UNDERGROUND MINING ENGINEERING 22 (2013) 49-61 UDK 62
FACULTY OF MINING AND GEOLOGY, BELGRADE YU ISSN 03542904

Professional paper

OPEN-PIT "FILIJALA" NORTHWEST SLOPE STABILIZATION IN ORDER TO REDUCE DAMAGE RISK AND ENVIROMENTAL PROTECTION

SANACIJA SEVEROZAPADNE KOSINE PK „FILIJALA“ U CILJU SMANJENJA RIZIKA ŠIRENJA OŠTEĆENJA I ZAŠTITE OKOLINE

Čebašek Vladimir[1], Gojković Nebojša[1]

Abstract: The development of the marl exploitation in the open pit "Filijala" caused the instability appearance in northwest final slope area. The location of this part of the mine in relation to surrounding objects demanded stabilization of the slope in order to prevent further spread of damage. For these purposes, a detailed analysis of the current state of slope stability were carried out, which used as a basis for determining appropriate stabilization measures for the slope.

Key words: slope stability, stabilization, risk

Apstrakt: Razvojem radova na eksploataciji laporca na površinskom kopu "Filijala" došlo je do pojava nestabilosti u zoni severozapadne završne kosine. Položaj ovog dela kopa u odnosu na okolne objekte su zahtevali sanaciju ove kosine u cilju sprečavanja daljeg širenja oštećenja. Za ove potrebe izvršene su detaljne analize stabilnosti trenutnog stanja kosine, koja su predstavljale osnovu za određivanje odgovarajućijh mera za sanaciju kosine.

Ključne reči: stabilnost kosina, sanacija, rizik

1. INTRODUCTION

The cement marl deposit near Beočin is known as the "Filijala" since 1838. Exploitation of marl, as raw materials for cement production in cement factory is being done since way back in 1860. Marl deposit "Filijala" is divided into three exploitation area "Severno polje", "Među polje" and "Južno polje". This deposit is located in the zone of village called Beočin selo from which it is about 1 km away and in the vicinity of the cement factory Lafarge BFC, from which it is about 2.5 km away "by air" and about 4 km away by asphalt road. From the Beočin it is located about 1.5 km away (Figure 1). The "Filijala" marl deposit covers the area of 792,563 m^2.

[1] University of Belgrade, Faculty of Mining and Geology, Đušina 7, 11000 Belgrade, Serbia,
e-mail: vcebasek@rgf.bg.ac.rs; ngojkovic@rgf.bg.ac.rs

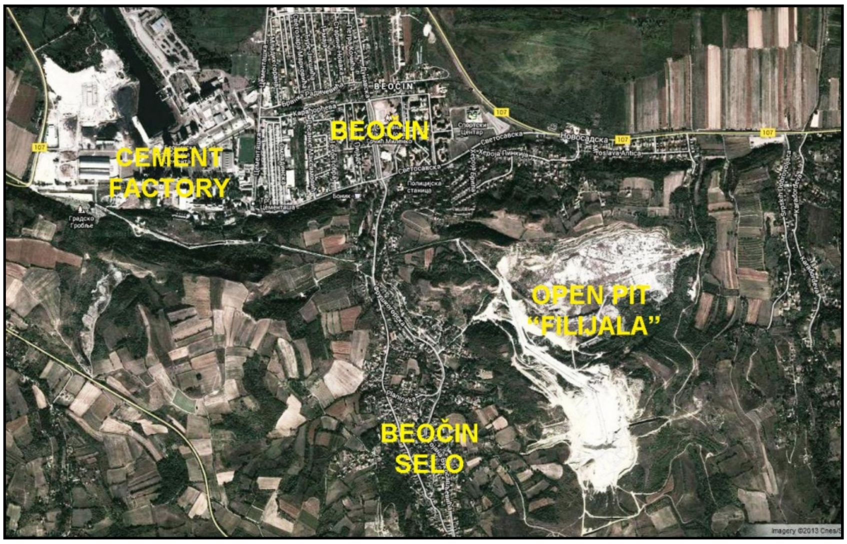

Figure 1 - The geographical position of marl deposits "Filijala"

Today, the exploitation process at open pit "Filijala" is carried out by the continuous technology, using bucket wheel excavator, which requires excavation front layout as long as possible without significant changes in route directions, in order to minimize the belt conveyor transfer. Due to deposit conditions, especially for the quality of marl, the continuous technology can not be applied exclusively, but the discontinuous exploitation technology is also used. Discontinuous technology is designed for excavating parts of deposits that can not be excavated by the bucket wheel excavator, as well as the simultaneous mining with both technologies to homogenize excavated marl quality.

2. SLOPE INSTABILITY APPEARRANCE

Figure 2 - Direction (—)of appearance of northwestern final slope instability

Figure 3 - Marl complex deformations - movements at floor of the open pit (elevation 120)

Instability of the northwestern slope was observed with progress of work on the excavation of marl in the open pit "Filijala". In the field these changes are manifested in deformations - marl complex movements at the bottom of the open-pit at a level of 120 m in this zone, Figures 2 and 3. Open pit mine in this area has come to its exploitation boundaries in the plan, while it was scheduled in the vertical to reach the altitude 80 m.

In the specified area of the open pit a geological heritage was recorded, with the best development of Pannonian period (Figure 4). For the above reasons, the Institute for Nature Conservation of Serbia passed a decision in which the northwestern part of deposit "Filijala" in mining area "Severno polje" with area of 24,720 m^2 in was excluded.

Figure 4 - Part od marle deposti "Filijala" with the best development of Pannonian period (geological heritage)

Figure 5 - Open pit "Filijala" slope appearnce with the best development of Pannonian period (geological heritage)

This paper aims to present a procedure for stabilization of the unstable northwest slope of the open pit by taking into account the position of the excluded part of the deposit (geological heritage) and the proximity of the village. Stabilization of unstable slopes is carried out in order to reduce the risk of spreading the damage (deformation) and thus protect the nearby and wider area of the open pit "Filijala" and provide continuation of exploitation process.

3. RESEARCH FOR SLOPE STABILIZATION

The analysis of existing technical documentation for "Filijala" marl deposit determined that on the basis of available geomechnical data it is not possible to verify stability of the northern part of the open pit (Figure 6). For these reasons, additional research was conducted in order to determine detailed geological structure of this part of the deposit, and to supplement the necessary geotechnical data of the characteristical lithological units. This research covers the drilling of five exploration boreholes, which are shown in Table 1, detailed geological and geomechanical mapping of core drilling was carried out, hydrogeological testing, sampling and geomechnical laboratory testing (Gojković and Čebašek, 2007a).

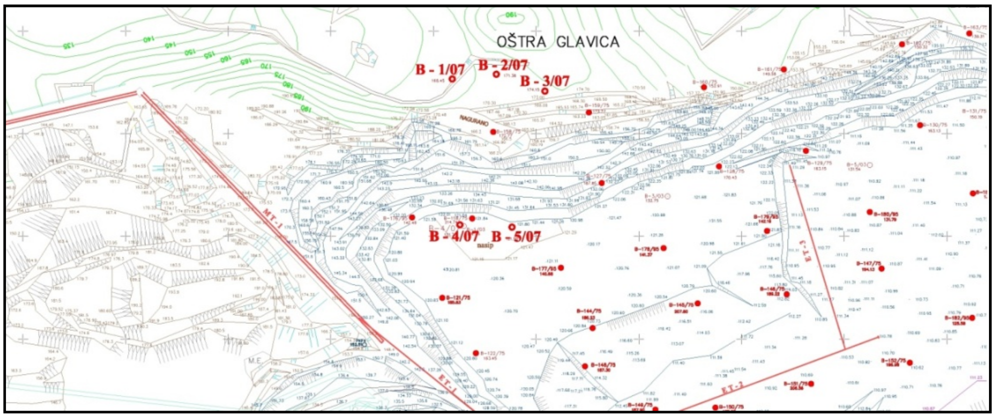

Figure 6 - North slope of open pit "Filijala" in which area additional research and slope stability analyses were conducted

Table 1 - Overview of exploration boreholes in the area North slope of open pit "Filijala"

Borehole	Borehole depth	Number of samples
B - 1/07	83.50	7
B - 2/07	110.00	7
B - 3/07	92.00	6
B - 4/07	37.00	5
B - 5/07	37.00	5

4. SLOPE STABILITY ANALISYS

In order to carry out the stabilizaton of northwest slope of the open pit, stability analysis of the current situation of the final slope in this area was performed. Based on this analysis the danger of appearance an spreading of slope instability was pointed out. After that, the impact of proposed measures for stabilization by constructing counterweight embankment in the lower part of the final slopes was analysed. Detailed calculations and slope stability analysis of the final slope in the northwestern area of the open pit "Filijala" were carried out on three geological-technological sections labeled as A - A', B - B' and C - C', and the position of these sections is shown in Figure 7

Sections that were analyzed consisting of marl complex, alluvial-prolluvial complex and loess deposits, Figures 8, 9 and 10. There are three faults in each section, in a slope toe, at the slope head and the third is located behind the top of slope and below the incline called "Oštra glavica". The geometry of the slope of individual sections is shown in Table 2 Taking into a account the geological structure and the geometry of the slope stability for further calculations the finite element method was adopted (www.rocscience.com, 2001-2004; www.rocscience.com, 2005).

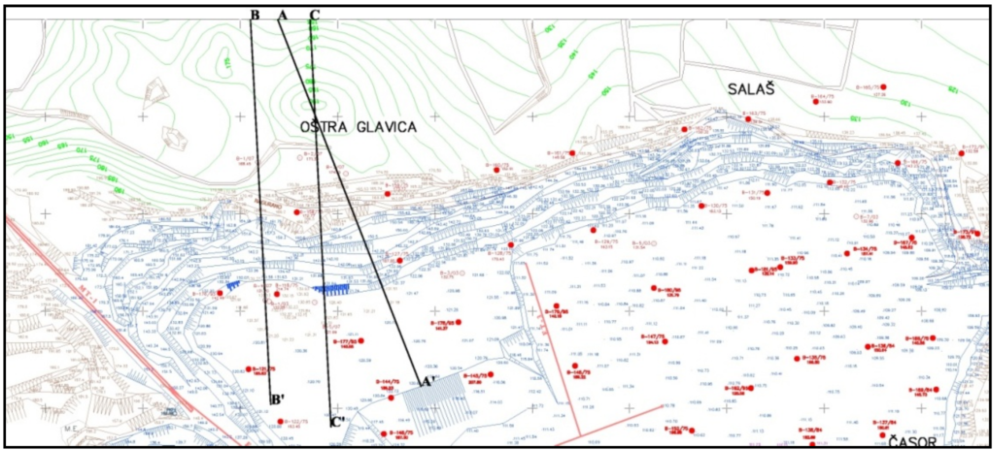

Figure 7 - North slope of open pit "Filijala" with position of geological-technological sections A - A', B - B' i C - C'

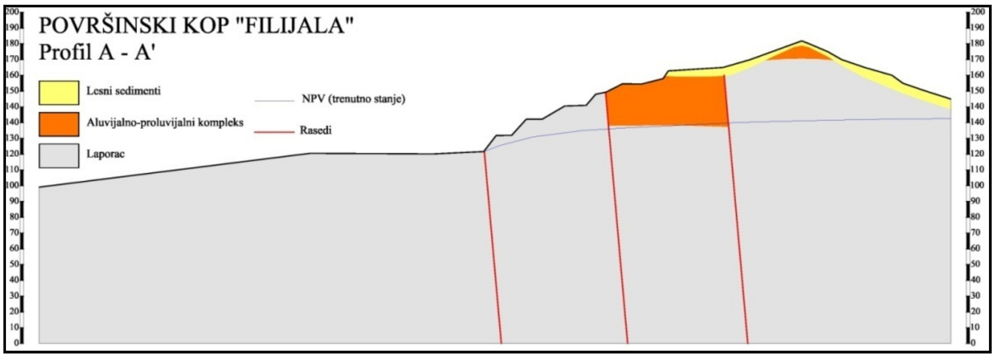

Figure 8 - North appearance of section A - A'

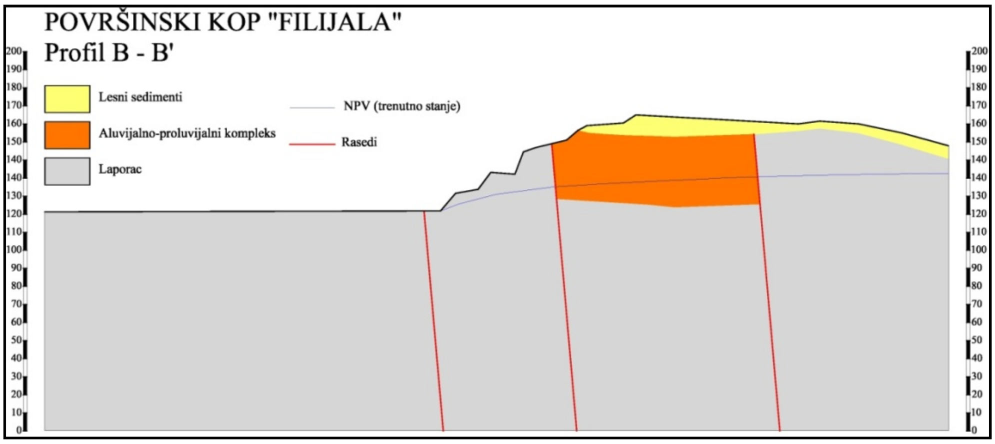

Figure 9 - North appearance of section B - B'

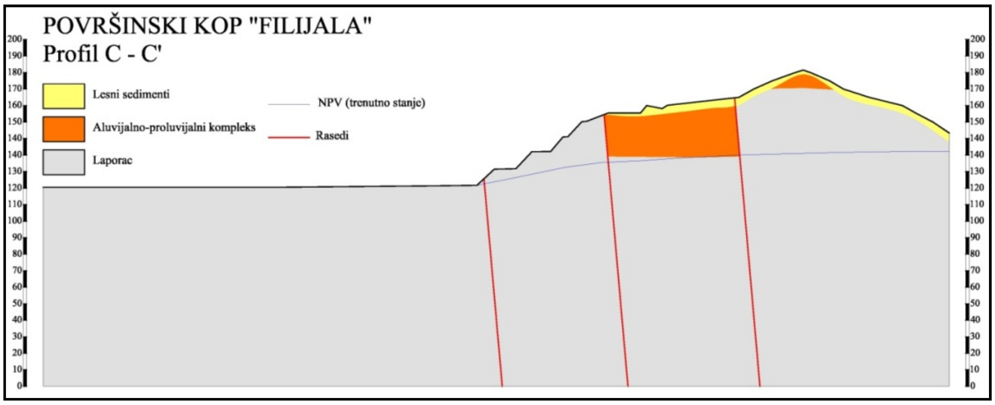

Figure 10 - North appearance of section C - C'

Table 2 - Overview of geological-technological sections slope geometry

Section	Slope heigth H [m]	Slope angle α [°]
A - A'	51.10	24
B - B'	53.16	26
C - C'	48.30	23

Parameters for further slope stability calculations were adopted according to the analysis of the results of geomechnical laboratory tests and performed statistical calculations for individual lithological units. These parameters were determined with 95% confidence, and are presented in Table 3. Values of angle of internal friction φ and cohesion c for marl complex were determined using the Hoek-Brown's failure criterion. For this purpose the software package RocLab - Rocscience Inc. 1.031 (freeware version) was used (Gojković and Čebašek, 2007b).

Table 3 - Calculation parameters for each lithological unit determined by statistical calculations

Material	*GSI*	m_i	*D*	Unit weigth γ [kN/m^3]	Internal friction angle φ [°]	Cohesion c [kPa]
Marl complex	40	7	0.7	18.55	18.51	63
Alluvial-prolluvial complex	-	-	-	19.20	28	1.45
Loess deposits	-	-	-	20.00	19.35	12.69
Waste rock material	-	-	-	20.00	19.24	11.99
Counterweigth embankment	-	-	-	13.33	19.24	11.99

Stability analysis of the current state of final slopes in this part are defined safety factors which amounted to $F_s = 0.94$ (section A - A'), $F_s = 0.84$ (section B - B') and $F_s = 0.90$ (section C - C'). The analysis of the distribution of maximum shear strain

(Figures 11, 12 and 13) shows that the maximum concentration is in the zone immediately below the toe of slope, which is fully consistent with the deformations that were observed at the bottom of the open pit during the field observation. Based on these results it was concluded that it is necessary to carry out stabilization of the final slope in this area.

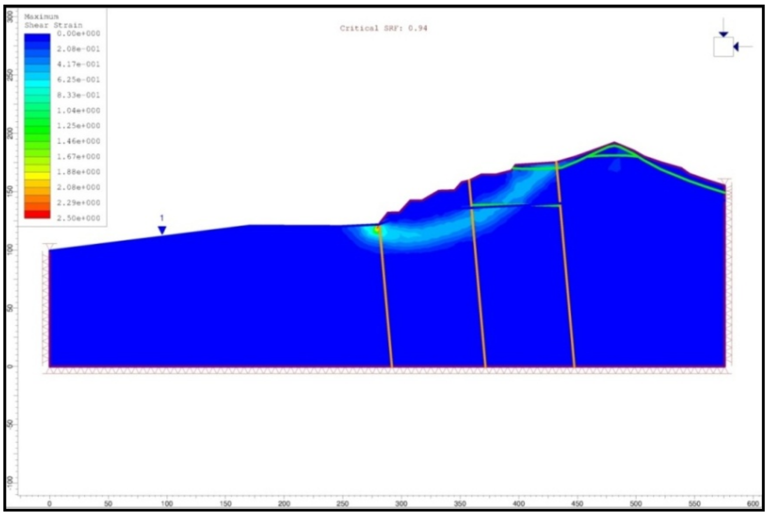

Figure 11 - Section A - A' slope stability analyses results with the distribution of maximum shear strain (potential slide plane)

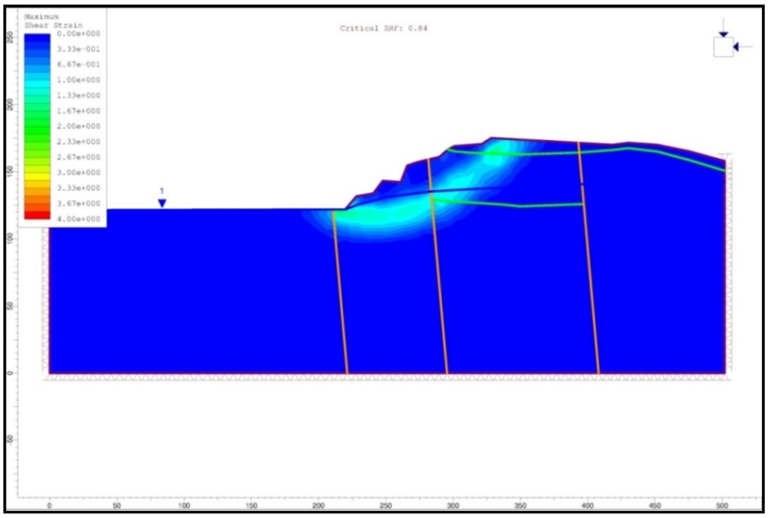

Figure 12 - Section B - B' slope stability analyses results with the distribution of maximum shear strain (potential slide plane)

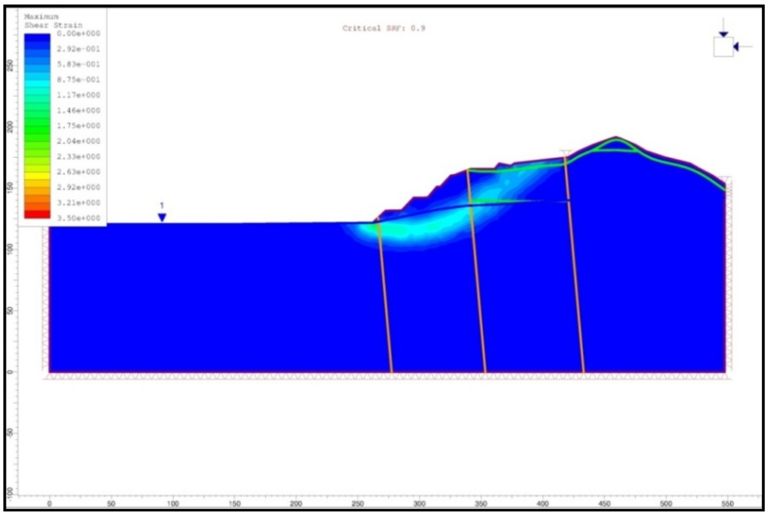

Figure 13 - Section C - C' slope stability analyses results with the distribution of maximum shear strain (potential slide plane)

5. SLOPE STABILIZATION

Stabilization of this part of the final slope is only a possible by change of slope geometry. Using other measures for stabilization, such as drainage and rock bolting was not possible because in this area of the open pit there is geological heritage, and application of technological measures was not the matter of subject because it was a final slope. In this case the construction of the counterweigth embankment in toe part of the slope has been applied as stabilization measure and removing earth material at the top of the slope was not possible because of the position of the zone of geological heritage, the configuration of the surrounding terrain and proximity to surrounding neighborhoods. construction of the counterweigth embankment in toe part of slope prevents any new rock mass movements and provide a satisfactory safety factor $F_s \geq 1.30$. In this way the environment and the nearest point of the settlements Beocin and Beocin Selo are protected, as well as the safety and secure movement of people and machinery that work in the open pit "Filijala" are provided.

Constructing the counterweigth embankments in toe part of the slope as stabilization measures increases the stability of the whole slope, and increases the stability of the openpit floor. Should the counterweigth embankment had an impact on the stability of the slope his height has to be (Gojković et al. 2004; Maksimović 2005):

$$H_n = \left(\frac{1}{3} \div \frac{1}{2}\right) \cdot H = \left(\frac{1}{3} \div \frac{1}{2}\right) \cdot 53.26 \approx 17.7 \div 26.6\,\mathrm{m}$$

where is:
H_n - embankment heigth in the toe part of slope [m],
H - stabilized slope heigth [m], $H = 53.16$ m.

In the previous part of this paper (Table 2) was indicated that the final slopes heigth in the northwestern part of the open pit "Filijala" is $H = 53.16$ m, and the required height of the counterweigth embankment ranges from 17.7 m to 26.6 m. For further analysis of the possibility of slope stabilization in this area, as well for stability calculations it is assumed that the counterweigth embankment height is $H_n = 20$ m, and the angle of the embankment slope is $\alpha_n = 25^o$. Embankment is about 110 m long and 162 m wide, and at the top it is 103 m wide and it is formed from 120 m to 140 m elevation. Groundwater level in the slope body is at elevation of 148 m. Appearance of the counterweigth embankment in toe part of slope is given in Figures 14, 15 and 16

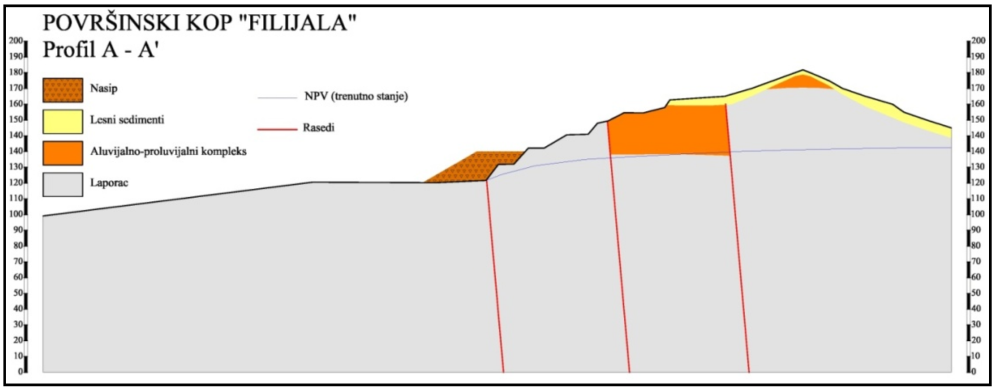

Figure 14 - Appearance of section A - A' with applied slope stabilization measures

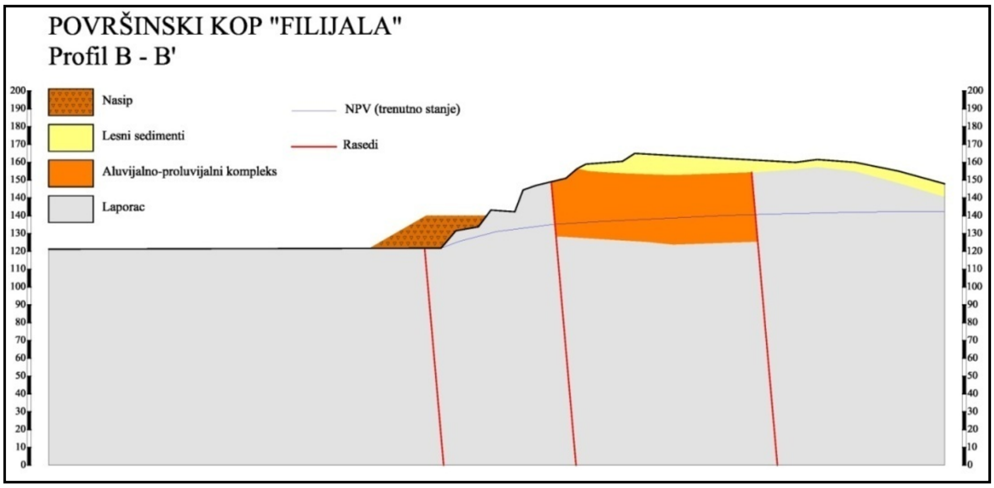

Figure 15 - Appearance of section B - B' with applied slope stabilization measures

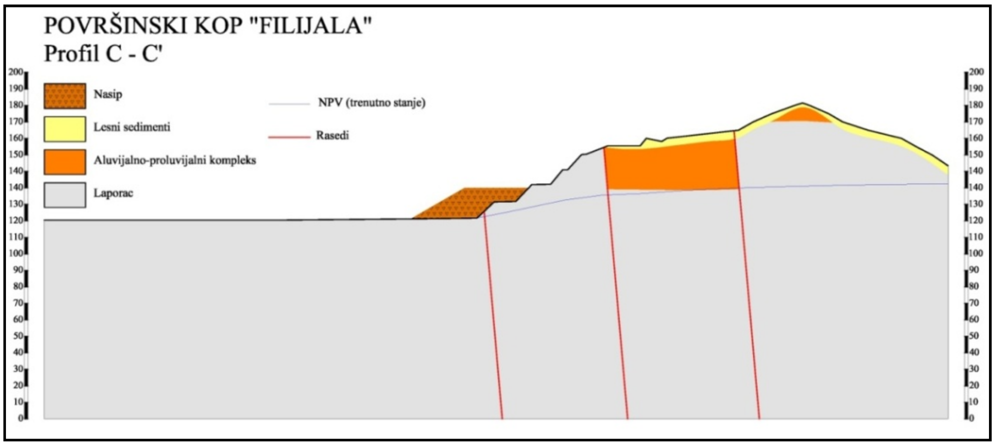

Figure 16 - Appearance of section C - C' with applied slope stabilization measures

Final slope stability analysis with applied stabilization measures by constructing the counterweigth embankments in toe part of the slope in this part have defined the safety factors which amounted $F_s = 1.38$ (section A - A'), $F_s = 1.32$ (section B - B') and $F_s = 1.39$ (section C - C'). The analysis of the distribution of maximum shear strain (Figures 17, 18 and 19) shows that the maximum concentration is in the zone below the toe of embankment slope, which is fully consistent with the required minimum value of safety factor $F_{smin} = 1.30$. Here it should be noted that the potential slide plane with a minimum safety factor of slopes in all analyzed sections with applied stabilization measures is located in the zone of the embankment slope. This indicates that the overall slope with applied stabilization measures safety factor is greater.

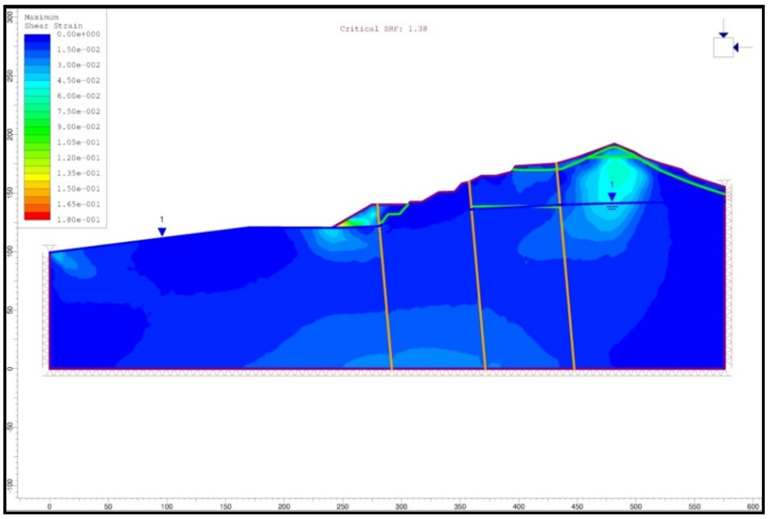

Figure 17 - Section A - A' slope stability analyses results with the distribution of maximum shear strain (potential slide plane)

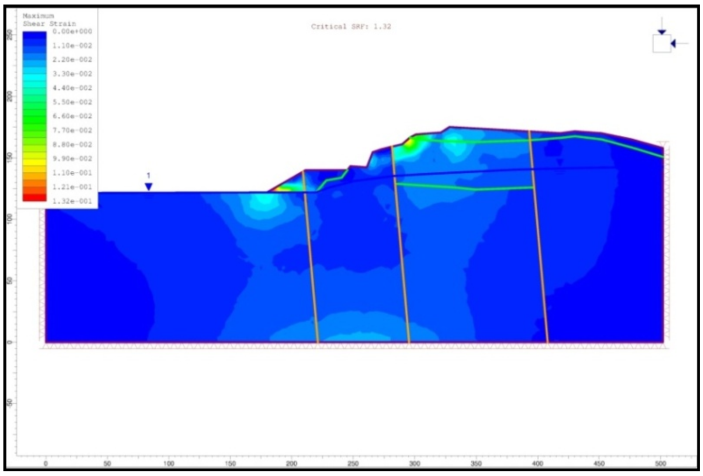

Figure 18 - Section B - B' slope stability analyses results with the distribution of maximum shear strain (potential slide plane)

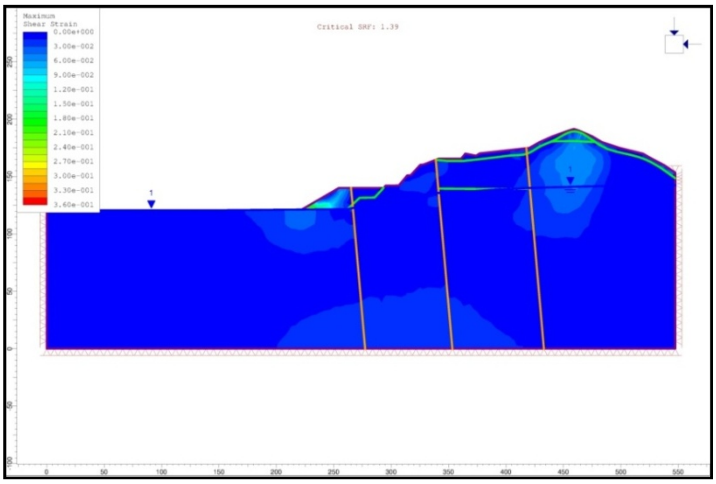

Figure 19 - Section C - C' slope stability analyses results with the distribution of maximum shear strain (potential slide plane)

Table 4 - Overview of slope geometry with slope stability analyses results using finite element method

Section	**State of slope**	**Slope heigth** H **[m]**	**Slope angle** α **[°]**	**Safety factor** F_s
A - A′	The current state	51.10	24	0.94
	With counterweigth embankment	52.56	19	1.38
B - B′	The current state	53.16	26	0.84
	With counterweigth embankment	52.56	19	1.32
C - C′	The current state	48.30	23	0.90
	With counterweigth embankment	52.56	19	1.39

Based on these applied stabilization measures on the sections A - A', B - B' and C - C' in the northwest slope area of the open pit "Filijala" the counterweigth embankment has been constructed in the toe part of slope. Construction of the embankment covered a broader area of the final slope, which has increased overall stability of the slope to the value of the safety factor ($F_s \geq 1.30$) which is issued by the law, Figure 20.

Figure 20 - Appearance of counterweigth embankment in northwestern slope area at open pit "Filijala"

6. CONCLUSION

The development of the marl exploitation in the open pit "Filijala" caused the instability appearance in northwest final slope area. The stability analysis of this zone of slope showed that the value of the safety factor F_s is somewhere in between $F_s = 0.84$ to 0.94, and that it is necessary to stabilize the slope. Subject to the preceding, and taking into account the position of the slope (near the location of geological heritage) and its environment (close settlements Beočin and Beočin Selo), an analysis of the possibilities of slope stabilization bz constructng the counterweigth embankment in the toe part of slope was carried out. Embankment provided the complete stability of the entire slope with the values of the safety factor $F_s = 1.32$ to 1.38. Based on the performed calculations and analysis teh embankment was constructed in this area of the open pit, covering the greater part of that which is shown in the proposed stabilization measures. In this way the safety factor was further increased, reducing the risk of the spread of damage and thus protecting environment and facilities.

ACKNOWLEDGMENT

This paper was realized as a part of the project "Monitoring and adaptive risk management in opencast mineral-raw material mining" (TR 33044) financed by the

Ministry of Education and Science of the Republic of Serbia within the framework of Programme of research in the field of technological development for the period 2011-2014.

REFERENCES

[1] GOJKOVIĆ, N. et al. (2004) *Stabilnost kosina površinskih kopova*. Beograd: Rudarsko-geološki fakultet.

[2] GOJKOVIĆ, N. and ČEBAŠEK, V. (2007) *Izveštaj o fizičko-mehaničkim svojstvima uzoraka stenskog materijala u zoni severne kosine na lokalitetu površinskog kopa "Filijala" kod Beočina*. Beograd: Rudarsko-geološki fakultet.

[3] GOJKOVIĆ, N. and ČEBAŠEK, V. (2007) *Elaborat o verifikaciji stabilnosti kosina za ležište laporca "Filijala" u Beočinu*. Beograd: Rudarsko-geološki fakultet.

[4] MAKSIMOVIĆ, M. (2005) Mehanika tla. Beograd: Građevinska knjiga.

[5] ROCSCIENCE Inc. (2001-2004) *Application of the Finite Element Method to Slope Stability* [WWW]. Available from: http://www.rocscience.com

[6] ROCSCIENCE Inc. (2005) *Slope Stability Module in Phase2 2D finite element slope stability analysis, Verification Manual, Version 6.0* [WWW]. Available from: http://www.rocscience.com