Journal of Mines, Metals and Fuels, 71(6): 722-727; 2023. DOI: 10.18311/jmmf/2023/34486

Print ISSN : 0022-2755

Journal of Mines, Metals and Fuels

Contents available at: www.informaticsjournals.com/index.php/jmmf

Numerical Modelling of Underground Coal Pillar Stability for Developed and Depillaring Panels for a South Indian underground Coal Mine

D Kotaiah[1*], Chitti Ravikiran[1*] and Manthri Rakesh[2]

[1*]*Assistant Professor, Department of Mining Engineering, UCE (KU), Kothagudem, India.*
[2]*Research Scholar, National Institute of Technology Raipur.*

Abstract

Mining is the practise of obtaining valuable minerals or other types of geological materials from the earth while abiding by reasonable social, legal, and regulatory restraints. The Bord and Pillar Method and the Longwall Method are the two most common underground mining techniques for coal. The majority of the pillars encountered in the earlier approach. The pillar, a structural element and important feature of the mine, is what gives it stability. A pillar support is intended to control rockmass movement across the mining zone while activities are being carried out. Too-small pillars would affect the mine's stability, increasing extraction percentage, and vice versa.

This research objectively evaluates the several optimal combinations of pillar dimensions that could be successfully incorporated in the mines. Geotechnical traits of a local underground coal miner have been identified in a laboratory setting. The safety and viability of a mining method are assessed using an ideal relationship between the safety factor and the extraction percentage. Numerical modelling was applied to determine the deformation of the pillar and the maximum stress generated across the pillar and gallery.

Keywords: *Pillar Stability, Panel, Deformation, ANSYS, FEM.*

1.0 Introduction

One of the most crucial industries for a country's continued growth or development is mining. Mining is the process of economically removing precious minerals from the earth for a variety of uses, including the production of electricity, pharmaceuticals, infrastructure, etc. It served as a foundation for civilization to develop in all of its forms and served as a model for other industries to reproduce. There are two ways to mine: subterranean and opencast. Longwall mining and Bord and Pillar mining are the two main methods of underground mining. In India, the latter is more frequently practiced than the former.

One of the earliest industries to emerge since the dawn of humankind is mining. It served as a foundation for the development of civilization in all of its forms and served as an example for other industries to flourish. Our nation's development has traditionally been fuelled by the mining industry. Even though mining has made enormous strides, the industry is still very dangerous. Many unknowns surround the mining of mineral wealth from subsurface sources. One such instance is the mining of underground coal. A sizable portion of the coal is still needed to support the roof. There have been numerous effective ways to lower the blocked coal's size without sacrificing safety.

*Author for correspondence

2.0 Field Data

2.1 Details about the panel selected for study

Table 1: Details about the panel

Name of the Panel	3S/SS-5
Total Thickness of the Seam	3.45 m
Extractable Coal	1,81,424 T
Nature of Roof	Sand Stone
Nature of Floor	Sand Stone
Length of Panel	199.5 m
Width of Panel	333.5 m
Number of Pillars	45
Size of Pillars	38*36
Depth Min	207.0 m
Max	326.0 m
Gradient of Seam	1 in 3
Height of Workings	2.83 m
Width of Workings	4.2 m

2.2 Geo-Mining Conditions of the Panel 3S/SS-5

The coal measure formation observed in borehole section are given below figure. Thickness of seam is about 3.45 m with an average gradient of 1 in 3.0. The strata overlying the Coal seam are composed of grey sandstone.

3.0 Numerical Modelling of Developed Panel

3.1 Model Preparartion

For the analysis of stress and displacement distributions around the pillar and gallery as well as the determination of the pillars' safety factors, three-dimensional finite element models have been created. For the creation of the numerical model, the lithology of the mine site in figure below is taken into account. Two different 3D Finite element models have been created overall, taking into account the typical lithology. Depillaring is one model, whereas development is another. The elastic behaviour of the rockmass is taken into consideration when analysing the two three-dimensional FEM models. The following is a description of the FEM models:

- The 4.2 m gallery width development model consists of pillars, galleries, and the surrounding rockmass.
- Slices, pillars, galleries, and the surrounding rockmass make up the depillaring model for the 4.2 m gallery width.

Figure 1: Panel layout

3.2 Finite Element Model for Development Operation

The lithology of the mine site and the material qualities of the mine site's rockmass are used to simulate the coal panel for development operation/workings in the ANSYS programme. The model's dimensions are 142.2m×306m×174 m for a 4.2 m wide gallery. All of the 4.2 m wide galleries along the strike and dip sides have been developed.

3.3 Rockmass Properties

The elastic modulus, poison ratio, and density of the rockmass are measured at the mine site and used for the stability study of the development operation or workings. For further study, the rockmass properties listed in Table 2 are applied to finite element models.

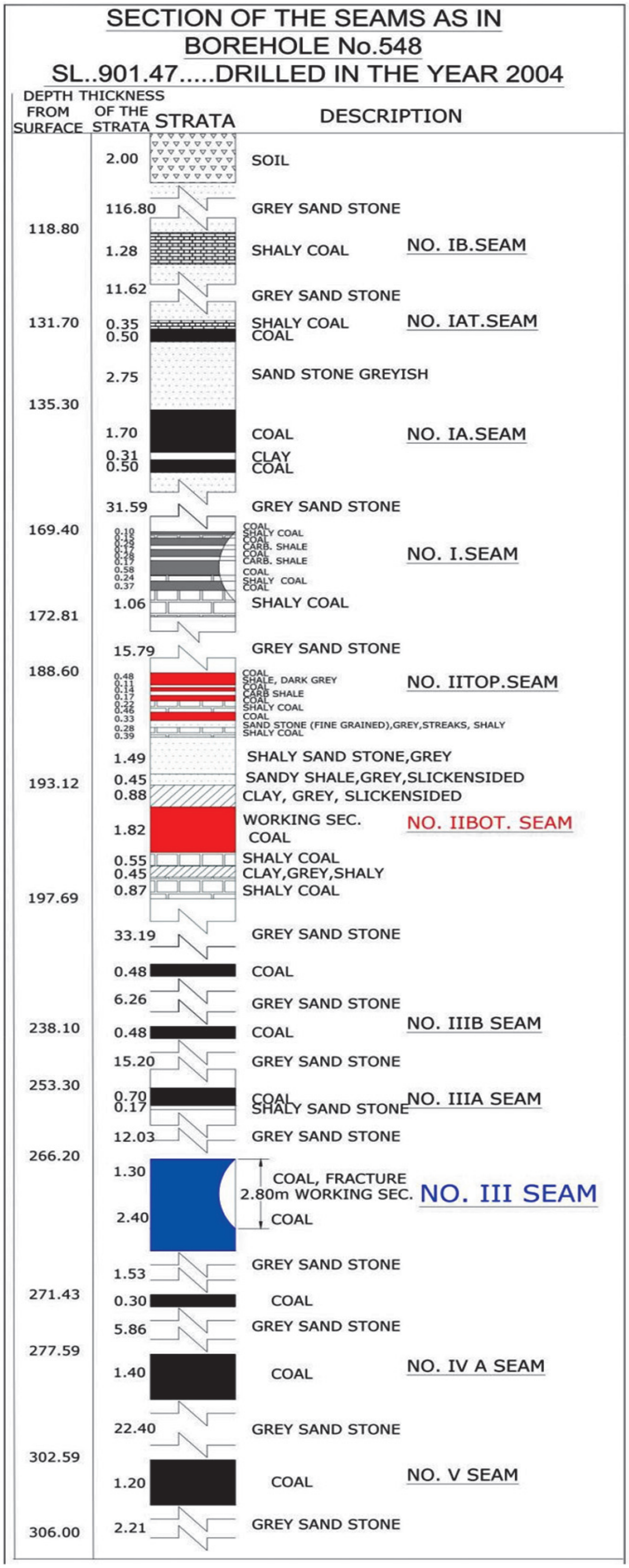

Figure 2: Borehole section

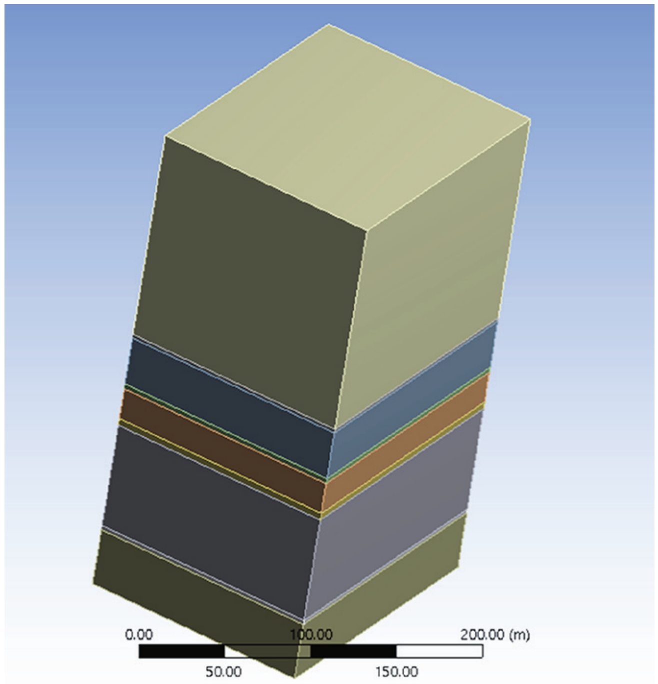

Figure 3: 3D finite element model for developing panel

Table 2: Rockmass properties

Rock strata	Density (kg/m³)	Modulus of elasticity (GPa)	Poison's ratio
Coal	1500	1.5	0.28
Sand Stone	2200	3.2	0.25

3.4 Generation of Finite Element Meshed Model

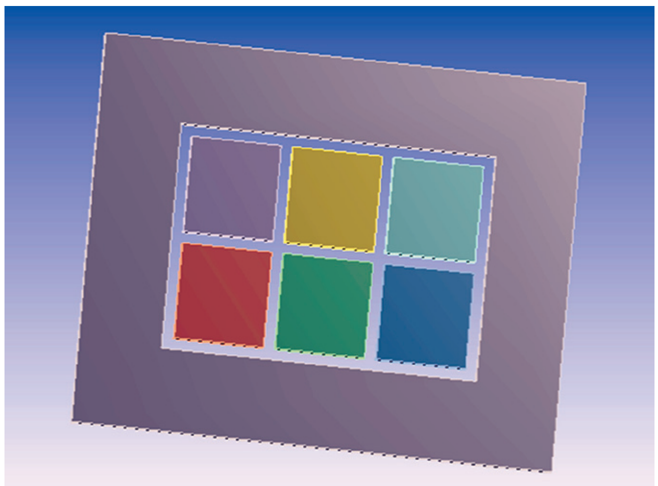

Figure 4: Development panel

More elements and nodes are produced by the finite element excavation and development workings model than by the excavation and development operation model. For a better assessment of displacements, stresses, and strains, a finer mesh is built around the excavation area (pillar and gallery). In the strata that contain coal, far from the areas affected by mining, coarse mesh forms (zone of no-rock movement due to mining). The mesh model of the development panel is displayed in Figure 4.

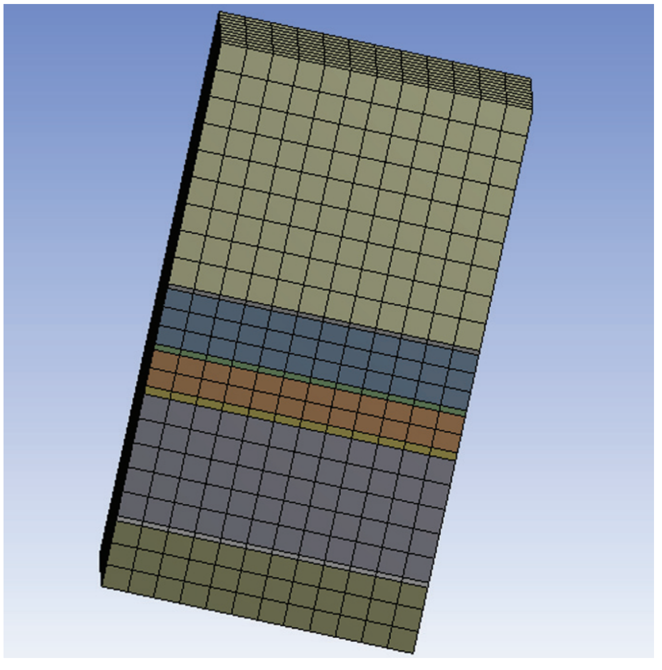

Figure 5: Meshed model of development panel

3.5 Boundary Conditions

The three-dimensional finite element model has been used in conjunction with the boundary conditions. The model's

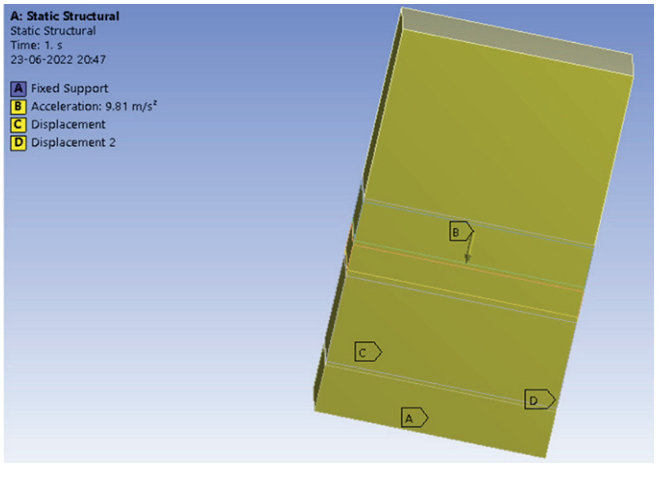

Figure 6: Boundary conditions

bottom is restricted in the Ux and Uy directions, and gravity is also applied along the model's vertical axis.

4.0 Analysis and Result for Development Model

The elastic behaviour of rock materials has been used to analyse each and every 3D finite element model. Vertical stress results from FEM are provided.

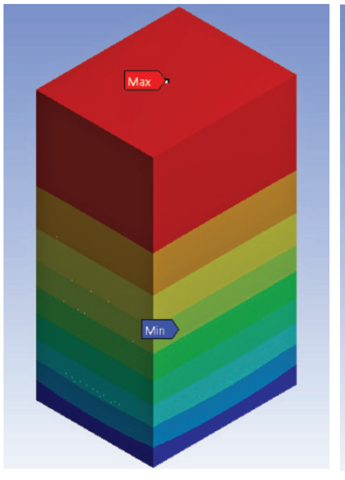

Figure 7: Total deformation

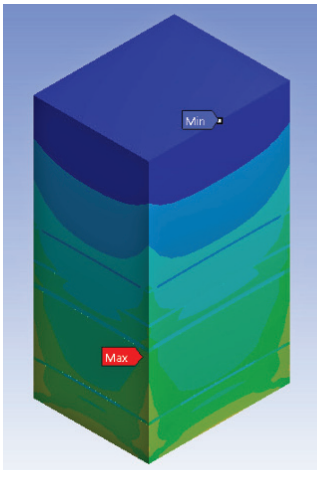

Figure 8: Max shear stress

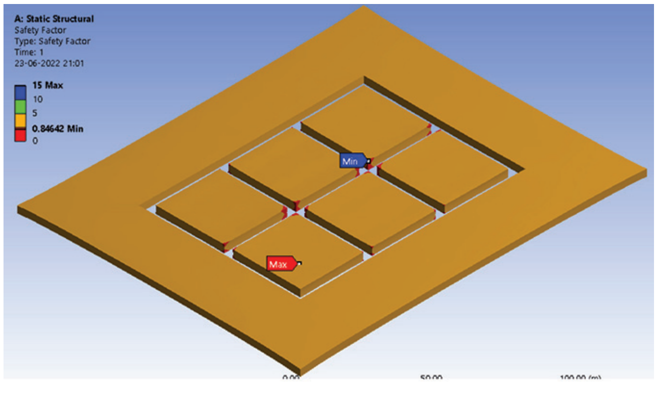

Figure 9: Safety factor

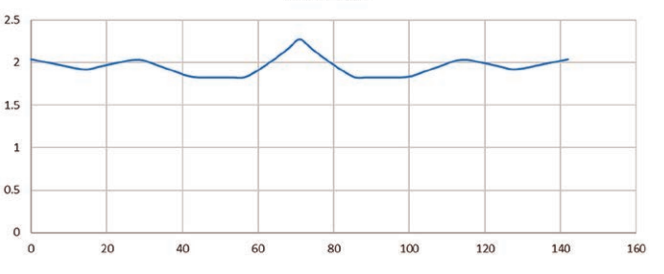

Figure 10: Graph for factor of safety

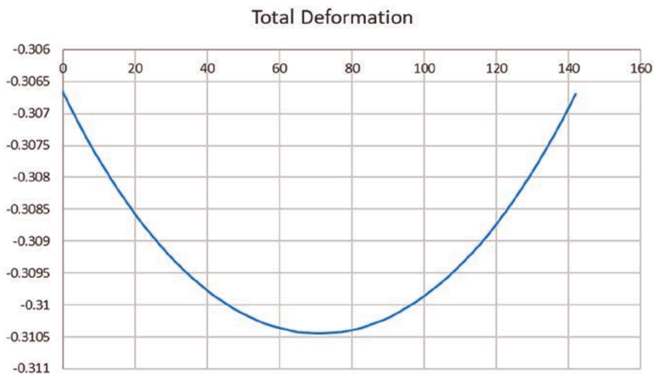

Figure 11: Graph for total deformation

The edges of the pillars have high chances of failure as their stability at that places is low which can be shown in the Figure 11

5.0 Numerical Modelling of Depillaring Panel

5.1 Finite Element Model for Development Operation

Six pillars make up the development panel, three of which are developed along the dip and two along the strike, respectively. Based on the lithology of the mine site and the material parameters of the mine site's rockmass, which are described in Table 3, the coal panel for development operation/workings is modelled in the ANSYS programme. The model's dimensions are 142.2m×306m×174m for a 4.2m wide gallery. All of the galleries on the strike and dip sides are constructed with 4.2 m wide galleries, and two splits are created by cutting a pillar into four equal sections, each measuring 15.3 m in length.

Table 3: Rockmass properties

Rock strata	Density (kg/m³)	Modulus of elasticity (GPa)	Poison's ratio
Coal	1500	1.5	0.28
Sand Stone	2200	3.2	0.25

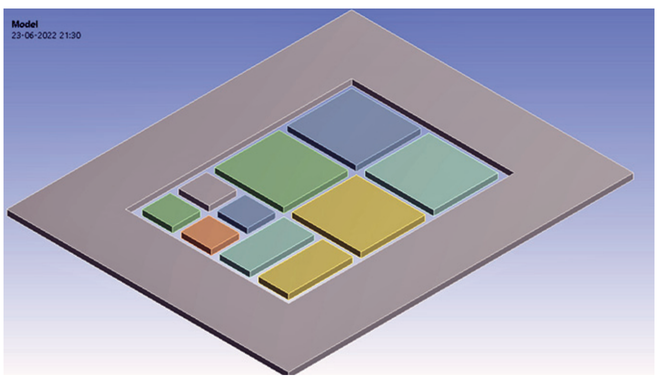

Figure 12: 3D model of depillaring panel

5.2 Finite Element Meshed Model Generation

While the in-situ model produces slightly fewer elements and nodes than the finite element excavation/development workings model, both models produce elements and nodes. For a better assessment of displacements, stresses, and strains, a finer mesh is built around the excavation area (pillar and gallery). In the strata that contain coal, far from the areas affected by mining, coarse mesh forms (zone of no-rock movement due to mining). The mesh model of the development panel is displayed in Figure 13.

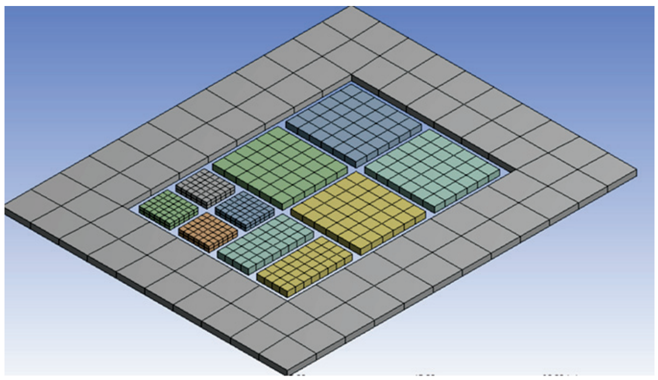

Figure 13: Meshed model of depillaring panel

5.3 Boundary Conditions

The three-dimensional finite element model has been used in conjunction with the boundary conditions. The model's bottom is restricted in the Ux and Uy directions, and gravity is also applied along the model's vertical axis.

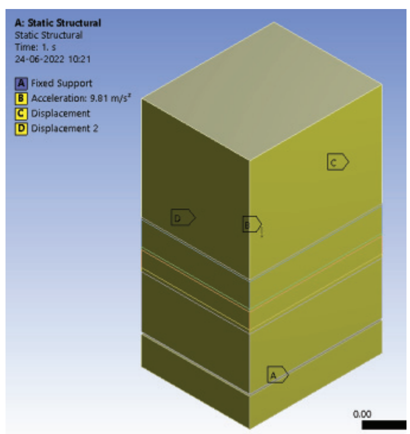

Figure 14: Boundary conditions

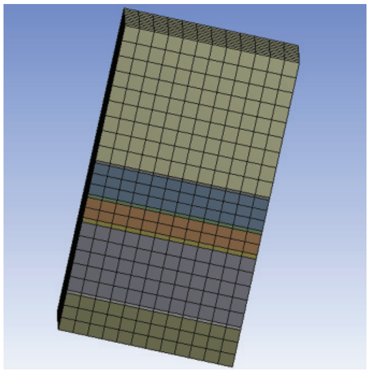

Figure 15: Total deformation

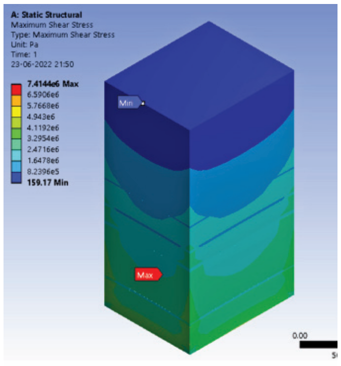

Figure 16: Max shear stress

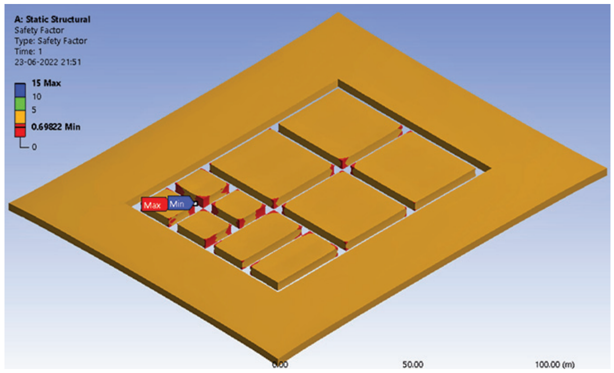

Figure 17: Safety factor

6.0 Analysis and Result for Depillaring Model

6.1 Analysis, Results and Discussions of 3D Fem

The elastic behaviour of rock materials has been used to analyse each and every 3D finite element model. Below are the FEM results.

These are results are showing that as long as the pillars reduces in their sizes their respective strength also increases respectively. So the depillaring process continues the stability of the pillars goes on decreasing.

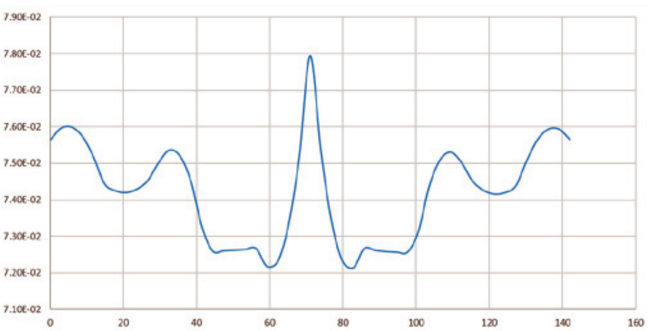

Figure 18: Directional deformation

7.0 Conclusions

The investigation's main objective was to assess the coal pillar at a nearby mine. From the analyses, the following findings are drawn. To include the information from the field trips, safety factor assessments, and stress-strain evaluation from numerical modelling, it is divided into two parts.

- The Bord and Pillar method of mining is used, and square-shaped pillars are used as guidance. The top has a 0.3 m overall distortion.
- The factor of safety of the development panel varies from the range of 0.84 to to 15 where as in depillaring panel the safety factor reduces to 0.698. This is showing that the stability of the pillar goes on decreasing during the extraction of pillars by splits, slices etc. We all know that, hence the ANSYS 3D was valid.

Safety factor reduces when line of extraction moves towards the centre of the pillar. Therefore, the two models i.e., the development model and depillaring model are illustrating the above statement, hence the models are showing conclusive results.

8.0 References

1. Singh R. et al. (2004): Instrumentation monitoring of strata movement during underground mining of coal, *Mine tech*, Volume 25, No.5, pp. 18.
2. Mark, C., (1981-2006): The evolution if intelligent coal pillar design, P.P: 2-4
3. Peng, S. S. (1978): Coal mine ground control. New York, John Wiley & Sons. pp. 181-182.
4. Wagner, H., (1980): Pillar design in coal mines. J.S. Afr. *Min. Metal.*, V80, pp. 37- 45.
5. Bieniawski, Z. T., (1984): Rock Mechanics Design in Mining and Tunneling, A.A. Balkema.
6. Singh R. et al. Instrumentation monitoring of strata movement during underground mining of coal, Mine tech, Volume 25, No.5 (2004): pp.18.
7. Shrivastava, B.K. & Jaiswal, Ashok, (2009): Numerical simulation of coal pillar strength, *International journal rock mechanics and mining sciences* 46, 779-788, Elsevier Ltd.
8. Y. Nakasone and S. Yoshimoto, (2006): Engineering Analysis with ANSYS Software, first edition, Oxford, London.