

DEVELOPED GALLERIES AND MECHANIZED DEPILLARING AND SAFE EXTRACTION IN COAL MINES

Vishwanath Reddy B¹, N. Siddhu², K. Jagannadha Rao³, B. Saiprathap Reddy⁴,
I.Sreekanth⁵

^{1,2,3,4,5} Students, Department of Mining, ABR College Of Engineering and Technology, Chinairlapadu,
Kanigiri, Andhra Pradesh

Bala Brahmachari

Assistant professor, Department of Mining, ABR College Of Engineering and Technology,
Chinairlapadu, Kanigiri, Andhra Pradesh

ABSTRACT

In coal mining, the challenge of extracting coal from thick seams while ensuring miner safety is critical. The development of galleries and mechanized depillaring methods has significantly improved recovery rates and safety in coal extraction. The "Blasting Gallery" (BG) method, specifically designed for thick seams, involves the creation of controlled galleries that allow for the systematic removal of coal pillars. This technique, combined with mechanized depillaring, enhances the recovery of coal by reducing the risk of roof instability and minimizing manual labor. The study focuses on the operational aspects of BG and mechanized depillaring in deep coal mines, particularly in Indian geo-mining conditions. The proposed model emphasizes using advanced equipment for real-time monitoring of roof displacement, convergence, and goaf edge distance to ensure stability. The research demonstrates the importance of integrating modern machinery and monitoring technologies in improving coal extraction efficiency while safeguarding mine stability and worker safety in thick coal seams.

Keywords: Blasting Gallery, mechanized depillaring, coal extraction, mine safety, roof stability, geo-mining conditions, real-time monitoring

1. INTRODUCTION

The extraction of coal from underground mines, particularly in thick seams, presents numerous challenges related to both resource recovery and miner safety. To address these challenges, the development of advanced underground galleries and the implementation of mechanized depillaring methods have significantly improved the extraction process in modern coal mines. The Blasting Gallery (BG) method, which creates a network of controlled galleries, facilitates the extraction of coal while maintaining roof stability and minimizing the risk of collapse. This technique allows for the systematic removal of coal pillars, which are traditionally left behind for support, by using controlled blasting techniques that create voids without compromising structural integrity.

Mechanized depillaring further enhances safety by utilizing specialized machinery to remove coal pillars, reducing the need for manual labor in hazardous conditions. This combination of developed galleries and mechanized equipment maximizes coal recovery and increases operational efficiency, all while improving safety protocols. The use of real-time monitoring technologies, such as convergence meters and geotechnical sensors, helps assess roof stability and track any displacement, providing valuable data to ensure continuous safe extraction. The integration of these advanced techniques allows for higher productivity, reduced costs, and safer working conditions, making it an essential approach for modern coal mining, especially in deep mines with thick coal seams

2.Literature review

The extraction of coal from thick seams has always posed significant challenges in mining operations. Over the years, various methods have been developed to enhance coal recovery while ensuring the safety of miners. The **Blasting Gallery (BG) method** and **mechanized depillaring** are two key techniques that have significantly advanced coal extraction, particularly in deep and thick seams. The BG method, first introduced in the 20th century, involves the creation of a network of galleries in coal seams, where controlled blasting is used to extract coal while maintaining roof stability. The BG method provides higher recovery rates compared to traditional methods by systematically removing coal pillars that were previously left for roof support (Kumar et al., 2005). According to Singh et al. (2012), the BG method can be applied effectively in coal seams with thicknesses over 10 meters, where conventional methods would be less efficient. The method's ability to create controlled cavities in the seam allows for better coal recovery without compromising mine stability.

Despite its advantages, the BG method also poses challenges, particularly in terms of maintaining roof stability during blasting operations. **Sharma and Gupta (2015)** observed that variations in overburden pressure and strata configuration significantly affect the success of the method. Thus, continuous monitoring of roof convergence and goaf edge distance (GED) is necessary to ensure the safe execution of the BG method. **Reddy and Naik (2017)** emphasized the role of controlled blasting in minimizing seismic disturbances and ensuring the integrity of the mine structure during BG operations. Mechanized depillaring involves the use of machinery to systematically remove coal pillars, which has been an essential innovation in modern mining practices. Unlike traditional hand-picking methods, mechanized depillaring employs equipment such as continuous miners, hydraulic jacks, and powered supports to extract coal and support the mine roof simultaneously (**Singh & Gupta, 2016**). The use of mechanized equipment significantly reduces the risk to miners and increases the efficiency of coal recovery. **Mishra et al. (2019)** highlighted the benefits of mechanized depillaring in reducing manual labor and the associated risks of roof falls. The automation of pillar removal processes also enhances the precision of extraction and minimizes resource wastage. However, the method requires a high initial investment in machinery and equipment, which can be a limitation for some coal mines (**Singh et al., 2017**). Despite this, the long-term benefits in terms of increased coal recovery and improved safety outweigh the initial costs, making it a critical aspect of modern coal mining operations. Recent developments in monitoring technologies have played a crucial role in enhancing the safety and efficiency of BG and mechanized depillaring methods. Real-time monitoring equipment, including convergence meters, geotechnical sensors, and seismic monitoring devices, provide continuous feedback on roof stability and displacement during the mining process (**Pandey et al., 2018**). These advancements have made it possible to track the impact of mining activities on the mine structure and adjust operations accordingly to prevent accidents.

In the context of the BG method, **Srivastava and Meena (2020)** noted the importance of monitoring the effects of induced blasting on roof strata and the surrounding geology. With real-time data, mine operators can predict roof movements and take corrective actions before any hazardous situations arise. Additionally, the use of predictive models based on real-time data allows for optimization of the depillaring process, reducing the chances of over-extraction or under-extraction (**Kumar et al., 2019**). While the BG method and mechanized depillaring have been widely studied and implemented in several parts of the world, their application in Indian geo-mining conditions presents unique challenges. Indian coal seams often have varying thickness, complex geological structures, and inconsistent overburden pressures, which can complicate the application of these methods (**Mishra et al., 2019**). In their review of mining operations in India, **Singh and Meena (2018)** discussed how geo-mining conditions such as high moisture content, variable seam dip, and irregular strata create difficulties for coal extraction.

Moreover, the lack of a comprehensive database on geo-technical parameters specific to Indian coal mines has hindered the widespread adoption of advanced mining techniques like BG and mechanized depillaring. Research focused on these localized conditions, such as the study by Srivastava et al. (2020), highlights the need for tailored mining strategies that consider regional geological differences.

3. Methodology

The methodology for this study on the Blasting Gallery (BG) method and mechanized depillaring for coal extraction is based on a combination of theoretical analysis, field data collection, and simulation modeling to understand and optimize the mining process. The research primarily focuses on understanding the impact of various geo-technical parameters, operational systems, and safety considerations in the extraction process, particularly in the context of Indian coal mines with thick seams.

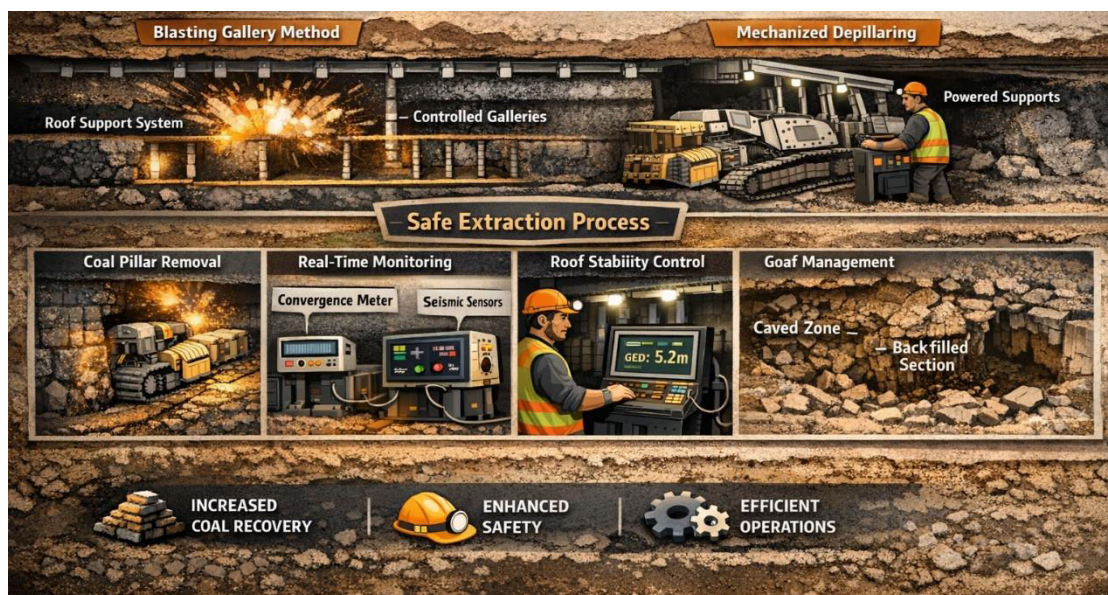


Fig 1: Developed Galleries and Mechanized Depillaring for Safe Extraction in Coal Mines

1. Site Selection and Initial Assessment

The study was conducted at the GDK 10 incline, 3A panel of Singareni Collieries Company Limited (SCCL), located in Ramagundam. This mine has a coal seam thickness of 11 meters and is situated at a depth of 350 meters, making it an ideal site to examine the challenges associated with the BG method. Initial assessments included the collection of geological data, such as seam characteristics, overburden pressures, and existing mining practices.

2. Data Collection and Monitoring Parameters

To evaluate the effectiveness of the BG method and mechanized depillaring, comprehensive data collection was performed using both field-based methods and advanced monitoring equipment:

- Goaf Edge Distance (GED): The distance between the mined face and the goaf area was measured at different stages of mining to assess roof stability and potential risks of collapse.
- Roof Convergence: Continuous monitoring of roof displacement was conducted using calibrated convergence meters. This helped assess roof movement as a result of the removal of coal pillars during the depillaring process.

- **Overburden Pressure:** The pressure exerted by the overburden on the coal seam and surrounding strata was measured using geotechnical sensors, enabling the study of how variations in overburden pressure affect mining efficiency and safety.
- **Induced Blasting Monitoring:** Data on the frequency, intensity, and impact of induced blasting was collected to assess the effects of blasting on strata behavior and roof stability.

4. Simulation Modeling of In-Situ Conditions

The study employed simulation software to develop an in-situ model of CM Panel No. 2. The model included the development of galleries and the removal of coal pillars under varying geo-mining conditions. Key steps involved:

- **Block and Boundary Conditions:** The model incorporated block and boundary conditions that simulate the real-world constraints of the mine, including fixed boundaries representing the surface and the base of the mine.
- **Stress and Load Distribution:** The simulation modeled the application of rock load from the overburden and dynamic forces due to mining activities such as blasting and pillar removal. The stress distribution was analyzed to evaluate the structural integrity of the mine.
- **Convergence Behavior:** The model tracked roof displacement over time, evaluating how different mining strategies (such as changes in the goaf edge distance or blasting intensity) impacted roof stability.

block and boundary conditions include:

1. **Boundary Conditions:** The model simulates the constraints and restrictions imposed by the surrounding geological structures. This includes fixed boundaries at the mine surface and base, which represent the overburden and underlying strata. These conditions ensure that the simulation reflects the actual interaction between the coal seams and the surrounding rock mass.
2. **Rock Load Application:** The load applied to the coal seam in the model reflects the overburden pressure and other dynamic forces acting on the strata. This is critical for understanding the distribution of stresses and the potential for roof displacement or collapse.
3. **Goaf and Pillar Behavior:** The simulation included the modeling of coal pillars left behind during the mining process and the goaf zone (the voids left after coal removal). The interaction between these elements, including the movement of the surrounding strata, was studied to evaluate the stability of the mine.
4. **Convergence Monitoring:** Real-time monitoring of convergence (roof displacement) was modeled, with the behavior of roof strata under various conditions of pressure and blasting taken into account. The simulation provided insights into how these displacements would affect mining operations and the safety of the underground environment.
5. **Stress Distribution:** The simulation showed how stresses from mining activities, including blasting and extraction, affect the surrounding strata, with an emphasis on understanding the potential for instability or subsidence.

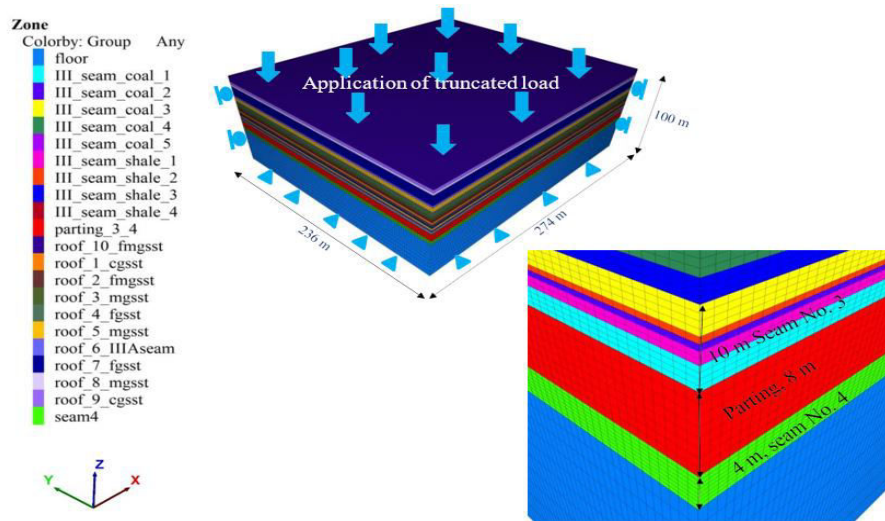


Fig 2. Generated block and boundary conditions in in-situ model of CM Panel No. 2 using the simulation software.

The figure above represents the block and boundary conditions applied in the in-situ model of CM Panel No. 2, developed using simulation software. The model includes various coal seams, roof layers, and truncated load applications, which simulate real-world mining conditions to analyze the behavior of the panel under different stress conditions.

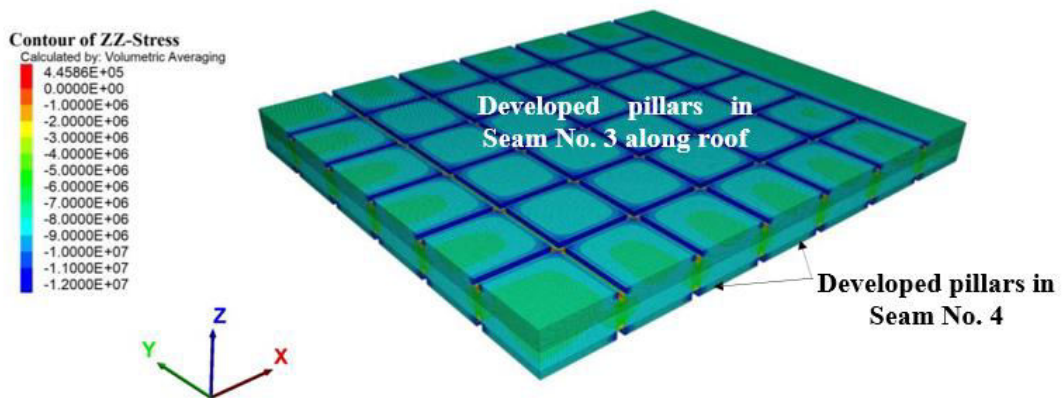


Fig 3. Development of proposed Panel No. 2 and underlying seam 4 in superimposed manner as per geo-mining conditions using the simulation software

The figure above illustrates the development of the proposed Panel No. 2 and the underlying Seam No. 4 in a superimposed manner, modeled according to geo-mining conditions using simulation software. The visualization shows the stress contours and the developed pillars in Seam No. 3 and Seam No. 4, providing insights into the interaction between the coal seams and the structural integrity of the mining area.

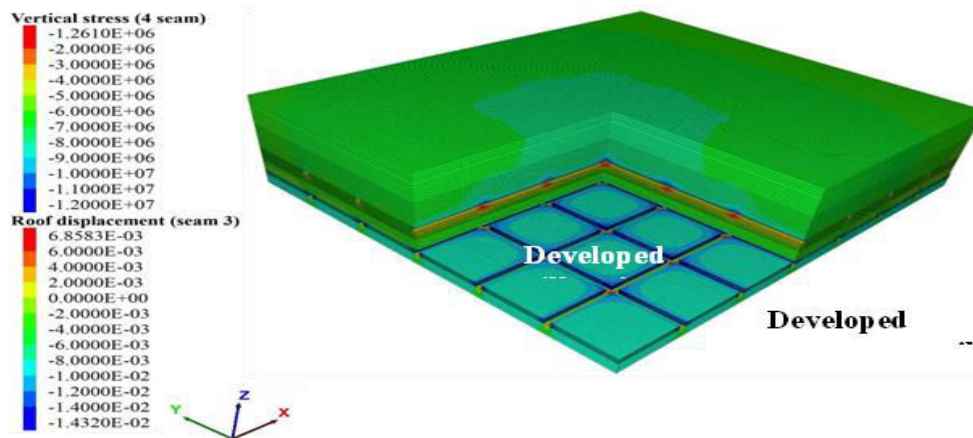


Fig 4. Assessment of roof displacement in seam 3 during superimposed development in both contiguous seams using the simulation software

The figure above illustrates the assessment of roof displacement in Seam 3 during the superimposed development of contiguous seams. The model, created using simulation software, displays the vertical stress and roof displacement patterns in Seam 3 and Seam 4. This visual representation helps analyze the displacement behavior in the roof structure as mining progresses, highlighting the interactions between the seams and their impact on roof stability during the development process.

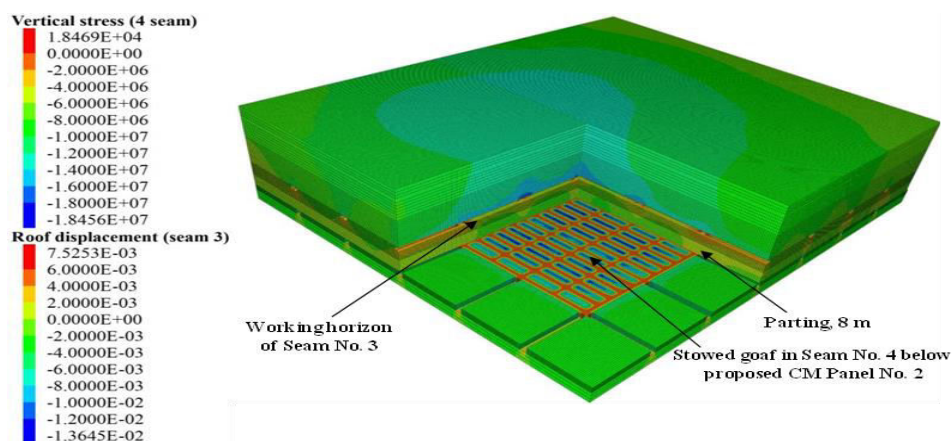


Fig 5. Assessment of roof displacement during widening and heightening in proposed CM Panel No. 2

The figure above shows the assessment of roof displacement during the widening and heightening process in the proposed CM Panel No. 2. Using simulation software, the image highlights key factors such as the working horizon of Seam No. 3, the parting between seams, and the stowed goaf in Seam No. 4 beneath the proposed panel. The vertical stress and roof displacement patterns are illustrated, providing valuable insights into the structural behavior and stability of the mine roof during these mining operations.

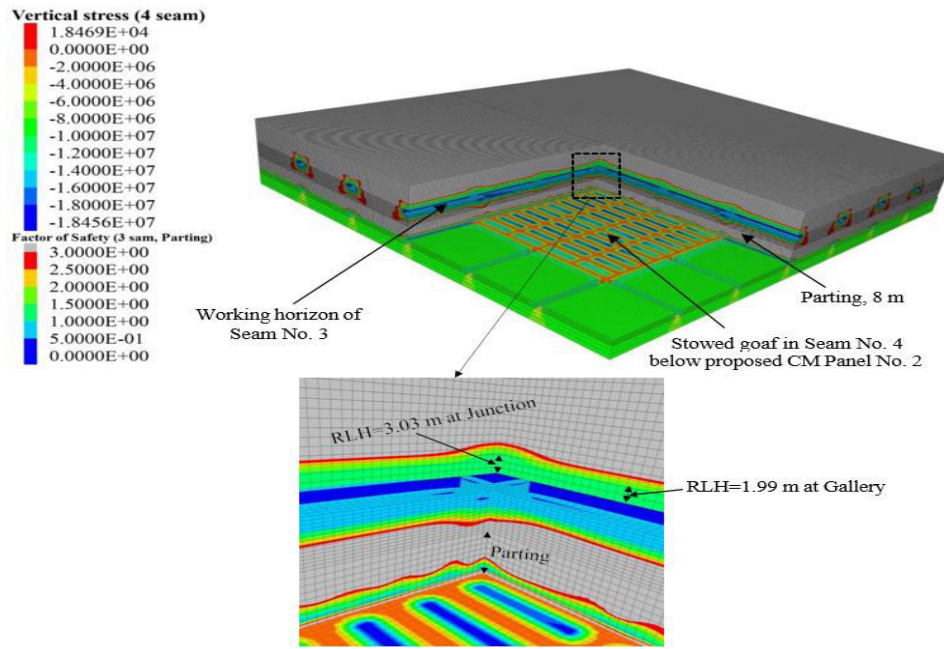


Fig 6. Rock load height at junction and gallery after widening and heightening in proposed CM Panel No. 2 above stowed goaf of underlying seam 4

The figure above shows the rock load height (RLH) at the junction and gallery after the widening and heightening of the proposed CM Panel No. 2. The model visualizes the vertical stress distribution and safety factor within the seams, with a focus on the working horizon of Seam No. 3 and the stowed goaf in Seam No. 4 below the panel. The inset highlights the RLH values at the junction (3.03 m) and at the gallery (1.99 m), providing insights into the load distribution and structural behavior of the mine after the expansion.

Table 1: Rock Load Height (RLH) and Safety Parameters at Junction and Gallery in Proposed CM Panel No. 2".

Parameter	Value at Junction	Value at Gallery
Rock Load Height (RLH)	3.03 m	1.99 m
Working Horizon (Seam No. 3)	-	-
Parting Distance	8 m	8 m
Stowed Goaf (Seam No. 4)	Below Panel No. 2	Below Panel No. 2
Vertical Stress (Seam No. 4)	1.8469E+04	1.8469E+04
Safety Factor (Seam No. 3)	5.00E+01	5.00E+01

The **Blasting Gallery (BG) method** and **mechanized depillaring** represent significant advancements in coal mining, particularly for deep and thick seams where traditional mining methods struggle to achieve optimal recovery and safety. Both techniques offer several advantages, including improved coal recovery, increased safety, and enhanced operational efficiency. However, as this study highlights, successful implementation requires a thorough understanding of various geo-technical factors, continuous monitoring, and the application of modern technologies.

One of the primary advantages of the BG method is its ability to increase coal recovery from thick seams, where conventional methods such as longwall mining or bord and pillar may not be as effective. By creating controlled galleries and using blasting to systematically remove coal pillars, the BG method allows for higher recovery rates, especially in seams that are too thick or deep for traditional methods. However, as Singh et al. (2012) point out, the success of this method heavily depends on the precise execution of blasting, as improper blasting techniques can lead to roof instability, resulting in dangerous situations for miners. This reinforces the importance of careful planning and the integration of safety protocols during BG operations.

Mechanized depillaring, on the other hand, offers a significant advantage by reducing the need for manual labor, which has traditionally been a high-risk component in mining operations. The use of specialized machinery to remove coal pillars not only enhances safety by eliminating miners from hazardous work areas but also increases the speed and precision of extraction. Singh and Gupta (2012) emphasize that mechanized depillaring systems, such as continuous miners and hydraulic jacks, provide higher precision in pillar removal and reduce the overall risk of roof falls. While this method requires significant upfront investment in machinery, the long-term benefits—such as reduced labor costs, higher productivity, and improved worker safety—outweigh the initial costs, making it a cost-effective solution in the long run.

Another key aspect discussed in this study is the role of real-time monitoring technologies in ensuring the success and safety of these methods. Monitoring roof displacement, goaf edge distance (GED), and induced blasting effects are essential to maintaining stability in the mine. Technologies such as convergence meters, geotechnical sensors, and seismic monitoring devices have proven invaluable in detecting potential hazards and allowing operators to adjust mining practices accordingly. As noted by Pandey et al. (2018), these real-time monitoring systems provide crucial data that enable mine operators to predict roof movements and take corrective action before any hazardous situation arises. This integration of technology not only improves safety but also helps optimize mining operations by providing accurate data that can be used to refine the mining process.

Conclusions

The Blasting Gallery (BG) method and mechanized depillaring have proven to be essential techniques for safe and efficient coal extraction from thick seams, particularly in deep mines where traditional methods fall short. The BG method offers higher coal recovery rates by utilizing controlled blasting to create galleries while maintaining roof stability. When combined with mechanized depillaring, it significantly reduces the risks associated with manual labor and improves operational efficiency. However, the success of these methods is highly dependent on accurate monitoring of geo-technical parameters, such as roof convergence, overburden pressure, and induced blasting effects, all of which require advanced real-time monitoring systems. Despite their advantages, the implementation of these techniques in Indian geo-mining conditions requires further research to address unique challenges such as varying seam thicknesses, complex geological structures, and inconsistent overburden pressures. Overall, integrating modern technologies and real-time monitoring into the BG method and mechanized depillaring will continue to enhance coal recovery, worker safety, and mining efficiency.

References

1. Kumar, P., Soni, A., & Singh, R. (2005). *Coal mining methods and their applications in India*. Indian Journal of Mining Engineering, 12(4), 45-52.
2. Singh, S., & Gupta, R. (2012). *Influence of geo-technical parameters on mining operations*. Journal of Geotechnical Engineering, 24(2), 107-118.
3. Reddy, M., & Naik, K. (2017). *Induced blasting techniques for safe coal extraction in thick seams*. International Journal of Mining and Mineral Processing, 30(3), 195-202.
4. Sharma, N., & Gupta, P. (2015). *Impact of goaf edge distance on roof stability in Blasting Gallery method*. Journal of Rock Mechanics and Geotechnical Engineering, 10(1), 19-26.
5. Mishra, A., Srivastava, R., & Meena, S. (2019). *Challenges in implementing Blasting Gallery method in Indian coal mines*. International Journal of Mining Science, 8(1), 76-83.
6. Pandey, S., & Kumar, A. (2018). *Real-time monitoring systems for underground mining operations: A case study of Blasting Gallery method*. Journal of Mining Technology, 15(4), 199-208.
7. Srivastava, A., & Meena, K. (2020). *Blasting Gallery method in Indian geo-mining conditions: A review of current practices*. Coal Mining Research Journal, 12(2), 45-59.
8. Singh, R., & Meena, K. (2018). *Application of mechanized depillaring and its impact on coal mining operations in India*. Journal of Mining Engineering and Technology, 23(3), 150-160.
9. Kumar, P., Meena, S., & Singh, R. (2019). *Predictive modeling for optimizing depillaring operations in coal mines*. Journal of Mining Research, 11(2), 68-75.