R467 REGIONAL ROAD, OLOVO-HAN PIJESAK SECTION ROADBED REPAIR
SANACIJA TRUPA REGIONALNE CESTE R467 DIONICA OLOVO-HAN PIJESAK

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Key words: geotechnical models, retaining structures, variant solutions, parametric analysis, case study, damage, repair

ABSTRACT:

Nowadays, there are different geotechnical software solutions for prediction of retaining structures and soil behavior, with satisfactory accuracy. Given the input parameters based on the quality exploratory work, the software provide a reliable assessment of the causes of certain structural damage to the designers of geotechnical structures, enabling them to choose cost-efficient and reliable technical solutions in remediation or construction of new structures. The potential in conduction of various kinds of researches using adequate numerical models are great, whereby variant solutions and corresponding parametric analysis can be compared. In this paper, the case study has been subjected to necessary analyses and a proposition for the repair of damage on the roadbed has been formulated. This proposition was realized and it has been described in the paper.

Ključne riječi: geotehnički modeli, potporne konstrukcije, varijantna rješenja, parametarske analize, studija slučaja, oštećenja, sanacija

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Danas su nam dostupni različiti softweri iz geotehnike pomoću kojih sa zadovoljavajućom tačnošću možemo prognozirati ponašanje potpornih konstrukcija i tla. Uz ulazne parametre zasnovanih na kvalitetnim istražnim radovima softweri omogućuju projektantima-geotehničkih konstrukcija pouzdanu procjenu uzročnika nastanka određenih oštećenja konstrukcija te da odaberu ekonomična i pouzdana tehnička rješenja na sanaciji ili izgradnji novih. Velike su mogućnosti u provođenju različitih vrsta istraživanja korišćenjem adekvatnih numeričkih modela, uz usporedbu varijantnih rješenja i odgovarajućih parametarskih analiza. U ovom radu na studiji slučaja (case study) provedene su neophodne analize i formuliran prijedlog sanacije oštećenja nastala na trupu saobraćajnice. Taj prijedlog je realiziran i opisan u radu.

1. INTRODUCTION

Nowadays it is inconceivable to solve the complex geotechnical problems without implementing numerical methods and contemporary software packages (Plaxis, Geo slope etc.). With their aid, primarily, various researches on a large number of numerical models – (numerical simulations) can be done, which provides a more realistic knowledge in prediction and solving of specific geotechnical

problems. The theoretical foundations, methods of numerical modeling with the instructions for use are described in the papers [2], [5], [6] and [7].
This paper analyzes roadbed repair of a road, accompanied with the corresponding research conducted on the numerical models, on whose basis the choice of the design solution has been performed. Numerical simulations of the current status and of the proposition of the repair are conducted. The results of the conducted analyses determined the type and the elements of the repair, which is presented in this paper.

2. SURVEYING

After the natural disaster of extreme rainfall in the area of Zeničko-Dobojski canton in 2014, a large number of landslides emerged. In such circumstances, there was a loss of stability of a part of the slope and of the existing road structure of the R 467 regional road, Olovo-Han Pijesak section, at the chainage 1+200, figure 1. For the purpose of obtaining relevant data for the landslide remediation, detailed geodetic surveys, engineering-geological and geomechanical test were conducted, which provided the following data:

- Landslide geometry;
- Engineering-geological composition, condition of the terrain;
- Geomechanical characteristics of the soil in and around the landslide;
- Hydrogeological characteristics.

Figure 1: Photographs from the spot

Figure 2: Photographs from the field – the existing gutter and ground ditch on the uphill side

The surveying revealed that one of the basic causes for instability of the slope is the impact of the uncontrolled influx of surface waters flowing in from the hill side, down the road. There was a partial or complete congestion of the existing drainage system (asphalt gutter, ground ditch and concrete pipe culvert, figure 2) which led to the ground water level surge, and to increasing pressures and loads on the road and embankment structure. In such cases, the characteristics of the clayey materials in the road base, slopes of the embankment and the contact layer with the substrate. The consequence of that is probably the emergence of land sliding on the downhill side of the road and the loss of structural stability with considerable damage of the existing culvert and outlet structure, figure 3. On the uphill side of the road, no land deformation was observed. A temporary repair was an intervention comprising filling in using the stone material.

The causes of occurrence of landslides essentially boil down to:

- Hydrological and hydrogeological: uncontrolled influx and infiltration of surface waters into the slope and embankment;
- Irregular influx and flow of ground waters above an water-impermeable layer;
- Geological and geomechanical structure of the slope composed prevalently of the clayey soil;
- Human factors: lack of maintenance of the drainage system.

Figure 3: Field photographs–the existing culvert and outlet structure on the downhill side

Figure 4: Exploratory excavations

Table 1. Geomechanical characteristics of the soil - taken from [8]

No.	Layer	Type	γ_{unstat}	γ_{sat}	E_{50}^{ref}	c_{ref}	Φ	ν_{ur}
			$[kN/m^3]$	$[kN/m^3]$	$[kN/m^2]$	$[kN/m^2]$	^{o}	-
1	Embankment	Drained	20	21	30000	0	20	0,3
2	Alluvial sand and gravel	Drained	19	20	15000	5	20	0,3
3	Substrate	Drained	25	25	130000	47	57	0,3

For the purpose of establishing engineering-geological conditions on the spot and of geomechanical properties of soil, two exploratory bores were made, figure 4. The exploratory works at the depth of 4.5-6.0m revealed the marlstone. During the exploratory works, no groundwater was encountered, [8]. Based on the previously described engineering-geological terrain characteristics and on the comparison of laboratory results conducted during these researches, comparison and experience with the similar materials, a geotechnical profile of the terrain with the calculation parameters is adopted, figure 5. The parameters of physical-mechanical characteristics of the rock mass are obtained using the Hoek-Brown criterion of intact rock strength, [8].

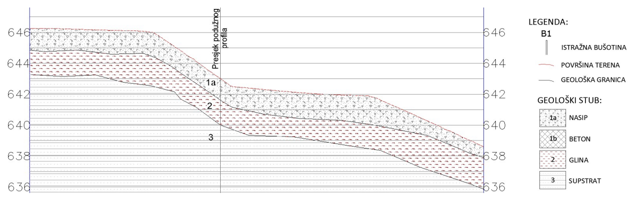


Figure 5: Engineering-geological terrain profile, [8]

After a thorough analysis of the abovementioned factors, conducted calculations and simulations on the numerical models, a repair model was proposed – a "L" shaped retaining wall, founded directly on the buttresses (concrete elements, resting on the substrate). Such a repair system is adequate, especially on the terrains where the load-bearing soil is at a greater depth, which is characteristic of this case [9].

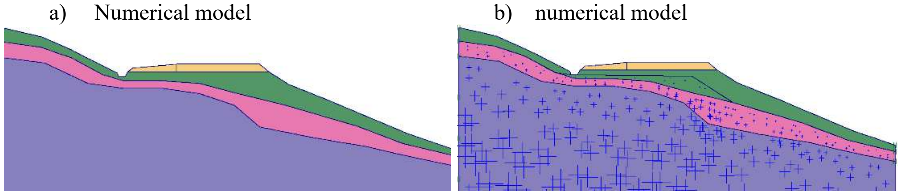
3. NUMERICAL MODELS

Modeling in geotechnics includes simulation of the existing state of stress and strain and calculation of the newly formed one. The numerical model is created in the Plaxis software package, and it consists of the soil elements, static conditions of external load, and boundary conditions. The reinforced-concrete (RC) "L" – shaped wall is modeled as a "plate" element. The behavior of materials/layers of soil is described by the elastic-ideally plastic Mohr-Coulomb soil model, while the concrete elements are described with a linear-elastic model, [4]. Triangular elements with 15 nodes are adopted. The finite elements mesh density is higher at the locations of the expected stress concentration, and in the other areas, the mesh density is lower. The chosen model geometry: height 15 m, width 35 m. Traffic load 20 kN/m^2. T contact between the concrete elements and the soil is modeled using the contact "interface" elements, [1], [2], [3], [5], [6], and [7].

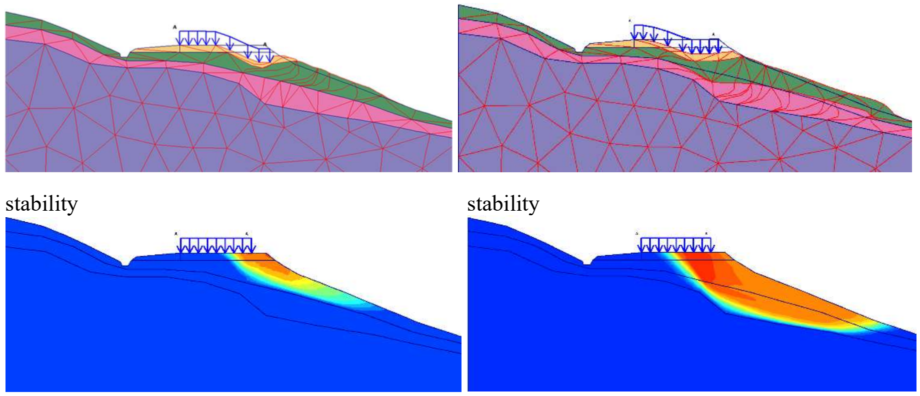
3.1. Numerical model of the current status

After making of the numerical model, an initial calculation of the current status is performed. Considering the obtained safety factor, it is concluded that the existing structure is stable in the drained conditions, figure 6, a). Let us mention that after the exploratory works it was assumed that the cause of landslide occurrence is the uncontrolled influx of water into the roadbed. When in the numerical model the action of ground water is simulated, it causes the reduction of the safety factor and the loss of stability of the existing structure, F_S, undrained=0.984, which confirms the assumption, figure 6, b).

a) Numerical model b) numerical model



strain strain



F_S,drained=1.082 F_S,undrained=0.984

Figure 6: Numerical models – current status a) drained, b) after water action

3.2. Numerical model – repair proposal

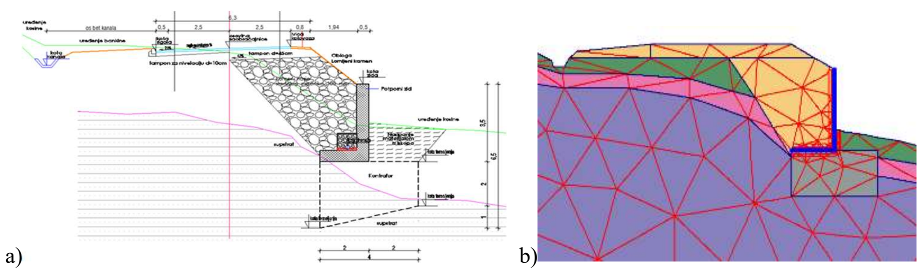


Figure 7: a) Proposed repair model – cross-section b) numerical model

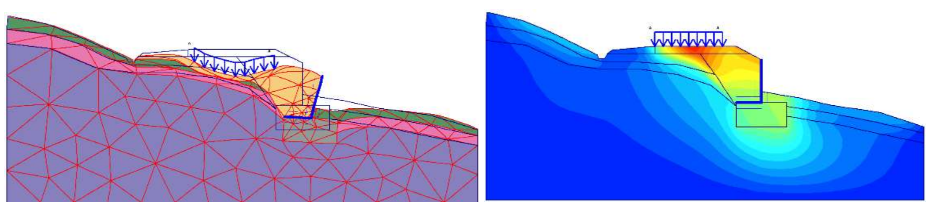


Figure 8: Numerical model: a) strain b) F_S=1,287

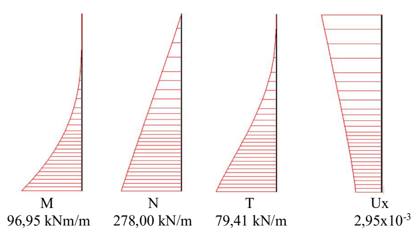


Figure 9: Static effects in the RC wall

4. PROPOSED REPAIR MODEL

The conducted numerical simulations on the models, along with the established facts and adopted assumptions, conditioned the selection of the road structure repair model.
The adopted dimensions of the retaining structure (buttresses and “L” wall) are provided in figure 7-a. Buttresses are constructed at the mutual axial distance of 6.0m and they can be also constructed with an inclined foundation footing which is anchored in the substrate. The excavation depth for buttresses must have a minimum of 30cm in the substrate. Construction of a drainage system is obligatory [9].
Regarding that it is an important geotechnical structure, it is necessary to perform the monitoring of its spatial displacement in time (vertical and horizontal) whereby an initial “benchmark” surveying after the completed structural repair is compulsory.

5. CONCLUDING REMARKS AND CONCLUSION

On the occasion of designing complex geotechnical structures, implementation of software packages, numerical calculation methods and contemporary soil models, is nowadays, indispensable. It enables the designers of geotechnical structures to have a view of the actual state of stress and strain in the soil immediately next to and around a retaining structure, which contributes to selecting cost-efficient and reliable technical solutions of the repair. The designers are recommended to pay a special attention to an analysis of the current status and to determining the potential causes of instability. It is necessary to include them, in an adequate manner, to the numerical model of the current state. The simulation of the new state may provide the guidelines for the repair model.
The results are analyzed form the aspect of safety coefficients, characteristic sliding planes and by comparing the strained models. The comparison is performed for the : initial state – drained soil; initial state – undrained soil and for the proposed repair model. Simulation in the numerical model confirmed the assumption of the cause of loss of stability of the existing structure. From that, implementation and limitation of the proposed repair model can be analyzed. The proposed model may serve as an example for solving of similar cases in practice.
It can be that the offered model is rational and very economical.
The proposed repair measures will considerably increase the secondary slope and roadbed stability. It is recommended to perform regular monitoring to detect potential displacem. of the wall or of its parts.

6. REFERENCES

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