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GEOTECHNICAL CHARACTERISTICS OF THE TERRAIN AND CALCULATION OF BEARING CAPACITY FOR BRIDGE No. 1 OF MOTORWAY LAŠVA – DONJI VAKUF, SUBSECTION INTERCHANGE LAŠVA – INTERCHANGE KAONIK

Talić Zlatan[1], Ćerimagić Đenari[2]

[1]*Divel d.o.o. Sarajevo, E-mail: zlatan.talic@divel.ba*
[2]*Građevinski fakulet Univerziteta u Sarajevu*

ABSTRACT

The paper present a review of the geotechnical characteristics of the terrain at the location of the bridge No. 1 of motorway Lašva – Donji Vakuf, subsection interchange Lašva – interchange Kaonik.

Also, given the suggestion of foundation structures for each column, as well as the calculated bearing capacity.

Key words: *geotechnical properties of soil, foundation, bearing capacity*

INTRODUCTION

As a base for compilation of this Geotechnical Design we used „Study on engineering – geological and geotechnical characteristics of the terrain, Volume Cig 0013“ (compiled by „Geotehnos“ Ltd. Sarajevo, January 2013) [1].

As a part of geotechnical explorations the following was done [2]:

- geodetic survey and pegging out of drill hole
- exploratory drill
- geological and engineering – geological works
- laboratory testing [3,4]

ENGINEERING – GEOLOGICAL AND GEOTECHNICAL CHARACTERISTICS OF THE TERRAIN AND ROCK

Based on engineering-geological mapping of the terrain and on exploratory drills at the structure location along the expressway route, the following categories are defined:

- Technogenic deposits /1b/
- Alluvial deposits /2b; 2e; 2g/
- Geological substrate /6d/

Technogenic deposits, i.e. deposits spread in roadway structures leading to meadows, are represented by sandy clay crushed material (1b). According to GN 200 that is category II of excavations.

Alluvial deposits include surface blankets of alluvial genetic type:
- pulverulent sandy clay (2b)
- gravel sand (2e)
- muddy sand (2g)

Thickness of alluvial deposits surpasses 6,00 m. According to GN 200 that is category III of excavations.

Geological substrate is represented by:
- meta sandstones (6d)

According to GN 200 that is category IV of excavations.

GEOTECHNICAL MODEL OF THE TERRAIN

Geotechnical model of the terrain consists of:
- cover
- geological substrate

Cover is represented by pulverulent-sandy clay (2b), gravel sand (2e) and muddy sand (2g). Thickness of the blanket ranges from 6,30 m to 9,00 m.

Based on terrain and laboratory exploratory works, as well as on engineering – geological determination, classification of exploratory drill core, the following calculation parameters were determined for pulverulent-sandy clay (2b), gravel sand (2e) and muddy sand (2g):
- deformability module $E_s = 8$ MPa
- volumetric weight $\gamma = 21$ kN/m^3
- angle of internal friction $\varphi = 29°$
- cohesion $c = 11$ kPa

Geological substrate is represented by meta sandstones (6d).

Based on terrain and laboratory exploratory works, as well as on engineering – geological determination and classification of exploratory drill core, the following calculation parameters were determined for materials of geological substrate layer (6d):
- deformability module $E_s = 50$ MPa
- volumetric weight $\gamma = 21$ kN/m^3
- angle of internal friction $\varphi = 32{,}5°$
- cohesion $c = 17$ kPa

Approved values of shear parameters for substrate materials are somewhat lower, i.e. they were approved based on the results of laboratory testing because it is assumed that drilling of piles will degrade the substrate materials in the same scope as the drilling of exploration well dide.

For the same materials somewhat higher value of deformability value was approved from the one reached in the laboratory. This is in accordance with the SPT experiments, as well as with the assumption that the degrading of substrate material by drilling will not significantly impact the scope of settling.

FOUNDATION OF THE CONSTRUCTIONS

Based on terrain and laboratory exploratory works, as well as on engineering – geological determination, classification of exploratory drill core, terrain morphology, heterogeneousness of terrain content and the location of the structures, the method of structures founding is determined.

At the location of the Bridge M-1 the depth up to substrate layer ranges from 6,00 m to 9,00 m. Substrate is made of meta sandstones materials, layer 6d. It is recommended for indirect founding of the structure to be applied, done on perforated piles of ∅ 1200 mm; piles' length from 12,00 m to 18,00 m.

CALCULATION OF BEARING CAPACITY AND SETTLEMENT

The calculation for piles for the bridge M-1 was done using software Geo5. The calculation represents *semi-analytical* approach to determining the required bearing capacity of the pile and the scope of settling, depending on applied external load [5].

The pile is modeled with beam elements; behavior of the surrounding terrain was described in solution based on Winkler-Pasternak model.

The value of shear strain at the contact of pile and surrounding terrain is determined using the assumption of Mohr-Coulomb criteria of elastic- ideal plastic model, while the range of the effective strain is derived from geotechnical strain and pressure caused by the terrain in its inactive state (K_0).

Calculation was done for terrain parameters mentioned in Chapter 3 of this design and for partial safety factors as defined by EuroCod 7, for PP3 [2], i.e. for combination of partial factors for limit values of STR and GEO: A1 + M2 + R3. Loads affecting the structure are multiplied by factors of effects (γ_F) and effect results (γ_E) : γ_G = 1,35 and γ_Q = 1,50.

The factors of material characteristics were approved (γ_M) 1,25 and resistance factor (γ_F) for perforated piles 1,0.

If we presume that 66,67 % of the load comes from permanent (own) weight of the RC structure, and that 33,33 % is variable load we determine that the average partial factor of vertical load onto piles is $\xi_3 = \xi_4$ =1,4 [2,6]. Average partial factor of vertical load onto piles of $\xi_3 = \xi_4$ is approved based on number of exploratory studies at the field, i.e. based on number of exploratory drills at the column location (1 drill per column location).

Bearing capacity of the pile determined by the calculation is divided by resistance factor (γ_F) for drilling piles 1,0and by factor of vertical load onto piles $\xi_3 = \xi_4$ = 1,4.

Construction of the Bridge M-1 consists of two separate structures: left and right bridge. The right structure has five spans 19,00 +3 x 23,00 + 19,00 = 107,00 m. The left structure has five spans 16,00 + 3 x 20,00 + 16,00 = 92,00 m.

Cross section is RC plate like cross section. Main dimensions are: structure height H_{kdesno}=1,20 m, $H_{klijevo}$=1,10 m. Consoles are of 2,50 m span, thickness 40 cm. Construction technology is spanned construction done on scaffold and formwork of RC concrete.

Middle columns of the left structure are founded on 4 piles Ø1200 mm with length of 16,00 m, except for the foundation of the column S2 where piles length is 17,00 m; while the middle columns of the right structure are founded on 4 piles Ø1200 mm with length of 18,00 m. Dimensions of the cap slab are 6,00 x 6,00 m. Thickness of cap slab is 1,50 m.

Abutment S1 of the right structure is founded on 4 piles Ø1200 mm, and abutment S6 is founded on 5 piles Ø1200 mm. Abutments S1 and S6 of the left structure are founded on 4 piles Ø1200 mm. Length of piles at abutments is 14,00 m

Image 1 demonstrate calculation model in software Geo5 for calculation of piles' bearing capacity [5]; and image 2 demonstrate calculation model in software Plaxis for calculation of foundation construction settling, figure 1,2 [7].

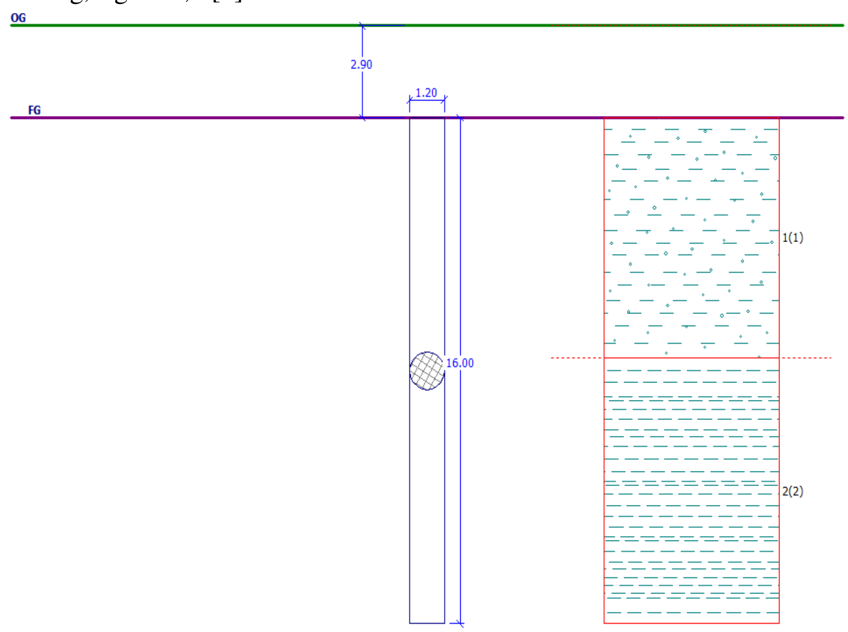

Figure 1 Calculation model of pile for Bridge M-1 in Geo5

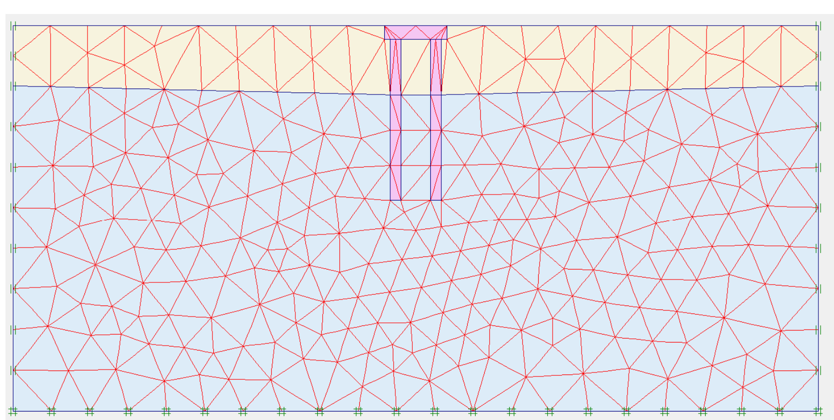

Figure 2 Calculation model of foundation construction for Bridge M-1 in Plaxis

Tables 1 and 2 show the results of calculations related to piles bearing capacity and settling for the left bridge, while tables 3 and 4 show the results of calculations related to piles bearing capacity and settling for the right bridge.

Table 1 Calculation results of ultimate forces for the left bridge

Column location	Pile length (left bridge) (m)	$N_{š,comb12(uls)}$ (kN)	Bearing capacity of the base R_{cd} (kN)	Bearing capacity of envelope R_{cd} (kN)	Bearing capacity of pile R_{cd} (kN)
S1	14	2500	1519	1097	2616
S2	17	3179	1784	1643	3427
S3	16	2770	1590	1309	2899
S4	16	2773	1590	1325	2915
S5	16	2924	1687	1495	3182
S6	14	2500	1585	1115	2700

Table 2 Calculation results of effective forces and settling for left bridge

Column location	Pile length (left bridge) (m)	$N_{š,comb5(sls)}$ (kN)	Settling *s* (mm)
S1	14	2380	12,0
S2	17	3027	11,0
S3	16	2701	8,6
S4	16	2040	5,5
S5	16	2763	5,8
S6	14	2380	12,0

Table 3 Calculation results of ultimate forces for the right bridge

Column location	Pile length (right bridge) (m)	$N_{š,comb12(uls)}$ (kN)	Bearing capacity of the base R_{cd} (kN)	Bearing capacity of envelope R_{cd} (kN)	Bearing capacity of pile R_{cd} (kN)
S1	14	2500	1493	1025	2518
S2	18	3585	1881	1840	3721
S3	18	3333	1784	1708	3492
S4	18	3040	1784	1711	3495
S5	18	3305	1784	1691	3475
S6	14	2500	1493	1068	2561

Table 4 – Calculation results of effective forces and settling for right bridge

Column location	Pile length (right bridge) (m)	$N_{š,comb5(sls)}$ (kN)	Settling *s* (mm)
S1	14	2380	12,0
S2	18	3414	14,7
S3	18	3275	12,6
S4	18	2870	8,6
S5	18	3053	10,7
S6	14	2380	11,0

In tables 1 and 3 the symbol for forces $N_{š,comb12(uls)}$ represents maximal ultimate force affecting one pile (multiplied by all factors), while in tables 2 and 4 the symbol for forces $N_{š,comb5(sls)}$ represents maximal force affecting one pile in exploitation stage.

Next figure 3 showes EG map on location of the bridge No. 1.

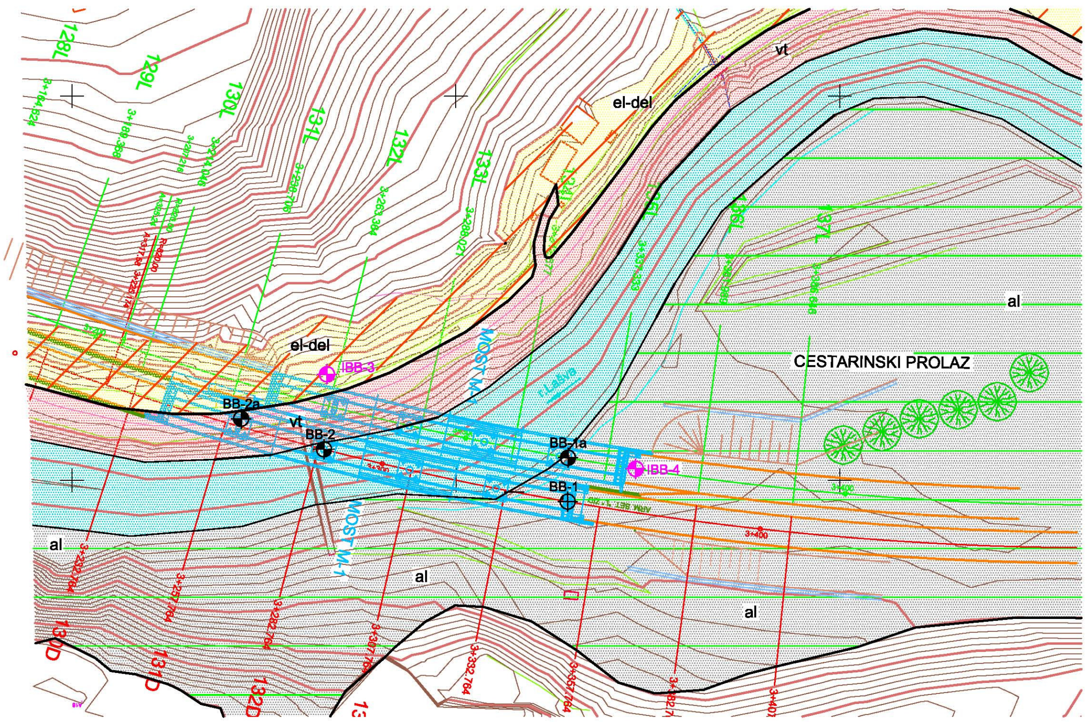

Figure 3 Engineering Geological Map

CONCLUSION

Construction of the Bridge M-1 consists of two separate structures: left and right bridge. The right structure has five spans 19,00 +3 x 23,00 + 19,00 = 107,00 m. The left structure has five spans 16,00 + 3 x 20,00 + 16,00 = 92,00 m.

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Foundations of bridge columns should be done on 4 perforated piles of ∅1200 mm per column location (2 x 2 piles).

Length and number of perforated piles are determined in such a manner conform to the requirements of borderline bearing state, borderline usability state (permitted settling) and to be inserted into materials of layer of geotechnical environment 2 minimally 2-3D [8], i.e. all there must be met.

Level of underground water was detected at the depth of 1,10 m below terrain surface, but during hydrological unfavorable period it could rise.

Design effects (maximal strain) are lower than calculated bearing capacity of the foundation soil.

For said founding conditions and designed loads, settlement of the piles could be expected ranging from 5,0 to 12,6 mm.

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LITERATURE

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