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Stability analysis of set-up room of a deep longwall panel of India using 3D numerical modelling technique

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Abstract

The installation gallery/set-up room of a longwall panel is driven for installation of the longwall face machineries to start the extraction of coal from the longwall panel. The width of the installation gallery is 8 to 9 m. This gallery needs to be stabilized till the face machineries to be deployed from the driving of the room as it required to stand more than 8 to 10 months and develop the high stress concentration, roof-to-floor convergence and yield zone in the roof and sides. Hence, in this study, a deep longwall mine of India is considered to analyze the behavior of set-up room. For this, a total of twelve 3D numerical models are developed and analyzed considering Mohr's-Coulomb failure criterion. Three panels located at 417, 462, 528 m having three different widths (8, 10 and 12 m) of set-up rooms are examined. The width of the set-up room is taken based on the length of the shield support. The results in terms of vertical stress distribution, vertical displacement, roof-to-floor convergence, plastic strain and yield zone distribution are presented.

1. Introduction

In the longwall method, the face gallery/set-up room is driven to connect the gate roads (main gate roadway and tail gate roadway) for accommodating the longwall face machineries such as powered roof supports (shields), cutting machine (shearer), coal transporting machinery (armored flexible conveyor) and other required equipments. The driving of this room for desired length and width, and erection of the longwall face machineries takes huge time. In the study mine, making of set-up room and installation of machines consumed about 8 to 10 months against standard period of 04 months (out of this 1 to 1.5 month for driving the room) due to certain operational limitations prevailing at thattime. After installing the machines, the face retreating commences and moves till the designed panel length (stop line). Then these machines will be removed, transported through haulage/transport route and install into the next panel's set-up room. As this set-up room plays important role in starting the face operation, the behavior of the gallery/room need to be analyzed for making the room stable till the commencement of retreating operation.

In the study mine, the set-up room of 8 to 9 m wide is driven to accommodate the face equipments. Out of this width, 5 m room is made from the intact barrier side for a length of 250 m which is equivalent to face length and then the room is further widened to 3 to 4 m in intact coal panel side. During the driving of the initially width of 5 m, the roof bolts of 2.4 m length are installed at 0.85 m x 0.5 m grid pattern and also in widened portion of the room with the same pattern. During this time, the excessive convergence and guttering is observed. As of now three set-up rooms are driven in the mine. Two panels already excavated and the third panel is being extracted.

There are many studies conducted to determine the behavior of the pre-driven recovery rooms and

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support system deployed in them, and also its effect if the equipments are not installed in a desired time as given below. Barczak et al. [1] estimated the conditions of the recovery room while progressing the longwall face to this room. Tadolini and Barczak [2] analyzed the behavior of recovery room and development of support load by installing the different support systems (bolts and cribs). Wichlacz et al. [3] developed the pre-driven recovery room evaluation program (PREP) by combining the various parameters such as strength of the floor, CMRR, depth of mining, reinforcement density index, seam height, panel width, room length, shield capacity, standing support and rate of mining. Karpov and Leisle [4] estimated the front abutment load on the pillar/intact coal/fender lying between recovery room and face while approaching the stop line. It reported that front abutment load of 6.5 to 8 MPa develops from 5 to 10 m intact coal. Wang et al. [5] conducted field monitoring study and estimated the occurrence of roof-to-floor convergence and stress in the recovery room in two different panels and revealed that development of the roof to floor convergence and pillar stress of 348.03 to 771.24 mm and 5 to 7 MPa respectively. Campbell [6] mentioned the various strategies adopted in the recovery room to encounter the cavity and other strata control problems for successful salvaging operation. Gabov et al. [7] investigated the duration of the face equipment installation in the set-up room from previous panel recovery room for 22 different longwall panels. Out of this, more than 17 panels could not be installed in desired time, 2 months (15 days for driving and 1.5 months for installation) and these panels incurred losses. This has resulted due to the instability of the pre-recovery rooms and their improper location. Yermakova and Fedusov [8] analyzed the salvage operation of SUEK-Kuzbass Underground Mines from 2011-2018 and found that time taken for the salvaging operation exceeded more than 900 days for the face width of 400 m at an average of 12 to 169 days' excess per year against the standard time. It caused the economic performance of the mine. Kazanin et al. [9] undertook a numerical investigation to evaluate the recovery room conditions and estimated its optimum location behind the crack of main roof. Aghababaei et al. [10] investigated 43 case studies of various countries and proposed models to predict the roof failure in the pre-driven entries and proposed the suitable recovery room method for this entry using RES system.

Also, there are numerous studies reported on the caving behaviour of the longwall workings [11-12], estimation of weighting interval [13-18], stress development on the face and barrier pillars [19-22] and extent of failure zone [23-25].

However, there is no study reported on stability of longwall set-up room for Indian mining condition and few studies undertaken on the stability of the set-up room of longwall panels belonging to other countries are presented below. Chugh et al. [26] investigated the stability of the set-up room for Illionois longwall panels using field monitoring and numerical modelling technique. It revealed that panel 1 develops the roof convergence of 0.7 to 3.78 inch and panel 2 develops 0.5 to 3.43 inches. Also it reported that vertical stress concentration factor lies in between 3.54 and 4.05 and horizontal stress concentration factor lies in between 1.56 and 5.2. Chugh et al. [27] conducted a numerical analysis to identify the various stability issues of the set-up room. Zhao et al. [28] investigated the roof failure occurred in the installation gallery of Chenjiazhuang coal mine supported with conventional support system. The installation gallery consisting of compound roof is studied with theoretical and numerical models to understand the deformation, plastic zone and stress development in and around the installation gallery. Based on the results of the study, the support strategy is altered by increasing support density to avoid the future accidents.

As the development of set-up room plays important role in the longwall operation, the stability of the set-up room need to be undertaken. Hence, a longwall panel operated in India is chosen for detailed examination. In this mine, three set-up rooms have already been developed as the third panel is under exploitation. Therefore, three set-up rooms situated at different depths and different widths are considered for examination. The results in terms of roof displacement, roof to floor convergence, vertical stress, plastic strain and yield zone developed in the face, roof and barrier pillars are presented.

2. Mine Description

The Singareni Collieries Company Limited (SCCL) is one of the prime coal producing company in India which is operating the Adriyala Longwall Project (ALP) in Telangana state. The depth of reserves lies in between 294 and 644 m depth. The mine consists of four seams namely, 1, 2, 3 and 4. At present, seam no. 1 is being excavated with longwall technology. The target production from ALP mine is 2.8 MTPA and the life of the project is 35 years. The size of the longwall panel is 2340 m in length and 250 m in width. The average dip of a coal seam is 9.46^0 from horizontal.

Seam no. 1 consists of weak and layered strata of coal, shaly coal, shale, and clay between the sandstone roof and floor. In this seam, two clay bands with 0.25 m and 0.7 m thickness lie at around 3.9 m and 6.2 m above the sandstone floor causing the instability of the set-up room and gate roads. The size of set-up rooms and gate roads is 8-9 m x 3.5 m and 5.2-5.5 m x 3.5 m. The borehole section of the panel depicting the details of lithology is given in Figure 1. In this seam, two panels namely, 1 and 2 are already retreated and panel 3 is under operation. Figure 2 depicts the panels of ALP mine.

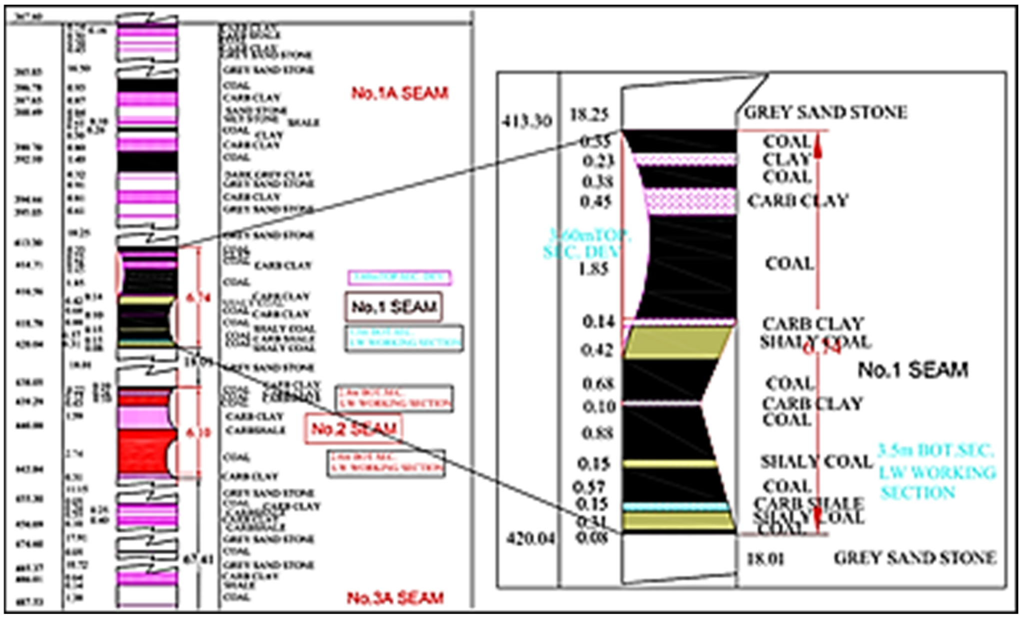

Figure 1. Lithology of the ALP mine utilized for the study

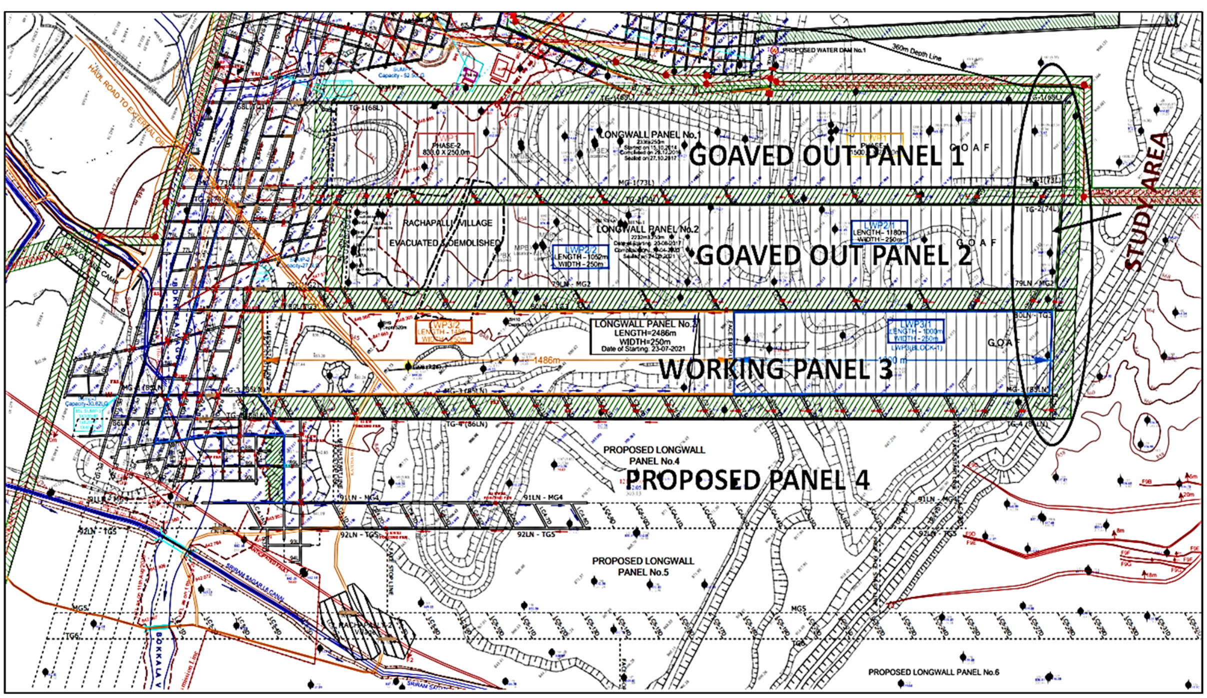

Figure 2. Longwall panels of the ALP mine

2.1. Experience in making the set-up rooms

The set-up room/face rise with 8 to 9 m width are driven for LWP No.1 and 2 with Road header (DOSCO), and LWP No. 3 is driven with bolter miner successfully. The longwall shields of 7.2 m length in closed position and required to make set-up room of 8 m (minimum) width. For initial two panels, the set-up rooms are driven in two phases/passes. The first pass (initial drivage) is 5 m width for total length of 250 m face length and further, it is widened to 8 to 9 m width. For third panel, set-up room is driven with first pass of 5.5 m width and second pass of 2.5m width.

The first pass is driven from TG1 to MG1, MG2 to TG2 and MG3 to TG3 for panels 1, 2 and 3 respectively. The first pass is supported with 6 nos 2.4 m length roof bolts in a row with row spacing of 0.5 m along with weld wire mesh. Tell tales are installed in the center of first pass at 25 m interval. In LWP No.1, during set-up room drivage, the maximum roof movement of about 5 mm is observed during the first pass drivage. The existing 5 m gallery is widened to 8 m from MG1 to TG1, with total 10 nos 2.4 m length roof bolts (4 bolts in widened portion of 3 m width) in a row with row spacing of 0.5 m, and also tell tales are installed for every 10 m interval. During the widening, after progressing for about 30 m length from MG1, daily convergence for about 35 mm is observed at 10 m and 20 m location from MG1 and also guttering is observed [29]. It has occurred due to the presence of the clay layers in the roof. Then the study is required to determine the stress regime, yield zone and dead load to stabilize the set-up rooms by adopting proper supporting strategy. Accordingly, support system is modified with the cable bolts of 6.1 m long 60-ton pretension bulbed cage type along with cement injection. Also, the guttering side of the room is injected with cement.

After supporting with cable bolts, the remaining set-up room is widened. The room after widening is kept idle for about 6 months. The strata monitoring is continued till installation of the shields and face machineries done. The maximum roof convergence is noticed as 94 mm and 43 mm where cable bolts installed after widening and before widening respectively. No abnormal strata problems are noticed. It means that cable bolting has reduced the development of roof convergence and thus effective strata control management is achieved.

2.2. Support installed at the gate roads and face

Main and tail gate roads are supported with fully grouted resin bolts of 2.4 m long and 22 mm diameter. These bolts are installed at 1 m x 1m grid pattern. The combination of wire mesh with w-strap is also used to avoid the skin failure of the roof. The fast resin and slow resin capsules of 600 mm and 800 mm are used as grouting material. During the installation of the bolt, the pre-tension torque of 150 N-m is also applied. Figures 3(a) and (b) show the support system erected at the gate roads and longwall face.

The longwall face is supported with skin to skin 2 legged shield support. A total of 146 shields are installed in the face. The width of shield is 1.75 m. The capacity of shield support is 2 x 1152 tonne. The setting pressure and yield pressure of the shield are 27 MPa and 45 MPa.

2.3. Support system at the set-up room

The set-up room/face gallery of 8 to 9 m wide is developed in the panel to accommodate the powered roof supports and longwall face machineries. The length of set-up room is 250 m which is equivalent to the width of the longwall face. From the centre of the room before widening, six rows of the roof bolts of 2.4 m long at 0.85 m (distance between bolts in a row) x 0.5 m (distance between two rows of bolts) is installed. A distance of edge of sides from the row of a bolt is kept as 0.15 – 0.25 m in either sides. After widening, in the intact side, the roof bolts at same grid pattern in four rows are installed. Figure 4 shows the support plan at the set-up rooms. In addition, the cable bolts of 6.1 m long 60-ton pre-tension bulbed cage type are installed during drivage of first pass at 2 m interval, after widening another cable bolt of 6.1m long is installed in the widened area, totalling a 3 cable bolts in a row of 8m wide gallery are installed. Distance between two rows of cable bolts is 2 m. Also, the cement injection holes of 4 m long are made up to stone roof at 2 m interval.

In order to monitor the condition of the roof, the tell tales are installed at 10 m interval all along the face. The distance between the side and tall tales is at 4 to 5 m. Installation of cable bolts during drivage of first pass in set-up room itself yielded better results in terms of stability and operational limitations. Few locations, roof-to-floor convergence crosses 100 mm, but the displacement is localised only.

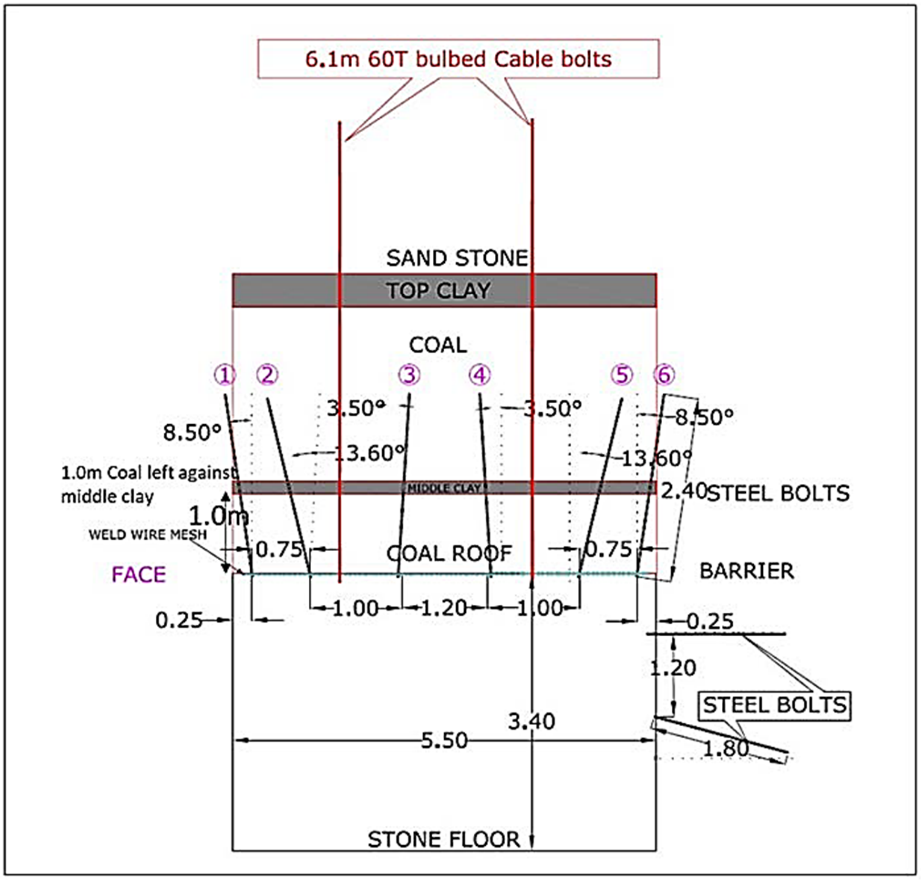

Figure 3(a). Roof bolts installed in the gate roads

Figure 3(b). Skin to skin support at the face

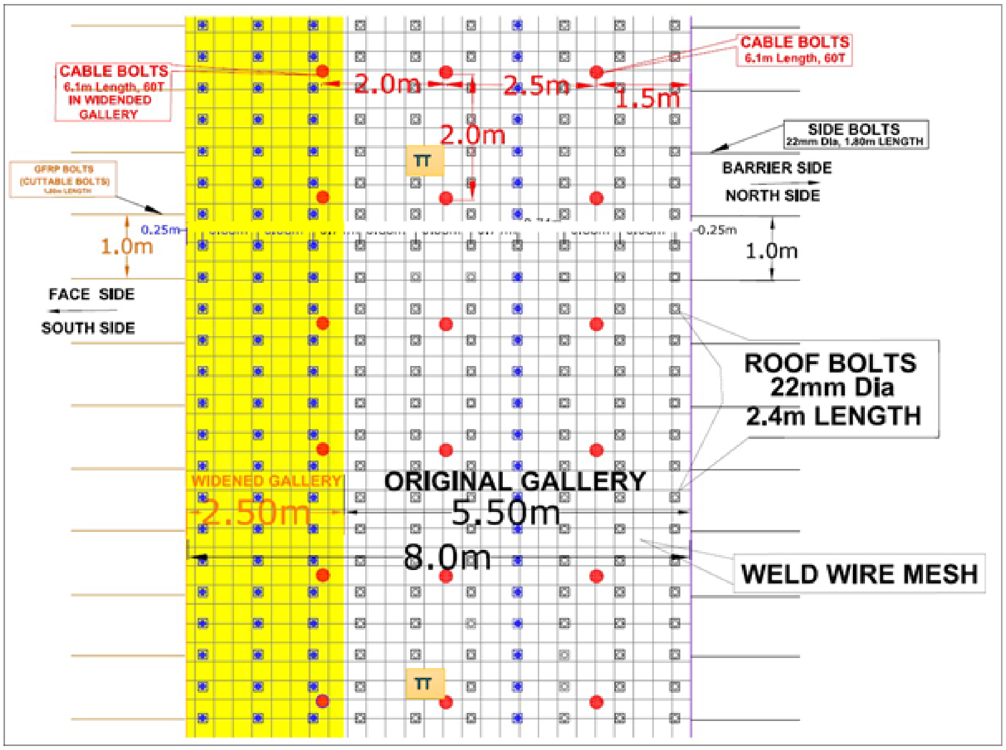

Figure 4. Support and Strata monitoring strategy at the set-up room of LWP No. 3

3. Development of 3D Numerical models for stability of set-up rooms

For the stability analysis of the set-up rooms, three panels/set-up rooms developed at different depths (417 m, 462 m, 528 m) is considered for detailed examination. A total of 12 three-dimensional finite element models are made based on the bore hole section of the study mine. All the layers up to main roof is incorporated in the model (Figures 1 and 5). Each set-up room model is developed and analyzed using Mohr's-Coulomb failure criterion in three different cases by varying the width of the set-up room as 8 m, 10 m and 12 m. Hence, a total of 12 numerical models includes 9 set-up room (excavation) models and 3 in-situ models are made for different geo-mining condition. Each numerical model consists of overlying strata, coal seam, set-up room, barrier pillars, goaf, cross cuts, gate roads and others. The coal seam of 6.73 m thick consists of coal (3.2 m), clay (0.5 m), coal (1.63 m), clay (0.5 m) and carb shale (0.9 m) from the floor of the seam is developed in the numerical model. The gate roads and cross cuts are developed with 5.2 x 3.2 m size.

Figures 5 and 6 show the 3D longwall set-up room model made for detailed examination. It can be seen from the Figure that the height, width and length of the model are taken as 716 m (Y-axis), 1657 m (X-axis) and 1567 m (Z-axis). The overburden layers which includes immediate roof, main roof and other roof strata is considered equivalent to the depth of the mining. For set-up rooms 1, 2 and 3, the thickness of overburden layer is developed as 417 m, 462 m, 528 m respectively. Figure 6 shows the inside view of the 3D numerical model showing the face, gate roads, set-up room, goaf, barrier pillars and other structures. From this figure, it can be understood that set-up room 3 is developed at 528 m depth and has the goaved-out panel in the rise side.

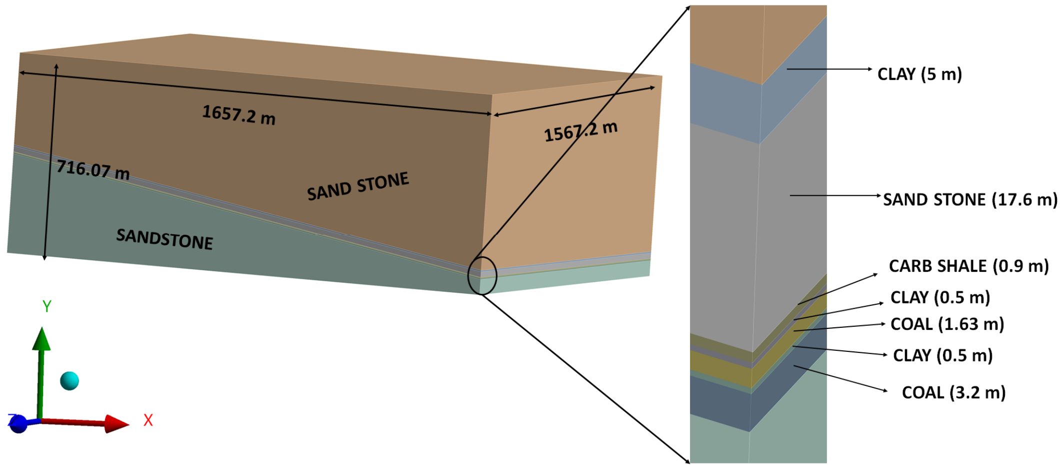

Figure 5. 3D numerical model of a longwall set-up room

The details of the set-up rooms and different cases of the models are given below for further investigations.

a) Set-up room 1 (SR-1): This SR is developed for the first panel. As mentioned earlier, the coal seam is depleted from rise to dip side. Hence, this room does not contain any goaved-out panels. This room has a barrier pillars in dip side between panel no.1 and panel no. 2. The width of barrier pillars is 50 m and length lies from 50 m to 200 m.

b) Set-up room 2 (SR-2): This set-up room is developed for the second panel. As this panel is situated in the dip side, SR-2 contains goaved-out panel (panel no. 1). Hence, the side abutment load will develop in the SR-2. This room has a barrier pillars in the rise (between panel no. 1 and no. 2) and dip sides (between panel no. 2 and no. 3). These pillars have the same length of SR-1 and width is 63 m.

c) Set-up room 3 (SR-3): This room is developed for the third panel. Similar to SR-2, this panel/SR-3 contains goaved-out panel (panel no. 2) and experience the side abutment load from panel no. 2. This room consists of barrier pillars in the rise (between panel no. 2 and no. 3) and dip sides (between panel no. 3 and no. 4). These pillars have the width of 69 m and length varies from 45 to 100 m.

All three rooms developed in three different cases based on the width of the room. The width of the room varies from 8 to 12 m. The case 1, 2 and 3 meaning that the width of the set-up room is 8 m, 10 m and 12 m respectively. The length and height of the set-up room are 250 m and 3.2 m respectively.

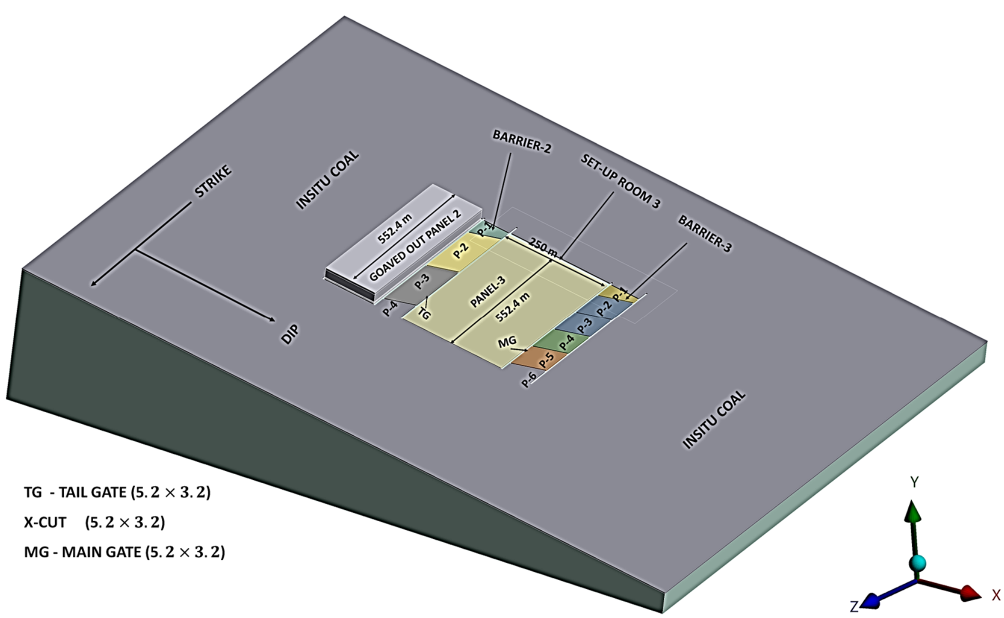

Figure 6. 3D numerical model showing the face, set-up room, goaf and other structures

As mentioned above, the set-up rooms 2 and 3 have side goaved-out panels in the rise side since the excavation is progressing towards dip side. To simulate these goaved-out panels, the height of the caving zone is estimated based on the relationship given in [24,30-33] as 16 m for bulking factor of 1.2 and mining height of 3.2 m. However, the caving height is observed in the mine till main roof (Figures 1 and 5). Hence, the height of caving zone/goaf height is considered as about 30 m. The properties of the goaf is considered from the study performed by Islavath et al. [34-35].

3.1. Meshing of the set-up room of a longwall panel and its loading conditions

Longwall set-up room models is developed with mesh of 10 noded tetrahedral elements. Figure 7 shows the 3D longwall set-up room meshed model. The finer mesh is developed with 1 m mesh size at the set-up room, immediate roof, barrier pillars and gate roads to determine the accurate displacement, roof-to-floor convergence, stress development and yield zone. However, the coarser size mesh is developed in the zone away from the set-up room zone. This 3D numerical model produces 3076329 elements and 4223226 nodes to estimate the conditions of set-up room.

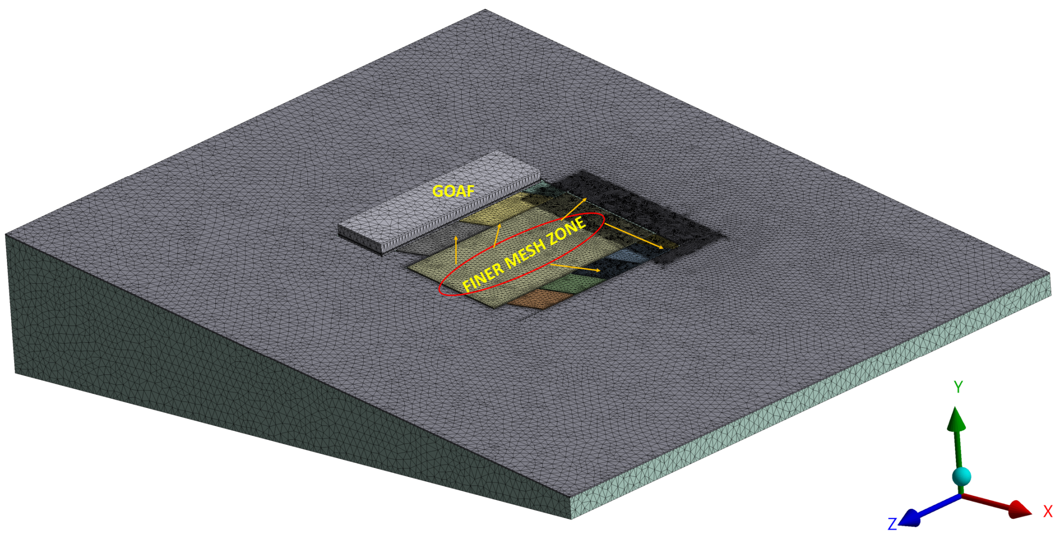

Figure 7. Finer mesh developed in the panel and the barrier pillars

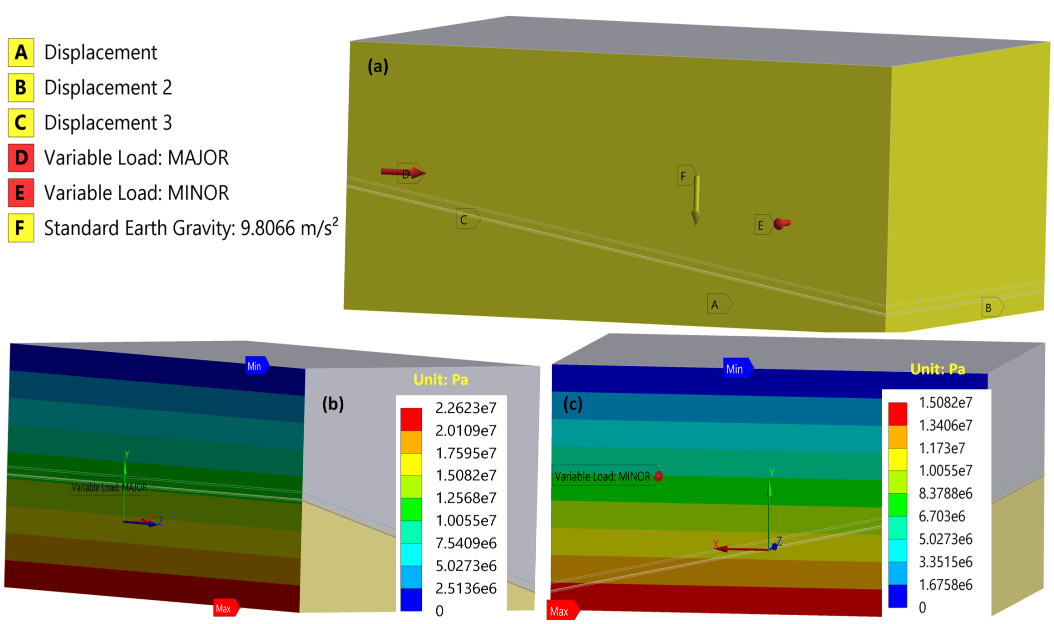

Figure 8. Loading conditions of longwall set-up room (SR-3) model

The horizontal stresses are applied as 1.5 and 1.0 times of vertical stresses in X (dip) and Z (strike) directions. Figure 8 depicts the application of horizontal stresses in a variable load or gradient load from 0 to 22.62 MPa and 0 to 15.1 MPa respectively. The opposite faces are constrained in X and Z directions, and the model is constrained in Y direction at the bottom. Also, the gravity of 9.81 m/s^2 is applied in vertical direction (Y direction). For set-up room 1, the major and minor horizontal stresses are of 0 to 18.22 MPa and 0 to 12.15 MPa respectively and that of 0 to 20.47 MPa and 0 to 13.65 MPa respectively for set-up room 2.

3.2. Rock Mass properties

The rock mass properties of sandstone, clay, coal and shale are collected from the study mine and used in the numerical models. The details of the material properties such as modulus of elasticity, poisson's ratio, density, friction angle and dilation angle listed in Table 1. In order to simulate the goaved-out panel, the well-packed goaf material is taken from the study conducted by Islavath et al. [34-35].

Table 1. Rock mass and goaf properties used in the study [34-35]

Rock strata	Density ρ(Kg/ m^3)	Compressive strength σ_c (MPa)	Modulus of elasticity E (GPa)	Poisson's ratio (υ)	Cohesion C (MPa)	Friction angle Φ^0	Dilation angle δ^0
Clay	1100	2.582	1.278	0.35	0.811	27	18
Coal	1500	4.13	1.535	0.35	1.00	31	21
Sandstone	2147	7.643	5.132	0.28	1.461	38	19
Carb shale	1276	2.980	1.400	0.35	0.904	28	19
Goaf	2100	--	0.50	0.25	--	--	--

4. Results and Discussions

4.1. Vertical displacement of set-up room

As mentioned above, the vertical displacement of the roof of the set-up rooms for different cases are extracted and analyzed. The paths are taken along the panel length passing through the middle of the set-up room. Figure 9(a) depicts the vertical displacement developed in the set-up room (SR-1) for different cases. From this figure, it can be clear that the vertical displacement of 22 to 29 mm occurred as the room width increases from case 1 to case 3. As expected and observed, the wider room develops the more displacement due to transfer of the stresses to nearby intact coal seam/sides. As a result, the roof layers gets relaxed and develops the vertical displacement.

Similarly, the SR-3 develops the more vertical displacement than SR-1 and 2 due to the room situated at more depth. Figure 9(b) depicts the vertical displacement profile of case 3 of various set-up rooms. From this figure, it can be noticed that the maximum vertical displacement of 45 mm occurred for SR-3 and that of 39 and 28 mm occurred for SR-2 and SR-1 respectively. It is also observed that the maximum displacement of 45 mm occurred for the case 3 of SR-3 and that of minimum 22 mm occurred for case 1 of SR-1.

4.2. Roof-to floor convergence of set-up room

Roof-to-floor convergence at the set-up room for each case is estimated by taking predefined paths in the roof and floor from in-situ and excavation models. From the models for each case of set-up rooms, the roof convergence (subtracting in-situ displacement from set-up room displacement taken in the roof) and floor heaving (subtracting in-situ displacement from set-up room displacement taken in the floor) is estimated [35]. Then, roof-to floor convergence of set-up is estimated as below.

$$RFC_{SR} = R_c + F_h$$

where, RFC_{SR} is RFC for set-up room, R_c is roof convergence and F_h is floor heaving.

Figure 10 shows the roof-to-floor convergence for different cases of set-up rooms. As expected, the RFC increases with increment in width of a set-up room and depth. It can also be clear that the minimum RFC of 37 mm occurred for case 1 of SR-1 and maximum RFC of 73 mm occurred for case 3 of SR-3.

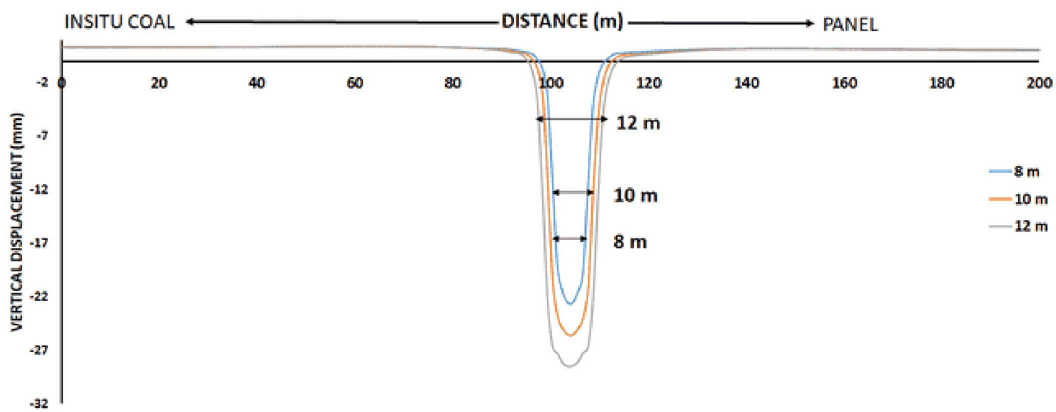

Figure 9(a). Vertical displacement of SR-1

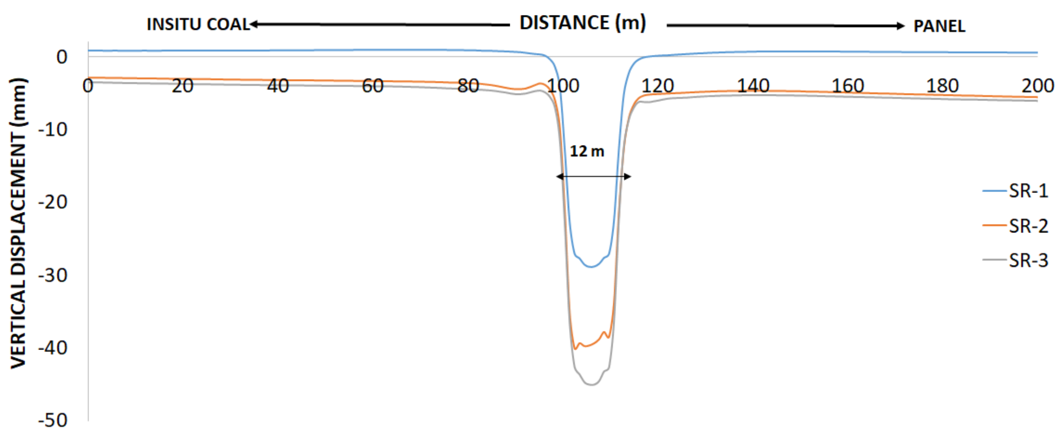

Figure 9(b). Vertical displacement of case 3 of various set-up rooms

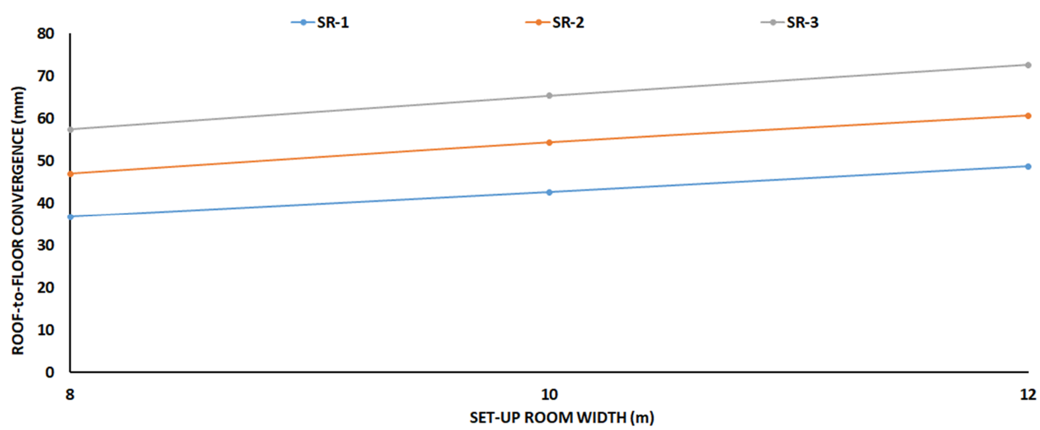

Figure 10. Roof-to-floor convergence of set-up roof for different cases

From this analysis, it can be found that the RFC of the room increases for cases 2 and 3 of SR-1 from 15.9 to 32.6% than case 1. Similarly, it increases from 15.6 to 29% and 13.7 to 26.5% for SR-2 and 3 respectively. Also, the RFC develops from 24.4 to 56.3% for the increment of depth from 462 m (SR-2) to 528 m (SR-3) than 417 m (SR-1).

4.2. Vertical stress distributions on the panel

The vertical stress development due to driving of the set-up room is extracted from the numerical models for various cases. Figure 11 shows the vertical stress distribution profiles for case 3 (12 m wide) of SR-1 to SR-3. From this figure, it is observed that due to driving of the room, the high stress is induced on the sides/corners of the room in intact coal/barrier and panel and reduces as it moves away from the room. As mentioned above, the high vertical stress induces due to more depth in SR-3 and low stress is induced in SR-1. The maximum vertical stress of 10.8-10.9 MPa, 11.9-12.4 MPa and 17.3-18.6 MPa occurs at the corners of SR-1, SR-2 and SR-3 respectively. The area away from the room develops the average vertical stress of 7.49-7.89 MPa, 8.10-8.90 MPa and 10-10.6 MPa in SR-1, SR-2 and SR-3 respectively.

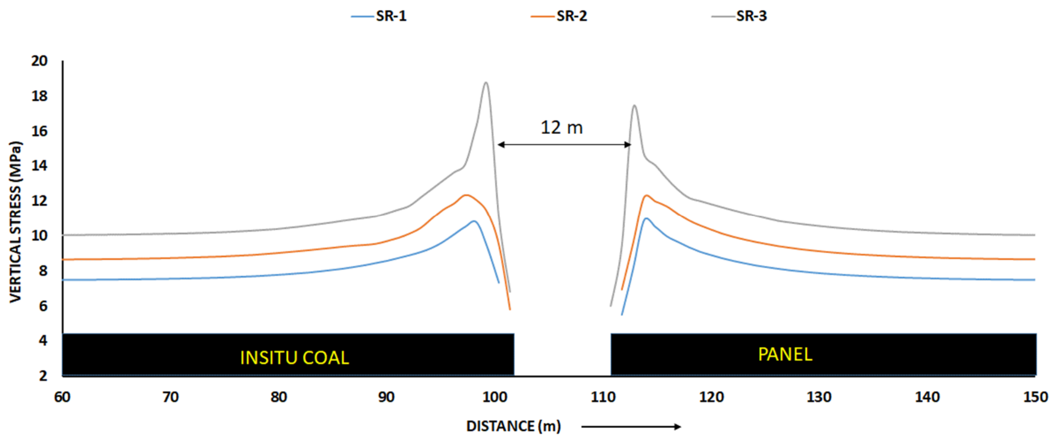

Figure 11. Vertical stress distribution at set-up room for different cases

Figure 12 shows the distribution of vertical stress for different cases of set-up room 1. It can be clear that with the increment of the set-up room width, the development of vertical stress is increasing. The average vertical stress developed near the set-up room is 8.5-9.2 MPa, 8.95-9.5 MPa and 8.73-10.7 MPa for cases 1, 2 and 3 respectively.

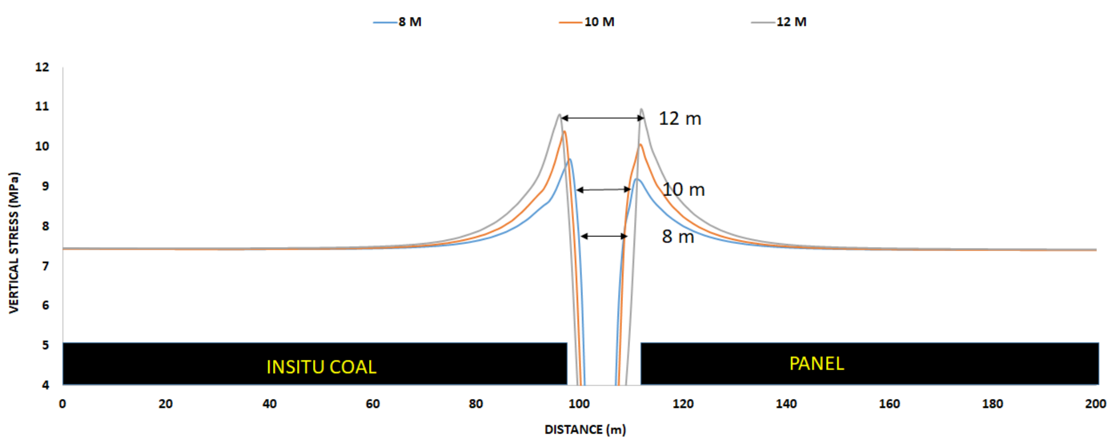

Figure 12. Vertical stress distribution of SR-1 for different cases

It is also observed that the maximum vertical stress concentration factor for the SR-3, 2 and 1 found to be 1.79, 1.39 and 1.38 respectively. This stress concentration may cause the yield zone in the sides, roof and floor of the room.

4.3. Vertical stress distributions on the barrier pillars

Figure 13 shows the development of vertical stress on the barrier pillars for different set-up room conditions. From this figure, it can be understood that the high vertical stress induces in the SR-3 than SR-1 and 2 due to the room lying at high depth. The average vertical stress concentration on barrier pillars occurs for SR-1, SR-2 and SR-3 is 8.29 to 8.49, 9.33-9.55 and 10.68-1.97 MPa respectively. The corners of the pillars develop the stress of 9.13-

10.58, 9.85-11.40 and 11.56-13.57 MPa for SR-1, 2 and 3 respectively (Figure 14). Figure 14 also depicts the vertical stress distribution profile of barrier pillars, intact coal seam and set-up room for SR-3. This developement of stress may result in the failure of the sides and corners.

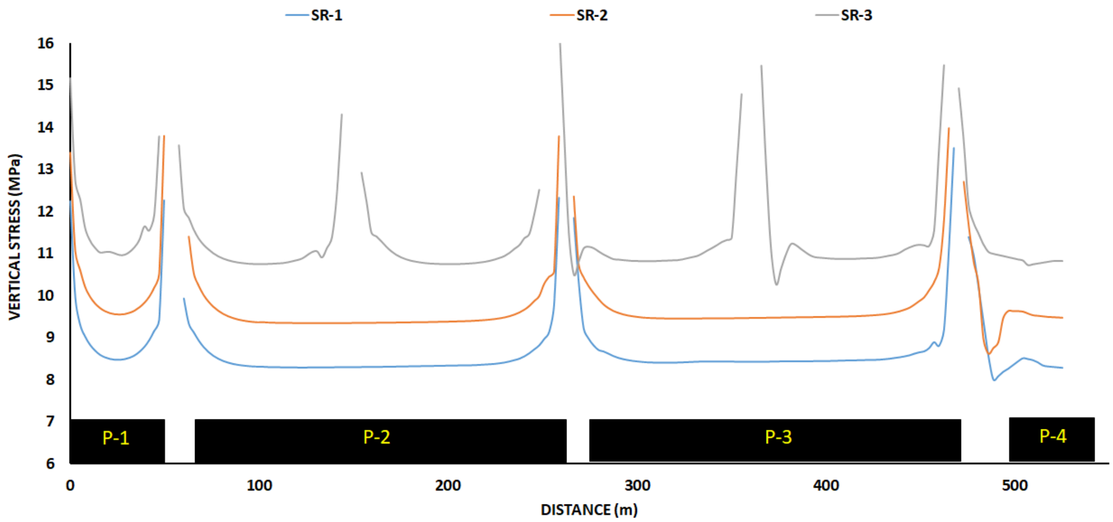

Figure 13. Vertical stress distribution profiles on the barrier pillars of different set-up rooms

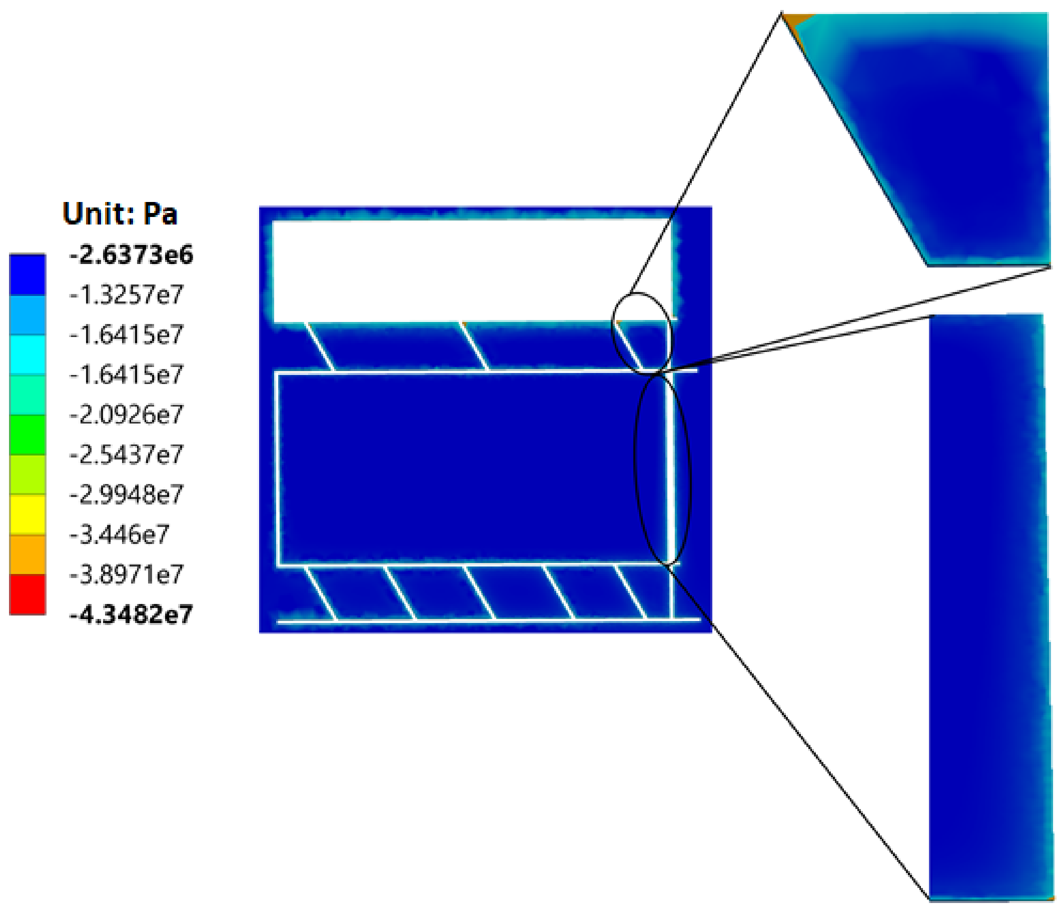

Figure 14. Vertical stress distribution contour profile on the barrier pillars, intact coal seam and set-up room

4.4. Yield zone in the panel and the barrier pillars

Figure 15 shows the yield zone/plastic strain occurrence around the set-up room at the middle of the panel. From the Figure, it can be noticed that a zone of 2.7 to 3 m may develop the plastic strain in either sides of the set-up rooms. Out of this, about 1 to 1.5 m in the sides can develop the high plastic strain and causes the failure in the sides.

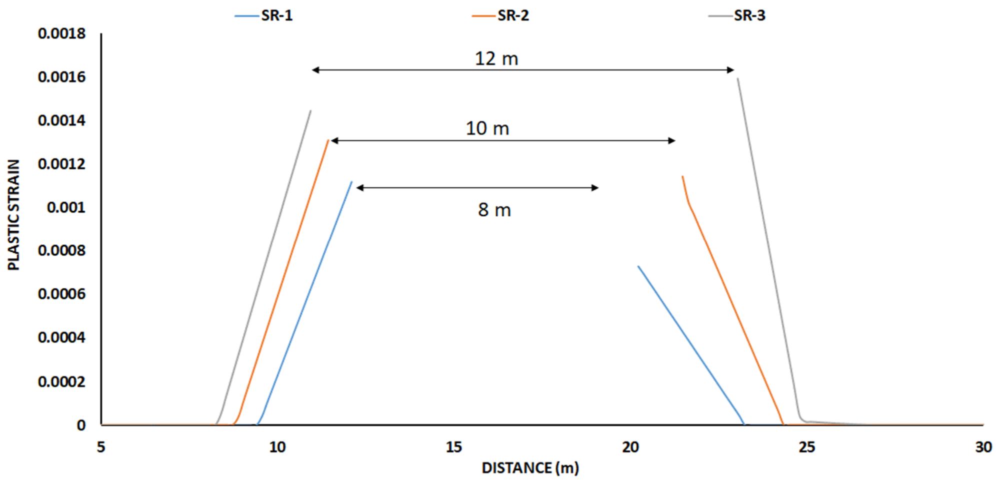

Figure 15. Plastic strain intensity profiles around the set-up rooms

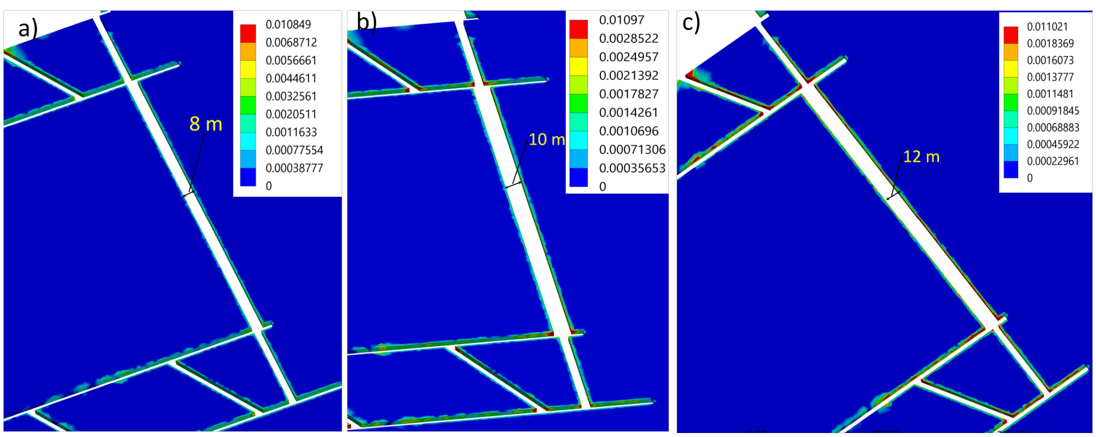

Figure 16. Plastic strain intensity contour plot of different cases of SR-3

Figure 16 shows the plastic strain distribution contour for set-up room 3 in various conditions. From this, it can be observed that the plastic strain intensity increases with the increase of the set-up room widths from 8 to 12 m. For 8 m model, it develops the maximum plastic strain of 10.84% and that of 10.97% and 11.02% for 10 m and 12 m respectively. The maximum strain develops in the corner of the pillars and may spall about 1 to 1.5 m (Figure 17). It is also observed in the study that the roof of the set-up room develops the plastic strain for height of 0.5 to 1.5 m, and as a result, the roof layers of clay and part of coal gets yielded. After that the separation can take place in the overlying roof rock layers specially in clay of 0.5 m thick and shale of 0.9 m thick. Therefore, the entire immediate roof of 3.54 m thick is needed to get stabilized with bulbed type cable bolting of 6.1 m height.

4.5. Validation of the study results with field instrumentation

As discussed in section 2.2, the tell tales of 2 m and 4 m anchors are installed in the set-up room at 10 m interval. Figure 18 depicts the development of roof convergence at 25 locations of the set-up room. From the figure, it can be noticed that the first three stations up to 30 m from the main gate developed the excessive convergence over 70 to 90 mm. Hence, the bulb type cable bolts are installed in this location and further widening of the set-up room is progressed. Due to this, the convergence is limited in between 11 and 43 mm.

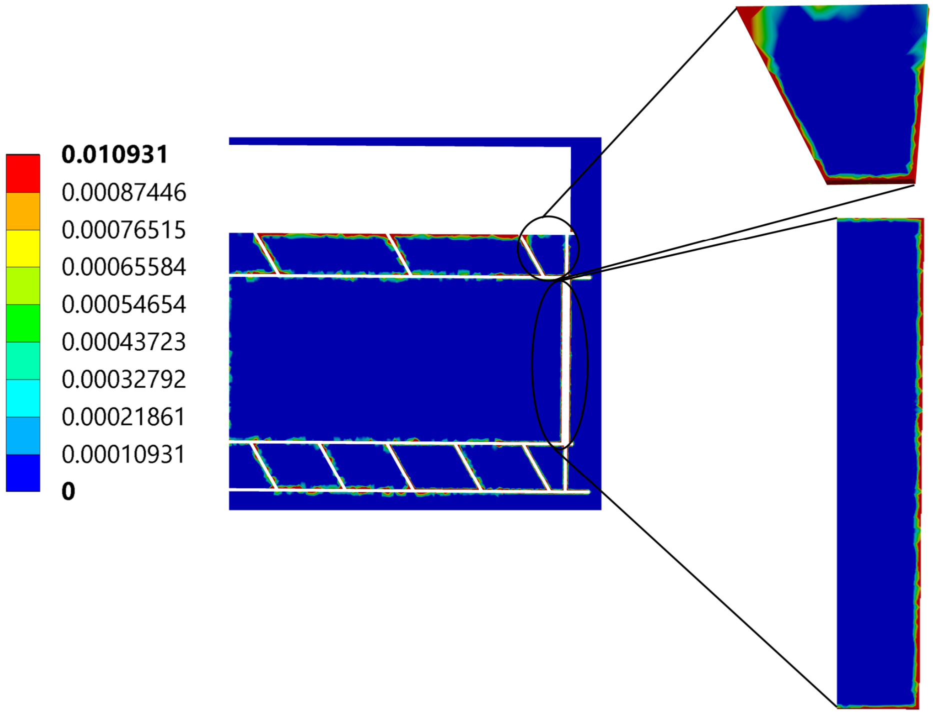

Figure 17. Zoomed view of yield zone development in the sides of set-up room and barriers

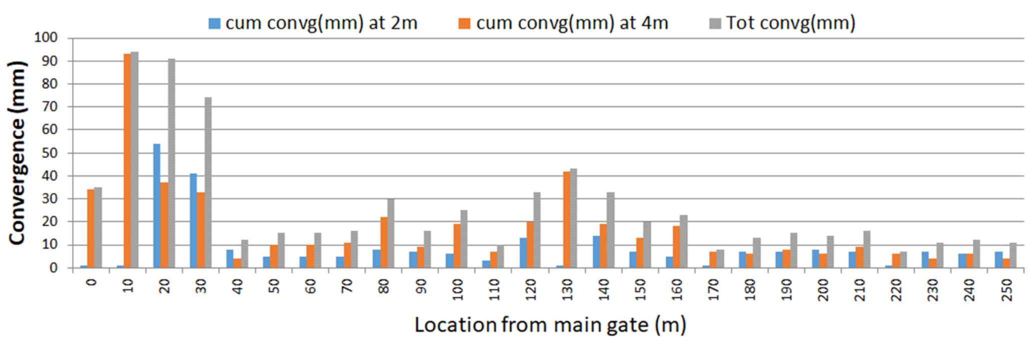

Figure 18. Convergence observed in the set-up room 1

Figures 19(a) and (b) shows the development of roof convergence in the set-up room at 120 m and 130 m location from the main gate. From these, it can be noticed that the convergence increases with further progress of the set-up room and time. The maximum roof convergence of 33 mm and 43 mm occurred at these two locations. It is also observed that the maximum roof convergence development rate is 0.13 mm/day. Similarly, it is observed that roof convergence of 122 to 136 mm and 37 to 63 mm developed at the middle of the set-up room for SR-2 and SR-3 respectively.

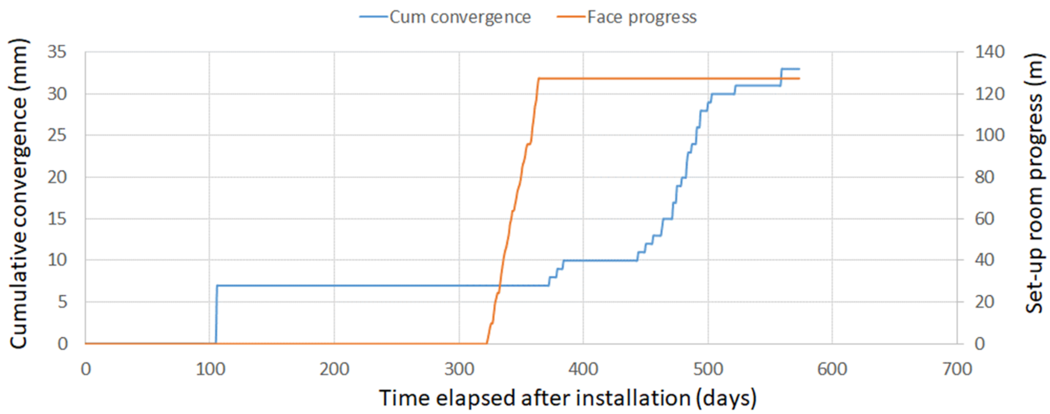

Figure 19. a). Cumulative convergence at 120 m distance from main gate of set-up room 1

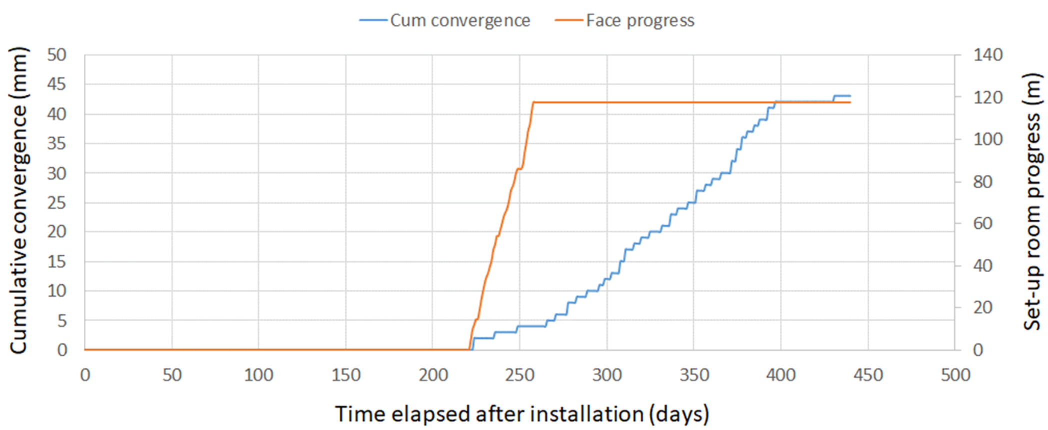

Figure 19. b). Cumulative convergence at 130 m distance from main gate of set-up room 1

As mentioned in section 4.1, the roof convergence observed in the study lies between 22 and 45 mm. These results are found to be in close to the field observed convergence data. Also, the vertical stress concentration factor of 3.54 to 4.05 and roof convergence of 12.7 to 96 mm observed in the literature [26] are also close to the results of the study.

5. Conclusions

The stability analysis of the set-up is performed for different geo-mining conditions (depths: 417, 462 and 528 m, and width of set-up room: 8, 10 and 12 m) using 3D numerical modelling technique. In this study, the vertical displacement, root-to-floor convergence, development of vertical stress on the barriers and set-up room, plastic strain distribution and yield zone in room and barrier pillars are estimated. From this analysis, it is observed that development of vertical displacement, roof-to-floor convergence and plastic strain increases with the increase of the depth and width. Similarly, the stress concentration on the face/sides of set-up room and barrier pillars is also increased with increase of the depth and width of set-up room.

- The vertical displacement of 22 to 29 mm occurred as the width of the room increases from case 1 to case 3 for set-up room 1. It is also found that the maximum vertical displacement of 45 mm is observed in case 3 of set-up room 3 (at deeper depth) and that of minimum 22 mm occurred in case 1 of set-up room 1 (at lower depth).
- Roof-to-floor convergence developed in the study lies in between 37 and 73 mm for case 1 of set-up room 1 and case 3 of set-up room 3. From this analysis, it is observed that RFC of the room increases from 13.7 to 32.6% with increment of case 2 to 3 than case 1. Similarly, it increases from 24.4 to 56.3% for the increment of depth from 462 m (SR-2) to 528 m (SR-3) than 417 m (SR-1).
- It is observed that the maximum vertical stress of 10.8-10.9, 11.9-12.4 and 17.3-18.6 MPa develops at the corners of set-up rooms 1, 2 and

3 respectively.

- It is also observed that the development of vertical stress concentration on barrier pillars lies from 8.29 to 8.49, 9.33-9.55 and 10.68-1.97 MPa for set-up rooms 1, 2 and 3 respectively.
- The maximum plastic strain of 10.84% develops for case 1 and that of 10.97% and 11.02% develops for cases 2 and 3 of set-up room 3 respectively. Based on the plastic strain, it is observed that 1 to 1.5 m may yield in the corner of the pillars and set-up room and 0.5 to 1.5 m yields in the roof of the set-up room.

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تجزیه و تحلیل پایداری اتاق راه اندازی یک پانل جبهه‌کار طولانی عمیق هند با استفاده از تکنیک مدل سازی عددی سه بعدی

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۲. پروژه جبهه‌کار طولانی آدریالا، شرکت سنگ گارنی با مسئولیت محدود، تلانگانا، هند

ارسال ۲۰۲۴/۰۳/۲۵، پذیرش ۲۰۲۴/۰۵/۱۵

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چکیده:

گالری نصب/اتاق راه اندازی یک پانل جبهه‌کار طولانی برای نصب ماشین آلات جبهه‌کار طولانی جهت شروع استخراج زغالسنگ از پنل جبهه‌کار طولانی هدایت می‌شود. عرض گالری نصب ۸ تا ۹ متر است. این گالری نیاز به تثبیت تا زمانی است که ماشین آلات صورت از رانندگی اتاق مستقر شوند زیرا نیاز به ایستادن بیش از ۸ تا ۱۰ ماه دارد و غلظت استرس بالا، همگرایی سقف به طبقه و منطقه تسلیم در سقف و ایجاد می‌شود. طرفین از این رو، در این مطالعه، یک معدن دیواری عمیق هند برای تحلیل رفتار اتاق راه‌اندازی در نظر گرفته شده است. برای این کار، در مجموع دوازده مدل عددی سه بعدی با در نظر گرفتن معیار شکست Mohr's-Coulomb توسعه و تحلیل می‌شوند. سه پانل واقع در ۴۱۷، ۴۶۲، ۵۲۸ متر با سه عرض مختلف (۸، ۱۰ و ۱۲ متر) اتاق های راه اندازی مورد بررسی قرار می‌گیرند. عرض اتاق راه اندازی بر اساس طول تکیه گاه سپر گرفته می‌شود. نتایج از نظر توزیع تنش عمودی، جابجایی عمودی، همگرایی سقف به کف، کرنش پلاستیک و توزیع ناحیه تسلیم ارائه شده است.

کلمات کلیدی: جبهه‌کار طولانی، اتاق تنظیم، تمرکز تنش، همگرایی سقف به طبقه، منطقه تسلیم.