CALCULATION OF SAFETY DISTANCE FOR THE OPERATION OF MINING EQUIPMENT IN THE WORKING ENVIRONMENT WITH WEAKENED CHARACTERISTICS AT THE OPEN PIT "NORTH MINING DISTRICT" OF THE COPPER MINE MAJDANPEK

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Abstract
At the Open Pit "North Mining District" of the Copper Mine Majdanpek, exploitation is planned in the northeastern part of the deposit. The total height of excavation is 195 m with floors of 15 m high. The works are partly performed in the working environment with weakened geomechanical characteristics. This paper presents the calculation of a safety distance for the operation of mining equipment on each floor of the exploitation.

***Keywords**: OP "North Mining District", stability calculation, safety distance.*

1. INTRODUCTION

The Copper Mine Majdanpek is located in eastern Serbia, in the immediate vicinity of the town of Majdanpek, in the south and west of it, in the Mali Pek river basin. Within the copper deposits "North Mining District" and "South Mining District", there are the same named open pits at a distance of 0.5 km from each other. In the immediate vicinity of the deposit there are the infrastructure facilities, which are used for the ore processing, as well as the waste and flotation tailings dumps.

Until 1977, within the Copper MineMajdanpek, only the open pit "South Mining District" was in operation, when the open pit "North Mining District" started operation. Until 1993, only copper ore was mined and copper concentrate was produced, when the excavation of zinc and lead ore began as well as the production of this concentrate. The works at the open pit "North Mining District" were developed within three work sites: "Central part", "Tenka" and "Dolovi".

The open pit "North Mining District" has an elliptical shape of approximate length along the larger axis of 1,900 m and along the smaller axis of 1,100 m. The highest point of the open pit is approximately at the level of k675 m. The lowest point that the open pit currently reached is k360 m. The operation was carried out on a floor with a floor height of 15 m. Up to the level of k452 m, the open pit is of a height type, and below the level of k452 m the open pit passes into a depth type. The current view of the open pit "North Mining District" is shown in Figure 1.

So far, about 33.5 Mt of copper ore and 600,000 tons of polymetallic ore have been produced from the open pit "North Mining District". About 130 Mt of waste was excavated [1].

During 2021 and 2022, it is planned to continue the works in the northeastern part of the open pit. A part of the working environment in which the excavation will be performed has the weakened geomechanical characteristics. The excavation technology is discontinuous: drilling, blasting, loading and transport, with the auxiliary mining works and drainage of the open pit. Therefore, it is necessary to determine a safety distance from the edge of floors for heavy equipment operation (hydraulic excavators and trucks) at all floors of excavation.

Figure 1 The Open Pit “North Mining District”

2. STARTING BASES FOR CALCULATION THE SAFETY DISTANCE

Calculation the safety distance for equipment operation in the working environment zone with weakened geotechnical characteristics was made on a geotechnical profile 3 - 3'[2], Figures 2 and 3. The calculated parameters of the working environment [3] are shown in Tables 1 and 2.

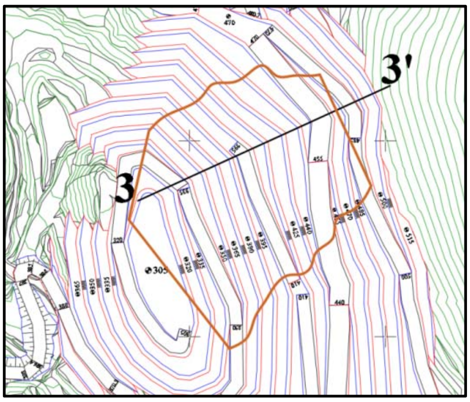

Figure 2 Position of geotechnical profile 3 – 3'

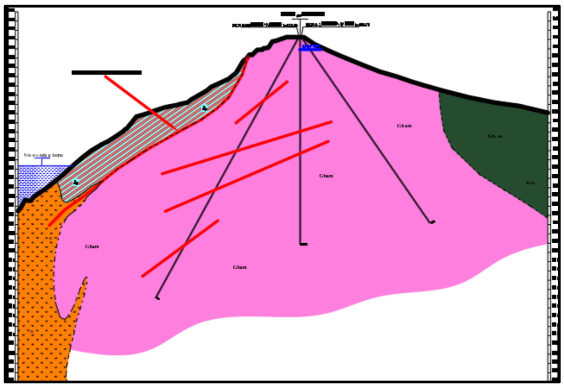

Figure 3 Geotechnical profile 3 – 3'

Table 1 Calculating parameters of the working environment 1

Working environment	Cohesion kPa	Angle of internal friction °	Bulk density kN/m^3
Massive and banked limestones	32	31	26.65

Table 2 Calculating parameters of the working environment 2 and 3

Working environment	UCS kPa	m	s	Bulk density kN/m^3
Gneisses - biotitic, amphibolitic, muscovitic	38.880	1.210300	0.000121896	27.00
Andesites and tectonic breccias	24.500	0.786973	0.000074391	26.03

A hydrogeological model of the deposit has not been developed yet. To determine the safety distance, the pore water coefficient ru = 0.2 was adopted for all working environments [3].

Technology of landslide removal is such that a complete floor is excavated, and then it is moved to a lower floor. The maximum surface load from equipment at the open pit was adopted on the basis of data on the types of excavators and trucks that are planned to be used. These loads are:
Hydraulic excavator: 2 x 61 kN/m; Rear axle of full truck: 2 x 324 kN/m

According to the Rulebook on technical requirements for the open pit exploitation of mineral deposits (Official Gazette of RS, No. 96/2010), for calculation the stability of the working slopes of the floor system for solid rocks at the open pits, the minimum allowable safety factor is Fs = 1.05.

3. SAFETY DISTANCE CALCULATION

The stability calculation was performed with the Rocscience software package [4, 5], i.e. its Slide tool on the basis of boundary equilibrium conditions [4 - 12]. Calculations were performed by the Morgenstern - Price and Bishop methods for the arbitrary sliding surfaces. The program allows automatic search of the critical sliding surface with a minimum safety factor.

Stability analysis on the 3 - 3'profile was performed for each floor of excavation, with the existing water lake up to elevation k383.5 m and for the situation that the water was removed.

The area of sliding surfaces with a safety coefficient of less than 1.05 is defined on each floor, i.e. the safety distance of excavators and trucks from the edge of floor. This distance is increased by 20% for safety, Figure 4.

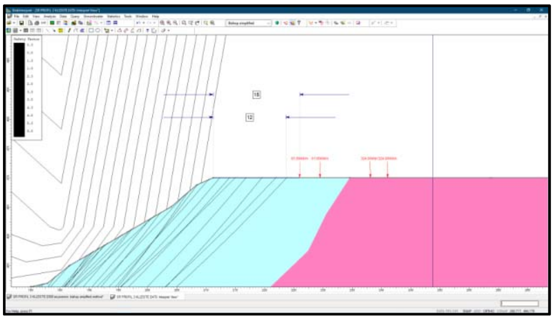

Figure 4 Safety distance from the edge of floor for equipment operation

The output interface of the Slide program for calculation the stability on 3 - 3'profile for one floor is shown in Figures 5 and 6. The safety distances from the edge for equipment operation on each floor are shown in Table 3.

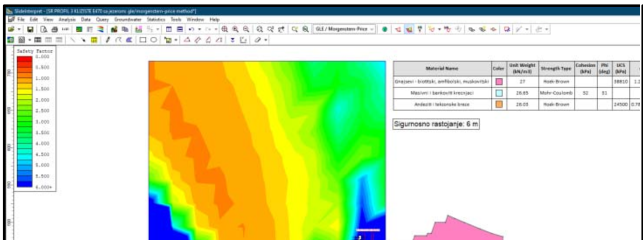

Figure 5 Calculation of stability with a water lake for thefloor E470 by the Morgenstern – Price method

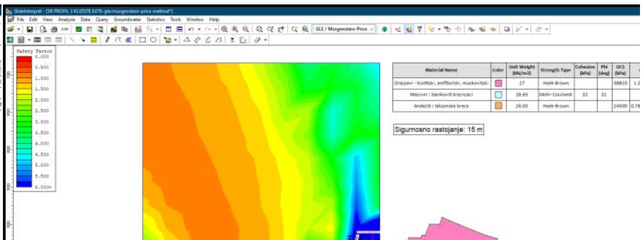

Figure 6 Calculation of stability without a water lake for thefloor E470 by the Morgenstern – Price method

Table3 Safety distances in the zone of weakened material

Floor	Without a lake on the open pit bottom		With a lake up to K383.5 m	
	Zone with Fs<1.05	Adopted safety distance from the floor edge m	Zone with Fs<1.05	Adopted safety distance from the floor edge m
E500	15	18	<10	10
E485	12	15	10	12
E470	12	15	<10	10
E455	20	24	<10	10
E440	49	59	29	35
E425	32	40	10	12
E410	23	28	<10	10
E395	<10	10	-	-

4. CONCLUSION

The safety distance of loading and transport machinery from the outer edge of floor was calculated on the basis of geomechanical characteristics of the working environment and load of machinery, with the required safety coefficient.

The existing accumulation of water on the bottom of the open pit has a great effect on the safety distance of floor from the outer edge of floor. The existence of a water accumulation reduces the safety distance because it acts as a ballast. Due to this reason, the dynamics of water pumping must follow the dynamics of excavation works. Only the amount of water that interferes with the descent to the lower floors should be pumped out.

Loading and transport equipment as well as transport routes on the floor level must be located within the safety zone.

From the moment of possible occurrence, the slope deformations, they must be visually and instrumentally observed. For each specific situation, a program of organized monitoring the occurrence of slope deformations must be made.

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