CETRA[2014]

3[rd] International Conference on Road and Rail Infrastructure
28–30 April 2014, Split, Croatia

Road and Rail Infrastructure III

Stjepan Lakušić – EDITOR

Organizer
University of Zagreb
Faculty of Civil Engineering
Department of Transportation

CETRA[2014]
3rd International Conference on Road and Rail Infrastructure
28–30 April 2014, Split, Croatia

TITLE
Road and Rail Infrastructure III, Proceedings of the Conference CETRA 2014

EDITED BY
Stjepan Lakušić

ISSN
1848-9850

PUBLISHED BY
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Kačićeva 26, 10000 Zagreb, Croatia

DESIGN, LAYOUT & COVER PAGE
minimum d.o.o.
Marko Uremović · Matej Korlaet

PRINTED IN ZAGREB, CROATIA BY
"Tiskara Zelina", April 2014

COPIES
400

Zagreb, April 2014.

Proceedings of the
3rd International Conference on Road and Rail Infrastructures – CETRA 2014
28–30 April 2014, Split, Croatia

Road and Rail Infrastructure III

EDITOR
Stjepan Lakušić
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Zagreb, Croatia

ORGANISATION

CHAIRMEN

Prof. Stjepan Lakušić, University of Zagreb, Faculty of Civil Engineering
Prof. Željko Korlaet, University of Zagreb, Faculty of Civil Engineering

ORGANIZING COMMITTEE

Prof. Stjepan Lakušić
Prof. Željko Korlaet
Prof. Vesna Dragčević
Prof. Tatjana Rukavina
Assist. Prof. Ivica Stančerić
dr. Maja Ahac
Ivo Haladin
dr. Saša Ahac
Josipa Domitrović
Tamara Džambas

All members of CETRA 2014 Conference Organizing Committee are professors and assistants of the Department of Transportation, Faculty of Civil Engineering at University of Zagreb.

INTERNATIONAL ACADEMIC SCIENTIFIC COMMITTEE

Prof. Vesna Dragčević, University of Zagreb
Prof. Isfendiyar Egeli, Izmir Institute of Technology
Prof. Rudolf Eger, RheinMain University
Prof. Ešref Gačanin, Univeristy of Sarajevo
Prof. Nenad Gucunski, Rutgers University
Prof. Libor Izvolt, University of Zilina
Prof. Lajos Kisgyörgy, Budapest University of Technology and Economics
Prof. Željko Korlaet, University of Zagreb
Prof. Zoran Krakutovski, University of Skopje
Prof. Stjepan Lakušić, University of Zagreb
Prof. Dirk Lauwers, Ghent University
Prof. Zili Li, Delft University of Technology
Prof. Janusz Madejski, Silesian University of Technology
Prof. Goran Mladenović, University of Belgrade
Prof. Otto Plašek, Brno University of Technology
Prof. Vassilios A. Profillidis, Democritus University of Thrace
Prof. Carmen Racanel, Technical University of Civil Engineering Bucharest
Prof. Tatjana Rukavina, University of Zagreb
Prof. Andreas Schoebel, Vienna University of Technology
Prof. Mirjana Tomičić-Torlaković, University of Belgrade
Prof. Audrius Vaitkus, Vilnius Gediminas Technical University
Prof. Nencho Nenov, University of Transport in Sofia
Prof. Marijan Žura, University of Ljubljana

CETRA 2014 28–30 April 2014, Split, Croatia
3rd International Conference on Road and Rail Infrastructure

SLOPE REMEDIATION METHODOLOGY ON THE ZAGREB-MACELJ HIGHWAY

Goran Grget[1], Katarina Ravnjak[1], Mladen Krpan[2]
1 Geokon-Zagreb, Zagreb, Croatia
2 Autocesta Zagreb-Macelj, Lepajci, Croatia

Abstract

This paper describes methodology used in slope maintenance in cut area on 18.5 km Krapina – Macelj section of Zagreb-Macelj motorway. Based on geotechnical investigations 15 cut locations were treated in main design and for another 15 locations detailed design is made. After motorway opening annual monitoring program was conducted. Program included measurement interpretation, visual observation of slopes and periodical reports. Report contained description of observed slope instabilities and defects and proposed one-time and periodical maintenance measures. The report conclusions initiated slopes remediation. This paper show 2 cut locations, Gornji Macelj 4 and Straža-jug. After defect detection detailed visual observation was done and crackmeters were installed. Based on displacement measurements and defect description back-analysis of slope stability was conducted. The result of analysis was remedial measures on slope protection system. Adaptation of slope stability protection within periodical maintenance allows on time detection of potential high risk situation, damage prevention and the use of optimal remediation measures.

1 Introduction

This paper describes design methodology and implementation of rock slope protection and stability measures on the Zagreb-Macelj motorway. Final slope protection is based on investigation works, local site experience, measurements and monitoring during construction and exploatation. The A2, Zagreb-Macelj, motorway is part of the Croatian motorway network and Pan-European Corridor Xa. It is part of Pyhrn motorway (Nürnberg–Graz–Maribor–Zagreb), which connects Croatian and European motorway networks. This paper describes the design solutions, slope excavation and exploatation phase for two locations: Straža Jug and Gornji Macelj 4, and also slope protection modifications based on the monitoring results.

2 Slope stabilization system

Straža Jug slope location is built of a limestone and a tuffaceous dolomite. These deposits are massive. Limestone is crystalline with dark gray-brown color and intersected with veins of calcite. Upper 4.0 – 5.0 m is an overlying clay layer with fragments of base rock material. Cut has four floors, each 10 m high with 4 m wide bench between them. Slope inclination of each floor is 2:1. On the lowest slope clogged perforated pipes were installed at 2.0 x 2.0 m grid. Slope was protected with shotcrete and the anchors. On the northern edge of the cut slope inclination mitigates from 2:1 to 1:1.5 and fits with the natural terrain outside the highway fence. Toe of the first floor slope finished on the embankment around the bridge abutment. Because of that the slope protection was freely hanging on that part of the slope.

Gornji Macelj 4 slope location is built of mostly a fine-grained sandstone covered with a weathering rind, 1.0-5.0 m thick. An overlying crust consists of clayey sand with fragments of base rock material. Crust thickness is about 3.0 – 4.0 m. Figure 1 presents the slope during excavation. There is a visible boundary between the weathering rind and the sandstone bedrock. During the exploatation, the cracks in concrete revealed locations with the thicker weathering rind. Upper crust had displacement on the contact with the bedrock.

Figure 1 Gornji Macelj 4 cut during construction.

Gornji Macelj 4 cut has one bench. The first, lower slope was excavated in the 2:1 slope and protected with shotcrete and the anchors. Southern part of the slope was mitigated and covered with stone concrete wall. Anchors were placed in two rows at 3.0 x 3.0 m grid. In the upper row 6.0 m long and 3.0 m long in lower row IBO self-drilling anchors were installed. Between anchors clogged perforated pipes were installed for drainage. At the peripheral areas of first slope floor MacMat with anchors was installed. The second, upper slope has 1:1 inclination and was protected with MacMat and 6.0 m long anchors. In the highest cross-section second floor has 4 anchor rows. Between the two slope floors there is 4.0 m wide bench with the drainage ditch with concrete lining.

3 Monitoring and slope remediation

Main design has prescribed periodical monitoring of motorway by geotechnical designer and the motorway maintenance service. Design demanded monitoring during exploatation and to the inception reports. In the inception report defects were detected and quantified and also remediation measures were estimated with their priority order. Based on the report, the Investor ordered additional displacement measurement and detailed remediation design. On Straža Jug location during the visual observation the cracks in the shotcrete were detected on the northern part of the cut. It is peripheral part of the cut were slope changes inclination from 2:1 to 1:1.5. Crack was detected on the slope about 8.3 m from the beginning of the bridge. It was a vertical crack formed in the full height of the first slope floor. Crack width extended from 1.0 cm at slope toe to 5.0 cm at 10 m height. In period from autumn 2010 till spring 2011 crack displacement measurements were conducted. Measurements showed that crack was spreading and developing new cracks. This damage progression formed unstable blocks of shotcrete in size of a few square meters with potential risk for the motorway traffic. Defects were detected on the peripheral part of cut and eroded material from upper slope was deposited on the first bench. Also some material was carried out with water underneath of shotcrete in slope toe. Shotcrete has lost its slope protection function and was covering slope sliding like a mask. Monitoring results didn't find global stability problem, but local surface erosion and a problem of contact between slope and shotcrete was confirmed. At the end of the winter period displacement progress decreased. Decision to start with the remediation measures was made because of the threat of shotcrete blocks to fall down on the motorway.

Figure 2 Defects and crack on Straža jug cut

Visual observation at Gornji Macelj 4 cut detected crack on the contact of concrete stone wall and shotcrete. During 2010 crackmeters were installed and displacements on the cracks were measured. Crack was continuing from the lower slope to the first bench and extended parallel to the motorway (Figure 3). Crack width was from 1.0 cm at the bench to 10.0 cm at the slope toe. At the slope toe soil material was flushed out through the crack. It happened because the large amount of water was drained from the slope in this zone. Wet stain on the slope surface was visible and increasing (Figure 3).

Figure 3 Gornji Macelj 4 – installed crackmeter and vertical crack on the slope

Measurement and detailed visual observation determined that bench had 1.0 cm settlement on the side towards the motorway. Figure 3 shows installed crackemeter for measuring displacement on the crack at the contact of two types of slope protection. The crack was expending and a measurement on installed crackmeters showed that slope with shotcrete protection was moving towards the motorway. This part of the slope had more than 5 mm displacement. Measured displacements and affected slope area indicated that defect was seriously impacting the road safety. The result of the monitoring was the decision to start slope remediation.

4 Mitigation and remediation

Interactive geotechnical design approach [1] prescribes monitoring in design and it is integral part of design process. Regular observation and monitoring during exploatation enabled prompt defect detection and effective remediation. Through interactive geotechnical design slope protection was modified during construction based on the monitoring. Visual observation and measurements gave data about actual material behaviour and the slope protection measures. Local and global instabilities occurred along the motorway section at the beginning of the slope excavation and also during the exploatation. On some parts during design some modifications of solutions were predicted [2]. Additional geotechnical investigations with engineering-geological mapping of excavated slopes and geotechnical measurements were performed on critical locations. For these detected instabilities and with the results of additional investigation works numerical analyses were conducted and new protection measures were applied. Since this two described locations were spotted by applying monitoring system, the idea was developed to analyse mitigation of impact on traffic safety, people and property. Mitigation of slope impact on people and property safety is presented by 4 measures [3] and described in Figure 4. First measure is “Altering”. On the slope this measure can be achieved by peripheral channels for collecting rainwater and with the drainage. Next measure is “Averting” and uses constructions like retaining walls or rockfall protection barriers for redirecting the impact and for people protection. Third mitigation measure is “Adapting”. Adapting is used when risk is pre-identified and solution can be modified and upgraded to protect people and property. Last measure, “Avoiding”, is applied in a way to prevent or to limit the access to the risk area and to avoid or to limit construction. This measure is suitable in the conceptual design phase and through the design phase. In described case when defect occurred in exploatation, one of first three measures can be used. For remediation of cuts Gornji Macelj 4 and Straža jug optimal remediation measure was “Adapting”. Existing slope protection solutions were used, but differences observed during monitoring were analysed and final protection measures were adapted accordingly.

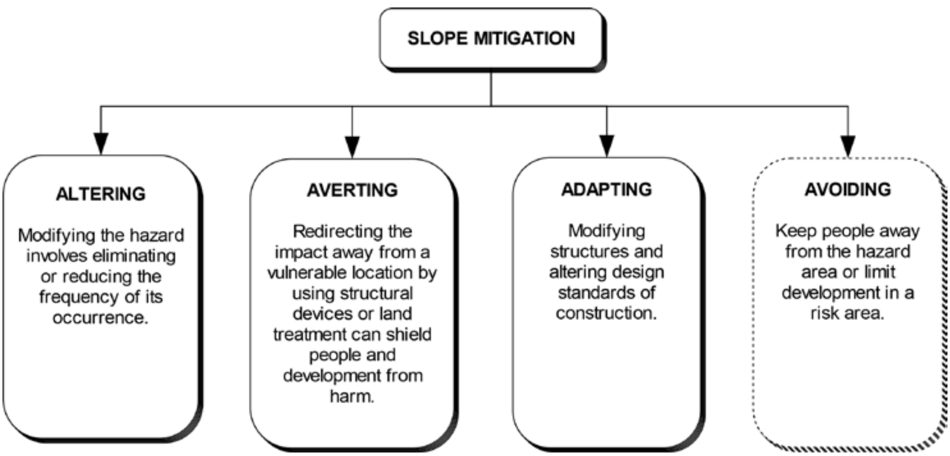

Figure 4 Slope mitigation

At Straža jug cut first was removed cracked shotcrete and eroded material from the slope. In slope toe trench was excavated to the solid ground for the concrete foundation beam which supports renewed slope protection. Four rows of IBO anchors were installed at an angle of 15 ° from the horizontal and at 3.0x3.0 m grid. In upper two rows anchors with a length of 6.0 m and 3.0 m in a lower two rows were installed. The whole slope surface prepared for remediation was covered with 10 cm thick shotcrete reinforced with steel fabric mesh. Existing clogged perforated pipes were protected with geotextile during shotcreting.

At Gornji Macelj 4 cut remediation covered 5 m of stone concrete wall for overlaping and through all area underneath a horizontal crack on the top of the first slope floor. Figure 5 presents a typical cross-section of slope remediation. 4 new rows of IBO anchors were installed at an angle of 15° from the horizontal and generally at grid 3.0 × 3.0 m. In upper two rows are installed anchor with a length of 9.0 m and 6.0 m in a lower two rows. The whole slope surface prepared for remediation was covered with 5 cm thick shotcrete reinforced with steel fabric mesh. Existing clogged perforated pipes were kept and protected during shotcreting and few extra were installed on places with detected water leaking.

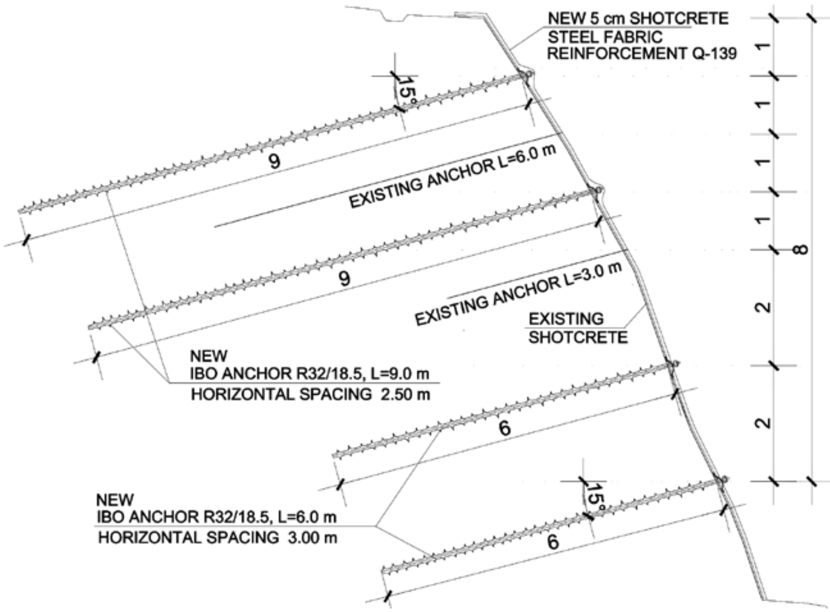

Figure 5 Typical cross-section of slope remediation at cut Gornji Macelj 4

5 Conclusion

This paper shows slope maintenance methodology at the Zagreb-Macelj motorway based on the interactive design approach. This methodology is suitable for linear structures, which in design phase are never ideally investigated and enables investor to seek for economically optimal solutions. The main design analyses the least favourable locations and provides clear guidelines for the construction phase and later exploatation. Continuous monitoring enables modification of solution and system optimization. This approach has benefit in economically favourable and faster construction, but demands planned and continuous maintenance and puts higher pressure on the designer. The final contribution for the user is constant level of safety for the structure, people and property achieved through continuous monitoring and remediation of weakened zones.

References

[1] Kovačević, M.S.: The observational Method and the Use of Geotechnical Measurements. In Proc. 13th Europ. Conf. on Soil Mech. and Geotech. Eng.; 2003; Prague. pp. 575-582.

[2] Humphries, R., Lister, D., Schlotfeldt, P.: Slope Redesign and Slope Remediation during Design/Build Construction at Kicking Horse Canyon– Phase 2. In Annual Conference of the Transportation Association of Canada ; 2009; Vancouver, British Columbia.

[3] Litz, T.: ESS315 Slope Remediation.; 2010 [cited 2010 March 05. Available from: http://faculty.washington.edu/tswanson/ESS/315/Student%20PP%20Presentations/sloperemediation.ppt.