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TRANSITION FROM OPEN PIT COAL MINE TO THE UNDERGROUND MINE IN SOFT ROCKS

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ABSTRACT

To achieve a successful and effective operation, the transition from open pit to underground mining requires accurate planning and analysis. Numerical modeling utilizing programs like FLAC3D has been an important tool for simulating and analyzing the complicated geomechanical behavior connected with this shift in recent years. The use of FLAC3D to develop a model for the switch from open pit coal mining to underground coal mining in soft rocks with using room and pillar mining method is explored in this abstract. It presents the development of model to analyze and simulate the complex dynamics of this transition.

The significant considerations that went into developing the model, such as geotechnical characteristics, rock mass behavior, and mine design parameters, are highlighted in the abstract. It highlights how essential proper input data are to producing reliable simulations and forecasts in soft rocks. The usage of FLAC3D for tracking pit wall stability during the transition period, evaluating the influence on nearby infrastructure, and optimizing underground mine design are covered in the abstract. The model's flexibility allows the investigation of various conditions and offers valuable insight about the transition process.

The research emphasizes the potential of the FLAC3D model to lead decision-making during the transition from open pit to underground mining through detailed analysis like choosing appropriate width for main entrance and cross section stopes and their interpretation. It emphasizes how important it is to understand the geomechanical behavior of the coal deposit, optimize the mine's design parameters, and ensure safety for employees. The room and pillar method is utilized to recover coal resources from deep underground mines, and the results from the model can help improve efficiency, sustainability, and risk prevention.

KEYWORDS: ***Underground mining, Open pit mining, Room and Pillar mining method, FLAC3D, Coal mining, Soft rocks.***

INTRODUCTION

Mining plays an important role in case the world's growing demand for mineral resources, but does not come with its challenges. The conventional approach of extracting minerals from deposits that are close to the surface is open pit mining. However, open pit mining's impact on the environment and society lead to questions about its long-term viability. Exploring alternative mining techniques that can reduce these effects while maximizing resource efficiency.

While this research it will be concentrated on the benefits of underground mining and steps which shows the problem solving related to open pit mining like social, environmental, and economic aspects.

The first important issue that needs to be paid attention is the impact on the environment. Open pit mining requires considerable rock, vegetation, and topsoil removal, as well as the resulting destruction of deforestation, ecosystem, and soil erosion. In contrast, underground mining leaves less of a surface imprint, causing less environmental disruption.

Another significant factor that supports the switch to underground mining is resource extraction. Underground mining technologies can effectively access deeper mineral reserves that are unavailable using open pit methods.

The impacts on local communities are also an important consideration. Open pit mining can cause visual disturbances, noise pollution, and dust production, which can all affect the quality of life for those living nearby. The majority of mining operations take place underground and out of sight, minimizing these negative effects and creating mutually beneficial relations.
In this paper room and pillar was chosen as a transition method in soft rock conditions. For the extraction of coal and resources from soft rock formations, room and pillar mining is a common underground mining method. This mining method has been used for many years and has shown to work well in a variety of geological conditions. In the soft rock deposit, a system of connected rooms or galleries is built using the room and pillar mining method, leaving behind a series of support pillars. These pillars support the underground mine's structural integrity and allow the systematic and effective exploitation of the coal.

The underground mine's transportation and ventilation becomes more effective by the room and pillar mining method. Air can circulate individuals, equipment, and materials may move regarding due to the interconnected system of rooms and pillars. Because of this, the mining operation can continue achieving its productivity and safety goals.

However, room and pillar mining have a number of difficulties. To maintain the stability of the pillars and prevent excessive ground movement, the extraction of minerals from soft rock sources requires accurate engineering and design. To maximize the recovery of the mineral resource while maintaining safety, the pillars' size, spacing and stability of entrance must be optimized.

METHODOLOGY AND SIMPLE DESIGN OF ROOM AND PILLAR MINING METHOD IN SOFT ROCKS

The stability of excavations and safety of working staff are important considerations when developing a mining plan. The dimensioning of coal pillars, width of entrance and stopes which are crucial to the mine's overall stability performance, safety is one essential component of ensuring stability. Researchers have spent a lot of time over the years trying to comprehend pillar strength, and numerous methods have been put forward by experts in the field.

Coal pillar design was initially developed by early research by Madden (1996), and Mark. C (1999) [1]. These researches gave empirical formulas and insights into the mechanics of pillar strength and stability of entrance of mining. Modern approaches, such as probabilistic design, have been developed, integrating numerical modeling methods to estimate stability of materials, however design methodologies have evolved through time [2].

The use of numerical modeling in designing performance analysis has become essential. It offers a practical and possibly better alternative to traditional stability methods. To determine stability of pillars and entrance, two-dimensional approximations and three-dimensional numerical FEA approaches have been used. When these numerical models are verified using data from actual excavations, they not only assist with predicting stability behavior but also improve our understanding of material performance.

In this work, a simple 3D model was created (Figure 1) and numerically analyzed using FLAC3D software. Based on geotechnical investigations, field observations, and global experience, geotechnical parameters of the coal orebody it was used average results of material properties for numerical model (Table 1). In case of soft rock materials like kaolin, coal, sandstone, limestone and several soft rock formations were taken into consideration and in the footwall and hanging wall in addition to a flat-lying, relatively shallow coal orebody with an average thickness of 5 m.

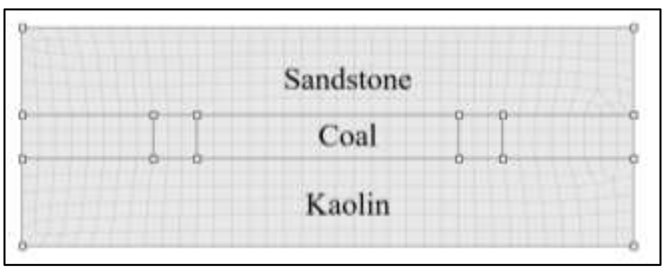

Figure 1. Simple model of soft rock formation

	UCS	Young's Modulus	Cohesion	Tensile Strength	Poisson's ratio	Bulk modulus (Gpa)	Shear modulus (Gpa)
Sandstone	53	15	19	5.2	0.30	12.5	5.76
Kaolin	19	7	6	1.9	0.37	8.97	2.55
Coal	9.7	2.5	2.7	0.85	0.31	2.19	0.95

Table 1. Input Parameters for Numerical Model

Given that both the kaolin and coal formations were categorized as weak rocks, the analysis used the Mohr-Coulomb failure criterion and assumed elasto-plastic deformation. Nine coal pillars altogether, made up of two main access tunnels which are Z1 and Z2, additional galleries Y1 and Y2, four perpendicular cross-cuts X1, X2, X3, and X4. (Figure 2)

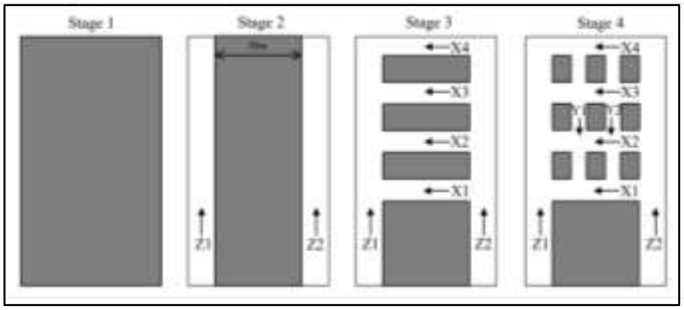

Figure 2. Different Phases of the Stoping Activity

The finite element model analyzed the structure, size, width, roof reinforcement, and excavation process in an effort to reproduce the excavation of room and pillar coal at a pilot scale. Insights into the stability of the coal pillars and the behavior of the excavations are offered by the findings of the numerical study. The use of numerical modeling tools allows a more thorough understanding of the performance of the mine, assisting in the creation of mining plans that are both safe and effective. The findings of this study add to our knowledge about coal pillar design and are helpful for planning future mining operations in related geological situations.

RESULTS

The finite element analysis conducted in this study provides valuable insights into the displacements and stability of the excavated galleries and pillars in the coal mine. The results indicate that the maximum displacements are observed at the middle of the excavated galleries, particularly at the central pillar where the X2 and X3 galleries intersect with the Y1 and Y2 galleries. These sections are identified as the most critical areas, with convergence values ranging from 50 mm to 70 mm. In comparison, the main access galleries (Z1 and Z2) and the back end of the mine (gallery X4) show lower roof displacements of around 40 mm.

The total displacements along the cross-section are showing that the maximum roof displacement is around 50 mm at the central rooms. The pillars also deform in all three main axes due to stress redistribution and increased loading from mining activity.

Actual convergence measurements were performed using topographical equipment with targets placed on the roof and middle section of the pillars. The measurements show good agreement with the numerical analysis, with deformations in the pillars' sidewalls ranging from 10 mm to 20 mm.

The convergence development at the roof of the Z2 entry stope is depicted, showing that the tunnel face progresses up to 25 m from the control point and then stops, with a measured convergence of 18 mm at that point. However, the convergence continues to increase beyond 25 m due to the excavation of neighboring stopes (X1, X2, Y1, Y2), leading to a final convergence value of 40 mm. This indicates that the stability conditions of the Z2 gallery's roof are influenced by the excavation of adjacent stopes.

The actual performance of the pillars, both during and after the mining period, verifies their stability. In the worst-case scenario, where the yielding area progresses through the core of the pillar, immediate support measures such as bolting, or clamping of the pillar's sides can be implemented to remediate stability conditions.

However, stability of entrance and stopes are not less important comparing to pillars. To enhance stability further, a comparison was conducted involving three different types of main entrances with varying widths. The purpose of this comparison was to gain a better understanding of the impact of entrance width on stability. The three models had main entrances with widths of 5 meters, 7 meters, and 9 meters, respectively. The results were evaluated based on the vertical displacement of tunnels. (Figure 3)

In the first model, where the main entrance had a width of 5 meters, the vertical displacement indicated a higher level of safety. However, adopting a 5-meter width for the main entrance would result in narrower stope entries, making it challenging to carry out excavations at the maximum level. Additionally, this width could create difficulties for the entrance of working equipment.

In the second model, with a main entrance width of 7 meters, the vertical displacement suggested a slightly lower level of safety compared to the 5-meter width model. However, opting for a 7-meter width for the main entrance would allow for slightly wider stope entries, ranging from 5 to 6 meters. This width is more suitable for the entrance of working equipment, facilitating smoother operations.

The third model, featuring a main entrance width of 9 meters, exhibited lower safety levels in terms of vertical displacement. This width could potentially pose safety issues in practice, highlighting concerns regarding stability.

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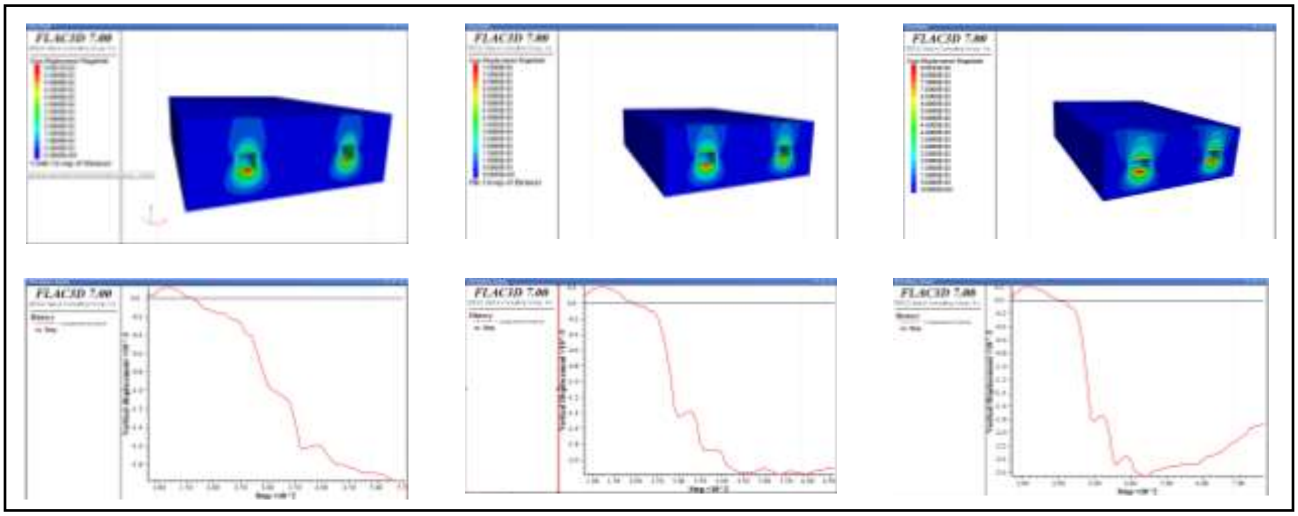

Figure 3. Excavated tunnels and vertical displacement results for different size of width for entrance.

Based on the comparison, it can be concluded that a 5-meter width for the main entrance provides a higher level of safety in terms of vertical displacement. However, the narrower width would limit stope entry sizes and create challenges for the entrance of working equipment. On the other hand, a 7-meter width, although showing slightly lower safety levels, allows for more manageable stope entry sizes and facilitates the entrance of working equipment. Lastly, the wider 9-meter width presents lower safety levels and potential safety issues.

Therefore, when considering the trade-off between safety, practicality, and operational requirements, it is recommended to select the 7-meter width for the main entrance, ensuring a reasonable level of stability while accommodating the necessary dimensions for stope entries and the smooth functioning of working equipment.

For the model of the main entries have been decided a width of 7 meters, while other apertures have a span of 5-6 meters, according to the measurements of the entry and openings. It was decided to set the width of stopes between 5-6 m and the width of the main entries as 7 m. Using 5 m high vertical walls cause the overall height of all galleries was 5 m, with matching the coal thickness. The pillars had a rectangular shape and were 5 m by 7 m in size.

The stability of the roof in tunnel excavations is a critical factor in ensuring the safety of personnel and preventing any potential hazards. The effectiveness of different support systems with varying widths and numbers of rockbolts was evaluated to understand their impact on roof stability.

The first support system design involved the installation of rockbolts with a width of 1 meter and a total of 6 rockbolts. The second design utilized a wider support system with a width of 1.4 meters and 4 rockbolts. The purpose of these designs was to compare their effectiveness in enhancing the stability of the roof.

The results clearly indicate that the implementation of a support system significantly improves the behavior and balance of the roof, thus preventing potential roof falls. The graph depicting the comparison demonstrates the increasing stability achieved with the installation of the support system.

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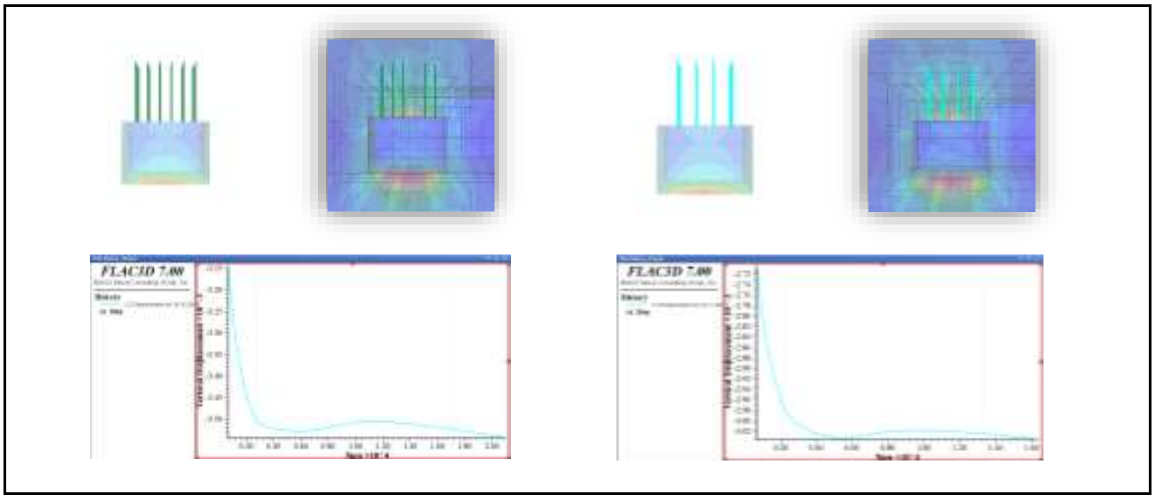

Figure 4. Two different rockbolts support and vertical displacement.

In the first design, where rockbolts were placed at a width of 1 meter with a total of 6 rockbolts, a noticeable improvement in roof stability was observed. This design effectively prevented the roof from collapsing and provided adequate support to withstand the surrounding pressure.

The stability of the roof was further tested by the second design, which made use of a wider support design with a width of 1.4 meters and 4 rockbolts. This greater separation also well made it possible to support the roof adequately, assuring its stability and lowering the possibility of any potential failures.

The rockbolts utilized in both designs had a length of 2.4 meters and a typical bearing capacity of 120 kN, which is essential to note. The roof structure was reinforced in the model by the installation of these rockbolts in a grid pattern with 1.4 meter spacing.

The results demonstrate that the implementation of a support system with rockbolts significantly improves the stability and strength of the roof in soft conditions. The wider spacing of rockbolts, as seen in the second design, can provide optimal support while maintaining a reasonable width for equipment access.

While choosing the best support system design for tunnel excavations, it is suggested to take the individual geotechnical conditions and the load-bearing capacity needs into consideration. The research study highlights the significance of a well-designed support system for providing secure and stable tunnel operations and can be a useful resource for engineers and tunnel building professionals.

CONCLUSION

In conclusion, modelling analysis conducted in this study provided insights into the displacements and stability of galleries, entrance and roof structures in underground coal mining. Critical areas with the highest convergence values were predicting at the intersections of certain galleries, particularly at the central pillar. Actual measurements validated the numerical analysis, confirming the deformations in the pillars' sidewalls and the impact of neighboring stopes on roof stability.

Regarding the stability of entrances and stopes, a comparison of different main entrance widths revealed that a 7-meter width balances safety and practicality. While a 5-meter width offers higher safety, it limits stope entry sizes and equipment access. A wider 9-meter width poses safety concerns. Therefore, a 7-meter width is recommended to ensure stability and accommodate necessary dimensions.
The evaluation of support systems showed that installing rockbolts significantly improves roof stability. Designs with different widths and numbers of rockbolts demonstrated effective stability enhancement. The wider design with a width of 1.4 meters and 4 rockbolts provided excellent stability and reduced the risk of roof collapses.

In summary, this research highlights the importance of modeling, proper support system design, and consideration of geotechnical conditions in transition to underground coal mining. The findings contribute to improving efficiency, sustainability, and safety in the transition to underground mining, providing valuable guidance for professionals in the field.

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