Stability analysis on slope PK dacite Ceramide

Vladimir Čebašek, Veljko Rupar, Vladimir Ivoš, Vladimir Petković

STABILITY ANALYSIS ON SLOPE PK DACITE ĆERAMIDE

V.Čebašek[1], V. Rupar[2], V. Ivoš[3], V. Petković[4]

ABSTRACT
Safe surface mining exploitation of minerals is possibile only if stable bench and overall slopes in the open pit are construct. In order to to construct stable open pit slopes, it is necessary to carry out certain physical and mechanical laboratry testing of mineral raw materials in order to determine the geomechnical calculating parameters. These calculating parameters represent the base ground for performing slopes analyses and the open pit design. In this paper, an stability analysis of benches and overall slopes in dacite open pit called „Ćeramide“ is presented.
***Keywords**: dacite, slope stability, surface mining*

Introduction

Mining field Ćeramide, as well as the dacite open pit mine, is located in the Zagrađe village area, which belongs to the municipality of Gornji Milanovac. It is about 16 km away from Gornji Milanovac and the 3 km from small town of Rudnik. At about two kilometers a distance south of the deposit the main road Belgrade-Čacak is located. Mining field Ćeramide covers an area of about 25.6 hectares.

Figure 1. Exploitation field and open pit Ćeramide

For the dacite open pit Ćeramide design purposes certain program of rock material laboratory testing was carried out. The results of these rock material laboratory testing, as well as the geological conditions of genesis and formation of rock masses made base ground for determination of necessary geotechnical data. Comprehensive analyses included the results of physical and mechanical rock material properties testing such as: unit weight γ, uniaxial compressive strength σ_c, tensile strength σ_t, angle of shear resistance φ and cohesion c. [1]

Mean values of shear strength parameters, angle of shear resistance and cohesion, which are determined on monolithic testing specimens, are necessary to convert to the rockmass. Analysis of the rockmass properties in which the slopes are constructed, is carried out by using Hoek-Brown failure criterion [2] and GSI (Geological Strength Index) classification [3]. In this way physical and mechanical properties of the entire dacite rockmass were determined.

[1] University of Belgrade, Faculty of Mining and Geology, Djusina 7, 11000 Belgrade, Serbia, vladimir.cebasek@rgf.bg.ac.rs
[2] University of Belgrade, Faculty of Mining and Geology, Djusina 7, 11000 Belgrade, Serbia, veljko.rupar@rgf.bg.ac.rs
[3] JP EPS Serbia, Branch RB Kolubara, PK Radljevo, 14210 Ub, Serbia, vladimir.ivos@eps.rs
[4] JP EPS Serbia, Branch RB Kolubara, PK Radljevo, 14210 Ub, Serbia, vladimir.petkovic@eps.rs

Adopted dacite rockmass geomechnical calculating parameters for working benches slope stability analyses are shown in Table 1.

Table 1. Dacite rockmass Hoek-Brown failure criteria calculating parameters for working benches slopes stability analysis

Rock material	**Unit weight (kN/m^3)**	**Compression strenght σ_{ci} (MPa)**	**GSI factor**	**The coefficient of rock mass m_i**	**Factor damage to the rock mass D**
Dacite - alterated	25.30	144.432	40 (35 ÷ 45)	8.774	1
Dacite - massive	25.30	144.432	50 (45 ÷ 55)	8.774	1

Adopted dacite rockmass geomechanical calculating parameters for overall slope stability analyses are shown in Table 2.

Table 2. Dacite rockmass Hoek-Brown failure criteria calculating parameters for overall slope stability

Rock material	**Unit weight (kN/m^3)**	**Compression strenght σ_{ci} (MPa)**	**GSI factor**	**The coefficient of rock mass m_i**	**Factor damage to the rock mass D**
Dacite – rockmass	25.30	144.432	45 (35 ÷55)	8.774	1

Calculation and slope stability analysis

Dacite open pit Ćeramide slope stability was carried out for the respective working benches and the overall slope. For the open pit working benches following geometry was analysed:

- benches height H = 7.5, 10.0, 12.5 and 15.0 m,
- benches slope angle α = 65÷85°.

Open pit Ćeramide working benches slope stability analysis was carried out for both types of rock material, massive and alterated dacite, according to the adopted geomechanical calculation parameters values for working benches slopes stability analysis.

For overall slope slopes height of H = 50, 75, 100, 125 and 150 m were considered, wherein the maximum slope angles were determined according to the Technical regulations for mineral deposits surface mining exploitation.

Open pit "Ćeramide" slope stability analysis of working benches and overall slope has been performed according to Hoek method for the slope planar failure [4], while the designed open pit slope stability analysis has been performed by finite element method.

Rockmass shear strength parameter values for each slope height were determined for the two isolated dacite rockmass zone by using Hoek-Brown failure criterion. These values are presented in Table 3.

Table 3. Dacite shear strength parameter values determined by Hoek-Brown failure criterion

Height benches H (m)	**Angle of shear resistance φ (°)**		**Cohesion c (MPa)**	
	Alterated	**Massive**	**Alterated**	**Massive**
7.5	49.22	53.03	0.152	0.332
10.0	47.56	51.81	0.163	0.342
12.5	46.20	50.76	0.174	0.352
15.0	45.04	49.84	0.184	0.362

Based on previously shown dacite shear strength parameter the position of fracture system with a minimum safety factor was determined. The minimum value of the safety factor for the analyzed working benches slope angles (α = 65÷85°) are shown in Table 4.

Table 4. Values of minimum safety factor for the analyzed working benches slope angles

Slope angles α (°)	Altereted dacite				Massive dacite			
	Height working bences H (m)				Height working bences H (m)			
	7.5	10.0	12.5	15.0	7.5	10.0	12.5	15.0
65	6.379	4.714	3.905	3.366	17.939	11.924	9.250	7.525
66	5.960	4.443	3.694	3.195	16.352	11.019	8.597	7.029
67	5.586	4.196	3.501	3.038	14.997	10.226	8.018	6.585
68	5.247	3.969	3.323	2.892	13.823	9.523	7.500	6.184
69	4.939	3.760	3.157	2.755	12.794	8.895	7.033	5.820
70	4.657	3.566	3.002	2.626	11.882	8.328	6.607	5.485
71	4.396	3.384	2.856	2.505	11.065	7.811	6.217	5.177
72	4.153	3.213	2.718	2.389	10.327	7.337	5.857	4.890
73	3.925	3.051	2.587	2.278	9.654	6.900	5.522	4.622
74	3.711	2.896	2.461	2.171	9.036	6.492	5.208	4.369
75	3.507	2.748	2.339	2.068	8.464	6.110	4.912	4.129
76	3.312	2.605	2.221	1.967	7.930	5.749	4.631	3.900
77	3.124	2.465	2.106	1.868	7.428	5.406	4.362	3.680
78	2.941	2.329	1.992	1.769	6.952	5.078	4.103	3.467
79	2.763	2.194	1.879	1.671	6.497	4.760	3.851	3.258
80	2.586	2.059	1.765	1.572	6.058	4.450	3.604	3.052
81	2.410	1.923	1.650	1.471	5.630	4.145	3.360	2.848
82	2.232	1.784	1.532	1.364	5.208	3.841	3.114	2.641
83	2.049	1.640	1.408	1.250	4.786	3.534	2.864	2.430
84	1.858	1.488	1.273	1.125	4.357	3.218	2.606	2.210
85	1.654	1.322	1.122	0.984	3.911	2.885	2.332	1.975

Stability analysis of open pit mine overall slope is carried out for the slope height of H = 50, 75, 100, 125 and 150 m and the slope angle α = 50 ÷ 75°. Dacite rockmass shear strength parameter values (GSI = 45) for above mentioned overall slopes heights are determined using Hoek-Brown failure criterion and are presented in Table 5.

Table 5. Dacite rockmass shear strength parameters values for oveall slope stability analyses determined by Hoek-Brown failure criterion

Height benches H (m)	Angle of shear resistance φ (°)	Cohesion c (MPa)
50.00	36.67	0.303
75.00	33.71	0.371
100.00	31.62	0.431
125.00	30.00	0.487
150.00	28.70	0.537

Based on previously determined shear strength parameters values the position of fracture system with a minimum safety factorof was determined. The minimum value of the safety factor for the analyzed overall slopes angles (α = 50 ÷ 75°) are shown in Table 6.

Table 6. The values of minimum safety factor for analysed the overall slopes angles

Slope angles α (°)	**Height overall slope H (m)**				
	50	**75**	**100**	**125**	**150**
50	4.295	2.973	2.432	2.154	1.931
51	3.966	2.808	2.322	2.065	1.864
52	3.689	2.664	2.223	1.985	1.802
53	3.452	2.536	2.133	1.912	1.745
54	3.247	2.421	2.052	1.845	1.692
55	3.068	2.318	1.977	1.783	1.643
56	2.909	2.224	1.909	1.726	1.597
57	2.766	2.138	1.845	1.672	1.551
58	2.638	2.059	1.786	1.622	1.506
59	2.521	1.985	1.730	1.575	1.462
60	2.414	1.917	1.678	1.529	1.419
61	2.316	1.853	1.628	1.484	1.377
62	2.224	1.792	1.579	1.439	1.335
63	2.139	1.735	1.532	1.395	1.294
64	2.059	1.681	1.484	1.351	1.253
65	1.984	1.629	1.437	1.309	1.214
66	1.913	1.576	1.391	1.266	1.174
67	1.845	1.525	1.345	1.224	1.135
68	1.780	1.474	1.300	1.182	1.096
69	1.717	1.423	1.254	1.140	1.057
70	1.657	1.372	1.209	1.099	1.018
71	1.597	1.322	1.164	1.057	0.979
72	1.538	1.271	1.118	1.016	0.940
73	1.477	1.220	1.072	0.973	0.901
74	1.416	1.168	1.026	0.931	0.861
75	1.355	1.116	0.980	0.888	0.821
76	1.293	1.063	0.932	0.844	0.780
77	1.230	1.009	0.883	0.799	0.737
78	1.164	0.953	0.833	0.753	0.694
79	1.097	0.895	0.781	0.705	0.649
80	1.026	0.835	0.727	0.654	0.602

Maximum overall slope angle was determined according to the presented overall slope stability analyses results and to the Technical regulations for mineral deposits surface mining exploitation (Table 7) where the minimum safety factor is from F_{min} = 1.30 to 1.5.

Table 7. The values of the maximum slope angle analyzed overall slopes

Height slope H (m)	**Maximum slope angle α (°)**	
	Minimum safety factor F_{min} = 1.30	**Minimum safety factor F_{min} = 1.50**
50.00	75	72
75.00	71	67
100.00	68	63
125.00	65	60
150.00	62	58

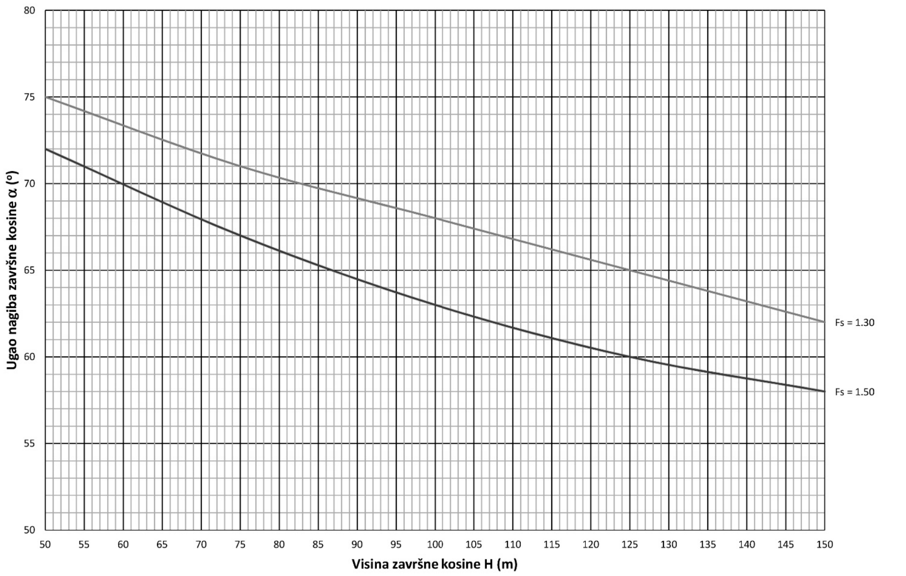

Figure 2. Slope angle (αz) as a function of the overall slope height (H) constructed in dacite rockmass (GSI = 45)

In the above profiles overall slope open pit mine built massive dacite. The geometry of the slope characteristic profiles is shown in Table 8.

Table 8. Geometry slope on characteristic profiles

Position profile	***Profile***	***Heigh slope H (m)***	***Angle of shear resistance α (°)***	***Safety factor F_s***
Open pit	I – I'	120.87	52	1.749
	II – II'	105.00	55	1.437
	III – III'	120.87	52	1.374
	IV – IV'	76.57	50	1.651
	A – A'	61.67	53	1.671

Dacite open pit slope design was carried out according to the previously shown results of benches and overall slope stability analyses. Designed open pit slope stability analyses was performed on five representative cross-sections: I-I', II-II', III-III', IV-IV' and A-A', which disposition is shown in Figure 3. Designed overall slopes are constructed in dacite rockmass. Slope stability analysis is carried out by finite element method. Appearance of analyzed cross-sections and the position of critical sliding zones are shown on Figures 4 to 8. [5]

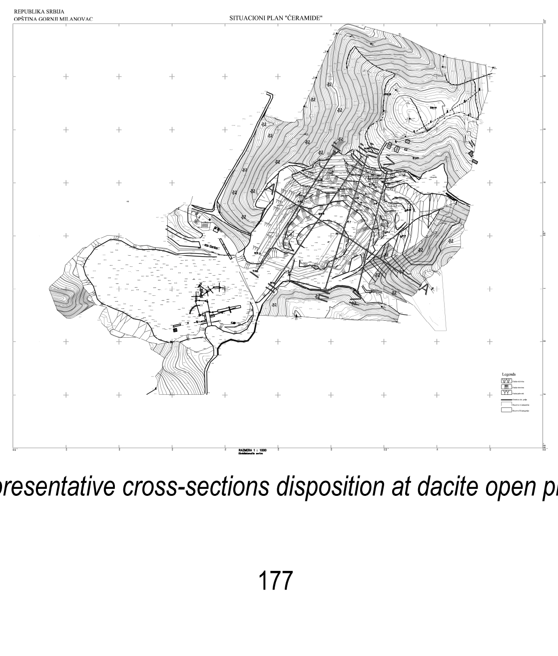

Figure 3. Representative cross-sections disposition at dacite open pit "Ćeramide"

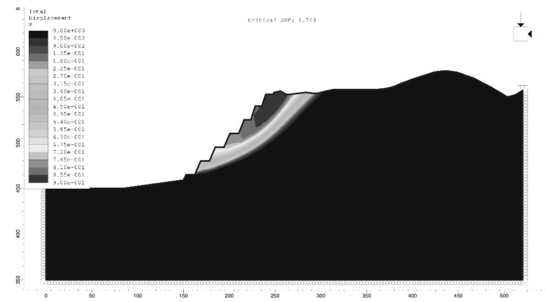

Figure 4. Appearance overall slope on cross-section I - I’

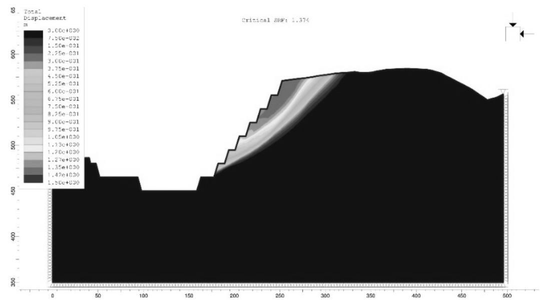

Figure 6. Appearance overall slope on cross-section III - III’

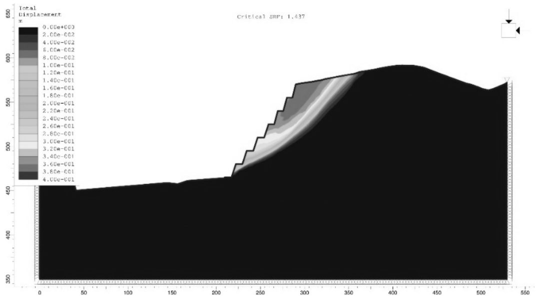

Figure 5. Appearance overall slope on cross-section II - II’

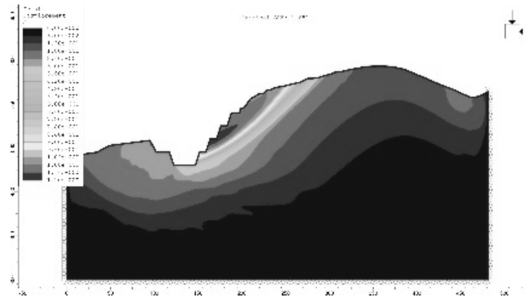

Figure 7. Appearance overall slope on cross-section IV - IV’

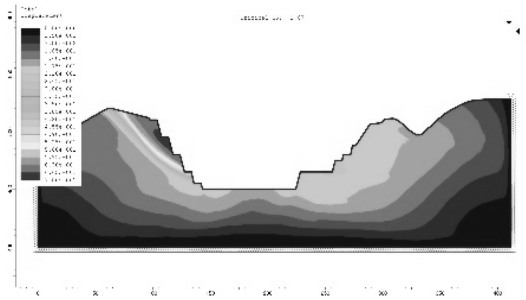

Figure 8. Appearance overall slope on cross-section A - A’

Conclusion

Dacite rock material properties were determined by comprehensive program of geomechnical properties laboratory testing that was carried out. Dacite rockmass geomechnical calculating properties analyses for slope stability analyses also included the statistical calculation of the rockmass properties and using the Hoek-Brown failure criterion and GSI (Geological Strength Index) classification. In this way physical and mechanical properties of the entire dacite rockmass were determined.

According to the results of slope stability analyses for the slope that are constructed in alterated dacite maximum slope angle of the woking bench is $\alpha = 84^0$ and maximum slope angle of the woking bench that is constructed in a massive dacite is $\alpha = 85^0$. Maximum slope angle of the woking bench are defined with the minimum safety factor Fmin is more than 1,05.

Based on the previously presented slope stability analyses results, an open pit overall slopes was designed. Open pit "Ćeramide" designed overall slopes stability analysis was performed on five representative cross-section as follows: II ', II - II', III - III ', IV - IV' and A - A '. Open pit overall slope is constructed in dacite rockmass on all these profiles. Safety factors values that are calculated by slope stability analyses meet the minimum for overall slope $F_{min} \geq 1.30$ that Is required by the Technical regulations for mineral deposits surface mining exploitation.

Literature

1. University of Belgrade, Faculty of Mining and Geology, (2017), Glavni rudarski projekat eksploatacije dacita na površinskom kopu Ćeramide kod Rudnika, Beograd
2. Hoek, E., Carranza-Torres, C. and Corkum, B., 2002, .Hoek-Brown criterion – 2002 edition, Proc. NARMS-TAC Conference, Toronto, 2002, 1, 267-273.
3. Hoek, E. and Karzulovic, A., 2000, Rock-Mass properties for surface mines. In Slope Stability in Surface Mining, (Edited by W. A. Hustralid, M.K. McCarter and D.J.A. van Zyl), Littleton, CO: Society for Mining, Metallurgical and Exploration (SME), pages 59-70.
4. E. Hoek, J. W. Bray, (1981), Rock Slope Engineering, Revised Third Edition, The Institution of Mining and Metallurgy, London
5. University of Belgrade, Faculty of Mining and Geology, (2016), Elaborat o rezultatima ispitivanja fizičko mehaničkih svojstava dacita sa PK Ćeramide sa analizom stabilnosti kosina, Beograd