Review paper
UDC: 551.2+556.34]:624.131)
DOI: 10.7251/afts.2014.0610.023O
COBISS.RS-ID: 4225048

GEOLOGICAL CONDITIONS FOR BUILDING OF THE NEUM-STOLAC ROAD ON THE SECTION BROČANAC-DRENOVAC

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RESUME

Within the project task for the road M-17,3 Buna-Neum, section Neum-Stolac, several variants have been considered and the section has been divided into several sub-sections. The sub-section Stari Neum-Kiševo in the length of cca 3 km has already been built, as well as the sub-section of Kiševo-Bročanac, with length cca 8,5 km. Within the sub-section Bročanac-Drenovac, which construction is in progress, two main variants of the route have been set aside, namely the blue and the red one. The blue route starts from east of the Bročanac village, on mileage km 11+300 if counting from the beginning of the road in Stari Neum, and it follows the corridor of the existing road between Bročanac and Drenovac.

The red variant, as well as the previous one, starts from east of the Bročanac village, passes south of the Hutovo village, near the Glumin village, and approaches to the blue variant in the region of Trnovski brijeg. After that, it goes again towards south and over the Burmazi plateau it approaches to Drenovac, while at Varda it approaches to the blue variant and the existing route on north. For adopted blue variant there have been analyzed geomorphologic characteristics, geological structure, and hydrogeological and engineering geological, as well as seismic characteristics of the terrain. Reconnaissance of the terrain has also been done, and all previous documentation has been used as well as results of the former conducted geological investigations. As a basic point there have been used the Main Geologic Maps, papers Ston and Metkovići 1:100 000 with legends.

Key words: *road, sub-section, geomorphologic characteristics, geological structure, hydro geological and engineering geological characteristics of the terrain.*

INTRODUCTION

The blue route starts from east of the Bročanac village, on mileage km 11+300 counting from the beginning of the road in Stari Neum and it follows the corridor of the existing road between Bročanac and Drenovac. It is divided up into two sub-variants. The first sub-variant is with sharp acclivity, what was avoided with the second variant at the place where viaduct should be built in length of 215 m. Within the blue variant there is a tunnel 780 m long and a viaduct 123 m long. Geological structure of the terrain within the blue variant has been presented in three parts. The first one covers the part from Bročanac to viaduct, and the second one with the two sub-variants, until the village of Cerovica. The third part is from the Cerovica village until the end of the designed route.

Sub-section Bročanac-Drenovac, mileage km 11+300 – km 38+341 has been analyzed in two variants: the blue and the red one.

The red variant, as well as the blue one, starts from east of the Bročanac village, goes south of the Hutovo village, near the Glumin village, and it approaches to the blue variant in region of Trnovski brijeg. Then it goes south again and over the Burmazi plateau approaches to Drenovac. At Varda, the route approaches to the blue variant and the existing route on north. The route then goes to northeast, somewhere towards north, and again to northwest, where it joins the starting point and the blue variant. In the following presentation in description of routes, the blue variant has been considered and adopted.

The paper presents geomorphologic characteristics, geological structure and engineering geological and seismic characteristics of the terrain, and as a base there have been used the Main Geologic Maps, papers of Ston and Metkovići 1:100 000 with legends.

THE BLUE VARIANT

Geomorphologic characteristics

The first part of the route passes across the plateau where gradually overrides saddle in the region of Obodin. Further, the route goes by shorter valley side along the slope which is cut with valleys, and bridged by viaduct, and then it enters the massif of the Kičin hill. After coming out from tunnel, the route goes by the rim of the massif until the viaduct. In morphological sense, along this part of the route one can notice the surface karst in terms of small karrens on flat parts of the terrain, while in the slope sides massifs have been built of layered limestones. The limestones are the most prevalent in this part of the terrain with smooth decline into hill.

The second part of the route with sub-variants, starting from the viaduct follows the smooth waved limestone terrain. In the first sub-variant, the route goes by the rim of the Prisoje hill over the flat part of the terrain, covered with numerous karrens and karst sinkholes all until Cerovica. The second sub-variant goes from the viaduct over the slope side of the Osoje hill and further over the flat plateau to Cerovica.

The third part of the route continuous mainly by the flat plateau covered with numerous karst sinkholes and karrens and with very smooth inclination. At the bottom of karst sinkholes the terrain is usually full with terra rossa. According to the level of karstification it is mainly karst. In the region of Drenovac village until the end, the route slowly descends and passes through smooth slope sides covered with limestones.

Geological structure

Sediments with similar genetic origin but different age participate in geological structure of the terrain, picture 1 and picture 2. Those are sediments of the Upper Cretaous ($K_2^{1,2}$, $K_2^{2,3}$, K_2^{3}), Palaeocene and Eocene (Pc, E, $E_{1,2}$) as well as quaternary sediments [1, 2, 3, 4]. This particularly must be in mind when building a future route.

Limestones and dolomites of the Upper Cretaceous ($K_2^{1,2}$) build south slopes of the Mountain of Žaba as well as narrow space of the Udora village. Those are mainly well layered limestones which are replaced with dolomites and dolomite limestones.

Limestones and dolomites with rudists ($K_2^{2,3}$) outspread west and east of the Cerovica village, as well as north of the Visoki karst overthrust (northeast of the Crnoglav village until the end of the observed road route). In northeast part of the terrain mainly limestones are presented.

Limestones with keramosphaerina and rudists (K_2^3) are prevalent in northwest and northeast part of the terrain between Hrasno and Čavaš on the rim of Popovo polje.

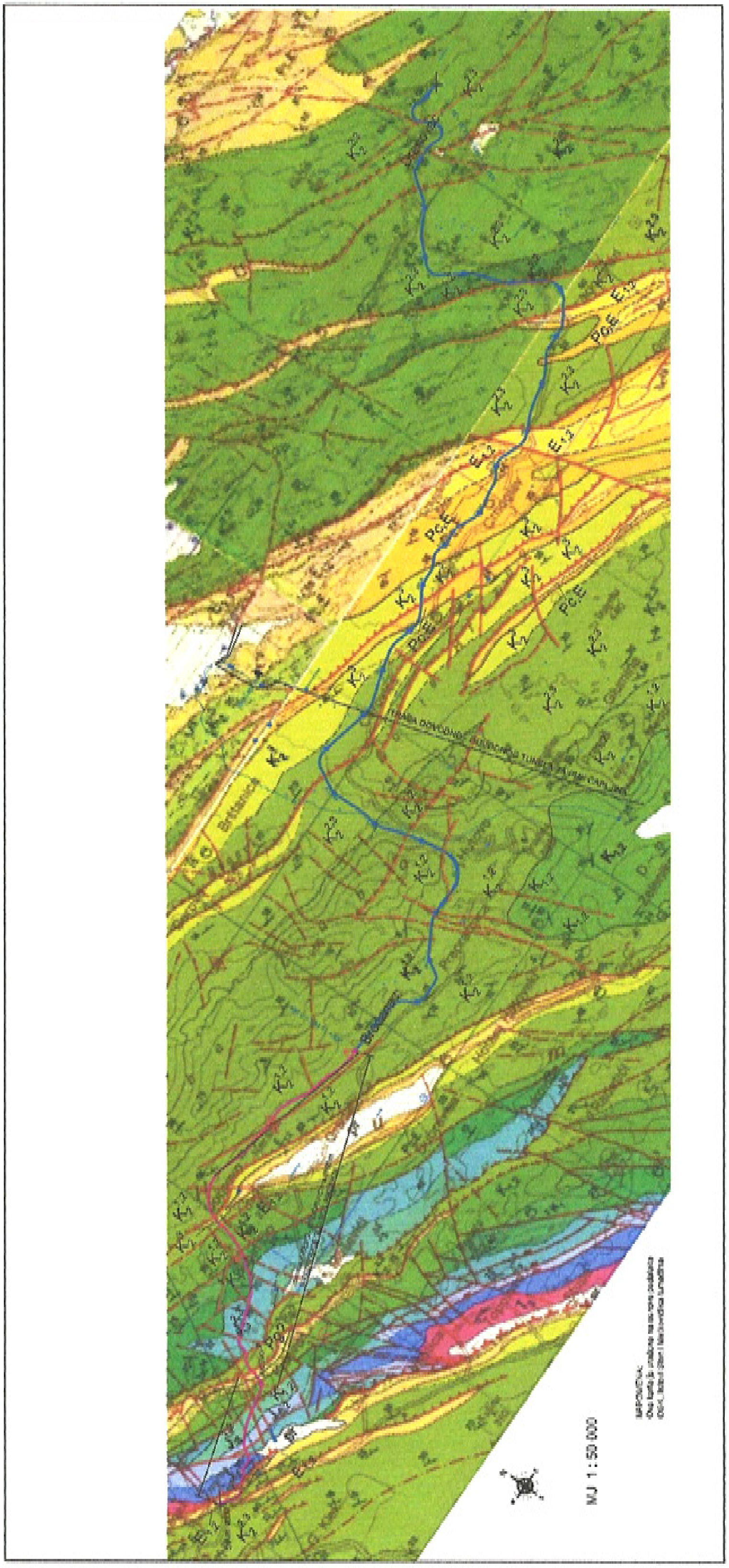

Figure 1. Geologic map 1: 50000. The Main Geologic Map paper Ston and Metković OGK map of SFRJ

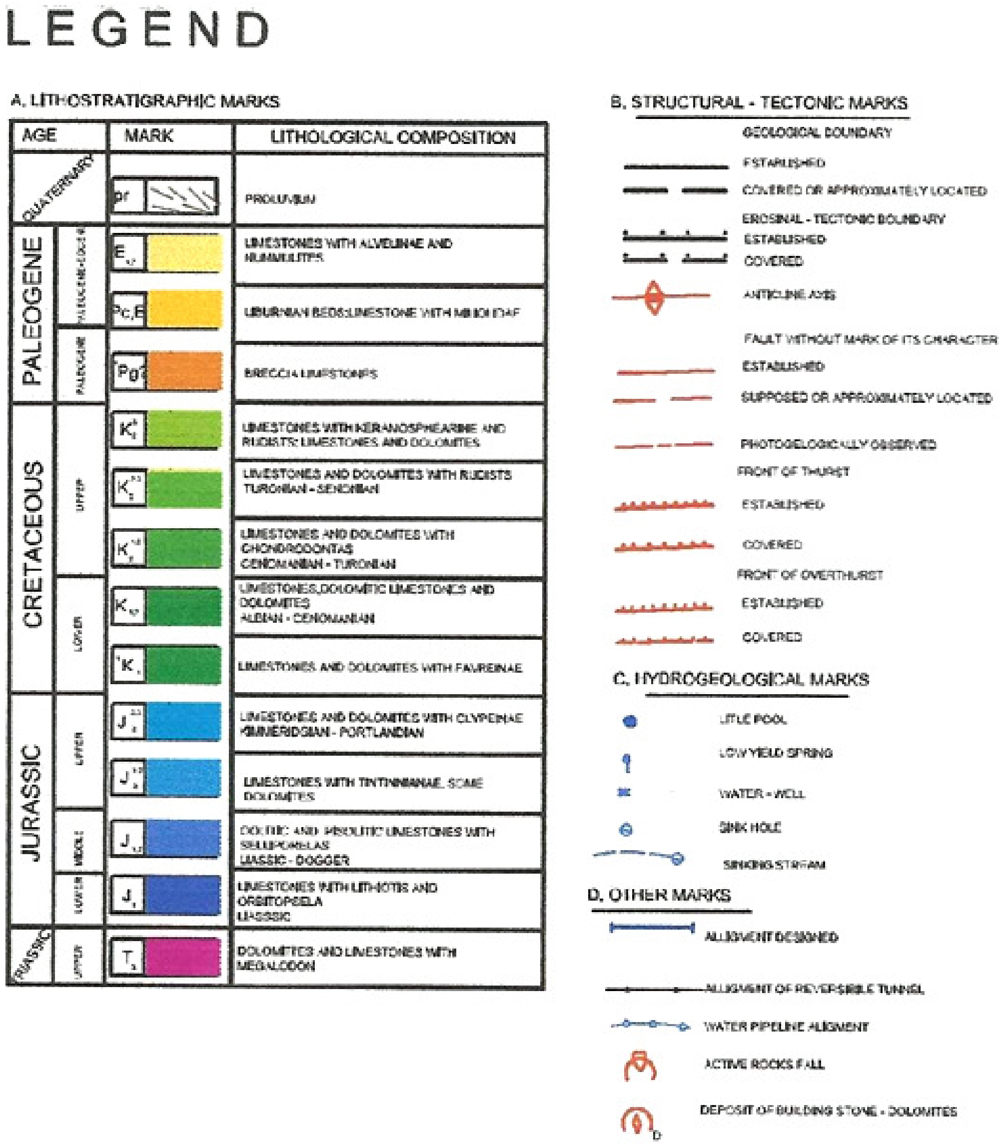

Figure 2. Legend for geologic map 1: 50000

Liburnian limestones (Pc, E) lie discordant comparing to Upper Cretaceous sediments. On the terrain they appear in shapes of wide and narrow belts, piercing beneath alveolus-nummulitid limestones or they are jammed between Cretaceous limestones along the reverse faults. They appear in a wide area of the Crnoglav village and west of the villages of Vinine and Kučinari.

Alveolus-nummulitid limestones ($E_{1,2}$) appear at places where liburnian layers are. Liburnian limestones are darker colour while alveolus-nummulitid ones are lighter, whiter and more crystalline.

Quaternary deposits mainly appear like thin clay-crushed cover, concentrated in valleys and karst sinkholes.

Hydrogeological characteristics of the terrain

According to hydrogeological function, rock masses can be divided into hydrogeological collectors made of limestones, dolomites and dolomite limestones. Limestones are of fracture-kind and cavernous porosity.

On the examined terrain there is no surface inflow, because all the surface waters run fast and they plunge into deeper parts of the terrain. At excavations of hacks, cuttings and tunnels, it is not expected the greater inflow of surface waters which, from the higher parts of slope, mainly plunge into deeper parts of the terrain. At excavation of tunnel, may appear the surface waters which directly plunge, in sense of leaks and drops, through privileged directions of fractures and faults.

In this part of the terrain, more significant hydrogeological appearances are not identified, except small lake situated close to Propratnica and Hutovo. The designed route is situated on hypsometrically higher terrain, so it cannot endanger the existing route.

Engineering geological characteristics of the terrain

In the structure of natural terrain construction there are cohesive and cohesionless rocks:

Cohesive are well-stoned carbonated rocks, where limestones and dolomites of various lithostratigraphic determinations belong to. They spread along the entire route. Those are compact rocks, light grey to light brown colour, thick layered to bank texture and crystalline to cryptocrystalline structure. Tectonically they are broken, block-divided by fracture discontinuities, and very much karstificated.

Layered limestones are situated also in a route of the future tunnel. Excavations such are hacks, cuttings and viaducts according to GN 200 will be performed in the VI category. The tunnel, according to GN 206, and on the base of geological structure belongs to light tunnels. Excavations in the tunnel will be performed in the I and II category.

Physical-mechanical characteristics of the limestone rock massif are presented on the base of geotechnical observations of the identified soil and firm rock masses as well as by usage of experienced data, and they are related to massive, bank, layered limestones, table 1.

Table 1. Physical-mechanical characteristics of the rocks

Solid rock mass	Volumetric weight γ (kN/m^3)	Compression strength σ (MPa)	Inner abrasion altitude (φ)	Cohesion c (MPa)	Bulk modulus E_e (MPa)	Deformity modulus E_d (MPa)	Poissonov koefic. (m)
Massive, bank and layered limestones	26,00	135,00	50	0,4	9 000	7614	0,30
Thin-layered limestones	26,0	92,0	45	0,2	16 000	4500	0,25

In the second part of the route with sub-variants, the route is situated in tectonically broken massif and bank limestones and dolomites. Excavations in this part of the route according to GN 200 will also be performed in the VI category.

The third part of the route is characterised mainly with tectonically broken limestones, monolites and limestone blocks. These layers are usually massive and bank ones. Flat parts of the terrain with karst sinkholes and depressions cover thin clay-crushed covering with limestone crushed . Those are mainly cohesionless rocks. Excavations which pass through these coverings will be performed in the III and IV category, and excavations which will be developed in geological substrate-limestone, will be performed according to GN 200 in V-VI category.

Limestones have good physical-mechanic characteristics and are suitable for the building conditions [5].

- Compression strength in water saturated condition σ = 98, 4-110, 0 MPa
- Volumetric mass γ =2, 65-2, 70 t/m^3

Cohessionless rocks are coverings made of terra rossa mixed with limestone, rare with dolomite crushed and clay fractions. These coverings arouse by processes of limestones physical decomposition and gradually drainage of decomposition products towards local depressions. Thickness of proluvial covering is very changeable what depends on paleorelief of the base over which it is deposited.

In the phase of running the earthworks on the route preparation when backfilling karst sinkholes, there will be necessary previously to remove surface cover of the covering to the depth of 0.5 m.

Excavations in these coverings according to GN 200 belong to the III – IV category.

The basic physical-mechanic parameters are:

- Inner abrasion altitude φ 30^0
- Volumetric weight γ = 20, 00-21, 00 kN/m^3
- Cohesion c= 0 kN/m^2

For this sub-section in the part of the rout bridged by viaduct, it is necessary to emphasize that in the valley side there is the existing water-supply route and hydrotechnic object intake-bend tunnel for PHE Čapljina. This tunnel goes from the Popovo polje, beneath the hills of Treštnica, Gradina in the region of Poljutak, Cerovica village and further in the region of Cerov do, until Mlinsko brdo hill and Svitavsko blato.

Seismicity of the terrain

Defining of seismic hazard has for its aim to provide the necessary information for determination of acceptable seismic hazard of the concerned technical-technology system.

On the base of available seism tectonic data and data from the Seismic map, the wide area of Neum and Stolac belongs to zones of different seismic intensity. On the maps, for different time periods has been shown the intensity of earthquake which probable occurrence at least once in that period amounts 63%, which means that default period is equal to the return period of earthquake.

Wide area of Neum belongs to the zone characterized for earthquakes with intensity 7-9^0 MCS scale. In a wider observed area, the basic degree of seismicity for various return periods on the route Broćanac-Drenovac amounts: 7^0 for return period of 50 years; 8^0 for period of 100, 200, 500 years and 9^0 for 1000 and 10000 years.

In wider surroundings of Neum there are more seism-tectonic blocks with specific movement's mechanism and character. However, on the base of insight in seism-tectonic constitution of this area, can be asserted that the Neum area with its direct hinterland is enhanced with earthquakes mainly from the region of Visoki karst overthrust which follows the coastal belt, with maximum of registered earthquakes of 9^o MCS scale. In this part, along the fault spreading northwest-southeast, which follow the Visoki karst overthrust, there is very actively seismic zone with a great frequency of earthquakes, which especially endangers the coastal belt around Neum and Dubrovnik.

In our valid law regulations, certain buildings are distinctly categorized, so the question is raised on the way of usage of above-mentioned maps and the way of determination of seismic hazard for certain area in function of defined duration of the object's exploitation.

The formula, on the base of which we can determine the return earthquake period "T" i.e. which seismic map and its oleates we can use for a certain duration of the object exploitation "t" (years) and default risk "R_i" (%) is:

$$T = \frac{-t}{\ln(1-R_i)}$$

Thus, for example, by usage of this formula we get that for a period of an object exploitation t = 50 years and risk size R = 10%, it is necessary to use seismic map for return period of 500 years. In these maps the basic seismic degree for wider area of the observed route amounts 8^o MCS.

On the base of literature data, narrower and wider area of Neum and Pelješac belong to seismically active area which is enhanced by earthquakes from own seismic focuses. The strongest earthquake in the area of Ston happened in 1962. It had intensity of 8^0 MCS with magnitude 6, 4 Richter scale and it inflicted great damages in the city itself as well as in the nearby places.

CONCLUSION

On the observed section, geotechnical conditions are quite equable from the aspect of geotechnical issues and constructions. All cuttings and hacks, viaducts and tunnels would be performed in fractured and karstificated massive, bank and thick-layered to thin-layered limestones. Those limestones are tectonically quite broken, and interlayer fractures in surface parts brought to instability of certain parts of the terrain in sense of activation of blocks or their falling outs when cutting. Spatial position of layers is of suitable orientation where stretching is approximately vertical to the route with fall to hill.

In hydrogeological sense, these limestones within the terrain represent hydrogeological collectors of ground waters. In future excavations it is not expected the admission of surface and ground water that would endanger the excavations alone.

Geological, hydrogeological and geotechnical conditions along the route are very favourable. Cuttings, concerning the geological structure, can be with slope inclination 2:1 and even steeper. Material from all the excavations is very favourable as building material and can be used for building of banks and the road body. As aggregate for concrete, recommended is limestone which can be getting from excavations of tunnels and cuttings. The terrain has suffered a big process of karstification so all the waters flow into the ground, which are situated deep beneath a surface of the terrain, mainly in fault zones.

(Received 20. december 2013, accepted 04. january 2014)

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