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GEOTECHNICAL CHARACTERISTICS OF THE TERRAIN AND CALCULATION OF BEARING CAPACITY FOR BRIDGE No. 3 OF MOTORWAY TARCIN – KONJIC

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ABSTRACT

In paper is given overview on geotechnical characteristics of the terrain on location of a bridge number 3, on highway Tarcin – Konjic. Complexity of geological structure, in near surface where it consists from sediments of weathering crust to depth of around 30,0 m, as well as in substrate that consists of sediments of clayey debris, determined the way of foundation.

On software package Geo 5 is done a semi-analytical approach for determining the load capacity of the pile and extent of subsidence in relation to given load. Pile is modeled with beam elements where is observed behavior of surrounding terrain according to Winkler-Pasternak modele, and shearing force to the contact of pile and soil are determined based on Mohr-Coulombo criteria. Changeable characteristics on the terrain demanded analysis of every pile for which are given propositions for foundation and allowed load.

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 at the location of the Bridge No. 3“ (compiled by „Geotehnos“ Ltd. Sarajevo, April 2012) [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]

GEOTECHNICAL MODEL OF THE TERRAIN

Geotechnical model of the terrain consists of:

- cover
- geological substrate

Cover is represented by clay sandy crushed material (3a), brown sandy clay (3d), sandy clay (3e), grey sandy clay (3f) and grey muddy sand (3g).

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 clay sandy crushed material (3a), brown sandy clay (3d), sandy clay (3e), grey sandy clay (3f) and grey muddy sand (3g):

- | | |
|------------------------------|------------------------------|
| • deformability module | $E_s = 15 \text{ MPa}$ |
| • volumetric weight | $\gamma = 20 \text{ kN/m}^3$ |
| • angle of internal friction | $\varphi = 25^\circ$ |
| • cohesion | $c = 13 \text{ kPa}$ |

Geological substrate is represented by clay crushed material, by-product of main rock disintegration (4) and marl clay (4f).

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 clay crushed material, by-product of main rock disintegration (4) and marl clay (4f):

- | | |
|------------------------------|--------------------------------|
| • deformability module | $E_s = 22 \text{ MPa}$ |
| • volumetric weight | $\gamma = 21,5 \text{ kN/m}^3$ |
| • angle of internal friction | $\varphi = 29^\circ$ |
| • cohesion | $c = 10 \text{ kPa}$ |

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-3 the depth up to substrate layer ranges from 8,00 m to 30,00 m. Substrate is clay crushed material made by-product of main rock disintegration (4) and marl clay (4f). It is recommended for indirect founding of the structure to be applied, done on drilled piles of $\varnothing 1500 \text{ mm}$; piles' length from 20,00 m to 26,00 m.

CALCULATION OF BEARING CAPACITY AND SETTLEMENT

The calculation for piles for the bridge M-3 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 2 of this design and for partial safety factors as defined by EuroCod 7, for PP2 [2], i.e. for combination of partial factors for limit values of STR and GEO: A1 + M1 + R2. Loads affecting the structure are multiplied by factors of effects (γ_F) and effect results (γ_E) : $\gamma_G = 1,35$ and $\gamma_Q = 1,50$.

The factors of material characteristics were approved (γ_M) 1,00 and resistance factor (γ_F) for perforated piles 1,1.

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 1,1 and by factor of vertical load onto piles $\xi_3 = \xi_4 = 1,4$.

Construction of the Bridge M-3 consists of two separate structures: left and right bridge. The right structure has ten spans $29,25 + 8 \times 39,00 + 29,25 = 370,50$ m. The left structure has nine spans $29,25 + 7 \times 39,00 + 29,25 = 331,50$ m.

Middle columns of the left structure are founded on 6 piles $\varnothing 1500$ mm with length of 25,00 m, except for the foundation of the column S8 where piles length is 26,00 m; while the middle columns of the right structure are founded on 6 piles $\varnothing 1500$ mm with length of 25,00 m. Dimensions of the cap slab are $11,30 \times 6,80$ m. Thickness of cap slab is 2,50 m.

Abutments S1 and S11 of the right structure is founded on 6 piles $\varnothing 1500$ mm. Abutments S1 and S10 of the left structure are founded on 6 piles $\varnothing 1500$ mm. Length of piles at abutments is 20,00 m.

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

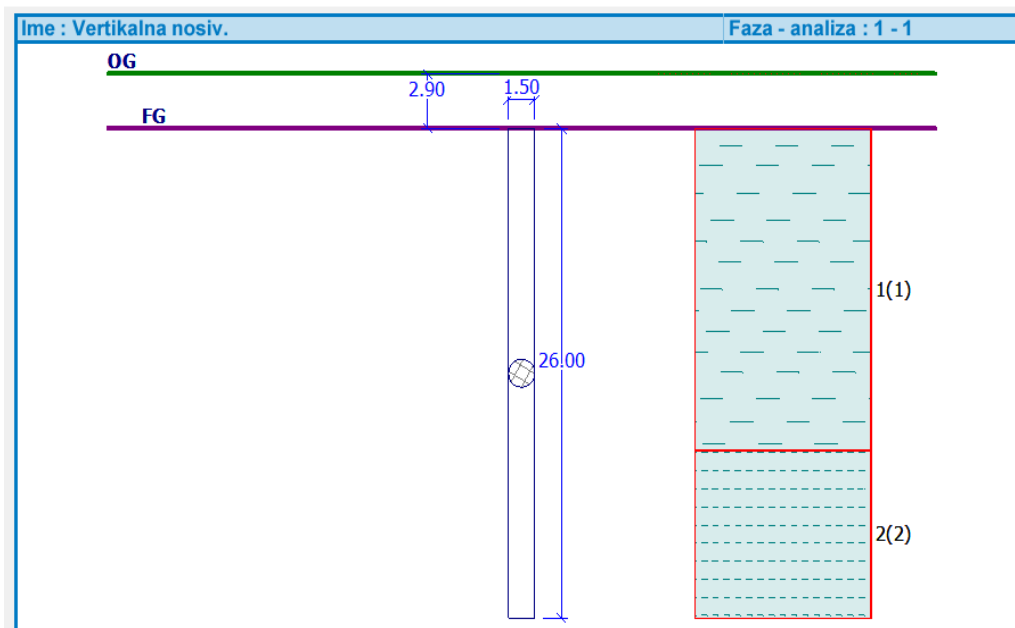


Figure 1 Calculation model of pile for Bridge M-3 in Geo5

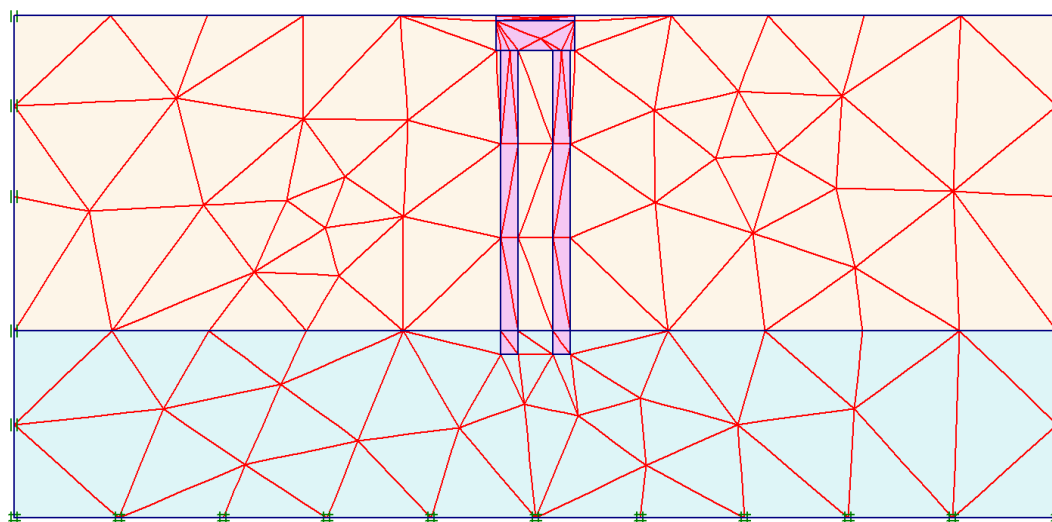


Figure 2 Calculation model of foundation construction for Bridge M-3 in Plaxis

Tables 1 and 2 show the results of calculations related to piles bearing capacity and settling for the left bridge.

Table 1 – Calculation results of ultimate forces for the left bridge

Column location	Pile length (left bridge) (m)	$N_{\xi, \text{comb}12(\text{ults})}$ (kN)	Bearing capacity of pile R_{cd} (kN)
S1	20		7000
S2	25		
S3	25	4816	8800
S4	25	5596	8800
S5	25	5345	8800
S6	25	4940	8800
S7	25	5201	8800
S8	26	5256	9200
S9	25	5001	8800
S10	20		7000

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

Column location	Pile length (left bridge) (m)	$N_{\xi, \text{comb}5(\text{sls})}$ (kN)	Settling s (mm)
S1	20	4000	5
S8	26	4991	11
S10	20	4000	5

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

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

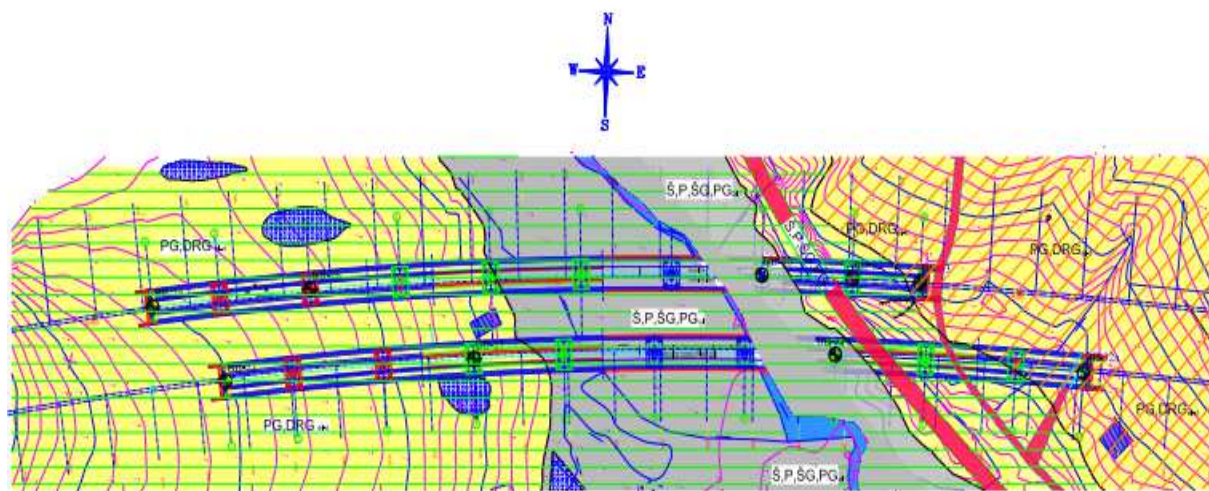


Figure 3 Engineering Geological Map

CONCLUSION

Construction of the Bridge M-1 consists of two separate structures: left and right bridge. The right structure has ten spans $29,25 + 8 \times 39,00 + 29,25 = 370,50$ m. The left structure has nine spans $29,25 + 7 \times 39,00 + 29,25 = 331,50$ m.

Middle columns of the left structure are founded on 6 piles $\text{Ø}1500$ mm with length of 25,00 m, except for the foundation of the column S8 where piles length is 26,00 m; while the middle columns of the right structure are founded on 6 piles $\text{Ø}1500$ mm with length of 25,00 m. Dimensions of the cap slab are $11,30 \times 6,80$ m. Thickness of cap slab is 2,50 m.

Abutments S1 and S11 of the right structure is founded on 6 piles $\text{Ø}1500$ mm. Abutments S1 and S10 of the left structure are founded on 6 piles $\text{Ø}1500$ mm. Length of piles at abutments is 20,00 m.

Foundations of bridge columns should be done on 6 drilled piles of $\text{Ø}1500$ mm per column location (2 x 3 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 geological substrate minimally 2-3D [8], i.e. all there must be met.

Level of underground water was detected at the depth of 1,20 m below terrain surface, but during hydrological unfavorable period it could rise.

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

For said founding conditions and designed loads, settlement of the piles could be expected to settle in the depth range of up to 11,0 mm.

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