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Professional paper

THE IMPACT OF CHANGES IN GEOMETRIC PARAMETERS AND THE AMOUNT OF WATER ON THE STABILITY OF THE WORKING SLOPE AND THE GENERAL SLOPE IN THE SURFACE MINE OF THE MARLS IN ELEZ HAN

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Abstract

The future of Kosovo's economic development relies on the exploration of natural resources, particularly, mining. Great importance has been paid to the exploitation of these resources via the surface utilization of marls. Marls being the prevalent raw material for cement production. Since the beginning of the 20thcentury, great achievements have been made in the geo-techniques field, leading to remarkable progress in the art of mining. This paper through the limit equilibrium solution examines the optimization of parameters for slope stability and presents the findings of the on-site research and lab workings conducted on the open-pit mines of marls near the cement plant "SHARR CEM" Elez Han.

Expansion of the mine to the south-eastern boundary will require significant stability analysis. Therefore, to determine represented parameters as realistically as possible, physic-mechanical parameters were drawn from the material on the slope. The lab results were processed from a statistical perspective their reduction was conducted under geotechnical conditions for safety. These parameters were adopted so that slope stability calculations could take place. Two analytic methods were used for geostatic analyses, The Bishop'smethod and Janbu's method.

Keywords: slope stability, geomechanic parameters, geometric working, safety factor, Hane i Elezit

1. Introduction

The continued economic development of Kosova is primarily dependent on mineral resources with mining being a significant industry and main contributor to the economy. Of particular importance is the extraction of marls from open-pit mines.

This paper presents the development of research techniques in the laboratory as well as in the field for the open-pit marls mines locations. In these locations, marls are found in abundance and are the main raw material in the production of cement. The proposed expansion of the mine on the south-eastern boundary requires an assessment of the stability of the slopes for this part of the mine. To find out the exact parameters of lithological strata for which the research has been conducted, some physico-mechanical parameters have been concluded.

For parameters gained in the laboratory, statistical calculations have been employed, resulted in a reduction of parameters on geotechnical conditions required for safety. For geostatic analysis in this paper, two analytical methods have been used: The Bishops' method and Janbus' method.

To date, a wide range of research has been published on the methodology of determining optimal parameters for slope stability in resource utilization. Therefore, in this paper, the application of 'limit equilibrium solution' (methods of potential sliding surfaces) has been applied, to reveal optimization of parameters for slope stability.

2. Current developments in surface mines of marls

Marls reserves are found in the vicinity of town “Elez Han”. Strata of marls are laid out on the eastern side of the town and along the road (motorway) Pristina – Skopje. Research has been conducted to include the terrain which extends into the municipality of Kacanik (road - Kacanik).

Transportation of marls from the open-pit mine to the factory is carried out with conveyor belts constructed over the bridge which crosses the motorway (Pristina – Skopje). The factory is situated on the western side of the road. For this reason, the factory has the desired position and good transportation links.

3. Axiom of the geomechanic parameters needed for geostatice analysis

To achieve a realistic analysis of the slope stability, the manner of selection of the representative geomechanical parameters is of paramount importance. The assumptions of geomechanics parameters were achieved based on the results gained with lab analysis, statistical workings:

- For Marls: φ =30.83 [^{0}], Cr = 31.84[KN/m^2], γ = 20.34[KN/m^3]
- For Sand: φ =26.00 [^{0}], Cr = 15.00[KN/m^2],γ = 22.00[KN/m^3]
- For formations: φ=36.00[^{0}], Cr=125[KN/m^2], γ=28.00[KN/m^3]

Figure 1. The situation map of the marls mine “Elez Han”

4. ANALYSIS OF THE SLOPE STABILITY

Based on the geological and hydrogeological results obtained in the field as well as calculated geomechanics parameters in the laboratory, appropriate geomechanics profiles have been constructed for analysis of the slope stability. The laboratory analysis and the lithology from the samples of test drills have indicated that profile 4-4’ and 5-5’, is more important for the analysis of the stability of the slopes.

Based on the profile mentioned above the following has been analyzed.

Geometric parameters of the working level [α and h] and Overall gradient of the slope[β]

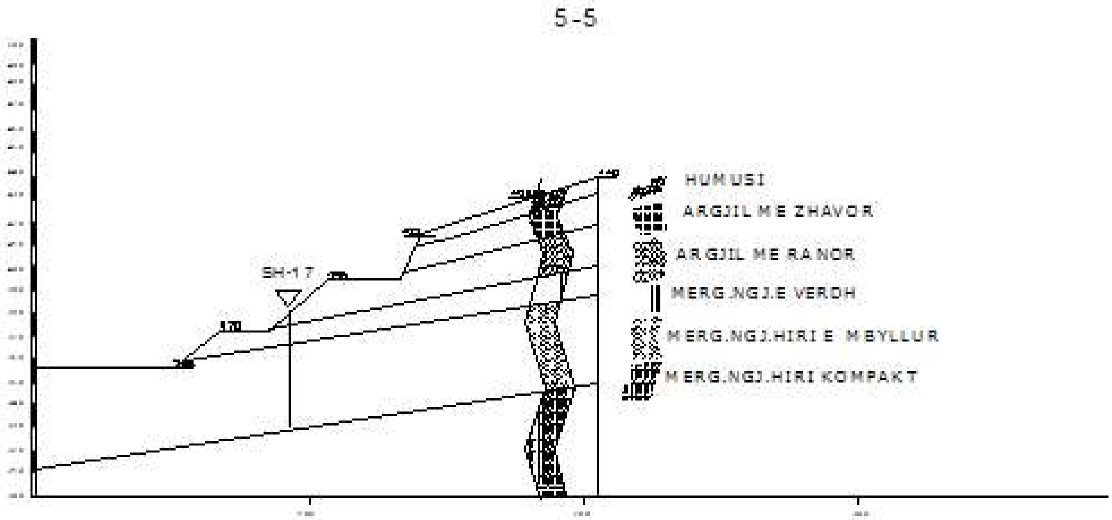


Figure 2. Profile of the working level 5-5

5. Assumption of optimal parameters of the geometric working level (height of the bench [h], angle of the working bench [α] and Overall angle [β])

To achieve a realistic analysis of slope stability the method used to determine optimal geometric parameters of the working level (the height and angle of the bench) is of utmost importance.

Table 1. Fonts, style and appearance

Height of the working level	Angles of the working level	Overall angle of the slope
h=15 [m]	α=50°; α=55°; α=60°	β=25°
h=17 [m]	α=50°; α=55°; α=60°	β=30°
h=18 [m]	α=50°; α=55°; α=60°	β=35°

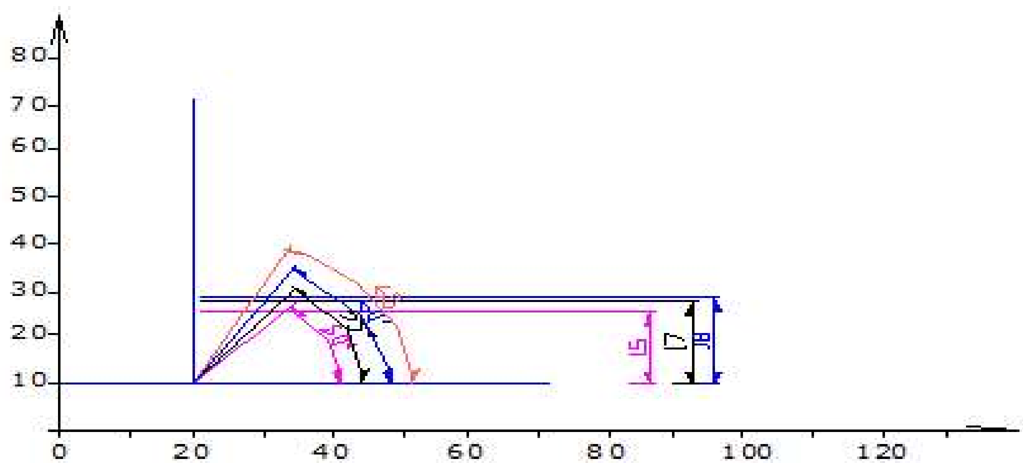


Figure 3. Profile of the working level 5-5

Figure 3. Presents angles of the working level [α] and height of the working level [h] which are being ascertained for geostatic analysis with: BISHOP'S and JANBU'S methods on profile 5-5'.

5.1. Assumption of pore water pressure

This Ratio is usually obtained from the existing tables with given values.
r_u= 0.00 , r_u= 0.10 ,r_u= 0.20 and r_u= 0.3

5.2. Determination of the safety factor

Before we can start analyzing the stability of the slopes, we must obtain the safety factor depending on the weight of the object and time span of the stability of the slope. In this instance, since the working level has a short time span, minimal safety factor. **Fmin= 1.10**, has been adopted. Whereas steepness of the final slope on the eastern side of the mine where there are no objects of any significance, safety factor **Fmin= 1.30**. has been adopted.
And on the western side, there are objects of capital value, like the motorway Pristina – Skopje, Ball mill and Petrol station; for the angle of the bench and angle of the final slope, safety factor **Fmin=1.50**. has been adopted.

6. Methods used for calculation of safety of the slope

Methods for calculating safety of slopes are:

- Sircular slip surfaces – Bishops' method.
- Non-sircular slip surfaces– Janbus' method.
- Diagrams or Hokeut's methods.

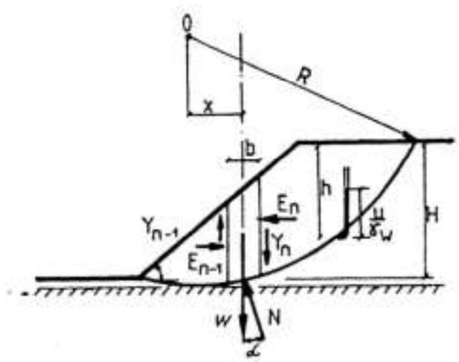


Figure 4. Bishops' method

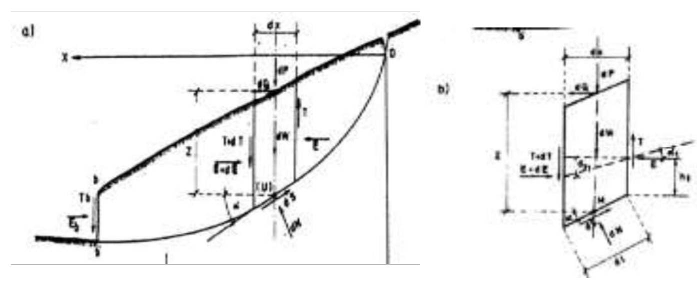


Figure 5. Janbus' method

6.1. Circular slip surfaces – Bishops' Method

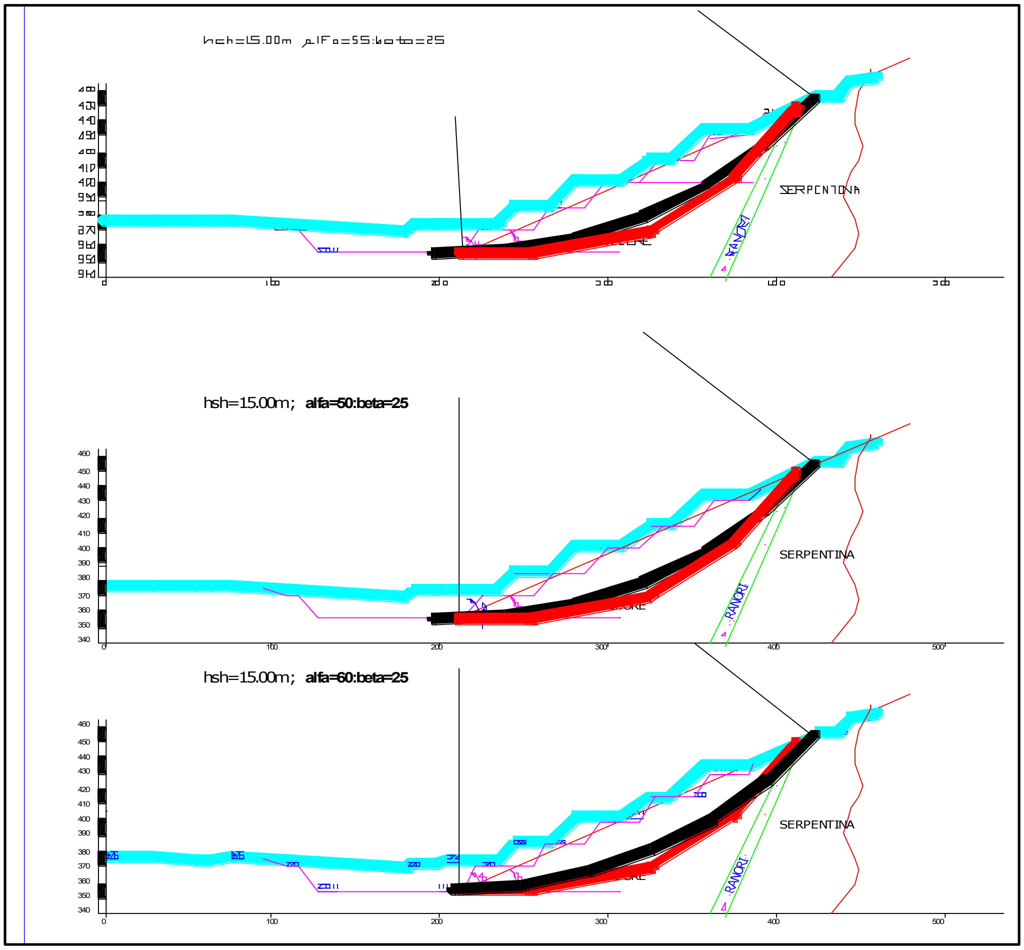


Figure 6. Cross-section profile of the working level

For working level, [Fs] optimal parameters will be:

- h=15[m], β=25° and α=60° if r_u =0.20. Fs=1.50
- h=15[m], β=30° and α=55° if r_u =0.10. Fs=1.24
- h=15[m],β=35° and α=50° if r_u =0.10. Fs=1.11

- h=17[m], β=25° and α=60° if r_u =0.10. Fs=1.42
- h=17[m], β=30° and α=55°if r_u =0.10 Fs=1.20
- h=17[m], β=35° and α=50° if r_u =0.00. Fs=1.21

- h=18[m], β=25° and α=60° if r_u =0.10. Fs=1.40
- h=18[m], β=30° and α=55° if r_u =0.10. Fs=1.18
- h=18[m], β=35° and α=50° if r_u =0.00. Fs=1.10

6.1.1. Analysis of the stability of the overall slope for gradiant

β=25° β=30° and β=35°
Presents the dependence of the safety factor [F_S] from these parameters [r_u],[h], and [α]
Overall angle β=25°

- h=15[m], β=25° and α=60° if r_u =0.10. F_S=1.50
- h=17[m], β=25° and α=55° if r_u =0.10. F_S=1.44
- h=18[m], β=25° and α=50° if r_u =0.10. F_S=1.44

- h=15[m], β=30° and α=60° if r_u =0.10. F_S=1.38
- h=17[m], β=30° and α=55° if r_u =0.10. F_S=1.35
- h=18[m], β=30° and α=50° if r_u =0.00. F_S=1.34

- h=15[m], β=35° and α=60° if r_u =0.10.
- h=17[m], β=35° and α=55° if r_u =0.10. F_S<Fmin.
- h=18[m], β=35° and α=50° if r_u =0.00

Table 2. Changes of F_S

β=25°												
	r_u =0.00			r_u =0.10			r_u =0.20			r_u =0.30		
h(m)	α=50⁰	α=55⁰	α=60⁰	α=50⁰	α=55⁰	α=60⁰	α=50⁰	α=55⁰	α=60⁰	α=50⁰	α=55⁰	α=60⁰
	Fs			Fs			Fs			Fs		
15	1,7	1,69	1,67	1,54	1,52	1,5	1,37	1,35	1,33	1,2	1,18	1,17
17	1,6	1,59	1,57	1,46	1,44	1,42	1,34	1,32	1,31	1,18	1,16	1,15
18	1,6	1,53	1,51	1,44	1,42	1,4	1,32	1,3	1,29	1,16	1,15	1,13

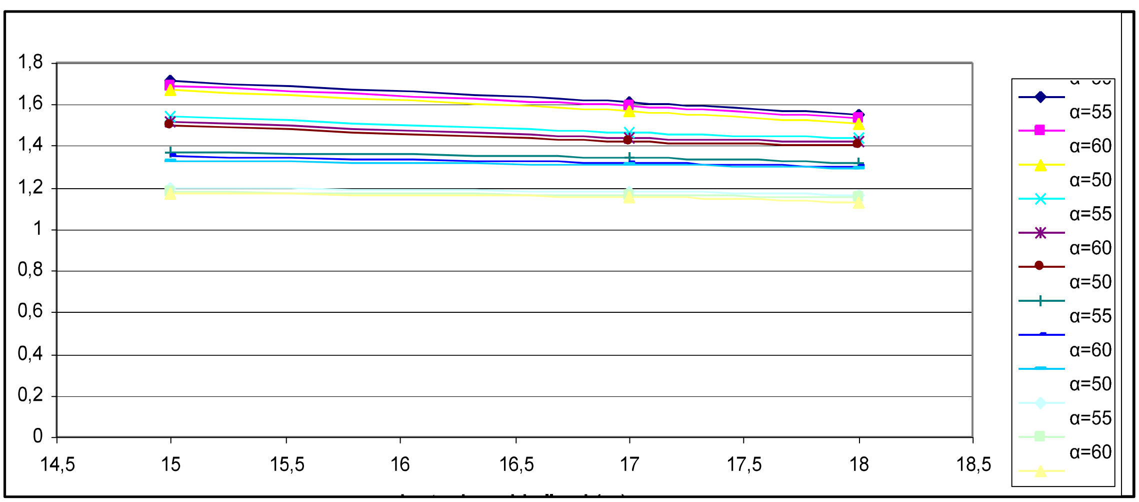
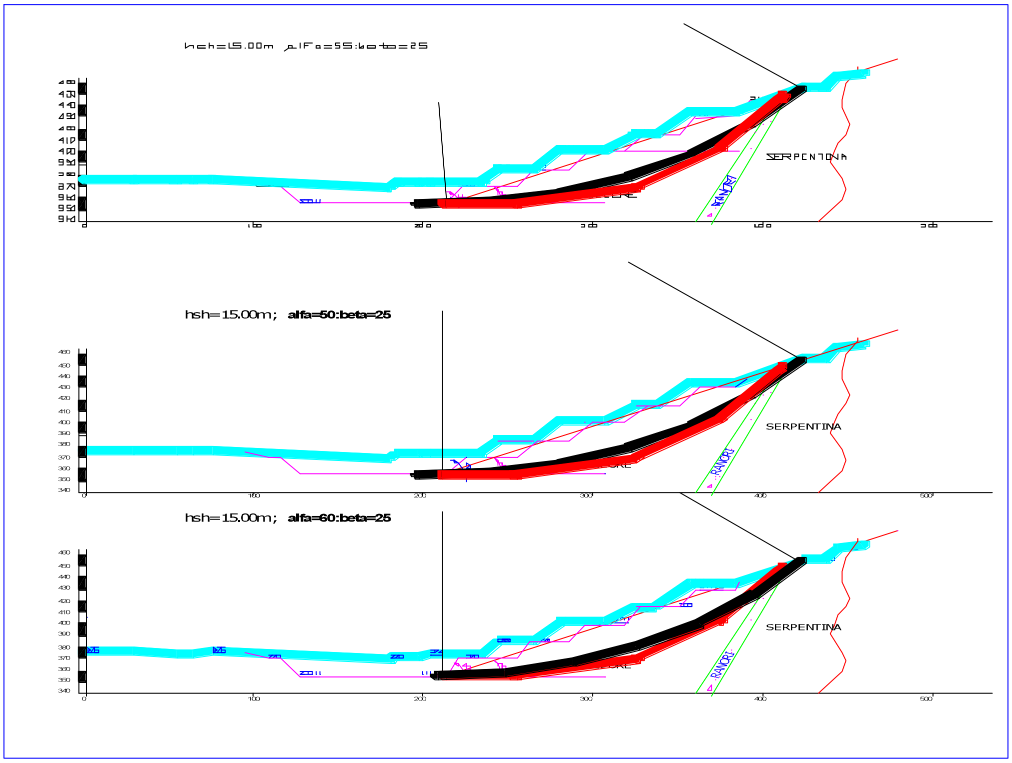


Figure 7. Changes of F_S the values of the parameters β and r_u

6.2. Non-Sircular Slip Surfaces - Janbus' Method

Figure 8. Cross-section profile of the working level



- h=15[m], β=25° and α=60° if r_u =0.10. Fs=1.50
- h=15[m], β=30° and α=55° if r_u =0.10. Fs=1.20
- h=15[m], β=35° and α=50° if r_u =0.10. Fs=1.10

- h=17[m], β=25° and α=60° if r_u =0.10. Fs=1.43
- h=17[m], β=30° and α=55° if r_u =0.10. Fs=1.17
- h=17[m], β=35° and α=50° if r_u =0.00. Fs=1.20

- h=18[m], β=25° and α=60° if r_u =0.10. Fs=1.38
- h=18[m], β=30° and α=55° if r_u =0.10. Fs=1.15
- h=18[m], β=35° and α=50° if r_u =0.00. Fs=1.17

6.2.1 Non-Circular Slip Surfaces - Janbus' Method

β=25° β=30° and β=35°

Represents dependence of the safety factor [Fs] for these parameters [r_u], [h], and [α] for overall angle β=25°.

For the final slope [Fs] optimal parameters will be:

- h=15[m],β=25° and α=60° if r_u =0.10. Fs=1.50
- h=17[m],β=25° and α=55° if r_u =0.10. Fs=1.45
- h=18[m],β=25° and α=50° if r_u=0.10. Fs=1.40

- h=15[m],β=30° and α=60° if r_u =0.10. Fs=1.35
- h=17[m],β=30° and α=55° if r_u =0.10. Fs=1.32
- h=18[m],β=30° and α=50° if r_u =0.00. Fs=1.30

- h=15[m],β=35° and α=60° if r_u =0.10.
- h=17[m],β=35° and α=55° if r_u =0.10. Fs<Fmin.
- h=18[m],β=35° and α=50° if r_u =0.00

Table 3. Changes of F_S

janbus -β=25°												
	r_u =0.00			r_u =0.10			r_u =0.20			r_u =0.30		
h(m)	$\alpha=50^0$	$\alpha=55^0$	$\alpha=60^0$	$\alpha=50^0$	$\alpha=55^0$	$\alpha=60^0$	$\alpha=50^0$	$\alpha=55^0$	$\alpha=60^0$	$\alpha=50^0$	$\alpha=55^0$	$\alpha=60^0$
	Fs			Fs			Fs			Fs		
15	1,69	1,68	1,66	1,5	1,51	1,5	1,37	1,35	1,34	1,2	1,19	1,17
17	1,59	1,57	1,53	1,5	1,45	1,43	1,34	1,32	1,3	1,17	1,15	1,13
18	1,53	1,51	1,49	1,4	1,4	1,38	1,31	1,29	1,28	1,14	1,12	1,11

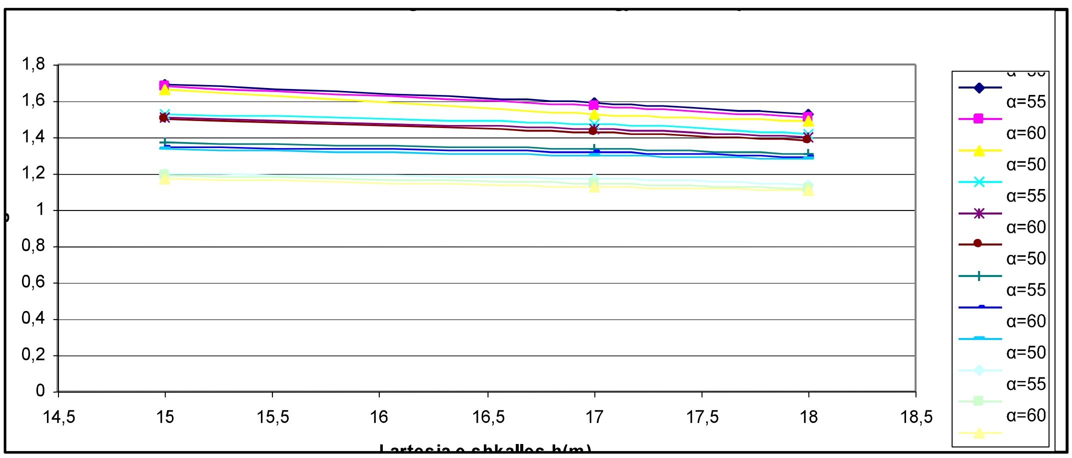


Figure 9. Changes of F_S the values of the parameters α and r_u

6.3. HOEK - Diagrams or Methods

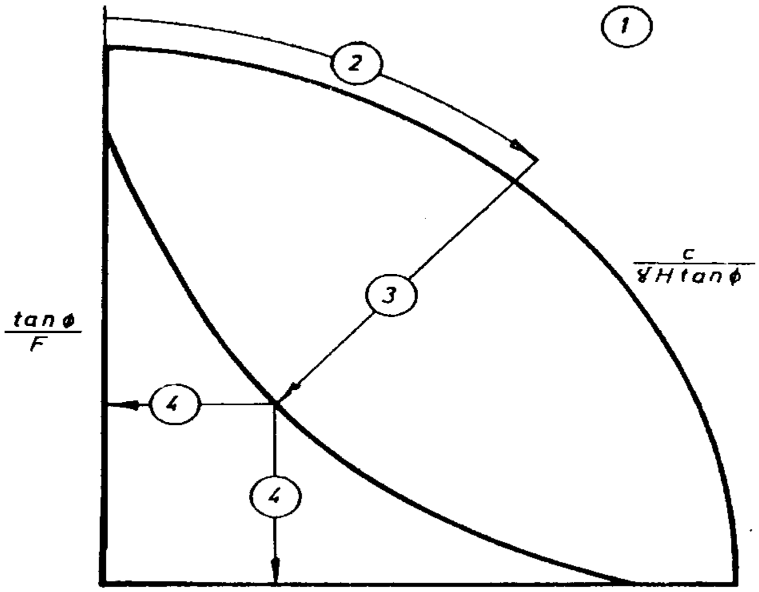


Figure 10. C

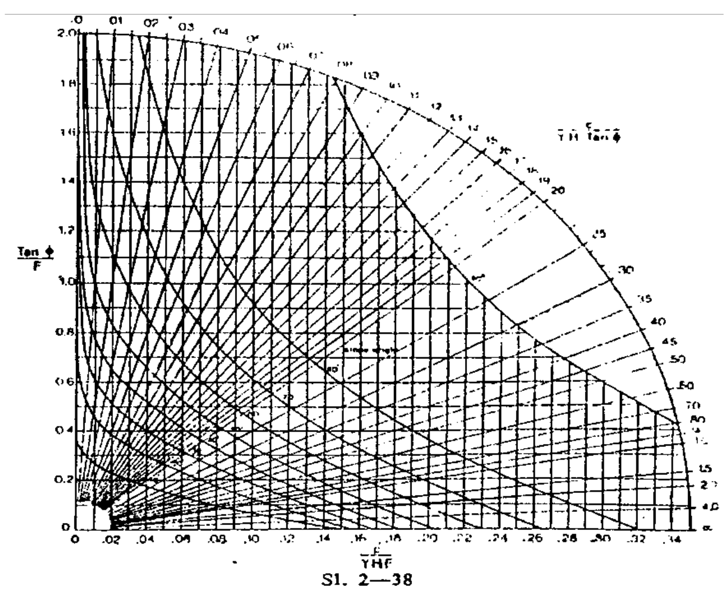


Figure 11. C

Case 1: [X = ∞]
Case 2: [X = 8H]
Case 3: [X = 4H]
For working scales, [Fs] will be optimal:

From table 35 and diagram 27 we notice that [Fs] will be optimal:
α=55°

- h=15[m] Fs=1.31
- h=17[m] Fs=1.22
- h=18[m] Fs=1.16

From table 36 and diagram 28 we notice that [Fs] will be optimal:
α=55°

- h=15[m] Fs=1.22
- h=17[m] Fs=1.18
- h=18[m] Fs=1.15

From table 37 and diagram 29 we notice that [Fs] will be optimal:
α=50°

- h=15[m] Fs=1.25
- h=17[m] Fs=1.18
- h=18[m] Fs=1.15

Table 4. Changes of F_S from angle α

	α =50°	α =55°	α =60°
	Fs	Fs	Fs
h=15	1,43	1,31	1,20
h=17	1,37	1,22	1,13
h=18	1,32	1,16	1,07

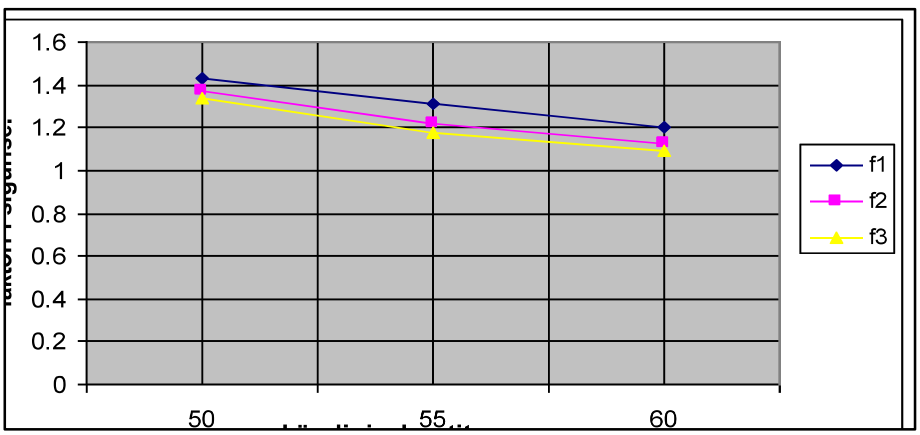


Figure 12. It represents the dependence of the safety factor [F_S]for : α=50° , α=55° and α =60° if x=∞

Case 1: [X = 8H]
Case 2: [X = 4H]
Case 3: [X = 2H]
For the general slope, [Fs] will be optimal:

From table 38 and diagram 30 we notice that [Fs] will be optimal:
$\beta=30^0$

- h=15[m] Fs=1.63
- h=17[m] Fs=1.51
- h=18[m] Fs=1.40

From table 39 and diagram 31 we notice that [Fs] will be optimal:
$\beta=30^0$

- h=15[m] Fs=1.47
- h=17[m] Fs=1.43
- h=18[m] Fs=1.40

From table 40 and diagram 32 we notice that [Fs] will be optimal:
$\beta=30^0$

- h=15[m] Fs=1.40
- h=17[m] Fs=1.35
- h=18[m] Fs=1.30

Table 5. Changes of F_S from angle β

	β=25°	β=30°	β=35°
	F_S	F_S	F_S
h=15	1,59	1,47	1,40
h=17	1,55	1,43	1,37
h=18	1,5	1,4	1,34

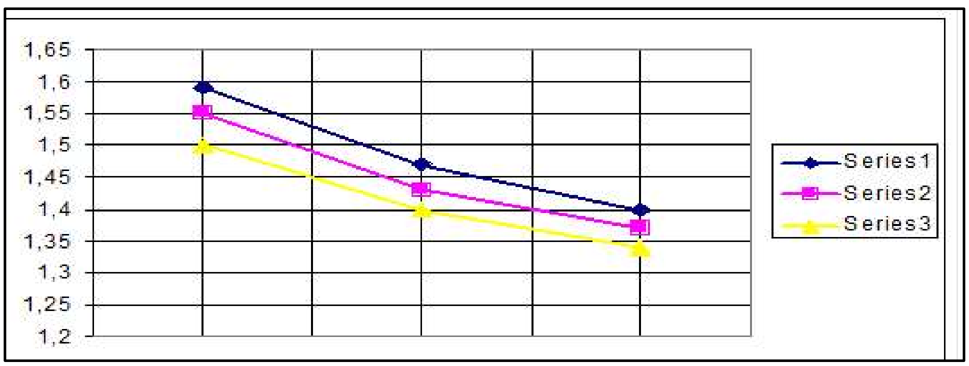


Figure 13. It represents the dependence of the safety factor [F_S]for: β=25°, β=30° and β =35° if x=4H

7. Conclusion

In this paper, we have assessed the stability of the slope in the south-eastern side of the mine, which includes profiles 5-5, 6-6, and 7-7 of the open-pit mine near "Elez Han".

From the existing data of the current state and results obtained from calculations of the slope stability for given geometric parameters for the bench, assumed optimal parameters for geostatic analysis have been adopted.

- h=15(m); α=50°; β=25°;
- h=17(m); α=55°; β=30°;
- h=18(m); α=60°; β=35°;

Results gained of the safety factor for geometric parameters of level, height (h) and angle of the working level (α) and pore water pressure (ru) obtained with Bishop's method, can be found on tables; 4.1, and with Janbu's method are presented on table 5.1.

Results from both methods, match, with some small error rate which is insignificant and poses no safety risk.

Assumed, geometric optimal parameters and research results from the above-mentioned methods lend estimates which give enough stability for optimal and rational exploitation of marls. In conclusion, the expansion of the mine on the south-eastern boundary is feasible.

In these optimally optimized geometric parameters, the geostatic analysis of the 5-5 'profile was used with the following methods:

1. With two analytical methods BISHOP and JANBO-S
2. With a graphical method of HOEK

-Analytical method of BISHOP

For the geometric parameters of the scale: the height of the scale [h] and the angle of the working scale [α] as well as for the porous pressure coefficient [ru] acquired with the Bishop method, the results of the safety factor [Fs] of which can be seen in the tables; 23, 24 and 25. From the results obtained we consider those coefficients of the safety factor [Fs] that are optimal, for the slope of the working scale and for the slope of the general slope to have stability.

-JANBO-S analytical method

For the geometric parameters of the scale, the height of the scale [h] and the working scale angle [α] as well as for the porous pressure coefficient [ru] acquired with the Jambo method, the results can be obtained which can be seen in the tables; 29, 30 and 31 where from the obtained results are used the optimal ones, which guarantee slope stability.

-Graphic method of HOEK

With this method, the methodology of finding the safety factor differs from those of the previous two. Here the distance of the water source from the top of the working slope is taken into account, therefore we have;

5 [five] cases; $X=\infty$; X=8H; X=4H; X=2H and X=0.

From the above cases we have obtained the results of the safety factor which can be seen in tables; 35, 36, 37, for work degree slope and tab. 38, 39, and 40 for the slope of the general slope.

From these results for the safety factor, we adopt the most optimal one.

The results obtained for the safety factor from the Bishop and Jambo methods match us with some small changes, which have no weight in practice, while from the Hoek method the safety factor coefficient is slightly higher in comparison with the two analytical methods but the change of results with the Hoek method for the safety factor is within the allowable limit as with this method another analysis methodology is used for slope stability from the two previous methods.

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