

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Rock Geo-Mechanical State Alteration upon Entry of a Mechanized Longwall Set of Equipment into Pre-Mining Break-Down Chamber.

Karpov G. N*, and Leisle A. V.

Department of Mining Engineering, National Mineral Resources University (The University of Mines), Russia.

Abstract

Rapid development of coal deep mining equipment and technology, that is connected with widespread introduction of high-performance longwall sets of equipment is accompanied with an increase of economic losses in case of its possible downtime. The analysis of dismantling experience in modern Russian mines has shown that in absolute majority of cases the actual duration of re-assembling with regard to a longwall set of equipment exceeds technologically required time five and more times. In addition to that, re-assembling time significantly depends on successful formation of a break-down chamber. Review results of the most wide-spread methods for break-down chamber formation in case of coal veins' underground development with the use of modern longwall sets of equipment are presented in the article. The numerical modeling method has been applied to have a clear view of the stress-strain state (SSS) of the coal-bearing rock solid mass in the vicinity of a break-down chamber. In the furtherance of the set goal, a finite-element model of rock solid mass in vicinity of a pre-driven break-down chamber was developed to estimate qualitative nature and SSS alteration rate. The received results of computer simulation reflect the SSS distribution pattern of a solid mass, which coincides with in situ studies and allows assumption on a line of further researches.

Keywords: mechanized longwall set of equipment, deep mining, break-down chamber, break-down chamber formation, pre-mining break-down chamber, numerical modeling, finite element method, strain-stress state

**Corresponding author*

INTRODUCTION

According to the results of work of Russian coal industry for 2014, the volume of coal, mined by the underground method, amounted to 105.3 million tons, which is 15% higher than rates of 2000. At that, the share of breakage faces equipped with mechanized longwall sets of equipment, of the total number of mining faces in Russia amounted to 89.7% in 2014. It should be noted that with increase in worker labor productivity in more than 2.5 times (from 110.3 tons per month in 2000 to 321.5 tons per month in 2014), the average effective number of integrated longwall mining decreased almost threefold (from 170 in 2000 to 64 in 2014) [5].

The main reasons for such significant increase in breakage face’s performance are the wide-spread introduction of the reliable high-performance mining equipment at coal pits of coal mining companies. At the same time, use of expensive equipment which allows stable production of up to 10,000 tons of coal per day and more in one face is continually accompanied by an increase in its idle-time cost. In this connection, the issue on minimization of longwall set re-assemble terms in case of their transfer to new working areas, which is relevant from the moment of their implementation, becomes particularly important.

Theory of issue. Statement of the problem.

When reassembling heavy longwall sets of equipment, time technologically required for fulfilment of all operations is about 16–20 days, depending on the mining parameters (face length, transportation route, installation and dismantling schemes, etc.). At the same time, the actual duration of re-assembling often exceeds 30 days, and sometimes reaches 160 and more days. As a result of this issue study, in the mines of Kuznetsk coal basin in the period from 2009 to the present time, it is possible to conclude that the duration of mechanized longwall set re-assembling directly depends on the successful formation of a break-down chamber.

At the present time, two fundamentally different methods of break-down chamber formation are the most used at deep mechanized longwall coal mining. The first one, the most commonly used method is to form a chamber with shearer-loader with simultaneous erection of a protective canopy over the powered support sections. The second method, developed in the 1980s as an alternative, involves entering the mechanized longwall set of equipment in a treed pre-driven pre-mining roadway (Figure 1).

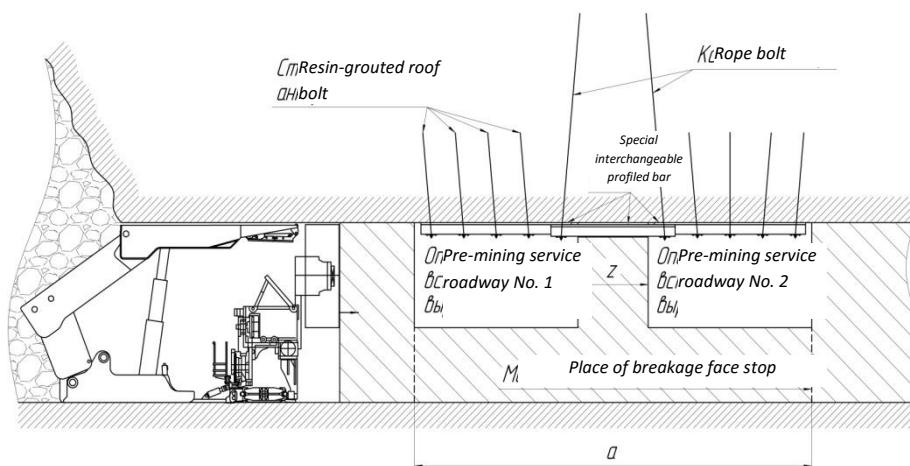


Figure 1: Scheme of break-down chamber formation by entering the mechanized longwall set of equipment in a pre-driven roadway

Each of the above methods has a number of advantages and disadvantages. At the present time, the method for break-down chamber formation in combination with polymer mesh as described in detail in [1] is the most widely used. Duration of 200–220 m length chamber formation, when applying this method, is 12 to 16 days in average. The second method of break-down chamber formation is applied less often. In the modern practice, cases are known when at its implementation the entry of a longwall set in a pre-mining roadway could took less than 1 day or more than two months. The main cause of major delays in this case is destruction

of a pillar between the pre-mining roadway and breakage face, as well as of roof rock in its neighborhood [2, 3, 4] upon longwall face approach to a withdrawal place (Figure 2).

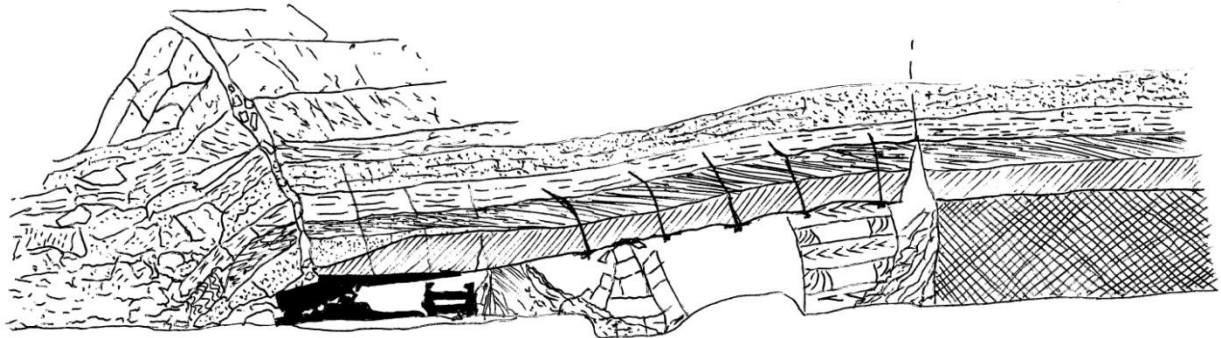


Figure 2: Possible destruction of a pillar and rock falls upon longwall face approach to a withdrawal place [3]

Despite the fact that modern specialists everywhere favor the first method, the second method, according to author' opinions, cannot be considered unviable even under conditions of a fractured roof. Thus, the decision was made to create a numerical geo-mechanical model in order to form more complete idea of the stress strain state (SSS) of rock solid mass (RSM) in the neighborhood of the pre-mining roadway, upon approach of longwall to it.

RESEARCH METHOD JUSTIFICATION

Research of mining influence on alterations of the stress-strain state of coal-rock solid mass is a complex mining and geo-mechanical task. As a rule, such tasks do not have the exact analytical solutions. According to the literature [6, 7, 8, 9, 10, 11], in the study of the stress-strain state of rock solid mass, use of physical or mathematical modeling is considered as the most efficient.

Application of numerical methods in the mining geo-mechanics has a number of advantages compared to other simulation methods, which include: universality; possibility of considering the large number of effecting factors; relatively low time- and labor-inputs for development of models (compared to physical experiments); no need for materials, special equipment, etc.

Numerical modeling methods refer to a class of grid methods which are used for approximate solution of boundary-value problems. From the point of view of theoretical estimates, the existing methods of numerical modeling — finite element method (FEM) and finite difference method (FDM) — have approximately equal accuracy, which mainly depends on the form of modeled area, boundary conditions, etc.

The main difference of these methods from each other is that, when solving tasks with the finite element method, the solution itself is approximated, and when solving with the finite difference method, derivatives of required functions are approximated.

The finite difference method is more often used when solving tasks functions of which have straight-line boundaries, since features of region geometry at build-up of regular grids are considered only in near-to-boundary nodes.

When solving tasks by the finite element method, in the process of splitting of the model into elements, geometric characteristics of its regions are considered. The process of building up a grid is performed in the direction from a border to ensure the best approximation of its geometry. Build-up algorithm includes possibilities to increase the grid density in the areas of model element's conjugation, as well as allows retaining proportions between lengths of each of triangular cells, virtually eliminating calculation errors associated with area splitting itself. Noted features allow use of the finite element method in calculating the strength of parts, structural components of various types, as well as SSS parameters of various media, including geological.

The stress-strain state of rock solid mass in the neighborhood of roadways is studied mainly in the elastic approach, whereby Hook's law in the volumetric setting is taken as a medium equation. This is due to the relative simplicity of the mathematical tools used in analytical calculations.

However, it should be noted that many rocks have a high ductility, resulting in the formation of limit-state zones (nonlinear straining zones) around them. For this reason, the use of elastic model of RSM behavior in calculations leads to results, which sometimes differ greatly from field observations.

Selected as the main research method, the finite element method within its mathematical tools technique allows consideration of rock behavior non-linearity. Therefore, to determine the stress-strain state of rocks in the studied area taking into account geometric parameters of the process scheme and medium properties, the finite element method in elastoplastic approach to the studied problem. Effectiveness of the solution of geo-mechanical tasks by the finite element method confirms expediency and adequacy of its application for research of the stress-strain state of rock solid mass within the framework of the present work.

Application of numerical modeling methods to solution of mining geo-mechanics tasks, in particular, at coal fields, is becoming more widely used with development of computer technology and improvement and increasing complexity of software. Thus, to simulate the stress-strain state of various elements of coal-containing solid mass, LaModel, Plaxis 2D, FLAC, FLAC3D, etc. software products are successfully applied [12]. Selection of one or another software is most often based on its applicability to specific tasks. Despite the relative easiness of use and proven effectiveness, such methods of SSS assessment have a number of disadvantages.

The most advanced numerical models at the present time allow simultaneous consideration of both spatial structure and state of rock solid mass, and alteration of any elements in time when studying of the most complex mining situations [13, 14]. Such cases to obtain representative results require the work of a whole team of highly-qualified engineers, high accuracy of initial data and, where possible, calibration of the model according to monitoring data of in situ solid mass state. However, when the rock solid mass has sufficiently evident spatial-inalterable mechanical characteristics within the framework of considered objects (roadways, pillars, linings, etc.), as well as the presence of generalized averaged data on its properties, SSS assessment is possible and expedient to carry out in plain-strain statement. This approach simplifies both the process of model build-up and its editing at repeated use in similar geological conditions.

MODEL DESCRIPTION, DISCUSSION OF RESULTS

For the purposes of physical interpretation of described process, the finite-element geo-mechanical model was developed (Figure 3), including the geometry of mined-out space, extracted bed and pre-mining roadway. The initial data for a model are taken in accordance with the terms of 5208 extraction pillar mining of "SUEK-Kuzbass" OJSC "Kotinskayya" pit.

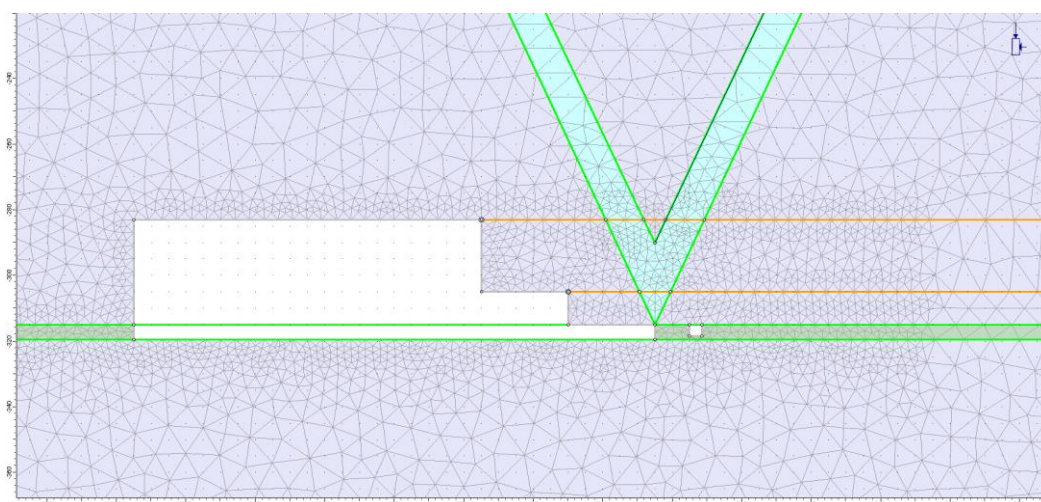


Figure 3: Geo-mechanical model of rock solid mass upon longwall face approach to a withdrawal place

The set task was solved in the elastoplastic plane-strain formulation. Worked-out space was simulated, which represented a cavity of finite dimensions with roof consoles hanging over the bed edge part. Interaction of consoles was simulated by assigning of contact conditions at their borders.

Figure 4 shows the displacement vectors of containing rocks. It is seen that rocks of basic and immediate roof create a torque with an arm which is set against the bed edge part. In this zone, a pillar is located between the longwall face and pre-mining roadway.

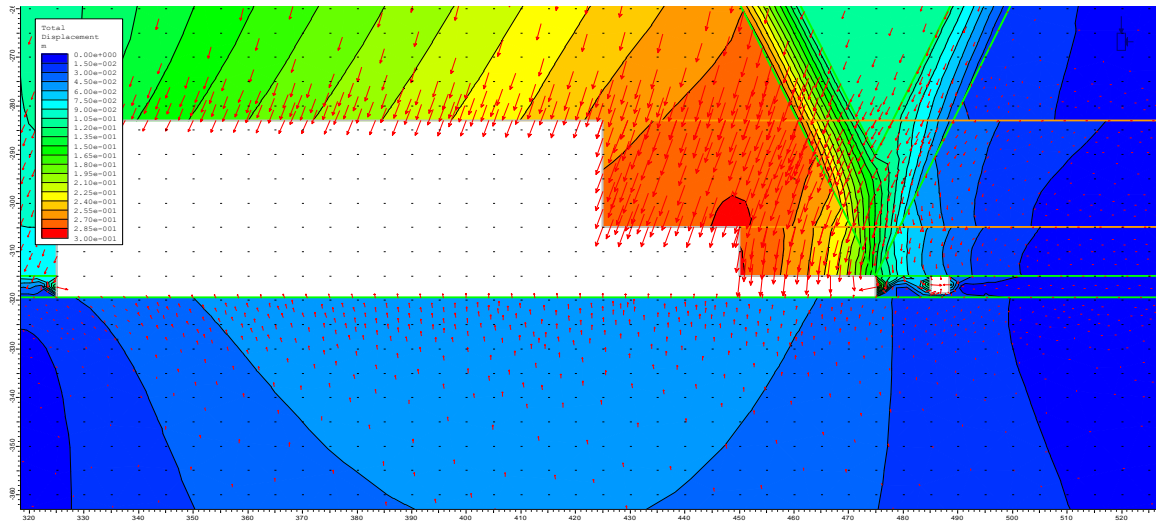


Figure 4. Field of total displacement's distribution in the neighborhood of a withdrawal place

This leads to an increase in rock pressure level in solid mass edge part, in rocks of roof above it, and, respectively, in a pillar.

When stresses exceed the bed strength, its destruction occurs, as shown in Figure 5 in the form of plastic yield development zones.

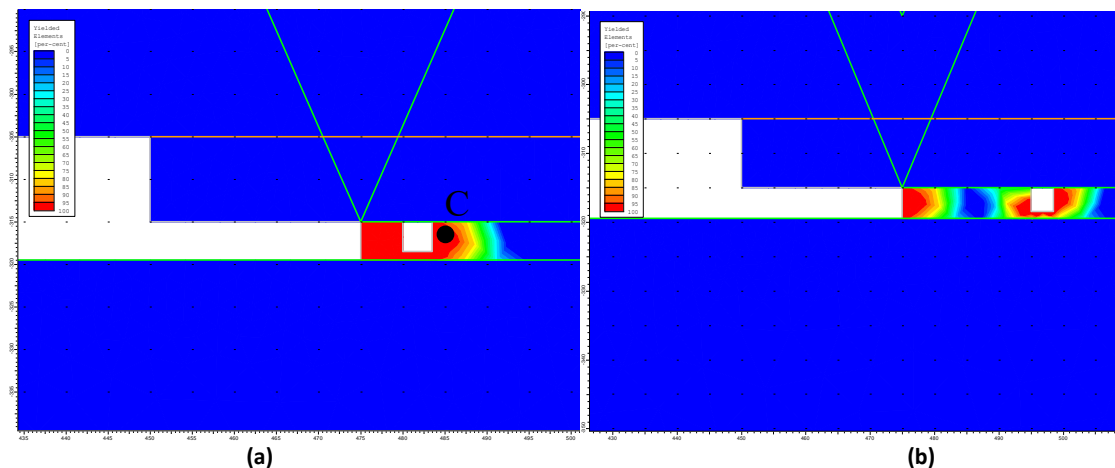


Figure 5. Field of strain distribution in the neighborhood of a withdrawal place for a pillar between the face and pre-traveled roadway of 5 m (a) and 10 m (b) width

At a certain size of pillar, it is completely destroyed. In this case, the picture of a pillar with width of 5 m (a) and 10 m (b) is shown. It is seen, that in the first case the bed in the neighborhood of the pre-mining roadway completely passed into out-of-limit state. In practice this means that these rocks are destroyed and their load bearing capacity is substantially reduced. Due to pillar stability loss, hanging-over console loses support. Its length increases. Support point moves to C point (Figure 5a).

Figure 6 shows the stress distribution diagrams ahead of the face at various pillar width.

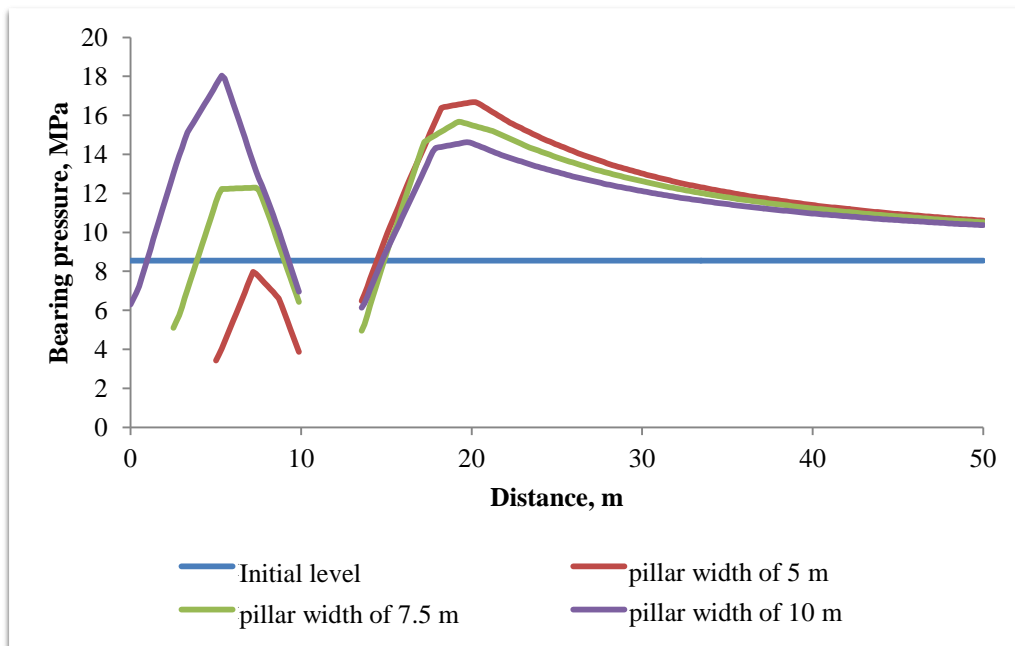


Figure 6. Distribution of front abutment pressure at various stages of face approach to the pre-mining roadway

At the maximum pillar (10 meters) from the considered dimensions, it retains its stability and therein develops the maximum of bearing pressure. At a width of 5 m, maximum of bearing pressure moves “behind roadway”. As a result of pillar destruction, the load on lining of a mechanized longwall set of equipment increases significantly. The described process can lead to a hard landing of the mechanized longwall set of equipment.

CONCLUSION

Thus, as a result of carried out studies:

- A methodical approach to assessment of RSM geo-mechanical state quality indices, upon approach of the breakage face to the pre-mining roadway, is developed.
- A geo-mechanical model (computational model), which describes transient processes of rock solid mass stress-strain state (RSM SSS) parameter alteration in the neighborhood of the pre-mining roadway upon entry of a mechanized longwall set of equipment into it.
- Significant increase in load on sections of mechanized lining of system is explained by decrease in pillar bearing capacity and, as a consequence, re-distribution of rock pressure.
- Currently used methods of pre-mining break-down chamber fixing are not always effective, and further researches should be directed to the improvement of existing and development of new methods for their fixing.

REFERENCES

- [1] Artemiev V. B. (2010). *Alternative technologies of break-down chamber formation under conditions of “SUEK-Kuzbass” OJSC [Al'ternativnyye tehnologii formirovaniya demontazhnyh kamer v usloviyah OAO «SUJeK-Kuzbass»]*. Artemyev V. B., Loginov A. K., Yutyaev E.P. et al. Moscow, Ugol' Journal, No. 3, pp. 20–23.
- [2] Oyler, D. (1998). *International Experience with Longwall Mining into Pre-driven Rooms* / Oyler D., Frith D., Dolinar D. R. et al. Proceedings of the 17th International Conference on Ground in Mining. Morgantown, Aug 4–6, pp. 44–53.

- [3] Tadolini, S. C. (2003). *Ground Control Support Considerations for Pre-Driven Longwall Recovery Rooms*. Ph. D. Dissertation submitted to College of Engineering and Minerals Resources. Morgantown: West Virginia University, 163 p.
- [4] Karpov G. N. (2013). *Substantiation of technology for withdrawal of mechanized longwall sets of equipment at the high concentration of mining works [Obosnovanie tehnologii demontazha ochistnyh mehanizirovannykh kompleksov pri vysokoy koncentracii gornyh rabot]*. Thesis for a PhD degree, National University of Mineral Resources (The University of Mines).
- [5] Tarazanov I. G. (2015). *Results of Russian coal industry work for January–December 2014 [Itogi raboty ugol'noj promyshlennosti Rossii za janvar'-dekabr' 2014 goda]*. Moscow. Ugol' Journal, No. 3, pp. 56–71.
- [6] Amusin B. Z. (1975). *Finite element method upon solving of problems of mining geo-mechanics [Metod konechnykh jelementov pri reshenii zadach gornoj geomehaniki]*. Amusin B. Z., Fadeev A. B. Moscow, Nedra, 275 p.
- [7] Bulychev N.S. (1989). *Mechanics of underground structures in examples and tasks [Mehnika podzemnykh sooruzhenij v primerah i zadachah]*. Textbook. Moscow, Nedra, 270 p.
- [8] Gallagher R. (1984). *Finite Element Analysis: Fundamentals*. Translated from English. Moscow, Mir, 428 p.
- [9] Gmoshinsky V. K. (1957). *Rock pressure on the flat-lying bed in the neighborhood of roadway [Gornoe davlenie na pologij ugol'nyj plast v okrestnostjah vyrabotki]*. Ugol' Journal, No. 6, pp.16–23.
- [10] Lanovskiy Y.M. (1999). *Finite element method (basics of theory, tasks) [Metod konechnykh jelementov (osnovy teorii, zadachi)]*. Novosibirsk, Publishing House of the Novosibirsk State University.
- [11] Fadeev A. B. (1987). *Finite element method in geo-mechanics [Metod konechnykh jelementov v geomehanike]*. Moscow, Nedra, 221 p.
- [12] Larson M. K., Whyatt J. K. (2009). Mining Publication: Deep Coal Longwall Panel Design for Strong Strata: The Influence of Software Choice on Results // Proceedings of the International Workshop on Numerical Modeling for Underground Mine Excavation Design. Esterhuizen GS, Mark C, Klemetti TM, Tuchman RJ, eds., Pittsburgh, PA: National Institute for Occupational Safety and Health; IC 9512, Jun 2009, pp. 75–87
- [13] Esterhuizen E., Mark C., Murphy M.M. (2010). Numerical Model Calibration for Simulating Coal Pillars, Gob and Overburden Response, 29th International Conference on Ground Control in Mining, Morgantown, WV.
- [14] Sarathchandran A. (2014). Three Dimensional Numerical Modelling of Coal Mine Roadways Under High Horizontal Stress Fields, M. of Sc. dissertation, University of Exeter.