The use of stiff geogrids to build the reinforced soil walls for Slovak Roads

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ABSTRACT: The paper presents five projects of the retaining walls reinforced by stiff integral uniaxial geogrids for a Slovak Road Administration. Four of these projects were realized. A combination of rock-filled steel gabion baskets and stiff geogrids was designed and used for several projects. The wall was used to stabilize not only a reconstructed road embankment but a new highway embankment also. A reinforced embankment as well as reinforced concrete wall were used in the course of the lifting of the road bridge. Original combination of two reinforced structures is designed for a highway on a steep mountain side slope.

1 INTRODUCTION

Reinforced retaining wall have become a useful and economical solution to many problems in geotechnical engineering practice. In recent years, more interest in Slovakia on these structures has been promoted both case studies in the world and the activities in the design companies.

Stiff integral uniaxial geogrids (SIUG) became suitable products for Slovak Road Administration especially in a reinforced walls (RW). The SIUGs as a geotextile-related products are suitable geosynthetic reinforcement for important and pretentious structures. The paper describes some of stiff integral uniaxial geogrid reinforced walls (SIUG-RW) applications used by Slovak Road Administration.

The paper presents five projects of this structure.

2 REINFORCED WALLS USED

The soil reinforcement technique with geosynthetics has been used in Slovakia region for almost 15 years. Geotextiles were used as reinforcing elements for the reinforced steep slopes and as a basal reinforcement for embankments on soft subsoil. The presented reinforced walls are the first structures of this kind in Slovakia.

One type of RW with different facing is presented, as shown in Figure 1. According to BS 8006:1995, the used facings are hard type (concrete wall and concrete panel) and flexible type (gabion).

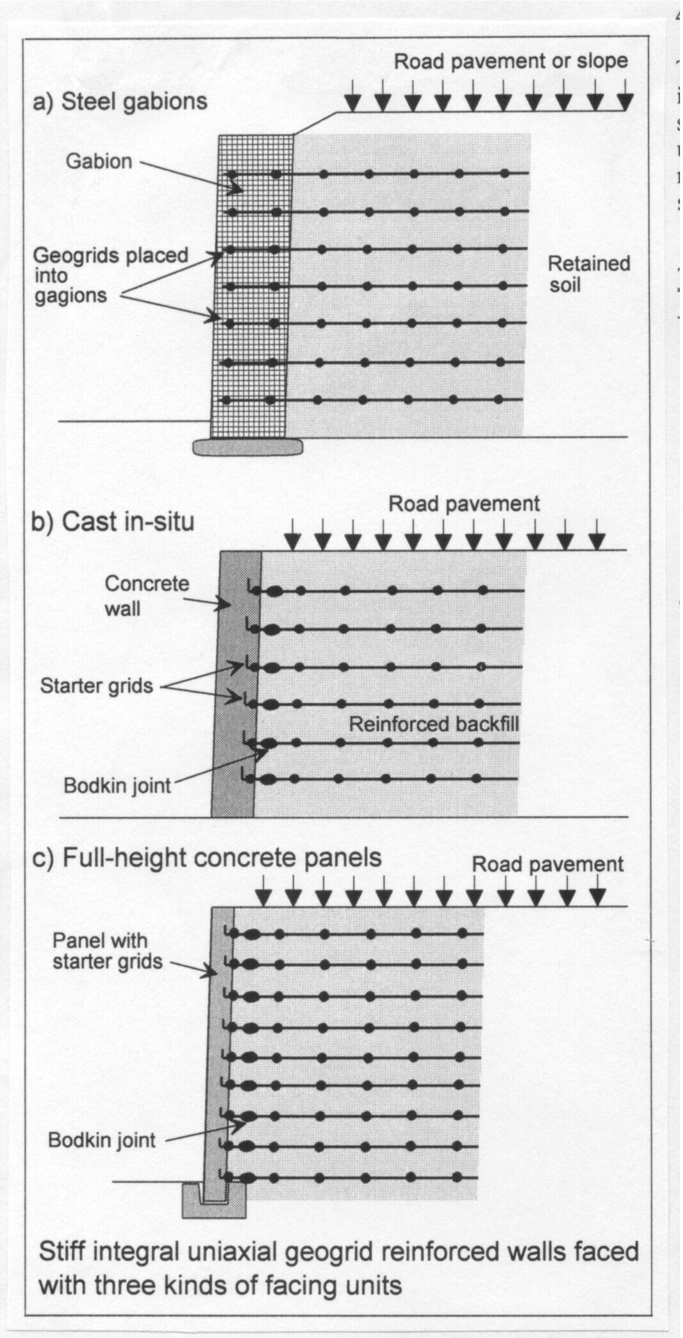

Figure 1. Stiff integral uniaxial geogrid reinforced walls (SIUG-RW) used by Slovak Road Administration

The reinforced walls were faced the following facing units:

- steel gabion baskets
- concrete wall cast in-situ
- full-height concrete panels

Gabions are manufactured from steel wire, electrically welded at every intersection. The mesh is rectangular. Gabions was assembled from flat components on site. Geogrid sheets are placed onto completed lower gabion and on compacted backfill. Crushed rock retained in upper gabion is placed on geogrid.

Second wall facing is concrete wall cast in-situ. A full-strength mechanical bodkin joint allows connection of the starter grid placed into concrete wall and the main geogrid length. The starter short geogrid is passed around panel steel reinforcement. This connection detail is assessed and approved by the BBA.

Third wall facing type is the thin facing full-height concrete panel. This hard facing unit is used typically for the vertical walls. The RW that is used in highway design was selected after considering other retaining structures appropriate to the loading conditions and required design life of the structure. Facing connection detail is the same as in second wall facing.

The structure details and technology are described below.

3 DESIGN PROCEDURES USED

The design of reinforced walls is a simple procedure based on the analytical methods. The Deutsches Institut für Bautechnik, Berlin (DIBt) design method was used for above mentioned RWs as a primary design procedure. However, to check the results of this design method, other design procedure such as BS 8006 tie-back wedge method was used for this reason.

The reinforced design strength T_D is obtained from tensile creep rupture graph (isochronous load-elongation curve after Jewell, 1996) derived from creep test data. Each SIUG with a 120 year design life made of high density polyethylene has a tensile creep rupture graph derived from a long-time tensile tests trying over 10 years.

Specific partial material factors are then applied to SIUG strength to define a design strength. The approach to partial factors presented in BS 8006 was used. The partial material factors for ultimate limit state which are covered by BBA certificates are shown in Table 1.

The design of presented reinforced walls was carried out using Tensar International´s Winslope and Winwall computer programs, Penman, Austin (1998). External, internal and overall stability were investigated in the design.

Table 1. Partial material factors applied to SIUGs used in projects

Partial material factor	Value
Consistency of manufacture, f_{m11}	1.0
Assessment of available test data, f_{m121}	1.05
Extrapolation to 120-year design life, f_{m122}	1.0
Short-term effects of installation damage, f_{m211}	1.07 to 1.20 (55RE) or 1.50 (SR55) according to used backfill
Long-term effects of installation damage, f_{m212}	1.05
Environmental degradation, f_{m22}	1.05

4 GEOGRIDS USED IN PROJECTS

The geogrids used in the projects for reinforcement application in RW shall conform to the properties required by designer. The stability requirements led to the adoption of Tensar stiff integral uniaxial geogrids as shown in Table 2. Only primary reinforcement was placed, the secondary reinforcement was not necessary.

Table 2. Specification of geogrids for reinforced walls

Parameter	Specification		
Reinforcement function	Primary reinforcement		
Type of geosynthetic reinforcement	High density polyethylene stiff		integral uniaxial geogrid
	55RE	80RE	SR80
Characteristic short-term tensile strength, (kN/m)	64.5	88.0	81.5
Approx. strain at failure, (%)	11.5	11.5	11.2
Tensile creep rupture strength, a design life of 120 years and a design temperature of 10^{o}C, (kN/m)	28.7	38.2	31.6

5 REPAIR OF DAMAGED ROAD EMBANKMENT PEZINSKA BABA AND CARADICE

5.1 *Problem*

Two reconstructions of damaged road embankment are presented.

First of these cases is Bezinska Baba road embankment on a steep mountain side slope in a small depression. During the autumn heavy rains a lower part of fully saturated embankment together with a road asphalt pavement were practically "blast out". The traffic on road was restricted and additional stability problems were expected.

Second case is Caradice road embankment. Both a foundation embankment and lower part of high road embankment were saturated by ground water from a new small water reservoir built near to the embankment for a long time. Slip failures began to occur on the embankment slope. The long-term settlement of pavement border and embankment slope caused by changes in the condition of the foundation soil, such as moisture content, saturation, variable compressibility has created continuously problems on the road. When the maintenance operations were not successful, a complete reconstruction of damaged embankment and pavement was required.

5.2 *Design*

Traditional method of slope failure repair was used in the bottom part of embankment. SIUG-RW helps designer to resolve issue how to stabilize upper part of embankment, Figure 2.

As a facing units the designer used steel gabions made of steel wire rectangular mesh. Gabions was assembled on site. There was designed a original connection of steel mesh and stiff geogrid sheet in the back side of gabion wall. Three gabion components and horizontal geogrid was laced together through every mesh by wire spiral.

RW height varied from 5.5m to 3.0m. The geometry of the wall was chosen to fulfil adequate stability as well as an aesthetic and environmental requirements in mountain area.

Geogrid sheets were placed from gabions up to drainage blanket in the backfill back part. Geogrids increase a internal stability of backfill and stabilize a vertical position of gabion wall.

The reinforced gabion wall Caradice has a similar arrangement and the same puspose.

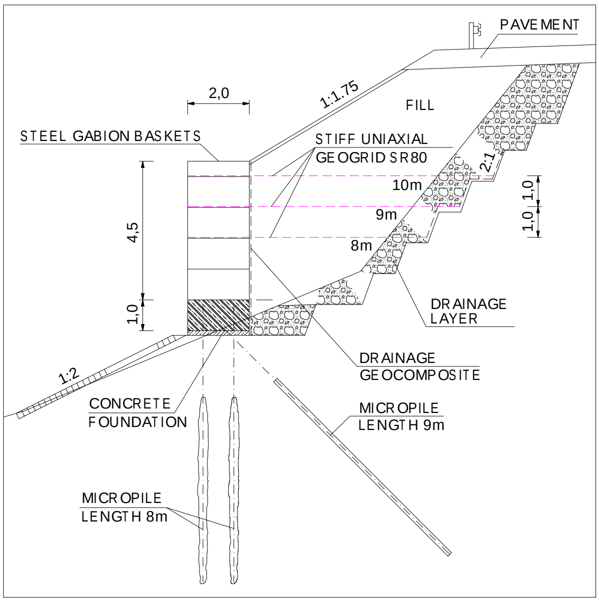

Figure 2. Cross-section of reconstructed road embankment

5.3 *Construction*

Reconstruction works included the following steps: /1/ reconstruction of a drainage system under the embankment, /2/ failured foundation stabilizing in the embankment toe, /3/ construction of SIUG-RW in two stages, /4/ stabilization of upper part of a new embankment which supports the roadway traffic surface.

Reinforced gabion wall Pezinska Baba was the first structure of this type realized in Slovakia. Therefore, the construction of this was very instructive for all participants. Our knowledge, however, is still rather limited, but each successful application is large step forward.

6 LIFTED ROAD EMBANKMENT NOVAKY

6.1 *Problem*

Another SIUG-RW was faced with cast-in-place rigid concrete facing. This wall has been constructed as part of a road bridge reconstruction project in central Slovakia. Lifting of the road Figure bridge over railway track to cause the lifting adjacent embankment also. The designer decided to replace a gravity wall on piles which was realized on lower embankment by reinforced wall on reinforced higher embankment near bridge abutments.

6.2 *Design*

The reinforced walls have a height of 4.5 m and 3.5 m, respectively and total length is of 120 m. Cast-in situ walls are placed onto surface of the improvement embankment. In the lower part as well as in the upper part are placed geoplate – a layer of crushed stone reinforced by several layers of stiff integral biaxial geogrids, as shown in Figure 3.

The reinforced wall is only widened in its lower part but without traditional foundation. The widened part is anchored into backfill by one layer of stiff geogrid.

The designer proposes a placement of the starter short geogrid into shutter and its passing around wall steel reinforcement.

It should be noted that this concept was used for the first time in Slovakia.

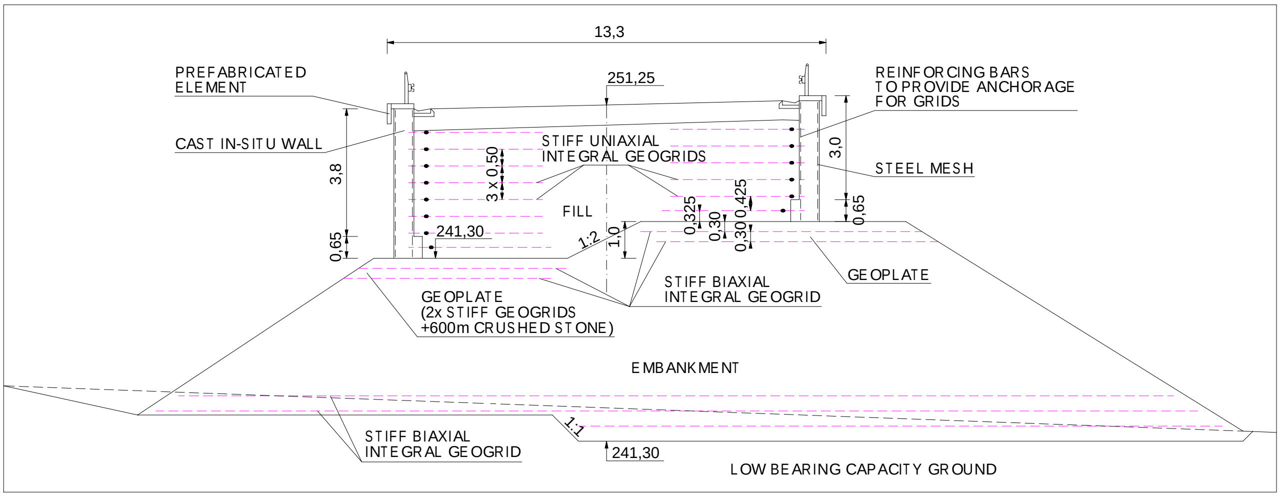

Figure 3. Cross-section of lifting road on reinforced structures

7 HIGHWAY BRIDGE WINGS

Third SIUG-RW system faced with steel gabions was used as highway bridge wings as shown in Figure 4. The reinforced wall has a maximum height of 7.5 m that tapered to minimum height of 2.0 m at the wings end. Both the reinforcement length and type of geogrid were adjusted to meet the minimum safety factors for each increment of wall height.

Figure 4. Reinforced gabion walls as highway bridge wings

8 HIGHWAY D18 ON A STEEP MOUNTAIN SIDE SLOPE

8.1 *Problem*

The highway in north mountain area of Slovakia is designed on a steep mountain side slope. The bridge section is combined with the reinforced wall section, as shown in Figure 5.

8.2 *Design*

The reinforced wall on the right side of cross-section is designed in two parts. Lower reinforced wall is faced with steel gabions baskets and upper structure is faced with thin full-height concrete panel. Gabions in the lower structure as flexible facing are considered to deform during construction of the upper RW. Finally, a hard finish on the gabions surface will be done. The Slovak Road Administration plans to carry out a long-term measurement program to verify the expected long-term stability and deformation of the structure.

The project should be realized in the close future.

9 CONCLUSION

Five types (four application and one project) of retaining wall reinforced by stiff integral uniaxial geogrids are presented. All applications are original in Slovakia. The walls were used to reconstruct damaged road embankments and to retain a new road and highway. A reinforced embankment as well as reinforced concrete wall were used in the course of the lifting of the road bridge. Original combination of two reinforced structures is designed for a highway on a steep mountain side slope.

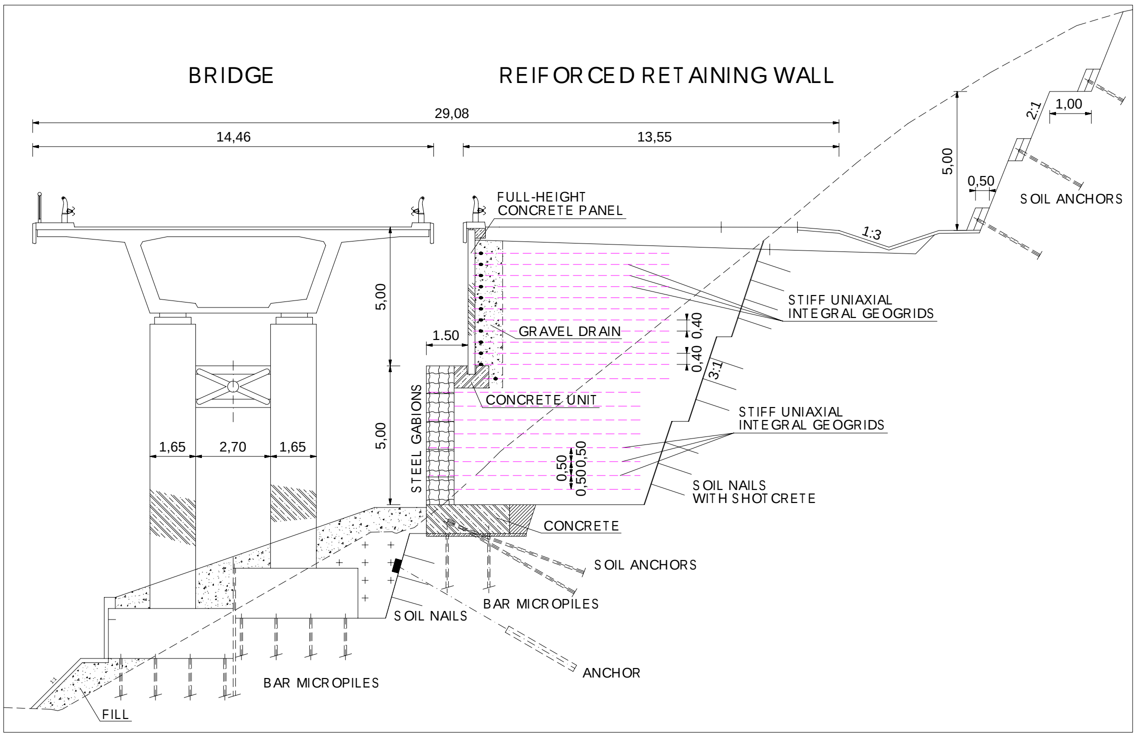

Figure 5. Reinforced walls in highway D18 project

SIUGs prove the high effectiveness in reinforced wall applications in Slovakia.

ACKNOWLEDGEMENTS

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