**INTERNATIONAL SCIENTIFIC CONFERENCE**

**CIBv 2010**

**12 – 13 November 2010, Braşov**

# METHODS FOR SLOPE PROTECTION AND STABILIZATION ON TRANSYLVANIAN MOTORWAY

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Abstract: The paper presents some subject studies applied on 2B Section, Luna-Gilau, of Transilvania Motorway and includes stabilization methods for cut slopes. The soil conditions along the motorway are analyzed, likewise the causes leading to slope failures, as well as the reconstruction methods applied.

*Key words:* slope stabilization, geogrid reinforced earth, finite element method.

## 1. INTRODUCTION

Braşov – Oradea Motorway is divided in three sections:

*Section 1*: Braşov – Târgu Mureş (Ogra), starts with Codlea, at the intersection with the last part of the Bucureşti – Braşov motorway, crossing Braşov, Sibiu and Mureş counties and finishes with Ogra village. The length of section 1 is 157,196 km.

*Section 2*: Târgu Mureş (Ogra) – Cluj, starts with Ogra village and finishes close to Gilau, at the intersection with NR1. The length of section 2 is 88.681 km.

*Section 3*: Cluj (Gilău) – Oradea L = 165.6 km, starts with Gilău, goes along Someşu Mic river until the Northen part of Cluj - Napoca, going to Zalău, then to the South of Marghita and finishes at the Hungarian frontier. The length of section 3 is about 175 km.

Section 2 of the motorway is crossing mountainous areas with altitudes of maximum 1104m and hills with altitudes ranging between 300 to 650m, as well as hydrographical basins of Mureş and Someş rivers.

The freezing depth of the natural soil is 80-90 cm (STAS 6054-77). According to SR 174-1 (July 1997), the section is located in a “warm area”. The content of the organic matter established during the execution of the pits along the road is less then 5%. The CBR determination (the Californian index of bearing capacity) shows values of smaller than eight for all the layers under the topsoil. These values place the layers in the “very bad” and “bad” soil foundations categories. According to Casagrande dates from STAS 2914-88, these layers are: “4b” type (– showing the “mediocre” quality as a fill material for embankments) and “4d” type (– showing the “bad” quality as fill material for embankments). According to STAS 1709/2-90, the above-mentioned layers are “very sensitive” to freezing.

The main causes that lead to slope failures are:

- ‘Readiness’ causes, which contribute in time to the slope instability;
- ‘Triggering’ causes, which contribute for a short period of time in bringing the slope from potential - unstable to active - unstable;
- Field conditions referring to the material type (plastic, cracked, sheared etc.) and the existing discontinuous surfaces (cleavage, geological faults and sedimentary contacts). The soil conditions cannot have an active role in producing the slope failures;
- Geomorphologic processes – such as processes of underground and aerial erosion, of mechanical expansion due to the glaciers melting;
- Physical processes – heavy or/and enduring rains, fast snow melting, continuous cycles of freeze – thaw or swelling – contraction etc.;
- Men-made processes – slope excavations or excavations at the toe of the slope, fast lowering of the water level from the retention ponds, irrigations, water supply and drains network, vegetation removing, mining works, vibrations produced by the heavy traffic and equipments.

The incorrect appreciation of the reasons, that cause the slopes’ instability, can lead to a reduced effect of the stability method. Forwards are presented some solution types for slope stabilization along the Transylvania Motorway.

## 2. SUBJECT STUDIES

### 2.1 Slope stabilization with drainage mask km 35+160 – km 35+660, right hand side

The motorway interval km 35+160 – km 35+660, right hand side, represents a cut area, where, for reaching the foundation level of the motorway, three slopes were excavated. These are: T1 (inferior slope), T2 (middle slope) and T3 (upper slope). The slopes have a 1V:2H gradient, with berms of 5 m. At the time of execution of F1 borehole, no underground water was found.

From the geological point of view, the soil lithology contains a stratification of cohesive rocks, low cohesive and non cohesive with lens shape, as follows: clayey silt, silty clays, clayey sands with or without gravel, sandy clayey silts, sand with gravel and no binder. Their colors are varying from reddish brown, yellow grey, reddish grey to yellow brown.

The physical-mechanical characteristics of the layers are presented in the bellow complex borehole profile:

Transilvania Motorway. Sector 2 Tg. Mures - Cluj ; Section 2B Campia Turzii - Gilau

Geotechnical Report IPT-2B-3-B-Z-0030-0803 Revision 0

**Complex borehole profile: F1**

Instalatia: DANDO

August 2006

Working: Autostrada Cluj - Oradea

Kilometric position: km 35+300 right, X=387005, Y=572336 Level:551.748m

| Stratum description | Symbol | Stratum thickness | Stratum thickness | Underground water | Sample | | Granular size | | | | | Natural humidity | Liquid limit | Plastic limit | Plasticity index | Consistency index | Density | Density humidity | Density in dry state | Porosity | Void ratio | Degree of saturation | Oedometer deformation | | Direct shear | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | No. | Depth | 7-20 cm | 2-70 mm | 0.05-2 mm | 0.005-0.05 mm | < 0.005 mm | | | | | | | | | | | | Deformation modulus | Specific settlement | Angle of internal friction | Cohesion |
| Gravel with silty sand and rare cobble | | 0.80 | 0.80 | | 1 | 0.10 | | 3 | 3 | 2 | 62 | 19 | 13 | 4 | | | | | | | | | (11111)* | (4.4)* | (21)* | (26)* |
| Gravel with sand and cobble; from 4.30m very dense | | 6.90 | 6.10 | | 2 | 3.00 | | 34 | 17 | 49 | | (18)* | (14)* | (6)* | | | | | | | | | (16667)* | (2.9)* | (18)* | (20)* |

NOTE: * values according to STAS 3300/1-85

** values recomandet from the specialty literature

As a result and due to the fact that slope T1 has an eroded surface with small slope failures, it was decided to use drainage mask for slope stabilization and to remove all the damaged soil from its surface.


Fig.1 Slope stabilization with drainage mask km 35+160 – km 35+660

**2.2 Slope stabilization with joining steps and drainage km 14+190 – km 14+880, right hand side**

The motorway kilometric interval 14+190 – km 14+880 represents a cut area where two slopes were excavated for reaching the foundation level of the motorway. These are: T1 (inferior slope), T2 (middle slope). The slopes have a 1V:2H gradient, with berms of 5 m. At the time of execution of F2 borehole, no underground water was found. The physical-mechanical characteristics of the layers are presented in the bellow complex borehole profile:

Transilvania Motorway. Sector 2 Tg. Mures - Cluj ; Section 2B Campia Turzii -Gilau

Geotechnical Report IPT-2B-1-B-Z-0060-0803 Revision 0

**Complex borehole profile: F2**

Instalatia: DANDO

August 2006

Working: Autostrada Cluj - Oradea

Kilometric position: km 14+554 m right, X=404603.104, Y=563848.384 Level:406.2m

| Stratum description | Symbol | Stratum thickness | Stratum thickness | Underground water | Sample | | Granular size | | | | | Natural humidity | Liquid limit | Plastic limit | | Consistency index | Density humidity | Density in dry state | Porosity | Void ratio | Degree of saturation | Oedometer deformation | | Direct shear | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | No. | Depth | 7-20 cm | 2-70 mm | 0.05-2 mm | 0.005-0.05 mm | < 0.005 mm | | | | | | | | | | | Deformation modulus | Specific settlement | Angle of internal friction | Cohesion |
| Compact, slightly humid, yellow brown, non uniform sand in mixture with gravel, with soft clayey binder | | 2.20 | 2.00 | | 1 | 1.50 | | 16 | 16 | 49 | 35 | | | | | | (2.0)* | | | | | | | | |
| Plastic stiff, yellow brown, silty clay; from 2.8m with gray and reddish insertions and calcareous concretions; from 4.1m soft sandy | | 6.00 | 3.80 | | 2 | 3.00 | | | 16 | 49 | 35 | 24.17 | 55.64 | 23.24 | 32.4 | 0.97 | 1.876 | .511 | 42.99 | .75 | 0.85 | 9090 | 5.8 | 16 | 26 |

NOTE: * values according to STAS 3300/1-85

** values recomandet from the specialty literature

Between km 14+545 – km 14+580, a slope failure occurred on slope T1. This slope failure is of medium depth, and about 25, 00 m width, with a shape of cracks in different widths (0,10 – 1,00 m) and depths (about 2,5 m). The shape of the slope failure is not a classical one (circular) but it is, most probably, a plane surface of a layer. This is indicated by the position of the four cracks, parallel to the stratification.

The contractile clays have been affected by swelling and contractions causing cracks and fissures and leading to the loss of shear force. This failure seems to be mainly caused by the excavations at the toe of the slope performed for the longitudinal drain of the motorway. The excavations were executed during a highly humid period, with heavy rains and high temperatures. Therefore, the slope was reconstructed with joining steps and drainage fill, with one row of gabions at the toe of the slope.

Fig.2 Cracks that occurred during the excavation for the longitudinal drain

Fig.3 Slope excavation with joining steps

**2.3 Slope stabilization with gridirons km 49+400 – km 50+300, left hand side**

Between km 49+400 – km 50+300, in order to reach the foundation level of the motorway, a number of 5 cut slopes with 1:2 gradients were executed. On these slopes a series of temporary exfiltration areas appeared and affected their stability. The region contains quaternary deposits represented by clays, silts and sands. There can be found also the quaternary deposits with the striped Palaeogene horizon which includes clay deposits, sand, gravel and conglomerates that are largely red coloured. The infiltrations are temporary and are influenced by rain conditions. The physical-mechanical characteristics of the layers are presented in bellow complex borehole profile:

Transilvania Motorway. Sector 2 Tg. Mures - Cluj ; Section 2B Campia Turzii -Gilau
Geotechnical Report IPT-2B-3-B-Z-0120-0803 Revision 0

**Complex borehole profile: F3**

Instalatia: DANDO
August 2006

Working: Autostrada Cluj -Oradea
Kilometric position: km 50+100 left, X=395165.989, Y=567553.883 Level:453.623m

| Stratum description | Symbol | Stratum thickness | Stratum thickness | Underground water | Sample | | Granular size | | | | | Natural humidity | Liquid limit | Plastic limit | | Consistency index | Density humidity | Density in dry state | Porosity | Void ratio | Degree of saturation | Oedometer deformation | | Direct shear | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | No. | Depth | 7-20 cm | 2-70 mm | 0.05-2 mm | 0.005-0.05 mm | < 0.005 mm | | | | | | | | | | | Deformation modulus | Specific settlement | Angle of internal friction | Cohesion |
| Clayey silt plastic firm with gravel and cobble fragments | | 2.80 | 2.80 | | 1 | 0.30 | | | 34 | 41 | 25 | 19.6 | 31.5 | 18.9 | 12.6 | 0.94 | 1.664 | 1.550 | 41.19 | 0.7 | 0.74 | 5667 | 6.3 | 15 | 37 |
| Dense sand | | 3.80 | 1.00 | Water | 2 | 2.50 | | | 88 | 12 | | 3.3 | | | | | (1.345)* | | | | | | 4.2 | 32 | 0 |
| Clayey sandy silt plastic firm with rare gravel | | 5.30 | 1.50 | | 3 | 4.50 | | 4 | 18 | 45 | 33 | 22.6 | 42.3 | 20.7 | 21.6 | 0.65 | 1.800 | 1.618 | 38.9 | 0.70 | 0.94 | 8666 | 5.5 | 17 | 53 |
| Weathered limestone | | 6.50 | 1.20 | | 4 | 6.00 | | | | | | | | | | | 2.500 | 1.591 | | 0.87 | 0.99 | | 4.3 | 30 | 0 |

NOTE: * values according to STAS 3300/1-85
** values recomandet from the specialty literature

Due to the fact that slope T1, which is made of cohesive soils with water infiltrations, presents surface erosions and small slope failures on limited parts, execution of gridirons in the infiltration areas were recommended for impeding the weathering caused by the water.

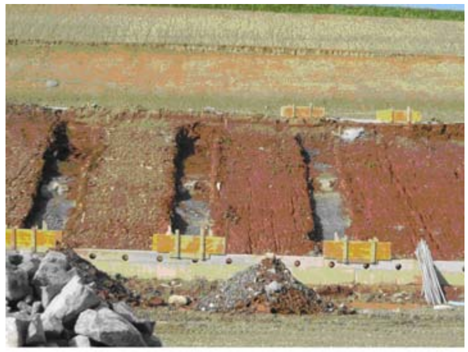

Fig. 4 Slope stabilization with gridirons

### 2.4 Slope stabilization with slope terracing km 45+680 – km 45+760, left hand side

In the motorway km interval 45+680 – 45+760, two slopes are designed on the cut area, on the left hand side. The gradient of the slopes is 1V:2H. From geomorphologic point of view, this interval represents the South – East slope of Fenes river valley, which is a slope with smooth gradients, with inclinations smaller than 30°. This area is made of temporary valleys belonging to the Fenes hydrographical basin. From the hydro-technical point of view, the water is present inder the form of infiltrations from the upstream slope, having a temporary character and being influenced by the weather conditions (rains, snow), but being also permanently connected with the phreatic level.

Between km 45+700 – km 45+780, slope T1 and T2, a slope failure of medium depth and about 75,00 m width occurred and developed mainly towards the upstream. The sliding plane has a classical circular shape; only in the upper part being concave. The physical-mechanical characteristics of the layers are presented in the bellow complex borehole profile:

Transilvania Motorway. Sector 2 Tg. Mures - Cluj ; Section 2B Campia Turzii -Gilau

Geotechnical Report IPT-2B-3-B-Z-0120-0803 Revision 0

**Complex borehole profile: F7**

Instalatia: DANDO

August 2006

Working: Autostrada Cluj - Oradea

Kilometric position: km 45+700 left, X=379584.698, Y=580607.331 Level 439.292m

| Stratum description | Symbol | Stratum thickness | Stratum thickness | Underground water | Sample No. | Sample Depth | Granular size 7-20 cm | 2-70 mm | 0.05-2 mm | 0.005-0.05 mm | < 0.005 mm | Natural humidity | Liquid limit | Plastic limit | | Consistency index | Density humidity | Density in dry state | Porosity | Void ratio | Degree of saturation | Oedometer deformation: Deformation modulus | Specific settlement | Direct shear: Angle of internal friction | Cohesion |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Interstratified alluvial complex sandy clayey with gravel | | 1.50 | 1.50 | | 1 | 1.00 | | 18 | 35 | 0.30 | 20 | 20.49 | 36.0 | 15.40 | 20.50 | 0.75 | 1.806 | 1.508 | 43.10 | 0.75 | 0.93 | 16667 | 2.9 | 18 | 20 |
| Brown clay | | 2.80 | 1.30 | | 2 | 2.50 | | | 27 | 44 | 29 | 19.60 | 44.20 | | 21.30 | 1.00 | 1.806 | 1.508 | 43.1 | 0.75 | 0.69 | 5163 | 9.9 | 16 | 21 |
| Dense coarse sand with gravel | | 3.30 | 0.50 | | 3 | 3.00 | | | 53 | 28 | 19 | 14.69 | 30.22 | 12.05 | 18.17 | 0.65 | 1.774 | 1.547 | 41.6 | 0.71 | 0.55 | 8333 | 6.2 | 16 | 19 |
| Weathered sandstone | | 6.00 | 2.70 | | | | | | | | | | | | | | | | | | | | | | |

NOTE: * values according to STAS 3300/1-85

** values recomandet from the specialty literature

The failures between km 45+700 – km 45+930, slope 1, were caused by: a period with high temperatures followed by torrential rains; heavy infiltration in the upstream part of the slope; presence of clays sensitive to temperature and humidity changes in a cohesive low mass and permeable material; alternation between cohesive and non-cohesive deposits oriented towards downstream and, thus creating a wide range of sliding plans because of the infiltrations.

Fig.5 Sliding km 45+700 – km 45+780

Fig.6 Laying back slope to 1H: 6V gradient

**Acknowledgements**

The physical mechanical characteristics of each layer are given by the geotechnical laboratory determinations from Bucharest, SC Central Laboratory CCF-SA, and by the Geo-mechanic Laboratory of Geology and Geophysics from Bucharest University. Boreholes equipped with piezometers were performed in order to establish the underground water level.

## REFERENCES

1. IPTANA S.A., *"Slope stability and protection"*, Technical Specifications XES-00216 Revision 3, 2009.
2. IPTANA S.A., Geotechnical Design Basis Report, 2007.
3. "*Normative regarding the characteristic values determinations and calculations of the geotechnical parameters"*, July, 2008.
4. FLUM D., *"Flexible systems for slope stabilization with steel wire net of high resistance combined with bares and anchors for soil and rocks"*, A IX-a Geotechnical and Foundation National Conference, Timisoara, 2008, page. 675 – 682.

*Received September 20, 2010*