MINING AND METALLURGY INSTITUTE BOR ISSN: 2334-8836
UDK: 622

UDK: 622.271:621.65:681.51(045)=20 DOI:10.5937/MMEB1303049R

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STABILITY ANALYSIS OF THE WASTE DUMP "OŠTRELJSKI PLANIR" OF THE OPEN PIT "BOR" IN A FUNCTION OF WATER QUANTITY[**]

Abstract

Stability analysis of the waste dump "Oštreljski Planir" was carried out using the Geostudio2007 software for critical profiles determined on 3D model of the site in Gemcom 6 software. The influence of water on the stability of dump is defined by varying the coefficient of pore water in disposed material.

Keywords: *Stability, GeoStudio2007 software, Gemcom 6 software, coefficient of pore water*

INTRODUCTION

In the period from 1975 to 1980, the waste from the open pit "Bor" was dumped in several locations in the vicinity of the open pit, where the external dumps were formed. One of them is the waste dump "Oštrelj" which is also called the "East Dump" or "Cyanidation". It is located in the far east of the open pit Bor next to the former plant Cyanidation which is no longer in operation, because a part of landfill slope for leaching slided in the eighties of the last century and disablee this facility. It is also the highest dump of the open pit "Bor", with the final plane at K +475 m, and foot at level K +375 m. Height of formed landfill is 100 m with slope of 38^0. The lake Robule is situated on the base of this dump on the southeastern side. During the period of dumping on the "Oštrelj" waste dump, the cut-off grade of copper in the ore was much higher than it is today, so there is the possibility of this dump exploitation by leaching or classical excavation. The amount of material in this waste dump is 95 million $m^{3.}$.[5, 10, 11]

SELECTION OF COMPUTATIONAL PARAMETERS AND CHARACTERISTIC PROFILES

Based on the existing map data, the 3D model of the waste dump "Oštreljski Planir" was developed in the software Gemcom 6 [1, 3, 4, 8, 9, 15], Figure 1. Critical profiles for calculation the stability were defined on this model. 1-1 'passes through a part of the waste dump near the lake "Robule", and profile 2 - 2' passes through a part of the waste dump with maximum height of disposed material. The position of the profile 2 is shown in Figure 2.

The values of the physical - mechanical characteristics of disposed material and background of waste dump sites defined in the project documentation for mining the open pit "Bor" [5, 10] and they are shown in Table 1.

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[**] *This work is the result of the Project No. 37001 "Impact of Mining Waste from RTB to Pollution of Waterways with a Proposal of Measures and Actions to Reduce Harmful Effects on the Environment", funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia*

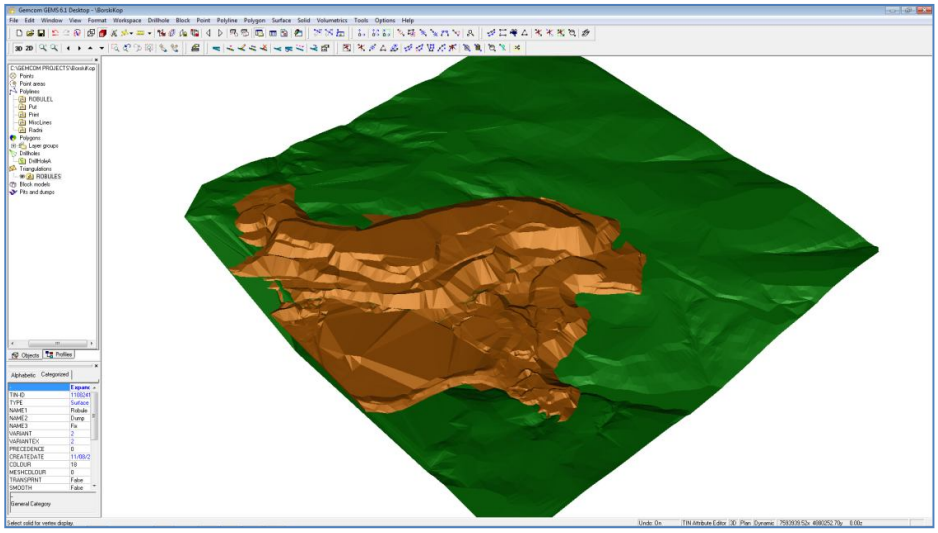

Figure 1 *3D model of waste dump in the software Gemcom 6*

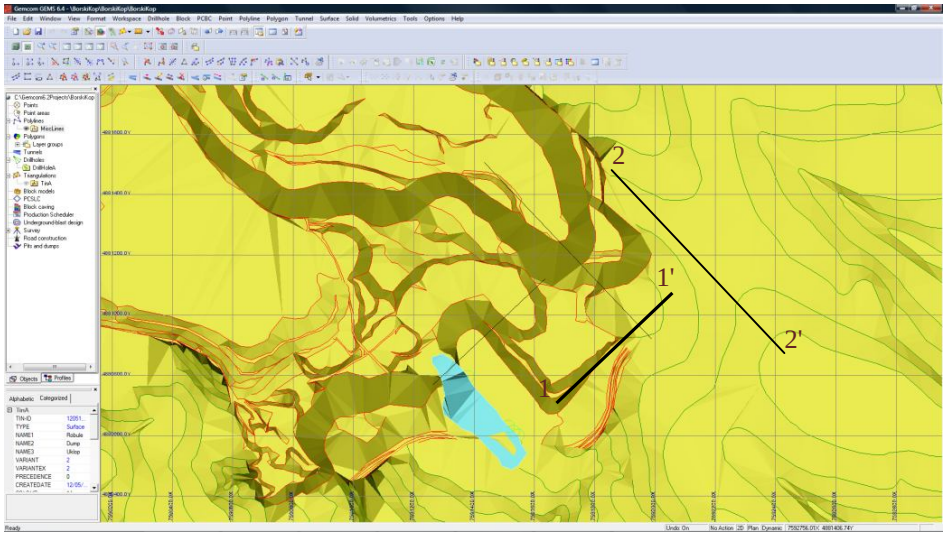

Figure 2 *Position of profiles for stability analysis*

Table 1 *Computational values of physico-mechanical parameters for calculation of stability*

Type of rock	Angle of internal friction, φ, °	Gravity, γ, kN/m^3	Cohesion, C kN/m^2
Background of waste dump	42.0	26.5	300
Disposed material	30.0	19.0	100

STABILITY CALCULATION

Stability calculation was made by the software GeoStudio 2007, or its subprogram SLOPE/W designed for stability calculation by the limit equilibrium condition, license no. 99803. The program includes methods of stability calculation by the limit equilibrium condition which are used today in the world: Bishop, Janbu, Spencer, Morgenstern - Price, Sarma et al. The impact of ground water on the stability in the software GeoStudio 2007 SLOPE/W can be modeled in several ways: piezometric water level, coefficient of pore water pressure r_u and pressure of pore water B-bar. The impact of surface loads on background could be also modeled by software as well as seismic effect [2, 6, 7, 12, 13, 14].

Stability calculation was made by the methods of Bishop and Morgenstern – Price. The impact of ground water on stability was modeled by the coefficient of pore water r_u, which is varied from 0.1 to 0.8. Stability analysis was carried out using the tool je Entry and Exit which defining the area where sliding plane cuts the field surface and radius area of potential sliding planes, Figures 3 – 5.

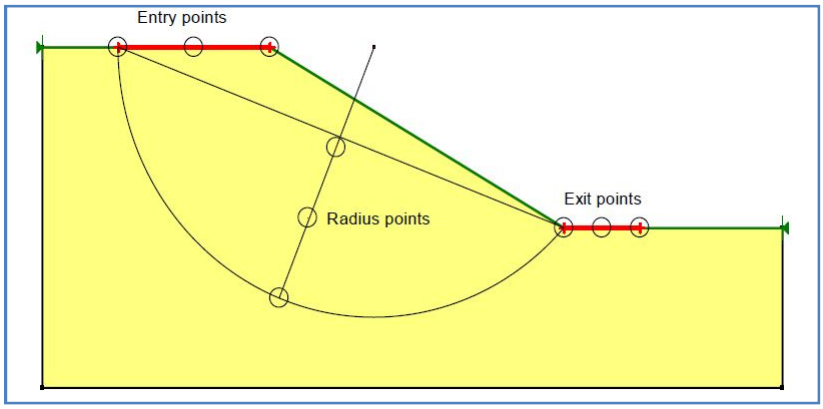

Figure 3 *Tool Entry and Exit*

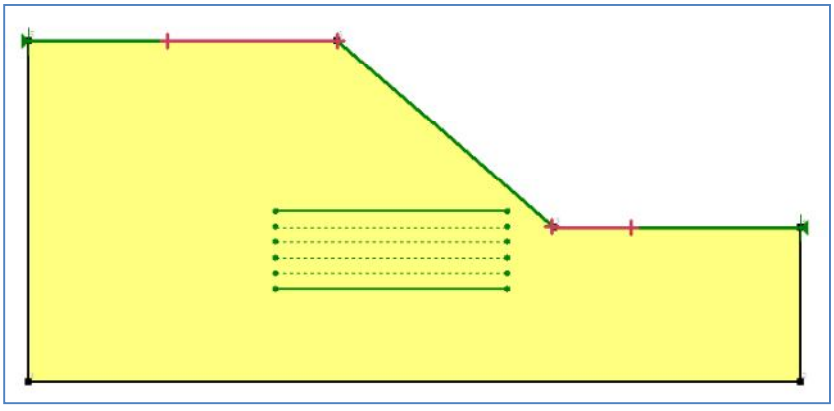

Figure 4 *Radius area of potential sliding planes in tools Entry and Exit*

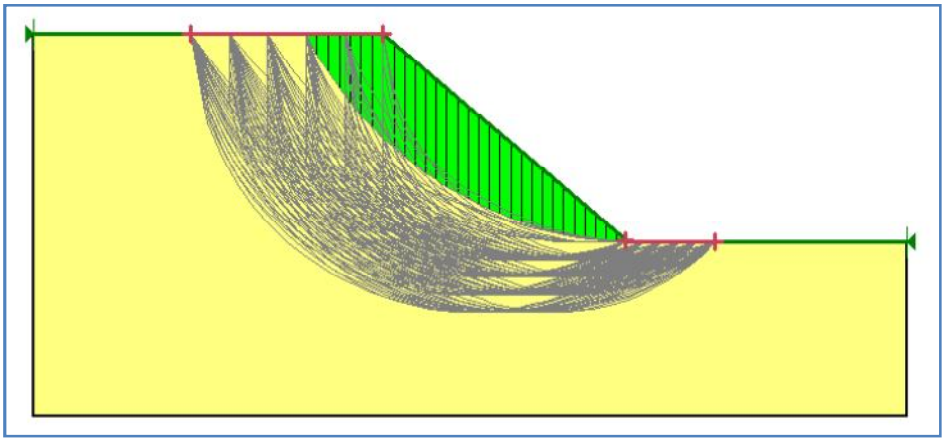

Figure 5 *View of potential sliding planes in tools Entry and Exit*

Stability calculation using the software GeoStudio 2007 on profiles 1 – 1' and 2 – 2' for the coefficient of pore water r_u = 0.1 is shown in Figures 6 – 9, and complete calculation results in Figure 10.

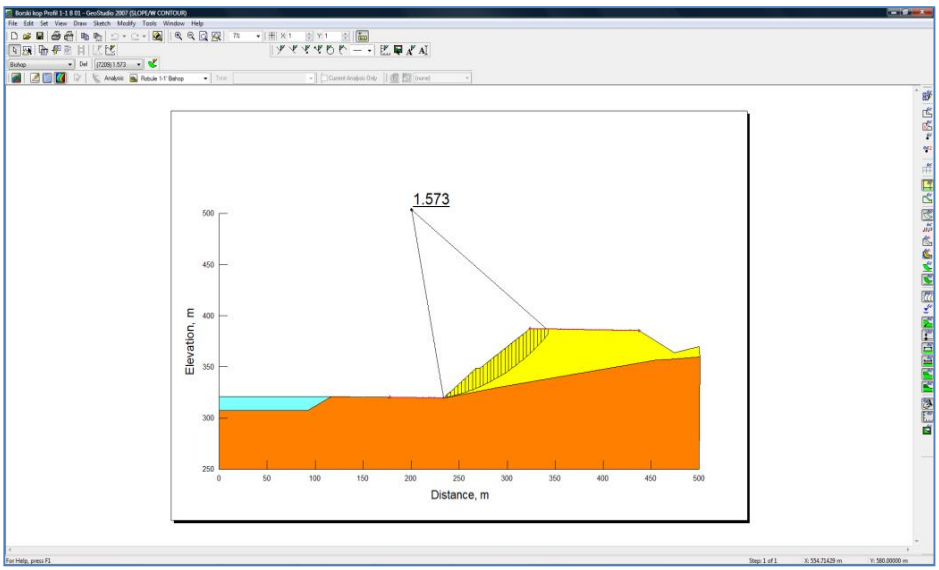

Figure 6 *Stability calculation for profile 1 – 1' by the Bishop method*

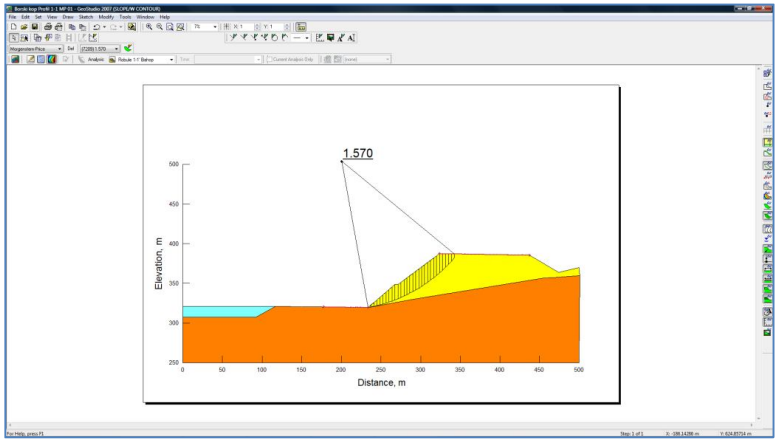

Figure 7 *Stability calculation for profile 1 – 1' by the Morgenster – Price method*

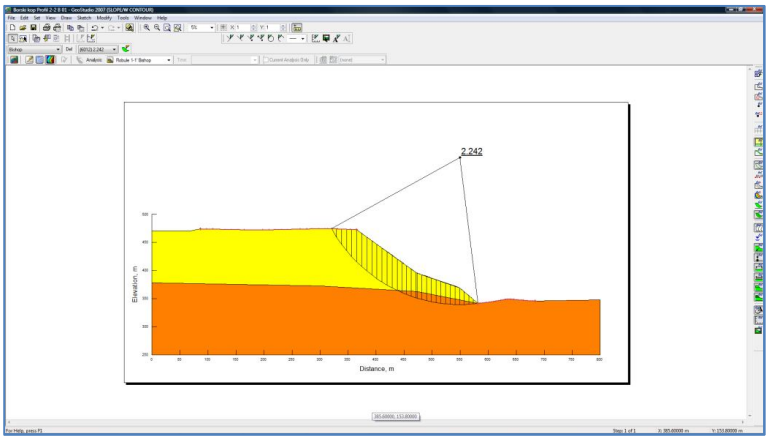

Figure 8 *Stability calculation for profile 2 – 2' by the Bishop method*

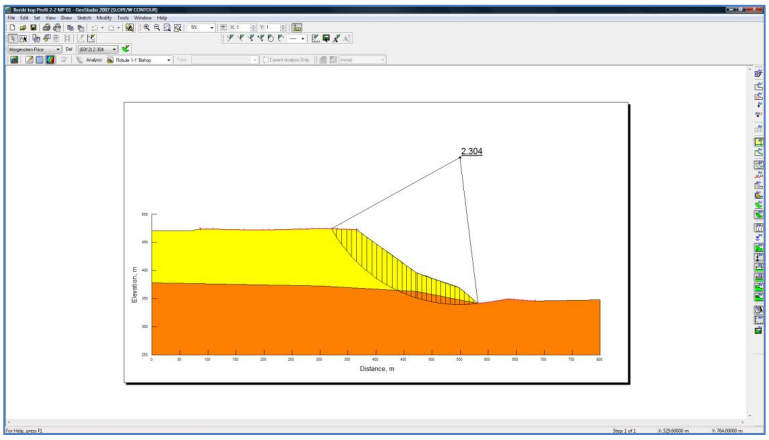

Figure 9 *Stability calculation for profile 2 – 2' by the Morgenster – Price method*

Figure 10 *Graphical view of stability calculation results*

ANALYSIS OF STABILITY CALCULATION RESULTS

Dependence of change the stability coefficient could be seen from graphical view with increasing coefficient of pore water for both analyzed profiles. The current Rulebook on technical requirements for surface mining of mineral resources (Official Gazette RS No. 96/2010) has stipulated the following minimum stability coefficients for waste dumps:

- Working slopes of partial individual floors: 1.05 to 1.10.
- Working slopes of partial individual floors and floor slope system: 1.10 to 1.15.
- Final slopes of waste dump: 1.30 to 1.50.
- Fracture of background and sliding along background: 1.50 to 2.00.

Maximum allowable values of pore water coefficient could be read from graph of stability calculation results, which meet the prescribed values of stability coefficient. If there is larger water quality than allowed, it is necessary to reduce the level of groundwater below the contact of disposed masses and background in possible exploitation. The waste dump must be regularly drained from surface water.

CONCLUSION

Softver GeoStudio 2007 – SLOPE/W is a program that can very accurately determine all relevant conditions for calculation the slope stability of open pits, waste dumps and earth dams. Each lithological member on a profile can be realistically modeled by spatial position and physico-mechanical characteristics. It is also possible to model the effect of ground water on stability by several ways as well as the surface loads on background. Using of this software significantly reduces the time of calculation regarding to the classical design.

For realistic assessment the problems of stability in the software GeoStudio 2007, the most important is a selection of reliable input parameters.

Since the data on physic-mechanical characteristics are older than three decades, in the case of this waste dump exploitation by leaching or classical excavation, it is necessary to check the geomechanical and hydrogeological characteristics of the background and disposed material. For calculation the stability in exploitation, a load of machinery have to be taken into account and determine minimum distance from the edge of the waste dump for its operation.

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INSTITUT ZA RUDARSTVO I METALURGIJU BOR ISSN: 2334-8836
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UDK: 622.271:621.65:681.51(045)=861 DOI:10.5937/MMEB1303049R

Radmilo Rajković[*], *Mile Bugarin*[*], *Vladan Marinković*[*]

ANALIZA STABILNOSTI ODLAGALIŠTA JALOVINE "OŠTRELJSKI PLANIR" POVRŠINSKOG KOPA "BOR" U FUNKCIJI OVODNJENOSTI[**]

Izvod

Analiza stabilnosti odlagališta jalovine "Oštreljski planir" urađena je programom GeoStudio 2007, za kritične profile određene na osnovu 3D modela lokaliteta u program Gemcom 6. Uticaj vode na stabilnost odlagališta definisan je variranjem koeficijenta porne vode u odloženom materijalu.

Ključne reči: *stabilnost, program GeoStudio 2007, program Gemcom 6, koeficijent porne vode.*

UVOD

U period od 1975 do 1980 godine, jalovina sa površinskog kopa "Bor" odlagana je na više lokacija u blizini površinskog kopa, pri čemu su formirana spoljna odlagališta. Jedno od njih je i odlagalište "Oštrelj" koje se još naziva i "Istočno odlagalište", ili "Cijanizacija". Nalazi se na krajnjem istoku od površinskog kopa Bor pored bivšeg pogona Cijanizacije koji nije više u funkciji, jer je deo kosine odlagališta za luženje kliznuo osamdesetih godina prošlog veka i onesposobio ovo postrojenje. To je ujedno i najviše odlagalište površinskog kopa „Bor", čija je završna ravan na K +475 m, a nožica na koti K +375 m. Visina formiranog odla-gališta iznosi 100 m sa nagibom kosine 38^0. U podnožju ovog odlagališta na jugoistočnoj strani nalazi se jezero Robule. Tokom perioda odlaganja na odlagalištu "Oštrelj", granični sadržaj bakra u rudi bio je znatno veći nego danas, tako da postoji mogućnost eksploatacije ovog odlagališta luženjem ili klasičnim otkopavanjem. Količina materijala na ovom odlagalištu iznosi oko 95 miliona m^3materijala. [5, 10, 11]

IZBOR RAČUNSKIH PARAMETARA I KARAKTERISTIČNIH PROFILA

Na osnovu postojećih kartografskih podataka urađen je 3D model odlagališta "Oštreljski planir" u program Gemcom 6 [1, 3, 4, 8, 9, 15], slika 1. Na ovom modelu definisani su kritični profile za proračun stabilnosti. Profil 1 – 1' prolazi kroz deo odlagališta u neposrednoj blizini jezera "Robule", a profil 2 – 2' prolazi kroz deo odlagališta sa najvećom visinom odloženog materijala. Položaj profila prikazan je naslici 2.

Vrednosti fizičko - mehaničkih karakteristika odloženog materijala i podloge odlagališta, definisane su u projektnoj dokumentaciji za eksploataciju na površinskom kopu „Bor" [5, 10] i prikazane su u tabeli 1.

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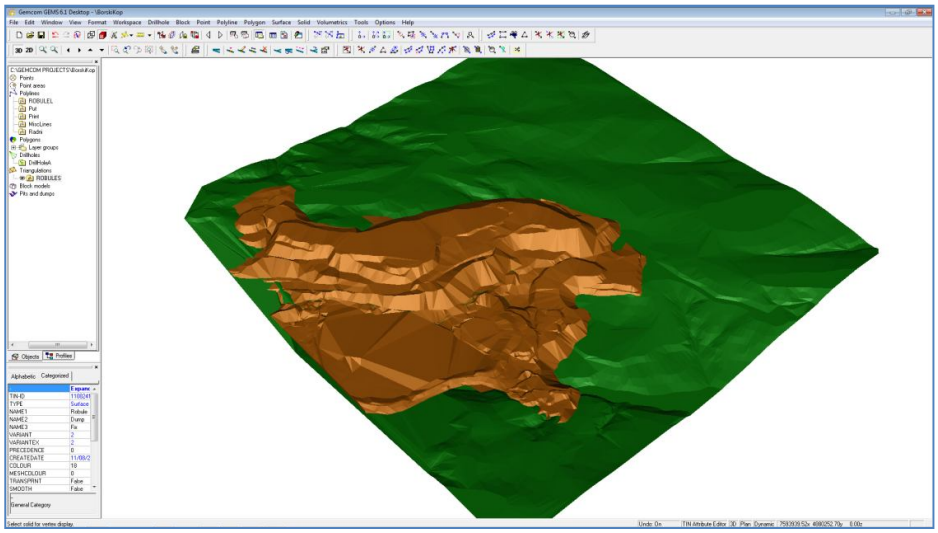
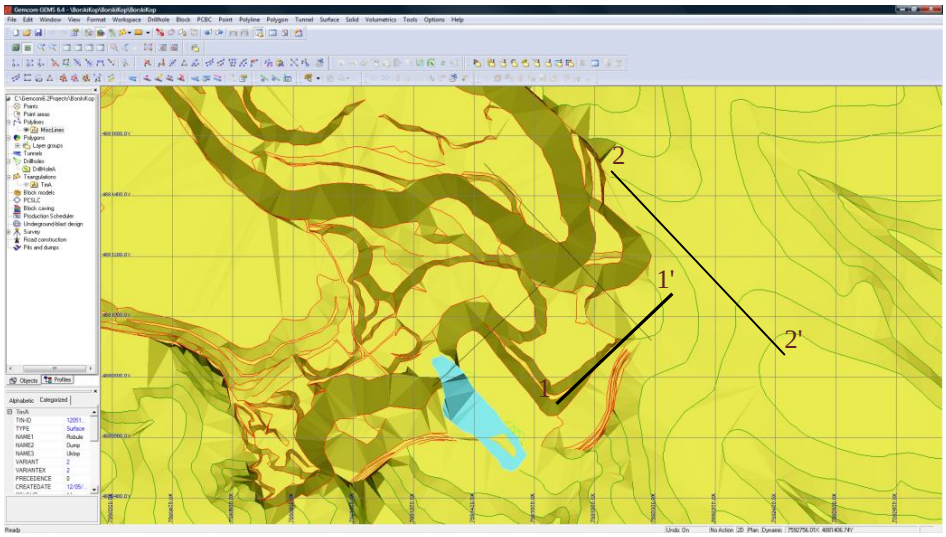
[**] *Ovaj rad je proistekao iz projekta TR37001 "Uticaj rudarskog otpada iz RTB Bor na zagađenje vodotokova, sa predlogom mera i postupaka za smanjenje štetnog dejstva na životnu sredinu", koji je finansiran sredstvima Ministarstva prosvete, nauke i tehnološkog razvoja Republike Srbije.*



Sl. 1. *3D model odlagališta u programu Gemcom 6*



Sl. 2. *Položaj profila za analizu stabilnosti*

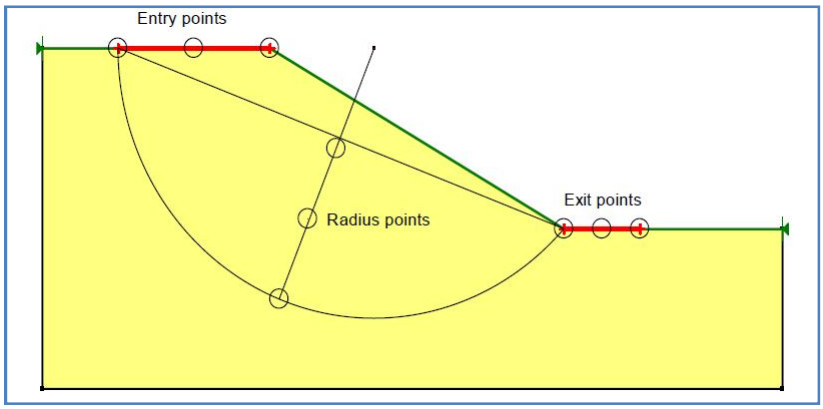
Tabela 1. *Računske vrednosti fizičko-mehaničkih parametara za proračun stabilnosti*

Vrsta stene	Ugao unutrašnjeg trenja, φ, °	Zapreminska težina, γ, kN/m^3	Kohezija, C kN/m^2
Podloga odlagališta	42,0	26,5	300
Odloženi materijal	30,0	19,0	100

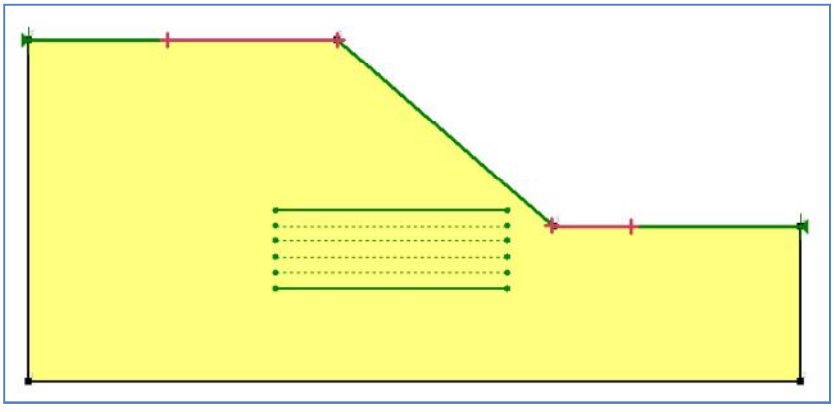
PRORAČUN STABILNOSTI

Proračun stabilnosti izvršen je programmom GeoStudio 2007, odnosno njegovim potprogramom SLOPE/W namenjenim za proračun stabilnosti uslovom granične ravnoteže, licenca br. 99803. Program sadrži metode proračuna stabilnosti uslovom granične ravnoteže koje se danas koriste u svetu: Bishop, Janbu, Spenser, Morgenstern – Price, Sarma i dr. Uticaj podzemnih voda na stabilnost u softveru GeoStudio 2007 SLOPE/W može da se modelira na više načina: piezometrijskim nivoom vode, koeficijentom porne vode r_u i pritiskom porne vode B-bar. Softverom se takođe može modelirati uticaj površinskih opterećenja na podlogu, kao i seizmički uticaj [2, 6, 7, 12, 13, 14].

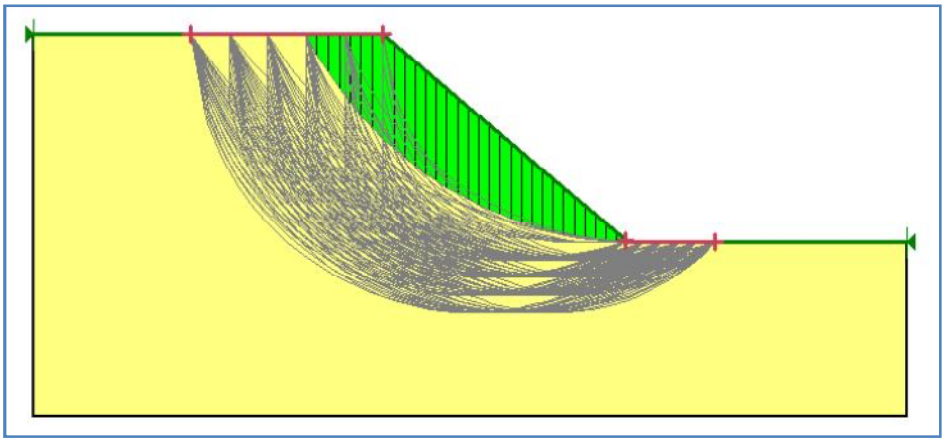
Proračun stabilnosti urađen je metodama Bishop i Morgenstern – Price. Uticaj podzemnih voda na stabilnost modeliran je koeficijentom porne vode r_u, koji je variran od 0,1 do 0,8. Analiza stabilnosti rađena je alatom Entry and Exit kojim se definiše oblast u kojoj klizna ravan seče površinu terena, i oblast radijusa potencijalnih kliznih ravni, slike 3 – 5.



Sl. 3. *Alat Entry and Exit*

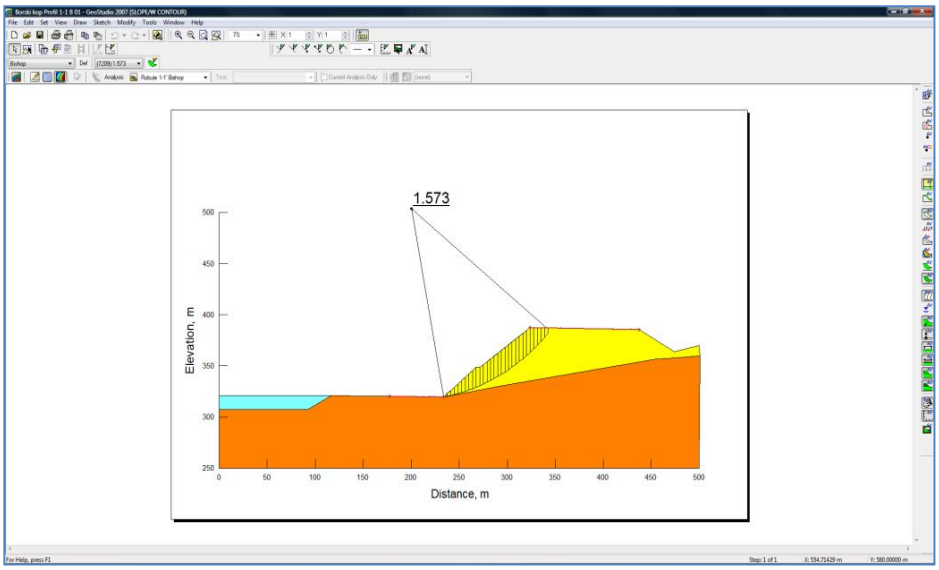


Sl. 4. *Oblast radijusa potencijalnih kliznih ravni kod alata Entry and Exit*

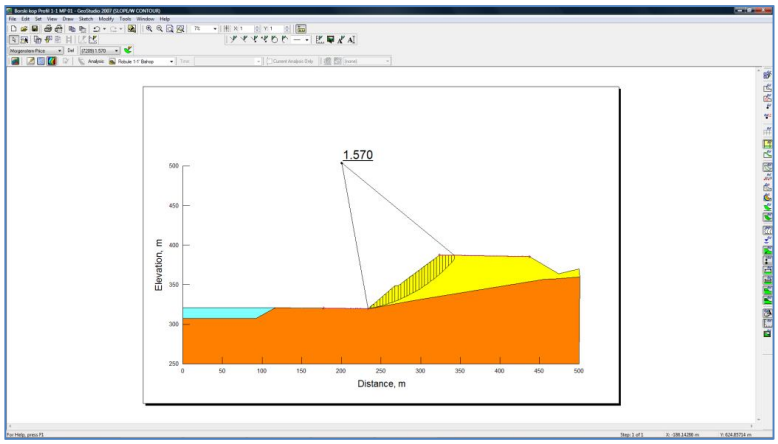


Sl. 5. *Prikaz potencijalnih kliznih ravni kod alata Entry and Exit*

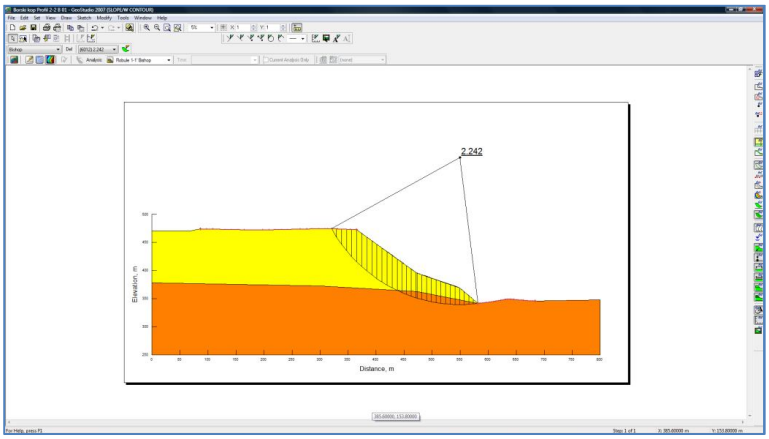
Proračun stabilnosti programom GeoStudio 2007 na profilima 1 – 1' i 2 – 2' za koeficijent porne vode r_u = 0,1 prikazan je na slikama 6 – 9, a kompletni rezultati proračuna na slici 10.



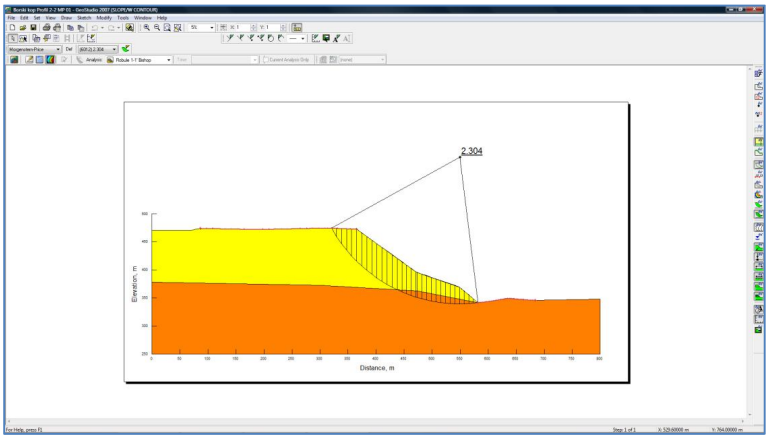
Sl. 6. *Proračun stabilnosti za profil 1 – 1' po metodi Bishop*



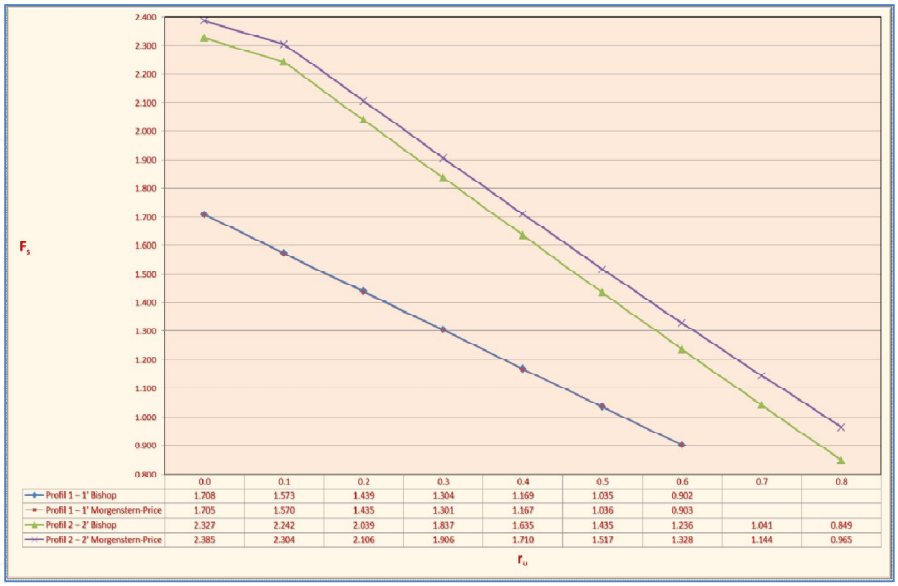
Sl. 7. *Proračun stabilnosti za profil 1 – 1' po metodi Morgenster – Price*



Sl. 8. *Proračun stabilnosti za profil 2 – 2' po metodi Bishop*



Sl. 9. *Proračun stabilnosti za profil 2 – 2' po metodi Morgenster – Price*



Sl. 10. *Grafički prikaz rezultata proračuna stabilnosti*

ANALIZA REZULTATA PRORAČUNA STABILNOSTI

Sa grafičkog prikaza rezultata proračuna stabilnosti može se videti zavisnost promene koeficijenta stabilnosti sa povećanjem koeficijenta porne vode za oba analizna profila. Važećim Pravilnikom o tehničkim zahtevima za površinsku eksploataciju mineralnih sirovina (Sl. glasnik RS br. 96/2010) propisani su sledeći minimalni koeficijenti stabilnosti za odlagališta jalovine:

- Radne kosine parcijalnih pojedinačnih etaža: 1,05 do 1,10.
- Radne kosine parcijalnih pojedinačnih etaža i sistema kosina etaža: 1,10 do 1,15.
- Završne kosine odlagališta: 1,30 do 1,50.
- Lom podloge i klizanje po podlozi: 1,50 do 2,00.

Sa grafika rezultata proračuna stabilnosti mogu se očitati maksimalne dozvoljene vrednosti koeficijenta porne vode za koje su ispunjene propisane vrednosti koeficijenta stabilnosti. Ako postoji veća ovodnjenost od dozvoljene, pri eventualnoj eksploataciji potrebno je izvršiti smanjenje nivoa podzemne vode ispod kontakta odloženih masa i podloge. Takođe se odlagalište mora redovno odvodnjavati od površinskih voda.

ZAKLJUČAK

Softver GeoStudio 2007 – SLOPE/W je program kojim veoma precizno mogu da se determinišu svi relevantni uslovi za proračun stabilnosti kosina površinskih kopova, odlagališta jalovine i zemljanih brana. Svaki litološki član na profile može biti realno modeliran prostornim položajem i fizičko – mehaničkim karakteristikama. Takođe je moguće na više načina modelirati uticaj podzemnih voda na stabilnost, kao i površinska opterećenja na podlogu. Korišće-

njem ovog softvera značajno se skraćuje vreme proračuna u odnosu na klasično projektovanje.

Za realno sagledavanje problematike stabilnosti u program GeoStudio 2007 najvažniji je izbor pouzdanih ulaznih parametara.

Kako su podaci o fizičko - mehaničkim karakteristikama stariji od tri decenije, u slučaju eksploatacije ovog odlagališta luženjem ili klasičnim otkopavanjem, potrebno je proveriti geomehaničke i hidrogeološke karakteristike podloge i odloženog materijala. Za proračun stabilnosti pri eksploataciji mora se uzeti u obzir opterećenje od mehanizacije i odrediti minimalno rastojanje od ivice kosine odlagališta za njen rad.

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