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High embankments on soft soils – geotechnical design based on field monitoring and back analysis, Romania, Sebeş-Turda motorway

Emploi élevé sur sols mous – conception géotechnique basée sur la surveillance de terrain et la rétro-analyse, Roumanie, autoroute Sebeş Turda

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ABSTRACT: This paper presents an analysis of a high embankment on a compressible soil area on the newly designed highway route Sebes Turda, 2nd Lot, km26+000 (Romania, Transylvania, Alba County). Due to the difficult soil conditions and hydro geological issues of the analysed area, the configuration of the newly designed structure of the railway passage and especially the proposed consolidation solution required validation by geotechnical monitoring. Given the intensity of some geomorphological processes and the acceleration of soil degradation in certain sectors as a result of anthropic intervention, several consolidation works were proposed consisting in the use of earthworks (reinforced with geosynthetics) and / or stone columns (with radial drainage and reinforcement function), that were numerically modelled and studied in order to determine the values of the settlements and especially consolidation time. The validation of the designed solutions is decided based on results obtained from experimental trials instrumented by means of monitoring deformations, pressures, and water level variations (free and under pressure). The results based on monitoring represent criteria for choosing the consolidation solution and especially a validation / correction of the constitutive model for the foundation ground. Details regarding laboratory test results correlated with in situ testing and modelling of soil structure interaction will be approached, as well as presented by comparison with back analysis results.

RÉSUMÉ: Cet article présente une étude de cas détaillée d'une solution de remblai élevé adoptée pour une zone de sol compressible sur la nouvelle route routière Sebeş Turda, 2e lot, km26+000 (Roumanie, Transilvanie, comté d'Alba). En raison des conditions pédologiques difficiles et des enjeux hydrogéologiques de la zone analysée, la configuration de la structure nouvellement conçue du passage ferroviaire et surtout la solution de consolidation proposée ont nécessité une validation par suivi géotechnique. Compte tenu de l'intensité de certains processus géomorphologiques et de l'accélération de la dégradation des sols dans certains secteurs suite à l'intervention anthropique, plusieurs travaux de consolidation ont été proposés consistant en l'utilisation de terrassements (renforcés de géo synthétiques) et/ou de colonnes en pierre (avec drainage radial et renforcement fonction), qui ont été modélisés et étudiés numériquement afin de déterminer les valeurs des tassements et surtout le temps de consolidation. La validation des solutions conçues est décidée sur la base des résultats obtenus à partir d'essais expérimentaux instrumentés par le suivi des déformations, des pressions et des variations du niveau d'eau (libre et sous pression). Les résultats basés sur le suivi représentent des critères de choix de la solution de consolidation et surtout une validation/correction du modèle constitutif du sol de fondation. Les détails concernant les résultats des tests en laboratoire corrélés aux tests in situ et à la modélisation de l'interaction sol-structure seront abordés, ainsi que présentés par comparaison avec les résultats des analyses rétrospectives.

Keywords: Compressible soil; high embankments; monitoring.

1 INTRODUCTION

The site is located along the Sebes-Turda motorway, which connects the cities of Turda, Alba Iulia and Sebes, figure 1. The monitored sector is a high bridge ramp, figure 2 located on a very compressible alluvial soil, figure 3. The foundation solutions consisted of a combination of several consolidation works in order to achieve the desired results according to the beneficiary's requirements, i.e. settlements of less than 2 cm. Therefore, due to the lithology and hydrogeological conditions of the foundation ground, the nature of the passageway structure, and particularly the proposed consolidation solution required validation through geotechnical monitoring.

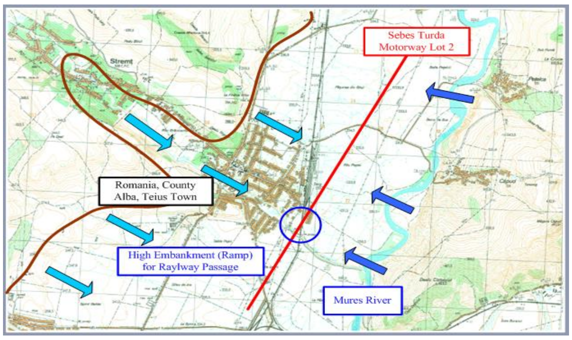

Figure 1. Plan.

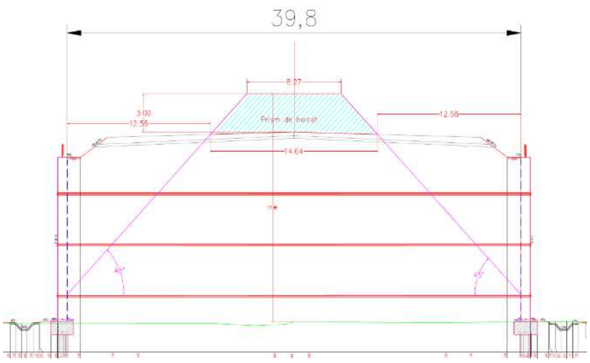

Figure 2. Analysed characteristic profile.

2 HYDRO, GEOLOGICAL AND MORPHOLOGYCAL CONDITIONS OF THE SITE

From a morphological point of view, the analysed site is located at the southern edge of the hilly area of the Transylvanian Depression, which presents various geomorphological processes. This perimeter is approximately 400÷600 m above sea level, surrounded on all sides, except for the north-western region, by the hilly area and mountains. The area has been divided by several rivers to form a rolling relief, with alluvial plains at the valley bottom.

For the site under analysis, it can be said that the relief is developed on clays and marls specific to the hilly regions of the Transylvanian Depression. The relief has regionally differentiated features, depending on the variety of clay rocks, on the stage of evolution and on the specificity of the action of the environmental modelling factors. The mineralogical composition, the physical-mechanical properties and the textural peculiarities show great differences from one relief unit to another.

A particular feature area is the montmorillonite clays present in marine and volcano-sedimentary formations, clays with high sensitivity to mass displacements. The analysed geographical area is mainly characterised by concave slopes with a broadly undulating or stepped profile, the lower third of which is covered by thick colluvial-deluvial deposits.

2.1 Selection the critical section

The profile was selected based on geometry, corresponding to an area with the highest embankment height and difficult foundation ground.

The calculation values for the geotechnical parameters resulted from the values determined from the corrected laboratory and field tests and following a statistical calculation of the values grouped by soil types, where these laboratory data were insufficient. The chosen section can be found in figure 2.

The parameters of the deformation process in time were determined (consolidation process) based on the in situ and laboratory geotechnical investigation. The lithological column used for the calculation and for the monitoring correlation is shown in the following figure. 3.

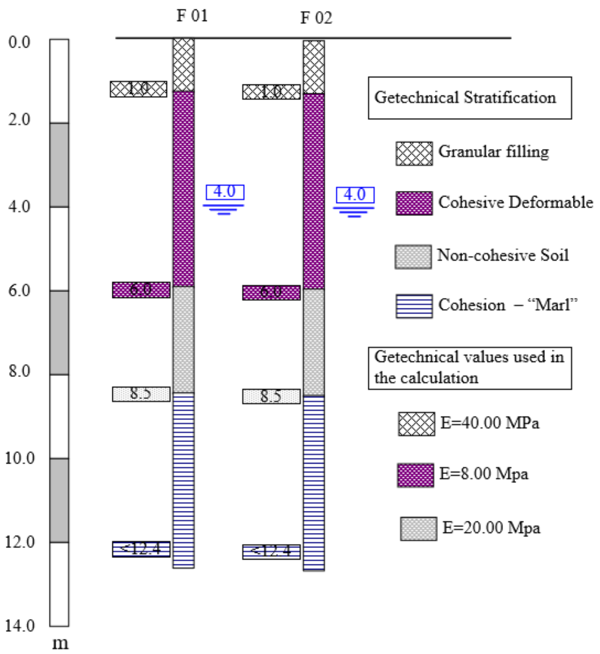

Figure 3. Lithology of the site.

2.2 Selection of the consolidation solution

The purpose of the calculation notes was to determine the maximum values of the settlement of the new embankment at the level of the foundation ground and in the upper part, in the axis.

If the results of the calculations show that the foundation ground does not have the capacity to bear the loads of the embankment or suffers from significant settlements that may endanger the safety of the construction, the possibility of improving the properties of the soil in the respective layer so that it meets the conditions of a proper foundation ground should be examined.

The proposed foundation solutions with the use of earthworks (reinforced with geosynthetics) and / or stone columns (with radial drainage and reinforcement function) have been numerically modelled in order to determine the values of the settlements and in particular the consolidation time.

The optimal solution chosen was the solution with stone columns (with radial drainage and reinforcement function), stone blocking and the application of an overload to speed up settlement. Following the analysis of this solution, figure 4, settlement values (S=31 cm) and the degree of consolidation, 80% that could be implemented in the project were obtained.

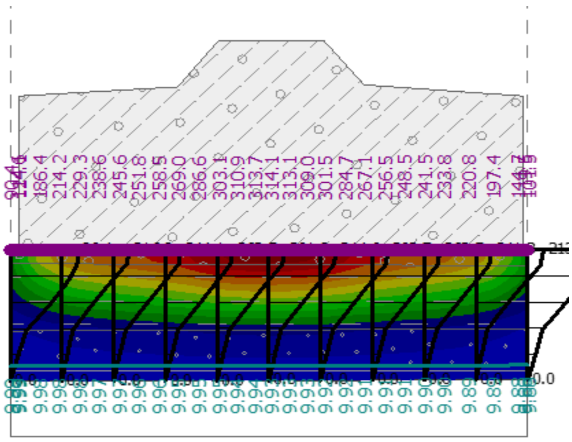

Figure 4. Settlement calculation result.

2.3 Geotechnical monitoring

Geotechnical monitoring consisted of the installation of a piezometer, outside the ramp, and a Tasometer, in the area with the highest ramp height, figure 5.

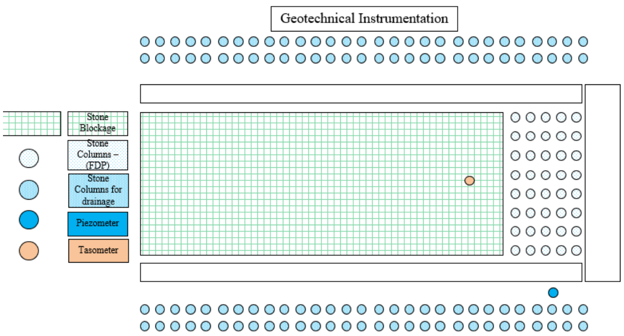

Figure 5. The location of the monitoring sistems.

For the Monitoring System - Piezometer with Free Level ""Right Wall" it was desired to identify the effects of the realization of the Embankment, the realization of the Overload and the Efficiency of the perimeter drainage conditions by correlating the Execution Stages versus Time with the measurements of the Water Levels (Compression and Drainage Process)

The monitoring was designed to cover all construction phases of the embankment and highlight the effects of each stage.

The following stages are presented as Preloading Structure Realization Stages and Monitoring Realization Stages respectively:

1.System Data Initialization Stage
2.Monitoring with reference to 1.0m Embankment figure 6.
3.Monitoring with reference to 5.0m Embankment
4.Monitoring with reference to 8.0m Embankment
5.Monitoring with reference to 12.0m Embankment
6.Monitoring with reference to 15.0m Embankment
7.Monitoring with reference to 15.0m Embankment 3m Overload– Ballast, figure 7

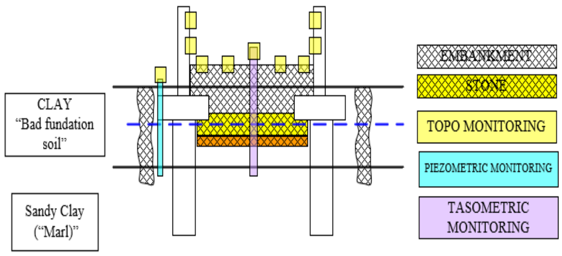

Figure 6. Etap 2 embankment 1.0 m.

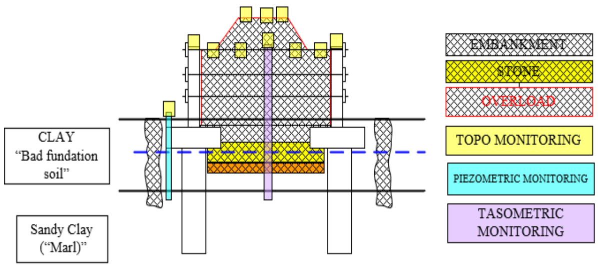

Figure 7. Etap 7 embankment 15.00 m plus overload.

The validation of the Design (solution) is decided based on results obtained from experimental sectors instrumented with equipment for monitoring deformations, pressures, variations of water level (free and under pressure). The results based on monitoring represent criteria for confirmed the consolidation solution and especially for validation / correction of the constitutive model for the foundation ground.

3 GRAPHICAL REPRESENTATION OF RESULTS

The recorded data allow the representation of the consolidation curve of the foundation ground (the high compressibility cohesive alluvial horizon being prioritized in the analysis).

The graphical representation indicates that the Primary Consolidation Process is 80% completed and that the applied overload (3.0 m ballast which represents ~ 20% of the structure height and 10% of the structure overload value) brings an additional contribution of 2÷ 3 cm (10% of the 26 cm of the Primary Consolidation Process), figure 8.

The period of occurrence of the recorded deformations indicates a high speed of the Settlement Process (2÷3 cm <30 days of overload application).

From the point of view of the recorded deformation values, it is accepted to eliminate the overloads and to continue the project, provided that the monitoring conditions for the tasometer are ensured during the operation of the infrastructure.

Table 1. Position of the sensor relative to ground elevation.

Sensor nr.	**Depth (m)**
6	0.42
5	1.270
4	1.390
3	7.920
2	13.000
1	14.100

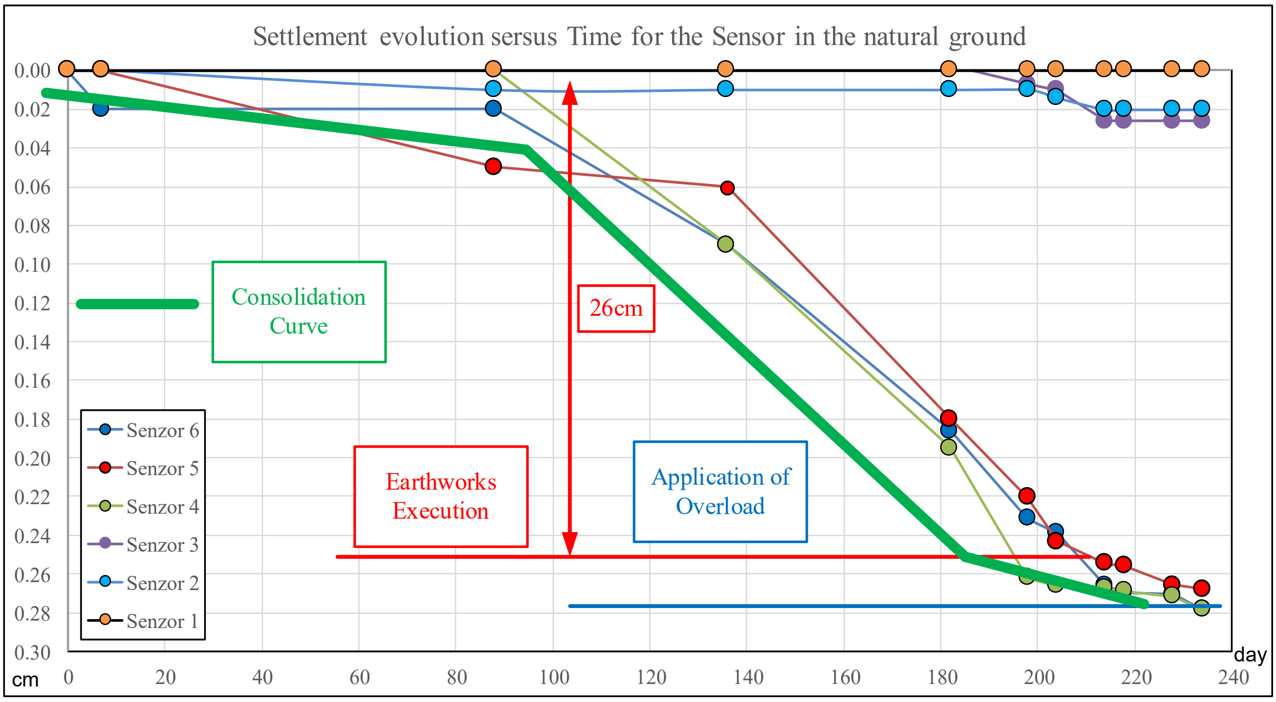

Figure 8. Graphical representation of the results.

4 CONCLUSIONS

The recorded deformations and their evolution over time confirm the effectiveness of the application of the Structure Preloading Solution in consuming settlements. For the foundation ground situation (CTN Reference) 2.0 m blockage, 4.0 m compressible ground E~8000kPa, the consolidation time related to a consolidation degree of 80% is considered. The high deformability of the foundation ground in the area adjacent to the support structures ("walls founded on fixed elements") is confirmed as a (possible) result of a reduced volume (geometry) of the blocking layer. It is confirmed that the blocking layer leads to the occurrence of a uniform deformation (it has the role of a "preliminary slab").

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