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Reconstruction of bridge abutments on Corridor 10 section Veles - Katlanovo in R. Macedonia

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ABSTRACT: Republic of Macedonia is positioned at the crossroads of Corridor 8 (East – West) and Corridor 10 (North–South). The Corridor 10 is the most important communication and transportation route connecting the Hellenic Republic with Austria and further with the rest of Europe. On the section between Veles and Katlanovo revitalizations of 10 bridges has been planned. The project is aiming to upgrade the structural capacity of the bridges as well as the abutments. It is financially supported by NATO as a strategic partner to R. Macedonia. In the past 30 years of exploitation significant settlements and deformations on the road-bridge transition elements had developed. Several unsuccessful attempts using surface improvement techniques have been made. Therefore this time, more comprehensive study has been prepared which considers different techniques, such as: jet grouting, earth reinforcement and end-bearing piles. The final decision regarding the methods used and reconstruction solution has been made considering two major aspects, namely the economic and technical.

1 INTRODUCTION

Good infrastructure is vital for rapid economic growth and development, better competitiveness of the economy, as well as faster circulation of people and goods. Republic of Macedonia is at the crossroads of two main corridors i.e. Corridor 8 (East – West) and (North – South). The Corridor 10 is the most important element of the central transport network connecting the Hellenic Republic and Austria which length is 1,451 km.

The Demir Kapija – Smokvica section of Corridor 10 will finalize the construction at the level of highway in R. Macedonia. In parallel to which there is another project for strengthening and revitalization of bridges on the route between Veles and Katlanovo. The project is fully supported by NATO through a grant of 6 million Euros. In fact, this is a continuation of a project which started in 2004 when more than 10 bridges on the same route were reconstructed. Besides the structural strengthening of the structural elements there has been an effort to reconstruct of the bridge abutments. Namely, during the explanation period of 30 years settlements of the abutments, in range of tens of centimetres, near the bridge transition plate had occurred as a result of inadequate and poor execution of the earthworks.

They were reconstructed on several occasions using surface improvement techniques, replacing the top soil layer with gravel and covered up with asphalt. All of these measurements did not produced stabilization of the abutments. In some cases the deformations even increased.

2 GEOTECHNICAL INVESTIGATIONS

The original design documentation for the bridges prepared by "Road Institute – Belgrade" in 1978 considered that most of the abutments are erected over gravely sands, only in some section they are locally clayed. According to the investigations they show different degree of natural consolidation. The allowable bearing capacity is determined for different types of foundations, depths and mechanical properties. Thus, the designer could choose rational dimensions and foundation depth. The settlements are estimated for loads of 400kPa and their value ranges between 7 and 10cm. The old boreholes are located along the axis of the bridge, next to the abutments. Sample material was taken on which laboratory tests for determination of granulometric content, plasticity limits, shearing strength and deformability were performed. Summarizing on the original investigations it has been concluded that the local material is with good quality heterogeneous consisted of sands, gravels and clays and satisfies the requirements to be used for construction of abutments.

Nowadays, new investigation set of field investigations and laboratory tests had been executed. The boreholes had been drilled up to depth of about 10m nearby bridge abutments. Also mapping of the gelogical conditions; macroscopic mapping profiles; sampling of materials and Standard Penetration Test (SPT) had been performed.

The location of bridges as well as the wider area, in terms of regional geological settings, is enclosed in one large geotectonic unit so called Vardar Zone. Thick Pliocene deposits are present in the terrain, all of which have deposited in tectonically depressions. The natural terrain is presented with Pliocene sediments: sandy to silty clay, well compacted. Above it, in the zone of the transitional slab, an embankment layer with thickness of around 5m is constructed from sandy gravel, silty to clayey. Its upper parts consist of different mixes of clay-silt, sandy and with rare gravels. The embankment ends with layer of sandy gravel and gravelly sand with silty-clayey components. All of the abutment material is from the quarry of the close cuts excavated in the Pliocene sediments described above. Representative soil samples are selected on certain depths which had been used to determine their mechanical properties. Appropriate laboratory tests had been conducted to define: water content, unit weight, specific unit weight, granulometric content, oedometer tests, triaxial test, direct shear test, optimum moisture content, plasticity limits.

All investigation works had been finished in April 2012. Based on the site investigation works the following materials had been confirmed to constitute the ground profile:

- Asphalt – the registered asphalt layer in some sections reaches up to 60cm.
- Buffer material (SP) – layer registered with maximal depth of 1.0m, built from gravely sand which has increased water content.
- GW – hillside gravel with fine to medium grained fractions, mid compacted and increased water content. It's located at a depth below 0.8m with thickness around 3m.
- SFs – silty-sand with optimal water content. This material is present at various depths and thicknesses.
- GFc/GFs – locally clayed sandy-gravel and clayey gravel with increased water content present at larger depths above 8m.

Finally summarizing on the geotechnical investigations, it can be concluded that the compression modulus is not adequate for embankments on roads. The Proctor's tests showed that the moisture content. The strength parameters are generally well estimated, thus the allowable bearing capacity of the base ground is relatively height (600kPa) and confirm that calculated in 1978. The SPT shows that in most of the abutments the number of hits decreases in depth which indicates that the material is not well compacted. Such materials as a part of abutments are in desperate need of repair in general but especially in areas near the bridge transitional slab where they get most of the punching.

3 AMBUTMENT RECONSTRUCTION METHODS

The abutments on the route E-75 have width of about 11m while the height is varying in different sections. The area around the bridge transition plate had been detected as most problematic where immediate repair measures had to be conducted. The following reconstruction solutions had been considered:

- Abutment strengthening with end-bearing piles with cap and transitional plate on width, and
- Abutment improvement by jet grouted columns with flexible slab formed by geotextile/geogrid system and stabilized slopes using geogrid in layers between compacted fill.

In both cases different dimensions on some of the elements e.g. pile or column diameter had been considered which did not improve the solution greatly. In the present paper for convenience reconstruction works on one of the bridges will be presented, namely the abutments on bridge B–65 (km. 67+521.00) Highway m1 (E–75) section: Veles–Katlanovo, see Figure 1.

Figure 1. Position of bridge B65 with abutments S-1 and S-2

The slope erosion on the bridge B65 abutments has been evaluated as critical. On S-2 abutment there is evidence of a sliding mass just below the bridge, while on abutment S-1 there is significant surface erosion, see Figure 2.

Figure 2. View of eroded ravine in front of abutments S-1 (left) and S-2 (right) on bridge B65

The observed soil deformations are alarming putting the structural integrity at risk. This fact is supported by the registered large deformation and cracks on reinforced-concrete bridge sections. Therefore, it has been decided to take immediate measures for reconstruction, thus as soon as possible prepare a technical documentation. The first bride to be reconstructed will be the presented bridge B65.

The proposed reconstruction solution 1 (RS1) is consisted of concrete piles (diameter 0.8m) with a height of 14m, placed in two rows with 4 piles in a row. The distance between rows is 4m while the pile spacing is 2.5m. The pile cap is 8,7m wide, 8.2m long and 0.4m thick. The transitional plate is inclined 1:10 with width of 8.7m, length of 5.2m and thickness of 0.3m. The total number of piles is eight placed in two rows. They are designed as end-bearing entering the basic terrain material not less than 2m. This material has been estimated with good bearing capacities. Since the predominant loads are vertical they are stressed in compression. Thus, the pile sections are reinforced (S500) fulfilling the minimal criteria cast in place with concrete (C30/37). The connection with the pile cap is rigid bypassing the week zone bellow the previous transitional plates, see Figure 3.

Additionally, the abutment stability is upgraded with repair of the slopes (inclination 1:1.5) below bridge (i.e. in front and sides of the abutment) as well as reconstruction of drainage system, see Figure 4.

The analyses of the problem showed that for maximal design exploitation load (heavy vehicles) the system of piles is quite efficient in bypassing the week (soft) deposits. No significant displacements appear while the internal quantities in the structural elements (piles and plates) are standard.

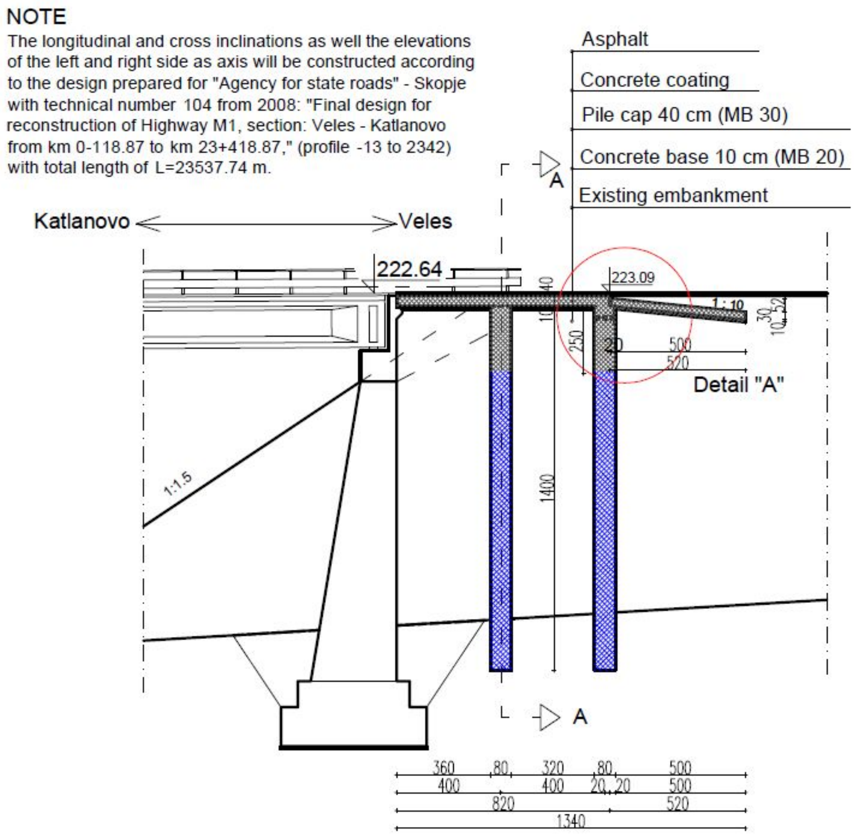

Figure 3. Longitudinal section of abutment S-2 with piles and pile cap (RS1)

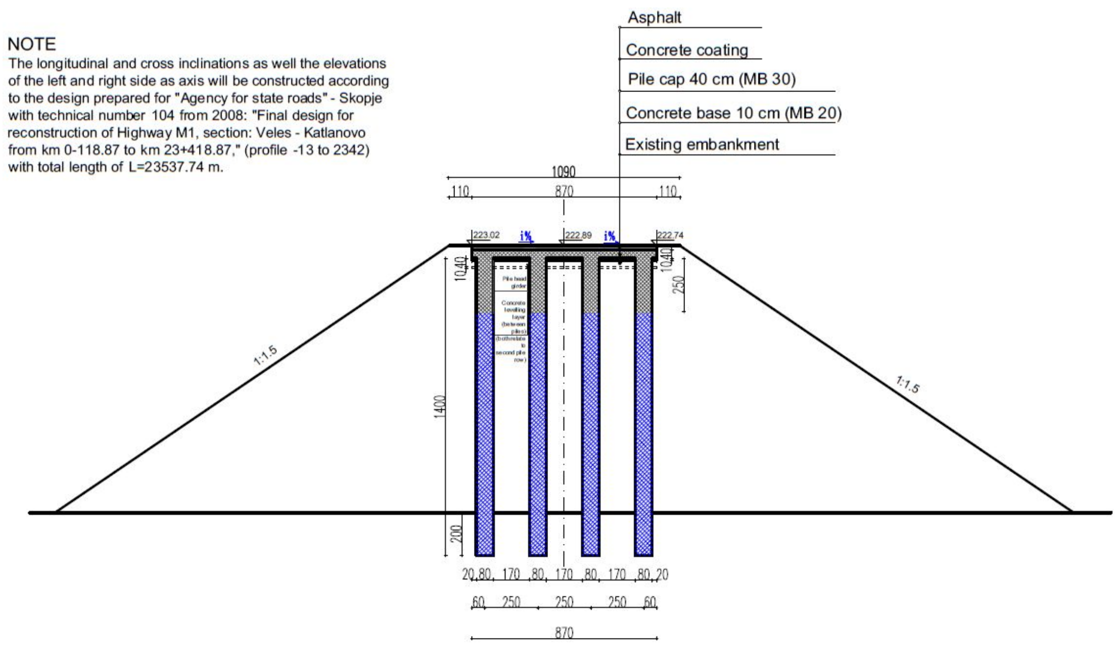

Figure 4. Cross section of abutment S-2 with piles and pile cap (RS1)

On the other hand, the reconstruction solution 2 (RS2) instead of reinforced-concrete piles uses jet grouted columns to strengthen the abutment mass. They have diameter of 0.6m and are positioned in three rows equally spaced on 1.8m. The total number of jet grouted columns is seventeen. In addition to the jet grouted columns it uses combination of different geosintetic materials to stabilize the abutments. The possibility, if necessary, to stabile the end bridge column, with micropiles is taken into account. The slope stability is ensured with 5 layers (total height 3m) of geogrids with length of 5m (Ibergrid 80/30) placed in between well compacted gravel material. In the upper part the abutment slope is change from the initial 1:2 (26^0) to 1.75 : 1 (60^0), see Figure 5.

For evacuation of water a drainage geocomposite strips are placed into the ambutment with width 0.5m, vertically spaced on 1.2m and horizontally spaced on 4m. The height of the drainage system is 5m with slope of 3%. On the top surface over the columns a woven geotextile (Porpex 7041) is placed after which a compacted fill material is placed above which binder is connected through geogrid asphalt reinforcement (Asphaglass) to the finishing asphalt layer (5cm), see Figure 6.

The analyses of the abutment with RS2 shows significant increase in the bearing capacity and stability of the soil masses. The geosintetic elements and the compacted act like stiffer geocomposite sandwich under which a jet grouted columns are used to gradually transfer the stresses to deeper stiffer layers.

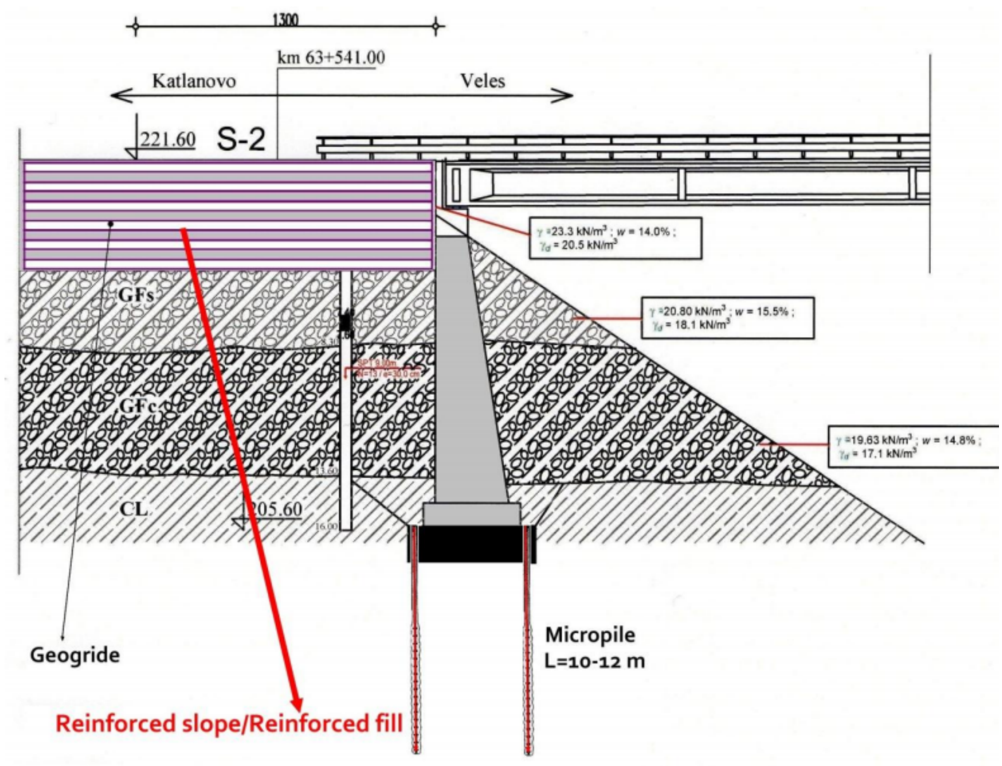

Figure 5. Longitudinal section of abutment S-1 with jet grouting columns and geogrids (RS2)

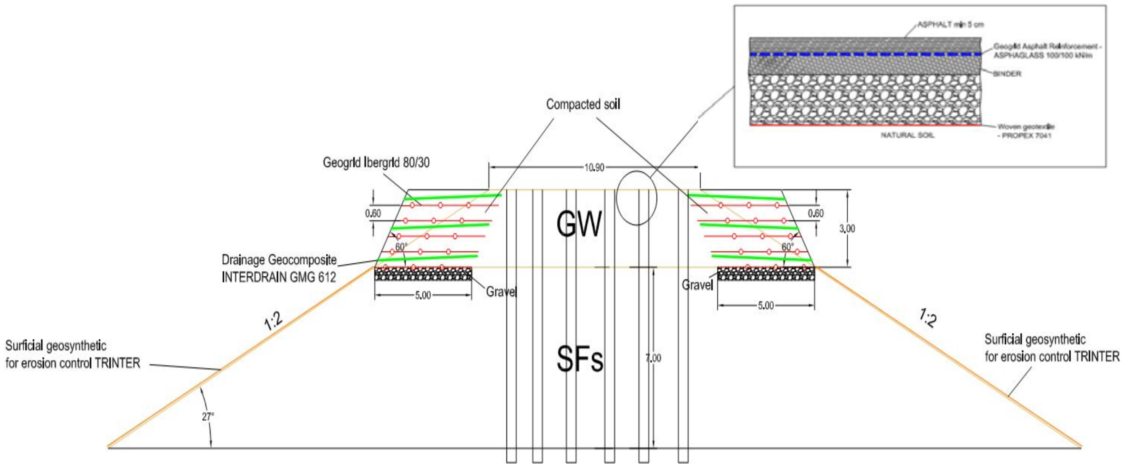

Figure 6. Cross section of abutment S-1 with geogrids and jet grouting columns (RS2)

For both cases of proposed reconstruction geostatical analyses namely, stress-deformation (with program Plaxis) and limit equilibrium (with program Slide) had been performed. The results confirm that both are efficient and fulfil the stability criteria (factors of safety). The provisions from the European norms were closely followed regarding the site investigations (EN 1997-2), geotechnical design (EN 1997-1) as well the execution of woks (EN1536, EN 12716, EN 14475). The design of reinforced sections was according to (EN 1992-2) using the software package CUBUS module FAGUS.

In purpose of monitoring on the repaired embankment, survey auscultations are proposed on three cross-road profiles with three points each. It is recommended that the measurement should start right after the traffic has started on each side of the road, according to the following time intervals: on each 3 months, in the first 6 months of service; on each 6 months, till the second year of service; once a year in the next three years.

4 CONCLUSION

The decision of the methodology which will be used for reconstruction had been manly brought considering two aspects namely, the economic and technical. The economic aspects were primary, thus the established quantities and total cost of both methods has been compared.

The proposed reconstruction solution integrates an additional pile structure into the existing abutments bypassing the week deposit and transferring the loads to the stiffer base material. This could be seen as conventional approach which certainly is very effective. On the other hand, the alternative represents more intuitive solution based on the concept of soil strengthening rather than soil replacement. It uses combination of different geosintetic materials to stabilize the abutments.

A cost-benefit analysis has determined that the jet grouting (with geosintetics) solution is 24 percent more expensive from the solution with pile foundation. Although the jet grouting has been able to assure good results in combination with different types of geosintetics it still represents expensive technology and material. Finally, the reconstruction of the abutments using piles with cap and transitional plate had been accepted as most favourable. Despite the choice, a personal opinion of the author is that the technical aspects should be more weighted in such decisions.

The reconstruction of the bridges should start in 2013 and last around one year. The completion of the project will transform Corridor 10 into a modern transport route in accordance with European standards. The main aim of this construction is to reduce transportation costs, save time and allow a faster circulation of vehicles, which will in turn influence positively the transit of persons and goods and increase the trade exchange between countries.

5 REFERENCE

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EN 1997-2 Geotechnical design - Part 2: Ground investigation and testing

EN 1992-2 Design of concrete structures - Part 2: Concrete bridges

EN 14475 Execution of special geotechnical works – Reinforced fill

EN 12716 Execution of special geotechnical works - Jet grouting

EN1536 Execution of special geotechnical works – Bored piles