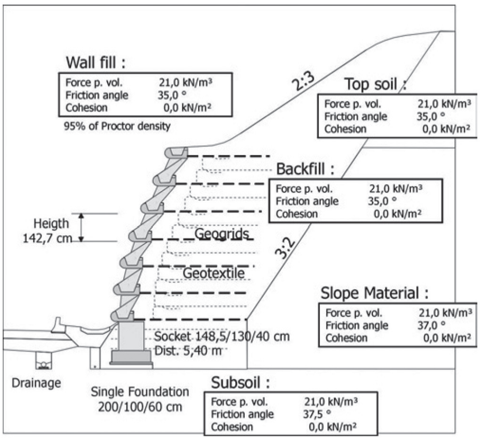

Figure 2. Wall system with soil parameters.

In the most critical case, the lateral pressure generated by the resultant of forces on the grid area

$A_g = 5.4 \times 1.427 = 7.71\ \text{m}^2$

requires a total long-term design strength in the geogrids and geotextiles of

$F_{\max} = 544.6$ kN (per grid area)

However, the force that can be anchored in the concrete element is limited to 51 kN for each of the 4 geogrids, i.e. 204 kN.

The remaining forces must therefore be accommodated in a different way.

3.1.1 *Wrap-around wall behind the precast elements*

Depending on the load uptake required, either 2 or 3 layers of a wrap-around reinforced wall were constructed, spaced vertically over the grid area. The design load per grid area is thus allocated to 1 layer of geogrid and 1 to 2 additional layers of high-strength geotextile.

The visible wall elements are anchored by the geogrids, and the wrap-around wall behind the elements is designed to enable the precast elements and the soil between the elements and the wrap-around face to be removed without loss of slope stability.

3.1.2 *Construction procedure*

- The precast elements are placed on a compacted layer of the retaining wall. Short lengths of geogrid cast in to the elements and protruding from their inside faces are connected to longer geogrids using bodkin connections, so that the required total reinforcement length is achieved.
- A concrete block 1 metre behind the precast elements serves as temporary shuttering for the construction of the wrap-around wall. The geotextiles are laid, and the soil placed and compacted.
- The concrete blocks are removed, soil is placed and compacted in the front area of the retaining wall, and topsoil placed.
- These steps are repeated once or twice on the formation layers thus created.

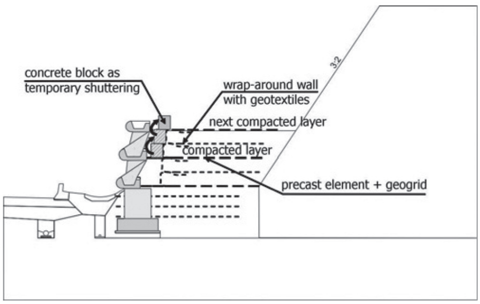

Figure 3. Wall-construction steps.

3.1.3 *Technical advantages*

The seemingly impossible requirement – that the concrete elements can be removed – was solved by constructing the additional wrap-around wall.

It soon became clear that this method offers additional advantages:

- The front soil mass provides optimum UV protection to the wrap-around wall, so that more cost-effective geotextiles were able to be used.

- The intermediate formation layers allowed the use of concrete blocks for temporary shuttering, a simple construction method.
- Of the tensile elements (geotextile or geogrid) required by the design to ensure slope stability, only a few lead forward to the precast elements and are anchored there, thus reducing loads on these elements. In addition, the design of the reinforced-soil body is not constrained by technical limitations imposed by the elements or the outer face. Only the tensile capacity of the geosynthetics and their vertical spacing need to be considered.

3.2 *Design*

In optimising the design of the wall, a specially modified design program (slip-circle program) was used to establish the slope stability.

The slip surface investigated is not defined by its centre and radius, as is usually the case, but by:

- the exit point – the point at which the slip surface exits the slope
- the entry point – at which the slip surface begins
- the distance between the slip surface and the centre point of the chord between the exit and the entry points, or
- a third point through which the circle is deemed to pass

All parameters required for this method of defining slip surfaces can easily be determined for the slope profile under consideration.

The calculation method adopted is not of fundamental importance. Of those available, the method according to H. Borowicka (DIN 4081) was chosen here.

3.2.1 *Determination of earth pressure*

Because the soil behind the retaining wall is layered and of non-uniform shape, the active pressure was calculated using the program described above.

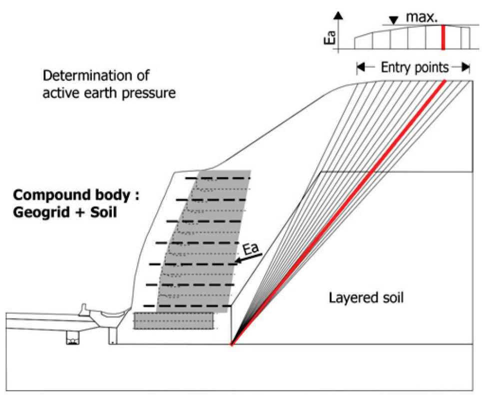

Figure 4. Determination of active earth pressure.

For the exit point of slip surfaces, a search area was defined along the rear face of the wall; the search area for entry points was defined along the slope above the wall.

The distance from the slip circle to the mid-point of the line joining the exit and the entry points, is kept small in order to obtain slip surfaces which are nearly flat.

Using these values, the retaining force required for a safety of s = 1.0 is calculated. The result corresponds to the active earth pressure according to Culmann, but for a soil profile of any shape and layer configuration, and, if required, with non-linear failure surfaces.

The procedure described was used in the case presented here, since the backfill material and the slope soil had different properties.

3.2.2 *Required width of base*

For the optimisation of the required base width – and therefore of the minimum length of the bottom reinforcing layer, lines of equal safety level (iso-safety-factors) were determined in the soil mass behind the wall. The length of the geogrid or geotextile must be chosen so that the line of minimum acceptable safety is intersected. Required anchor lengths must be provided for behind this line.

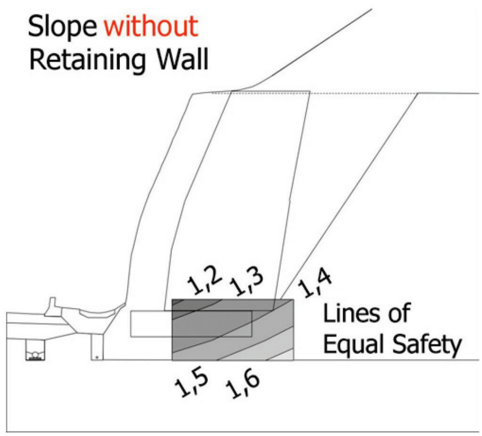

Figure 5. Lines of equal safety factor **without** Wall.

A search area is defined for exit and entry points respectively, and a search grid established for the third point of the surface under investigation. The lowest value obtained for all surfaces investigated through one point is assigned to that point. Lines of equal safety level can then be calculated and plotted within the network of points with their assigned safety levels.

In contrast to the usual presentation of safety levels assigned to the mid-points of slip circles, this form of presentation gives an excellent overview of the local safety levels at discrete locations within the soil body. It also allows non-circular failure surfaces to be depicted, and is a powerful tool in the constructive determination of support/propping measures.

Finally, using the same procedure, the safety levels through the rearmost point of the base of the wall are investigated according to ÖNORM B 4433 or DIN 4084.

3.2.3 *Design of tensile elements*

For the reinforcement of the soil behind the retaining walls along the A8 motorway, Tensar geogrids 120 RE or 160 RE were used when the geosynthetic was to be connected to the precast elements, and Btex300 geotextiles were used in the construction of the wrap-around wall.

Taking the reduction factors from the existing approval, design loads are as shown below:

The vertical spacing of the tensile elements and the type of geogrid were chosen to ensure that even slip surfaces passing through the wall did not have safety levels below the acceptable limit.

Table 1. Permissible design loads.

Geogrid/Geotextile	Width [m]	Design load [kN]
120RE	1,30	36
160RE	1,30	51
Btex 300	5,00	313

It was thus possible to find a technically sound, economically optimised solution to the problem of retaining the cut slope.

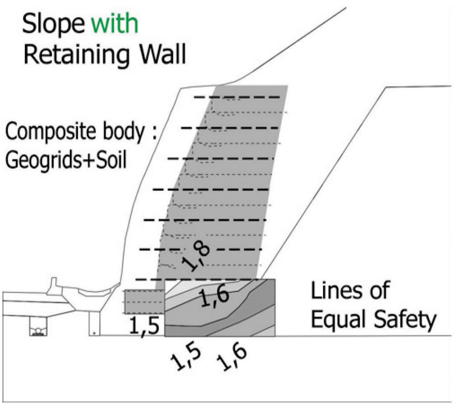

Figure 6. Lines of equal safety factor with wall.

3.2.4 *Isosafety-factors*

Independent of this project, lines of equal slope safety (isosafety-factors) have proven very useful in finding sound technical solutions to soil-mechanics problems.

A development of this method considers anisotropic soils, i.e. soils with directionally dependent properties.

4 SUMMARY

For the design and construction of vegetated retaining walls along the new A 8 Wels-Sattledt motorway, a solution was developed which led to several novelties for the wall system chosen.

Figure 7. The completed walls.

- Any wall section damaged by, for example, a traffic accident can be replaced without compromising the stability of the wall.
- The combination of geogrids and geotextiles led to a very economical solution.
- Lines of equal slope safety were developed into a powerful tool for the planning and design of retaining structures.

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