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STOPE STABILITY ANALYSIS IN ROOM-AND-PILLAR MINING METHOD USING CEMENTED PASTE BACKFILL***

Abstract

Significant economic and environmental advantages can be expected using cemented paste, especially in mining as a backfill for room-and-pillar excavated method. But, it is necessary to investigate the behaviour of cemented paste backfill within mine stope. In this paper will be presented results of stress-strain analysis of stope stability in room-and-pillar excavation method, before and after backfilling with cemented paste on a model developed in a plane (2D) with corresponding boundary conditions. This model was developed in order to analyze stress-strain stability of the room-and-pillar system in excavating block with included loading and drilling corridors. Model was analyzed before and after backfilling. This excavation method will be applied in "Borska Reka" mine, Bor, Serbia.

Keywords: *cemented paste, backfill, room-and-pillar method, stope stability analysis*

INTRODUCTION

Development and application of filling for underground facillities has undergone its development over past three decades in the world. The mining industry was particularly interested in this technology due to a reduction of costs associated with the filling of large underground facilities. In addition to the basic application, filling, construction of pillars and so on, one more important aspect should be taken into consideration, which is the storage of large quantities of tailings underground (up to 60%). This is especially important for the preservation of the environment, especially if the tailings are chemically aggressive (acidic, basic). Back-fill consists of a dehydrated flotation tailing and up to 7% of a binder, such as Portland cement, fly ash, high-pressure furnace slag or a combination of these binders [1], [2], [3].

Canadian scientists Mostafa Benzaazou and Tikou Belem have made a special contribution to the study of the characteristics of various types of filling, obtained by combinations of flotation tailings and binders. In their work *Mechanical behavior of cemented paste backfill* [23], these scientists described the mechanical properties of the backfill obtained from two different types of flotation tailings from polymetallic ores, with increased sulfur content in them. Physico-mechanical properties (specific mass, granulometric composition, uniaxial compressive strength and triaxial testing) were examined on nine different recipes (combination flotation tailing + binder + water) [23], [13].

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Similar researches have been carried out all over the world. Researches are based on the study of various pasta recipes, with different materials, such as: alkali-activated blast furnace slag [4], sulphide-rich mill tailings [10], maple-wood [15], super-fine unclassified tailing [21]. Tests that were carried out on so-obtained pastas are: determination of physical [9], [19], mechanical [14], [17], [21], and rheological properties [8]. Analysis of these properties was performed on 2D and 3D mathematical models [16], [5].

Many of mentioned tests were carried out in Laboratories of Mining and Metallurgy Institute Bor, in purpose to determine the best recipe for cement paste backfill, which will be used in a sublevel stopping method in ore body Borska reka. After determination of the recipe, five models were created for analyzing the stability of underground facilities. Only two of them will be present in this paper, as characteristic models for analyzing stress state in the corridors, before and after they have been filled with cement paste backfill.

It is also very important to monitor the behavior of the surrounding rocks during and after the excavation has been completed [24].

PHYSICAL-MECHANICAL CHARACTERISTICS OF ADDOPTED CPB

Underground cemented paste backfill (CPB) is an important component of underground stope extraction. As mining operations progress, paste backfill is placed into previously mined stopes to provide a stable platform for miners to work on and ground support for the walls of the adjacent adits by reducing the amount of open space that could potentially be filled by a collapse of the surrounding pillars.

CPB, presented in this paper, is a result of tests, which were carried out in the laboratories of Mining and Metallurgy Institute Bor. Basic material for CPB was flotation tailings, together with cement and water. Researches showed that the best results were achieved with CPB which consists of 5% cement, 24% water and 71% noncycloned flotation tailings. In terms of consistency, this CPB belongs to a group of materials with liquid consistency. The binding time is longer than 12 hours. From graph, Fig. 1, it can be seen that the basic condition for uniaxial compressive strength (UCS) of 1.0-1.5 MPa, after 28 days, is fulfilled. Beside the proper physical and mechanical characteristics, this backfill also meets the economic parameters [12], [18].

VERIFICATION OF ADOPTED RECIPES IN THE MODEL

Stability analysis of the isolated stope (chamber – drilling corridor - filling of the excavation with backfill)

In order to analyze the stability of the main corridor, whose dimensions are 4.5 x 4.0 m, a model was constructed in which was analyzed stress-strain state of rock massif around it, as shown in Fig. 1.

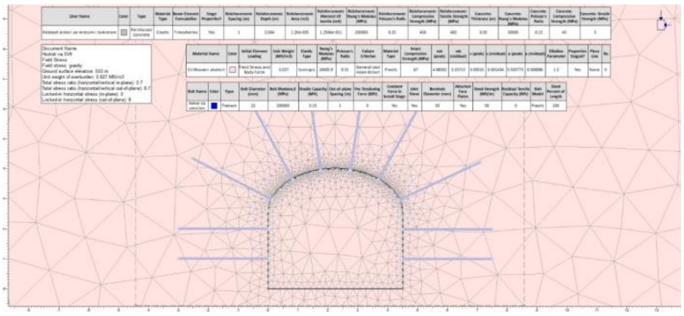

Figure 1 *Construction of the Model for stability analysis of the main corridor*

In such working environments, when plastic deformation of the rock massif is occurring in the excavation environment, only anchoring should not have a major impact on the strength factor and the plasticity zone. However, anchoring, in combination with mesh and sprayed concrete, significantly reduces the number of broken finite elements that will be shown in further analysis.

The excavation chamber, which will be dug up with parallel or fan boreholes, is divided in five segments. Each segment is 4m long, since the height of the transverse corridors is 4 m. The model itself is shown in Fig. 2.

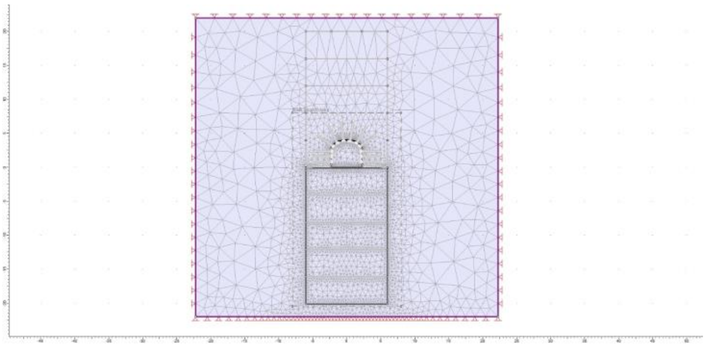

Figure 2 *Model of excavation developing of the chamber – drilling corridor*

The purpose of this model is to analyze the stability of the system drilling corridor - open chamber. It is necessary to be seen what kind of stress appears and whether such a system can be statically balanced and under what conditions.

This is very important because in the next stage, when the works are raised for one floor, the drill corridor will have the function of the loading corridor, which means that the stability of this corridor must be preserved until the moment of closing the chamber and the time required to achieve the full carrying capacity of the paste backfill.

In order to determine how the corridor with an anchor, mesh and sprayed concrete is behaving in such situation, the stress-deformation analysis and the results are presented in Fig.s 3, 4, 5 and 6.

With mounting of anchors through the contour of the corridor, the following values of stress on the anchor and displacements along the depth of the massif were obtained.

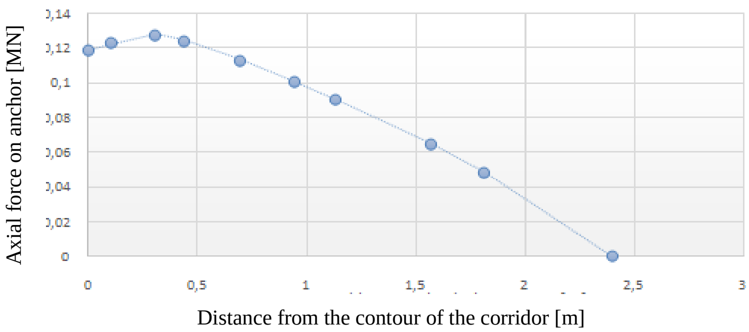

Figure 3 *Graph of changes of axial load on the built-in anchor in the rock massif by the contour of the corridor in the zone of elastic deformations*

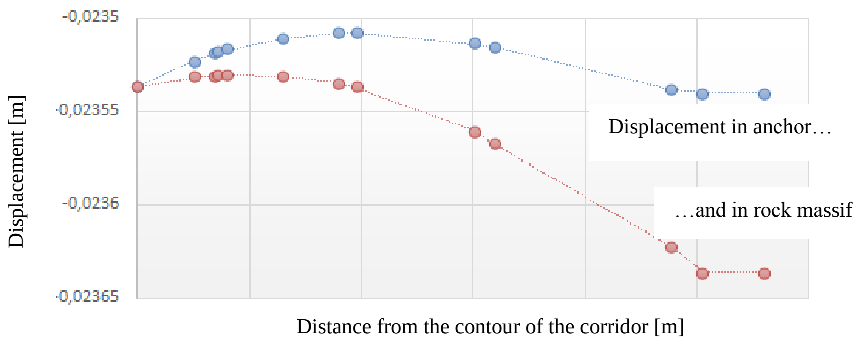

Figure 4 *Graph of displacement in anchor and rock massif by the contour of the corridor in the zone of elastic deformations*

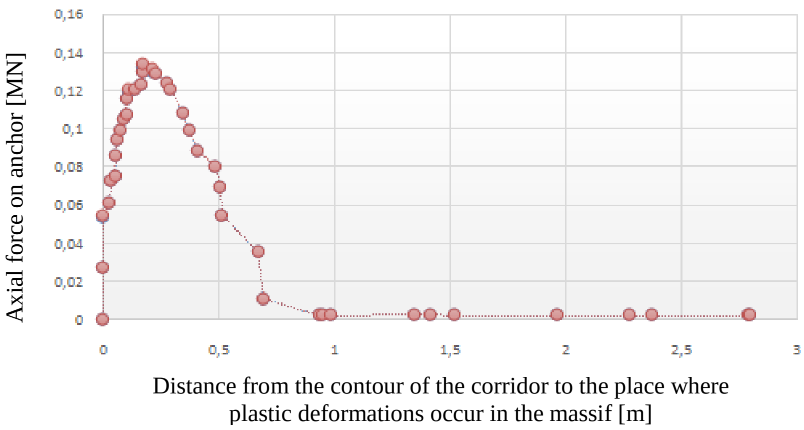

Figure 5 *Graph of changes in axial load in the anchor when plastic deformations occur in the massif through contour of the corridor*

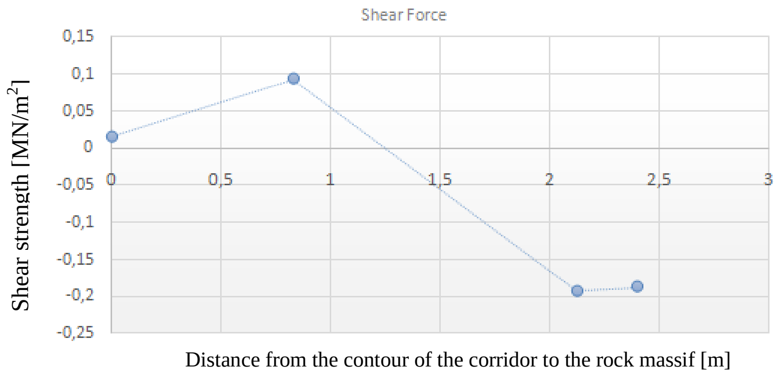

Figure 6 *Graph of changes in shear strength, by length, on the built-in anchor in rock massif over the contour of the corridor*

Plasticification of a rock massif in the surroundings of corridor does not mean that the corridor itself will collapse. The broken material may still have significant strength which will limit the size of the plasticized zone in relation to the width of the corridor. In this case it is noticeable that this zone can be up to one meter, taking into account the quality of the rock massif, depth of the corridor and pressure. Plastification can be manifested only as a few cracks or as a "peeling" of the contour of the corridor in a smaller extent.

During closing the chamber, time required filling the chamber on one side and the time required for solidification of the paste up to reach the final load parameters must be taken into account.

It was tried to be simulated in the model. The results show that number of finite elements in the side of chamber, in which the safety factor is less than 1, is reduced. It is interesting that, when the chamber is fulfilled to its final height, the hardening of the last level of paste results in strains in the floor of the corridor and that zone remains in the plastic deformation zone. It is important that this zone no longer has an impact on the overall stability of the excavation - the chamber + the drill corridor. The plasticization zone switched from the primary pillar from the rock massif to the contact zone of the secondary pillar, created from paste backfill.

The question arises: how does this system behave in the vicinity of the nearest stope?

For this reason, the isolated chamber system in the excavation block was developed as the next model that could answer this asked question.

Stability analysis of the isolated excavation system chamber - loading and drilling corridor

First of all, it is necessary to determine the behavior of the rock massif during the formation of the trial excavating block, especially the stability in the pillars during chamber opening. Development of the model through 15 phases is simulated, which includes various variants in the dynamics of preparation and opening of the trial excavation.

In the first phase was simulated making of the loading and drilling corridors with a distance of three widths of the pillar and without supporting.

In the next phase was observed the case of excavating chambers from the level of the drilling corridor, which are also without supporting, Fig. 7. It can be concluded that there is no interaction between these chambers.

A zone of plasticity is shown in Fig. 8, when there is a beam formation above the chamber, in case the corridors are secured by sub structuring system. The next phase analyzes making of preparation chambers in the middle pillar between the chambers, located at a distance of three widths of the pillars.

The next few phases show different variants of preparation to determine the mutual dependence, shown in Fig.s 9 and 10.

However, if we have the simultaneous opening of two chambers between pillars of hardened paste, Fig. 11, we can expect great instability in pillars, which would jeopardize preparation and opening of the next sublevel. Fig. 12 shows that, when the work is carried out on the higher floor and we are standing on the hardened paste, we have a completely stable system.

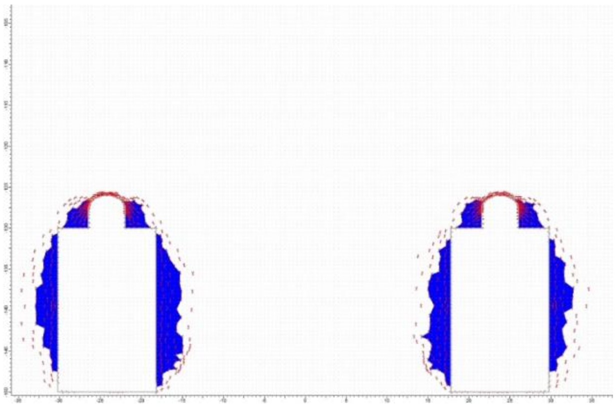

Figure 7 *Plasticization zone during opening the chamber (non-supported corridors)*

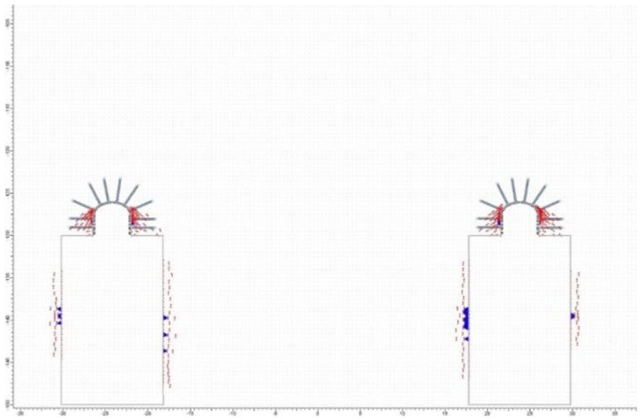

Figure 8 *Plasticization zone at the opening of the chamber (supported corridors with the anchor system + mesh + sprayed concrete)*

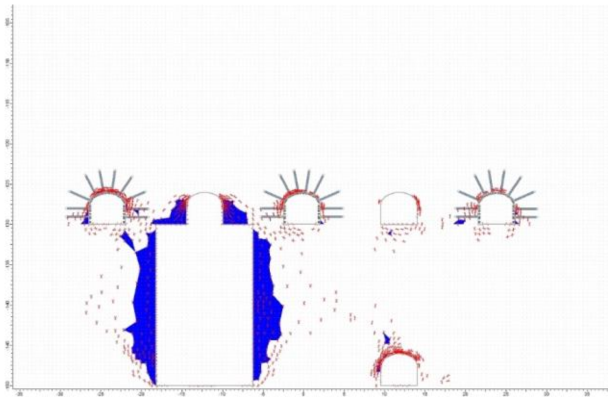

Figure 9 *Plastic deformation in fulfilled primary pillars with backfill, during opening the chamber without supported corridor*

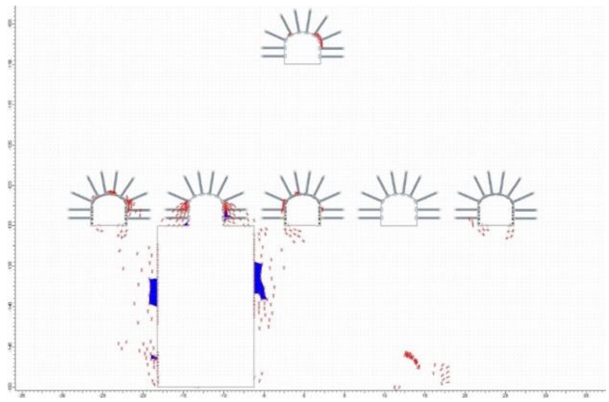

Figure 10 *Plastic deformation in fulfilled primary pillars with backfill, during opening the chamber with supported corridors with the anchor system + mesh + sprayed concrete*

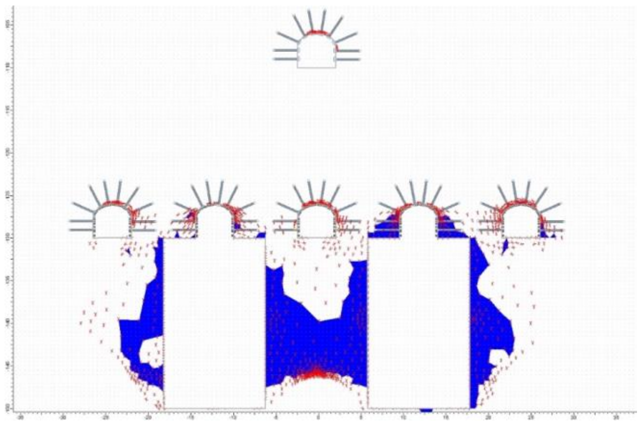

Figure 11 *Simultaneously opening of two chambers between pillars made of hardened backfill and supported drilling corridors*

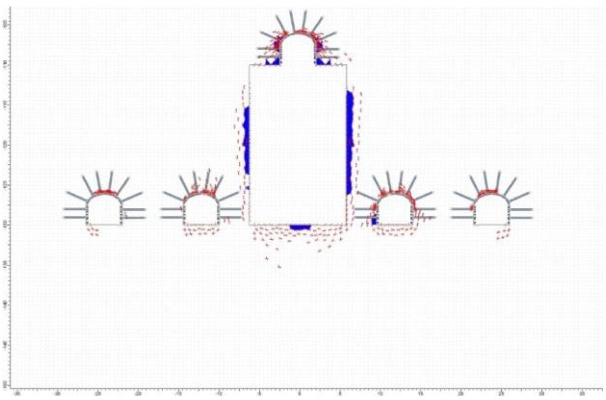

Figure 12 *Drilling corridor opening with chamber on the next sub level, with primary and secondary pillars of hardened backfilling located under them*

CONCLUSIONS

Reviewing the results of numerical analyzes (only plasticization zones are interpreted), it can be said that the security pillars will break along whole section, although its width is 12 meters, when the pillars are made in the room-and-pillar chamber system, regardless of whether is a pillar of a rock massif or a hardened paste.

The state of deformation, plasticity zone and progressive fracture, which can occur in the pillars, can be controlled by proper dynamics of preparation and opening. Works on the construction of corridors, both for loading and drilling, should be avoided in the pillars, beside the open chambers.

It is also a conclusion that the simultaneous opening of every second chamber, in a vertical plane analysis, poses a major problem for stability of pillars. As a measure for overcome of this problem, it is recommendded to accept a larger distance in simultaneous opening of chambers, in order to prevent negative impact of open chambers on one another.

After fulfilling of these chambers, the analysis shows that there is no increase in deformation, but on the contrary, the plasticization zones are in the range of acceptable, above all because of application of insurance system in the drilling corridor.

At the same time, the filled chambers perform relaxation of the primary horizontal stresses in its direction of affect.

Since this is only a 2D analysis and it is difficult to take out the right conclusions without analyzing the complex 3D model, models that provide interpretation of stability in the horizontal cross-section must also be analyzed, and therefore analyze the boundary length of the chamber.

Nevertheless, it can be concluded that the adopted recipe of cement paste backfill fulfilled its purpose. This means, it can be used as a good material for creating artificial pillars for support.

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