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ENGINEERING-GEOLOGICAL AND GEOTECHNICAL ASPECTS OF THE SAVA TERRACE SHOWN IN THE EXAMPLE OF THE TUZLA – ORAŠJE HIGHWAY PROJECT

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Abstract

This research paper is concerned with the chosen variant of the route of the Pečuh – Osijek – Županja – Tuzla – Zavidovići highway. On the lowland part of the analysed section Orašje – Brčko there are thick layers of the so called Sava Quaternary terraces which are the product of sedimentation of disintegrated rocks brought there by water streams. It has been found out that the sedimentation of the Sava terraces is cyclical, with silty, sandy and clayey soils alternations. This paper also presents the results of bore-holes explorations, laboratory and "in situ" research which has ensured more realistic evaluation of the analysed route variants. Two basic issues have been discussed in this paper:

- designing and elaboration of technology concerning the construction of road embankments up to 10 meters tall on the clayey, silty and sandy soils, with the maximum use of local materials from the borrowing places in the area between the Sava, Tinja and Brka rivers.
- building foundations of the road structures (bridges, road junctions, overpasses and supporting constructions) which require adequate soil improvements at deeper layers

1 Introduction

The planned route of the Pečuh – Osijek – Županja – Tuzla corridor is a part of the international project of regional cooperation Dunav – Drava – Sava. The corridor should connect three states with a huge industrial and human potential. Bosnia and Herzegovina has started the preliminary design of the Orašje – Tuzla highway. The first section Orašje – Brčko should start on the Sava river with stationary of 0+000,00 and it should end to the west of Brčko with stationary of 18+400,00. The route should run over lowlands and undulating terrain. The terrain is mostly covered with alluvial sediments composed of a clayey and silty soil. One part of the terrain is covered with mine-fields remained from the last war, which made it impossible to carry out a complete research. The major part of the route should be built over the artificial embankment and already existing subsoil consisting of alluvial sediments. There are no tunnels, cuttings nor unstable slopes on the marked route. The main characteristic of the terrain is a danger of inundation, so that the grade level of the route must be set up over the hydrological maximum.

2 Traffic characteristics of the existing road and the new highway

The existing main road M1.8 Šićki Brod – Orašje, 71.2km in length, was built within the parameters adequate for that type of a road, with the maximum speed of 80km/h, traffic lanes 2x3.5m, and the bank width of 1.0m. However, the higher density of traffic and building settlements in close proximity of the road have caused a slower movement of vehicles and

increased danger for traffic participants. A new speed limit from 40 to 60km/h has been set on 1/3 of the road because of these problems. Considering the traffic growth in the years to follow, the decision to build a new Tuzla – Orašje road becomes completely justifiable. This communication would be the most important connection of north-eastern Bosnia with Europe. It would connect over 1 million people and the most developed part of Bosnia and Herzegovina with Beograd – Zagreb highway.
The maximum speed on the highway would be 120km/h in lowlands and 80-100km/h in highlands. It would be nearer Brčko unlike the existing main road. It would have one tunnel, about 300m long under the Majevica mountain. The highway junction for Tuzla would be located to the west, 10km away from the city. The marked route of the highway would continue towards Sarajevo and in Zavidovići it would connect with the corridor Vc.

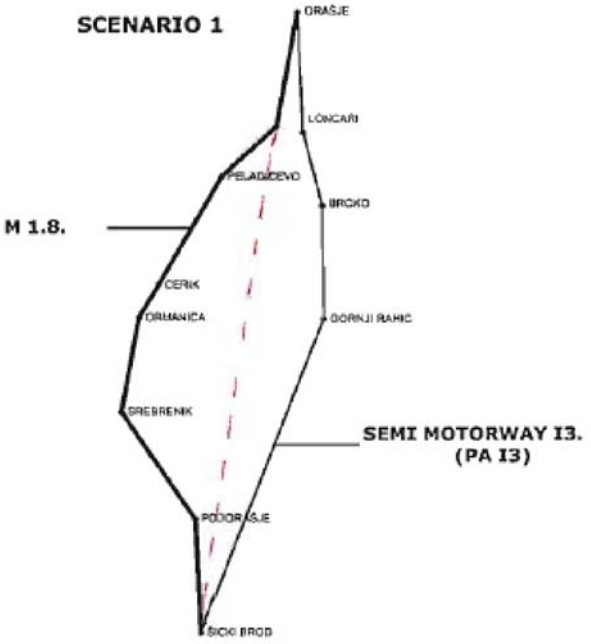

Figure 1 Existing road M1.8 and the new highway

Table 1 Traffic characteristics: vehicles/day

SECTION	2005	2015		
	Existing road M1.8		the new highway	
Orašje – Lončari	3514	5997	Orašje – Lončari	11146
Lončari - Pelagićevo	6373	10863	Lončari – Brčko	20187
Pelagićevo – Cerik	4230	7217	Brčko – Gornji Rahić	14607
Cerik Ormanica	4608	7878	Gornji Rahić -Šićki Brod	16556
Ormanica – Srebrenik	5002	8550		
Srebrenik – Podorašje	3782	6466		
Podorašje – Šićki Brod	3953	6754		

3 Engineering-geological characteristics of the terrain

3.1 Geological and geomorphologic characteristics of the terrain

Geological structure of the terrain contains Quaternary formations which belong to the continental facies. They were formed in fluvial and lacustrine conditions.
The Quaternary formations that have been found are the following: Pleistocene formations (found in the layers of the second (t_2) and the first terrace of the Sava river (t_1) and Holocene formations (found in the alluvial sediments - ap - alluvial deposited matter – as well as by organogenic sediments – ob. The vertical development of these formations is shown in Figure 2.

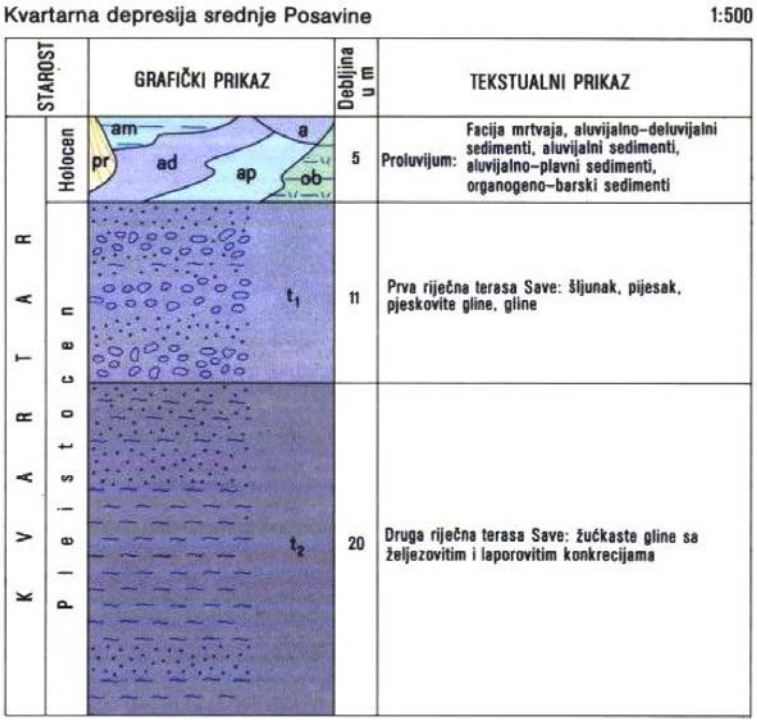

Figure 2 Formation of the Quaternary sediments of the terrain

In geomorphologic terms, the terrain planned for the highway construction belongs to the accumulative relief of south Posavina. According to the genetic type, it is a fluvial accumulative type of relief, and according to its morphochronology the terrain corresponds to Holocene (Q4), with mud and silt deposits, sand and gravel deposits and coarse clastic rocks. The terrain is characterized by its rather simple engineering-geological structure. Some parts of the terrain are mined, and for this area the engineering-geological mapping has been done on the basis of approximation.

3.2 Engineering-geological characteristics of the terrain

According to the degree of homogeneity, the soils have been classified into the main taxonomic units, i.e. lithologic types (LT) and lithologic complexes (LC). According to the degree of diagenesis and cohesion of minerals and mineral aggregates, it has been established that the taxonomic units belong to the group of semi-cohesive and non-cohesive soil. On the basis

of the information got from the mapping of the terrain, explorations and laboratory testing it has been established that the surface of the terrain of S1 Orašje – Brčko section is covered by semi-cohesive soil.

Clayey silt and clay have not been found by drilling, but there is some evidence that they are presented on the small surfaces of the terrain, in other words, their range is limited. They are yellowish-brown and grey-brown organic clayey silt and clays.

Clays, sandy clays, silty clays and silty sediments have been isolated as a lithologic complex of alluvial sediments. They mostly appear at morphologically lower locations. Their thickness is variable and it varies from 1.2 to 3.6m.

Clayey, silty and sandy sediments of the terrace (t_1) have been found on the terrain and they are shown on the longitudinal profile as a part of loamy complex, the formation of the first river terrace. The thickness of these sediments is estimated to be about 3 meters.

The sand and gravel sediments with an admixture of clay belong to the group of non-cohesive soil. They are presented in the lower part of the lithologic complex of alluvion, alluvial sediments and the first terrace of the Sava river (a, ap, t_1). The most important representative of the sediments mentioned above is sand, with regard to its presence in the terrain as well as to the sense of the future object building.

Sand (t1,a,ap) has been isolated as a single lithological type in the complexes of the terrace sediments, as well as a lithological complex in the facies of the terraces, alluvial sediments and alluvions. It has been estimated that the sand composing the terrace sediments is placed at the depth of 2.5 to 6.5 meters from the terrain surface. The terrace sands have also been explored and it has been found out that their thickness is variable, from 3.0 to 4.5 meters.

Gravel (t_1,a,ap) has been isolated as a lithological complex in alteration with sand, and it is associated to the facies of the terrace sediments. Sporadic layers of gravel have also been found in the facies of alluvial sediments and alluvions, but their thickness is almost irrelevant and they are usually lens-shaped. It has been estimated that the gravel composing the terrace sediments is placed at the depth of 6.0 – 8.0 meters from the terrace surface. These sediments are associated with emerging of underground waters.

3.3 Hydrogeological characteristics of the terrain

The hydrogeological research was carried out during the period from October to December in 2009. It consisted of collecting, systematization and analysis of the results from past researches and testing, hydrogeological mapping of the terrain along the route, covering approximately 500m wide belt of the route, carrying out exploration work (bore-hole) and installation of piezometers, observation of the underground waters level in sediments and in the end, laboratory analysis of the information.

The Sava and the Tinja rivers, as well as their smaller tributaries: the Lukavac, the Tinjica, the Lomnica, the Smrdulja and the Burim channel, have given the basic characteristics to the terrain in hydrological and hydrogeological sense. In the lower stream of the Tinja, as well as in the tributaries mentioned above, there is a small longitudinal inclination of the stream, meandering, accumulation of deposits and frequent inundations. The other characteristic of this area is shallow river-beds which rivers frequently abandon leaving muddy soils with small bearing capacity.

In terms of water permeability there are permeable and impermeable soils, and according to their functions there are aquifers and hydrogeological barriers. The aquifers have been classified on the basis of their water permeability, estimated filtrating parameters, thickness, range and structural system.

Soils as weak water permeability are organogenic (ob), alluvial (ap), and alluvial deposits (a). They are composed of sandy-silty clays. The thickness of these sediments is variable and it varies from 2.8 to 9.2m. depending on the sedimentation conditions. In hydrogeological terms

they have a function of the soil without an aquifer because their water permeability coefficient varies k = $1{,}0\times10^{-5}$-$1{,}0\times10^{-6}$cm/s which represents a hydrogeological isolator.
Soils as medium water permeability are sand and gravel of the first river terrace (t_1). The thickness of this terrace is about 11.0m depending on sedimentation conditions. The water permeability coefficient ranges from to k = $1{,}0\times10^{-5}$-$1{,}0\times10^{-4}$cm/s. In hydrogeological terms these soils have a function of the subsoil aquifer of a wider range and considerable depth. They are fed by precipitation, rivers and water from Pliocene-Quaternary sediments which can be found at the Brčko area. The level of the underground waters in the aquifer has characteristics of the subartesian type.

4 Geotechnical aspects of the section Orašje – Brčko

The major part of the section S1 route should be built on alluvial sediments composed of silty and sandy clay. About 4 – 5m tall embankments should be built over these clays for the major part of the section. They should be built of sand and gravel materials from the Sava river. The bearing soil should be grey-brown silty clay. In case of weak soils as organic soils, it would be necessary to build soil improvement. Foundations of the other objects on the route should be laid in the sandy soil using the method of an indirect, deep foundation over pillars.
On the basis of the laboratory research we have determined the following geomechanical parameters of soil:

- Clay, silty, grey-brown,
  - bulk density 18,0-19,5 kN/m^3
  - natural water 20-30 %
  - cohesion 20-40 kN/m^2
  - inter friction angle 18,0°-25,0°
  - water permeability coeff. $1{,}0\times10^{-7}$-$1{,}0\times10^{-6}$ cm/s
  - AC classification CH/CI
- Clay, silty-sandy, grey-brown,
  - bulk density 18,8-19,5 kN/m^3
  - natural water 25-30 %
  - cohesion 8-20 kN/m^2
  - inter friction angle 15°-20,0°
  - water permeability coeff. $1{,}0\times10^{-5}$-$1{,}0\times10^{-6}$ cm/s
  - AC classification CI
- Sand, with clay and silt,
  - bulk density 19,0-20,0 kN/m^3
  - natural water 15-30 %
  - cohesion 0-15 kN/m^2
  - inter friction angle 19,0°-30,0°
  - water permeability coeff. $1{,}0\times10^{-5}$-$1{,}0\times10^{-4}$ cm/s
  - AC classification SFc / SW

Within the whole length of the section S1 there are smaller and limited locations which have been under water for a long time or which are composed of the materials with unfavourable geotechnical characteristics (organogenetic sediments). The parts of the terrain mentioned above need a plan of a dewatering system construction and replacement or improvement of the soils.
On the basis of everything that has been mentioned above, the terrain of the section S1 has been classified into the category of stable terrains.

5 Conclusion

This paper presents the explorations of the geotechnical and engineering-geological conditions for the construction of the Tuzla – Orašje highway route, the Orašje – Brčko section. We have described the present condition of the main road M1.8 which is overburdened by traffic with numerous speed limits. The new Tuzla – Orašje highway would have a connection with Brčko. It would be about 10km shorter as compared to the road M1.8.
The Orašje – Brčko section runs across low-lands. The base consists of alluvial sediments, of silty and sandy clay. Engineering-geological characteristics of the terrain are satisfactory as well. The terrain is composed of the Sava terraces Quaternary sediments. On the surface there are alluvial sediments with thickness of 3 – 5m. The first terrace lies underneath, marked as t_1, with thickness of 3 – 4.5m, and then comes the second and the third one. The major part of the route would be built on 4 – 5m tall embankments. Geomechanical characteristics of the soil are satisfactory in relation to its bearing capacity. The foundation of single engineering objects would be done in deeper sand layers.

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