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Methodology of Continuous Miner

K V Shanker[1],Sumant mohanto[2]

KV Shanker1.Prof,,DeptofMiningEngineering,MallaReddyEngineering College(Autonomous)Maisammaguda,Dhullapallypost,viaKompally,Secunderabad-500100India

Sumantmohanto[2],Prof, Deptof MiningEngineering,Malla ReddyEngineering College(Autonomous)Maisammaguda,Dhullapallypost,viaKompally,Secunderabad-500100India

ABSTRACT

Field investigations were carried out at VK-7,KOTHAGUDEM of S.C.C.L, Mine site for evaluation of strata behavior during extraction of coal in a 6.5 m thick seam by continuous miner at a depth of 323 m .

Continuous mining is is new method of mining and done with high cost .so the safety of the machine is also very important , this is done by daily monitoring of strata and taking readings of convergence so that proper support is to be installed.

Introduction

General

A developing country like India has ever-growing thrust on faster economic development. As energy is the lifeline of all economy, India is genuinely concerned about its energy security. To meet the projected energy demands, Government has declared that fossil fuels, particularly coal, are going to be the mainstay fuel for power generation. Coal provides the single most vital input for the growth of Indian industry. It is the key Contributor to the Indian energy scenario. Out of the four major Indian fuel resources i.e. oil, natural gas, coal, and uranium, coal has the largest domestic reserve base, and the largest share of India's energy production. The most economical method of coal extraction from coal seams depends on the depth and quality of the seams, and the geology and environmental factors. Coal mining processes are differentiated by whether they operate on the surface or underground..

Surface mining and underground mining are the two basic methods of mining. The choice of mining method depends primarily on depth of burial, density of the overburden and thickness of the coal seam. Seams relatively close to the surface, at depths less than approximately 50 m, are usually surface mined.

Coals that occur at depth of beyond 50 m are usually underground mined, but in some cases surface mining techniques can be used. For example, some of mines, coal that occur at depths in excess of 60 m are mined by the open pit methods, due to thickness of the seam 20–30 m. Coals occurring below 100 m are usually deep mined. India is the world's third largest coal consuming nation after China and the USA. Coal is the dominant energy source in India, accounting for more than half of the country's requirements.

Mass Exploitation of Coal

Mass exploitation of coal refers as "economically excavation of coal with due method of higher productivity, safety and conservation". Present intermediate mechanization, based coalmining may not be suitable to meet the global competitiveness (arising due to open economical policy) of productivity. There is a need of fully mechanized or even an automated

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underground method for a safe coal mining, which may also strengthen our industry to meet the global competitiveness of productivity.

1.2 Strata Control Technology

The term "strata control" principally refers to controlling the strata to maintain stability around the mine openings in underground where operations are or will be taking place. The need for strata control may extend into a goaf area for a short distance, essentially to the goaf edge, however strata control within the goaf is generally of no interest. In order to analyze strata reactions, properties such as strength (tensile and compressive), modulus of elasticity, Poisson's ratio, etc are required, as well as details of the likely stress fields to which they will be subjected.

If these are unknown or cannot be measured, then its value is assumed with excessive conservative designs likely to result. A reasonably detailed knowledge of any geological structures is also required as these can affect both strata properties and stress fields locally. Strata control techniques which are used include:

1.Mine design relating to dimensions and shape
2.Mine design relating to mining direction
3.Sacrificial support external to strata
4.Reusable support external to strata
5.Strata reinforcement
6.Retention of failed strata

1.3 Continuous Miner in Underground Coal Winning

Mass exploitation technology using Continuous Miner (CM) is one of the suitable alternatives for Indian coal mines in order to efficiently boost the coal production from underground mines. The scenario of a higher production share from surface mines is not going to be sustainable because of reduced near surface coal reserves and other concerning issues attached with surface mining. Considering these restrictions the two state owned coal companies, Coal India Limited (CIL) and Singareni Collieries Company Limited (SCCL), have taken a lead to boost the coal production from underground mines through CM mining technology.

Objective of Report

The Objective of the report presented in this thesis is to improve the understanding of the fundamental mechanisms of roof behavior and the essential of support design and a safety based design methodology for their amelioration. To meet the main objective of the study, these are the primary objective of this study is to: Study of Strata Behavior with respect to convergence during extraction of coal in a thick seam (6.5 m) by continuous miner with diagonal slicing.To verify the suitability of existing support system for ensuring safety based on field observations and numerical models.Formulation of guidelines for Strata Management.

General

Strata control is the science (some would suggest art) of utilizing various techniques to prevent or control failure of the strata around mine openings at least for the period where access is required. For different locations in the mine this period may be for the life of the mine (which can be considered as permanent), such as the main mine accesses from the surface, or for a matter of less than an hour, such as a lift off a coal pillar with a continuous miner. Strata refers to rock in all the possible forms that it may take from a high strength material to an extremely weathered, very low strength, essentially soil like material. Strata control refers to the methods applied to manage the risks associated with various forms of strata instability in underground coal mines.

There are some cases where pillars are actually designed to yield (i.e. at least partially fail) in order to relieve stress on adjacent roadways. During second workings with continuous miners, remnant pillars or stooks may be designed to remain stable for only a very short time and then be allowed to fail in the longer term (in fact this may be desirable to improve caving).With regard to pillar stability, it is not only the plan area which is of importance but also the height to width ratio – a tall, thin pillar is more likely to fail than a short, fat one. The length and/or width required for a stable pillar is therefore going to increase as the working height increases.

The shape of an opening also affects its stability. A circular opening is the most naturally stable shape and has been used at mines, notably for shafts and drifts. While a circular profile may be more stable a flat floor is required for most purposes – generally there is little point in removing strata in the lower portion only to re-fill it again afterwards. An arch shape provides the benefit of a circular profile in the upper section while retaining a flat floor. The drawbacks of an arch section are:

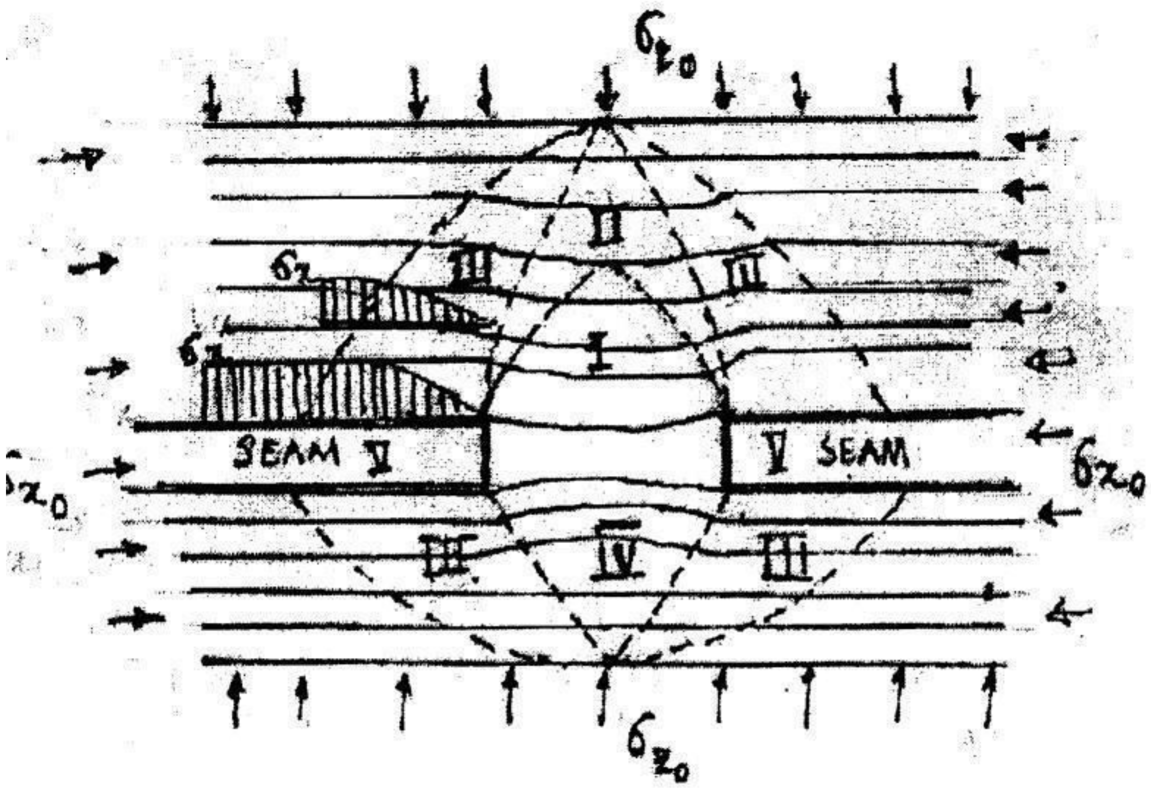
Because the width of an arch narrows towards the top, an arched roadway may need to be mined wider and/or higher than a rectangular roadway to obtain the dimensions required for given equipment to pass.

For these reasons, nearly all mines cut rectangular profile openings, apart from in shafts and drifts. Strata reinforcement is used in almost every mine today to some extent, most commonly in the form of roof bolts. The earliest roof bolts were steel rods with a split end with a steel wedge inserted. were clamped together to form a stronger beam. The bolting pattern density was increased until the roof then became self supporting. Such bolts were often installed through timber bars to spread the support over more area and to aid in retaining broken material. At times steel cross members were used instead of timber, the bolts being installed through brackets or "saddles" to hold them in place.

2.1 Strata Mechanism

Underground excavations in rock cause redistribution of stress around the opening. Depending on the strength and deformation behavior, the rock adjusts itself by moving into the opening. Sedimentary rocks have low tensile strength normal to the bedding plane, and low shear strength along the bedding planes. Adverse geological conditions in any area may further reduce the overall strength of rock mass. The deformation of roof has added advantages having gravitational forces, hence are liable to failure. Timely and proper support is necessary to prevent collapse of roof.

In layered strata like coal measure rocks, bed separation and subsequent roof sag take place in the immediate roof. Simultaneously, the load originally carried by the coal is transferred on to both the sides of the solid pillar. These “abutment stresses” are much higher than the average pressure on the surrounding area. Figure showing details for typical underground excavation (A) of coal seam V.



Bed separation and distribution of stresses

Zones-I and II are distressed areas. The bed separation in zone one-I gradually reduces towards the top mainly due to clamping action of abutment pressure and frictional resistance between the layers. The arches above the opening depend on the component layers, uniformity in thickness and the magnitude of horizontal pressure. Depending on the conditions or rock and stress fields,

floor heaving and side spalling may also occur.

2.2 Factor Influencing Strata Mechanism

These are the following factors influencing roof stabilities in any underground excavation are as:

Span

One of the major influencing the stability of roof and support requirement is the width of the roadway. This factor becomes increasingly important with increasing RMR.

Profile

A curved profile as compared to a rectangular section almost invariably improves the inherent stability of the roof by substantially reducing stress concentration. Theoretical concentration indicates that the tangential stress at the corners of a rectangular opening approaches infinity.

Virgins stress

To ascertain the total stress condition at any point it is necessary to measure stress value in three conditions. The vertical stress field value is generally given by:

Vertical stress (MPa) = Depth (m) x 0.024

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Induced stress

These are caused by mining activity in another seam or in proximity in the same seam. Induced stress as and when they appear call for secondary support, which should ideally be erected to prevent damages due to the stresses induced.

Physico-mechanical properties

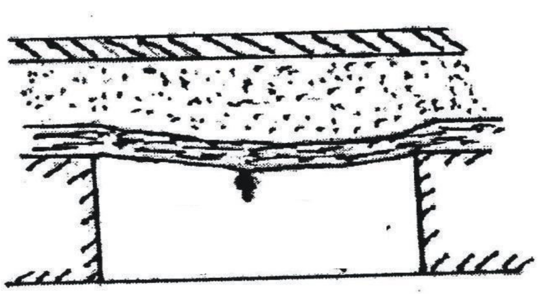
For, all practical purpose only the compressive strength of roof rock is taken into consideration, except when mathematical modeling is attempted using various other strength parameters, such as tri-axial strength, shear strength etc. Slaking/swelling is an important property. Clay particularly on exposure to moisture display instability and poor anchorage to roof bolt. Joints reduce rock strength, particularly, in tension and shear. The worst drivages direction will be parallel to the major joint plane Depending on throw, clay filling and joint swarms, faults will affect the roof variably and call for substantial up rating of support system. In addition to above there are other structural features, like false-bedding, slickenside, streaks of clay or coal etc.

2.3 Reasons of Strata Failure

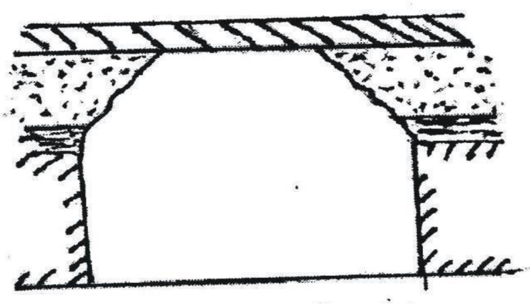
2.3.1 Tensile failure

Tensile stress in strata is generated by the gravity loading of the sagging strata. Cracks form along the edge and the centre of the roadway, when the failure planes join up, the strata cave. These failures occur under low horizontal stress conditions. Typical cases of span failures are shown in Figures. Obvious remedy is to prevent roof sag by reducing span and/or by roof bolting to increase the tensile strength of the roof beam or to provide suspended support. Repeated span failure may end up in an arch failure.

Another form of failure known as “skin failure” can be attributed to tensile failure, but other inherent weakness in the rock mass like friability, cross bedding, slickenside etc.



Span Sag



Span Failure

Contribute more towards such failure. In this type of failure thin layer of immediate roof caves in small segments. Such layers may be dressed down or coal may be left in the roof. Alternatively, bars and/or wire mesh may be used between supports.

2.3.2 Shear failure

These failures are manifestations of lateral stress. Mid-span failures occur under relatively uniform stress field or where beam failure has already weakened the material.

Shearing may occur along the pillar side when the lateral stress is high. This is the first stage of the failure mechanism and is known as guttering. The shear planes usually extend over the roadway.

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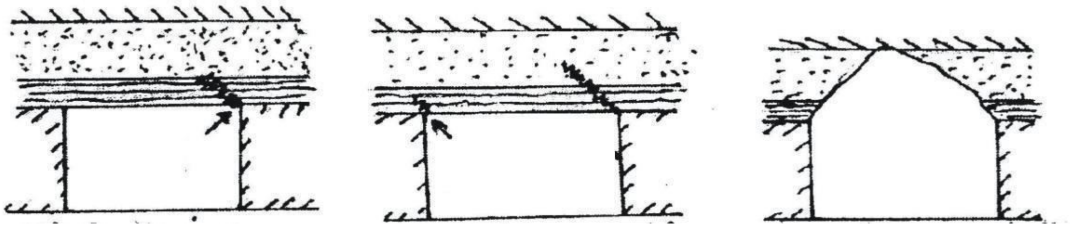
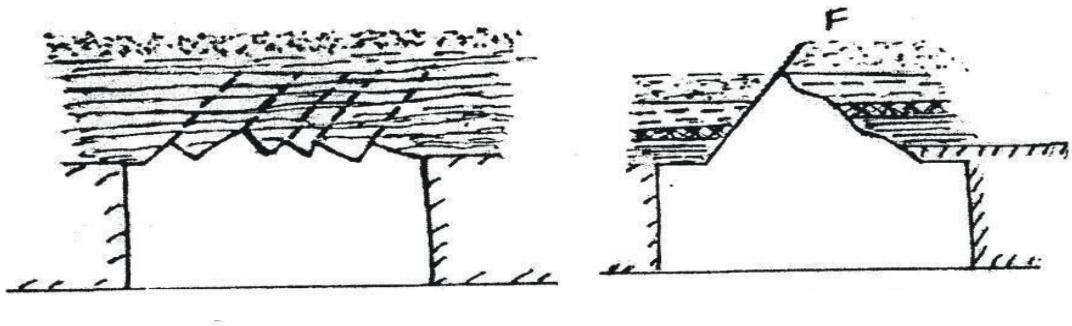


A. Guttering B. Cantilever action C. High arch failure

Skin failure or flaking or unraveling

2.3.3 Structural failure

These failures are caused by structural defects in the roof rock. These defects bring in discontinuities in the rock mass and it reduces the strength. The most common structural defects are joints, faults, dykes, slickenside false bedding, etc.



Structural failure

2.3.4 Arching action

Arches action is the natural process by which a fractured material acquires a certain amount of ability to support itself partially through the resolution of the vertical component of its weight into diagonal thrust. If support is installed before the initiation of roof separation, it strengthens the ground structurally, and enables it to support itself. The strength of such support is only a fraction of that which would be needed to support the full weight (dead weight) of the roof strata overlying the opening. The supporting force need only be sufficient to prevent failure (by shearing) of the strata under compressive stresses.

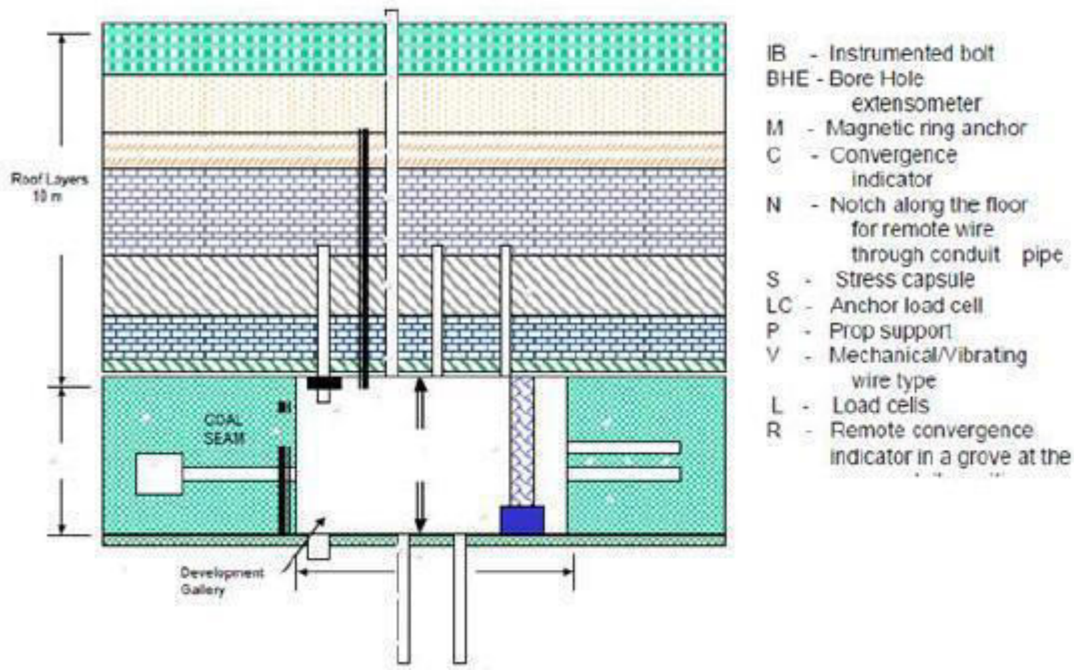
In case of an opening overlain by fractured strata, the fractured blocks will be prevented from falling because they are not allowed to rotate about their edges. The restraining forces preventing rotation are simply the general reactions. Friction forces at the end of the blocks resist shear forces and prevent the blocks from moving vertically downwards.

Even if the roof is cut numerous fractures, the result will be the result provided no lateral movement is allowed. This is the reason why opening in moderately fractured rock will stand without any support, and those with badly fractured rock will stand with a minimum amount of support. Such decoupled rocks are supported entirely by compressive and shear resistance, and strength of the linear arch does not depend at all on the tensile or flexural strength of the rock, but depends on the compressive strength of the rock (which is normally at least 4 to 5 times as great as flexural strength in unfractured rock, and infinitely greater in fractured rock). The presence of large lateral stresses tends to stabilize a linear arch. After understanding the failure mechanism of strata, we can establish numerous techniques and can design specific supports to counteract the predominant failure mechanisms. Keeping in view, as mine manager should be determine and should deploy the appropriate technique to work safely in the mine.

Strata Behavior

Development or pillar extraction affect the magnitude of strata pressure and hence, its manifestation in convergence of advance workings and extraction area, stress over ribs, stooks and pillars during depillaring (Singh, 1998). Foreseeing the strata behavior problems during
depillaring in thick coal seams, Singh (1992) states “Strata movement of unprecedented nature are likely to occur with underground mining of thick seam. Strata control engineers will be required to constantly monitor these movements and review their concept of ground control so as to offer adequate solution to the problems that may arise and which are mostly site specific”.

Particularly when the thick seam working with caving operation, such critical conditions occur, and maximum pressure over ribs, stooks and pillars and convergence are more common observed during depillaring (CMRI, 1997; Singh et al: 2000). A proper understanding of the influence of strata characteristics on progressive convergence behavior and support performance is essential for reliable planning, rational support selection and thick seam coal mining by continuous miner. Strata and support behavior monitoring is required for understanding the performance of support system. Figure illustrates the instrumentation required for strata monitoring in a typical development gallery of underground coal mine.



Typical Instruments for Strata Monitoring

Convergence recording stations should be installed at all junctions situated within two pillar distance from pillar under extraction in the proposed panel. Monitoring of readings at convergence recording stations should be done in every shift by a competent person duly authorized by the manager and the measurements should be recorded in a bound paged book and the same should be counter signed daily by the Under Manager of the shift and Asst. Manager in charge. All the work persons should be withdrawn from the abutment zone if the

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ration of C1/C2 is equal to or more than 2 as given above and steps should be taken to release the goaf abutment pressure by induced blasting. The Safety Officer should co-ordinate recording, analysis and interpretation of the readings and advises the Officers/ Officials daily at the mine.

2.7.0 Convergence

Convergence is the manifestation of the forces which goes out of equilibrium due to underground excavation when the underground excavation are made, the sides of excavation tend to flow into the excavated area – the roof sags and the floor heaves. The net result is that the excavated area gets reduced. The distance between side and that between roof and floor decrease. The relative movement between roof and floor measured in the vertical plane is known as relative convergence or more commonly as convergence. Underground roadways suffer convergence during development and extraction, the former being essentially a logarithmic function of time (Unal, 1983). The convergence in Longwall workings follow more or less a predictable pattern, While it could be erratic in bord and pillar extraction because of the stocks and ribs, (Singh, 1998)

A number of tools have been described by, but measurement of roof to floor convergence is a common practice in Indian coalfields for estimation of roof Strata behavior. On the basis of roof to floor convergence (C) recorded in and around the depillaring faces under hard and massive sandstone roof, Coal Mines Regulation (CMR, 1957) states following two criteria for anticipation of a roof fall

$$\frac{C_1}{C_2} \geq 2.0$$

$$\frac{C_1 - C_1^{'}}{C_2} \geq 1.5$$

Where, C1 is daily convergence at a site in a day n, C2 is average daily convergence at the site up to the previous day i.e. up to day (n-1) and C'1 is daily convergence on a day (prior to day n)

when C1/C2 ratio is less than 1.5. It is also mentioned that the second i.e. eqn. provides better result.

An analysis of some convergence data (Satyanarayana et al., 2005; Mandal *etal.*, 2006) with the help of eqns. (1.1) and (1.2) showed dubious results than the indication ofroof fall picked up by a complete cycle of observations as shown in Figure

Roof to floor convergence study works well for strata movement study during development of a coal seam (Ghosh and Ghose, 1992) but the operational constraints makes it difficult to be measured in and around a depillaring face. Further, for a stratified formation, there is a good chance that the roof to floor convergence may provide false indication of major strata equilibrium dynamics mainly due to movement of the immediate roof only .A recent strata movement study scheme (Shen et al., 2008) integrated three tools: roof deformation, mining induced stress change and seismicity for successful prediction of roof fall.

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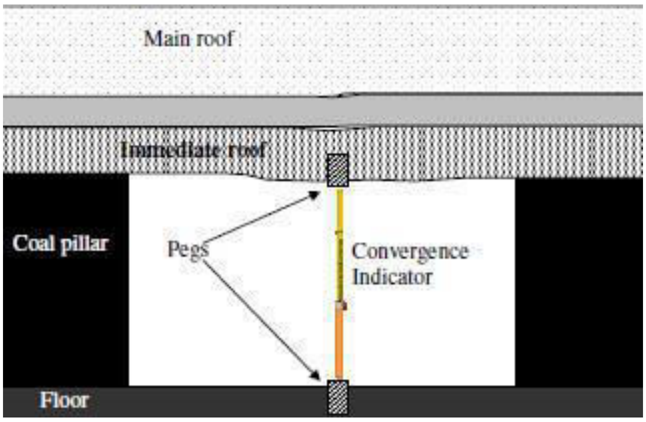


An instrumentation scheme to study roof to floor convergence.

2.8 Roof Support Design Methods in Mechanized Board and Pillar for wider entry (6m)

Various methods for the design of roof support systems have been proposed through the last 20 years with the ultimate objective of maintaining safe conditions in underground mining environments. The effectiveness of roof support systems is intimately linked to the geotechnical behavior and geologic makeup of the rock mass comprising the roof. Detailed geotechnical investigations are therefore, important to design effective roof support systems.

Empirical and analytical tools round out the primary design references which were investigated to determine the most effective roof support system for the different geomining conditions.

Development of the Coal Seam with Continuous Miners: In this mine R-6 there was usualpractice of development of the seam along bottom of the Seam. But this CMP8had been developed along roof of the seam. So as seam was developed along roof of the seam with as height of 4 mtrs leaving coal at the floor. Some portion of coal seam already developed with the 4.8 mtrs gallery development of the Seam along bottom of the Seam with SDL thereafter introduction of continuous miner widening of gallery has been done for more space and its maneuverability for efficient utilization of the continuous miner. The following practices adopted in development of coal seam.

1. Size of the pillars should not be less than 22m x 22m centre to centre in Panel No. S-1 and solid pillar should not be than 16m x 16m corner to corner. The width of galleries should not exceed 6m and height should not exceed 4.0m while leaving coal along the floor.

2. Development should be done always along the roof and if possible some coal may be left on the floor.

3. The maximum cut out distance should not exceed 12.0 m.

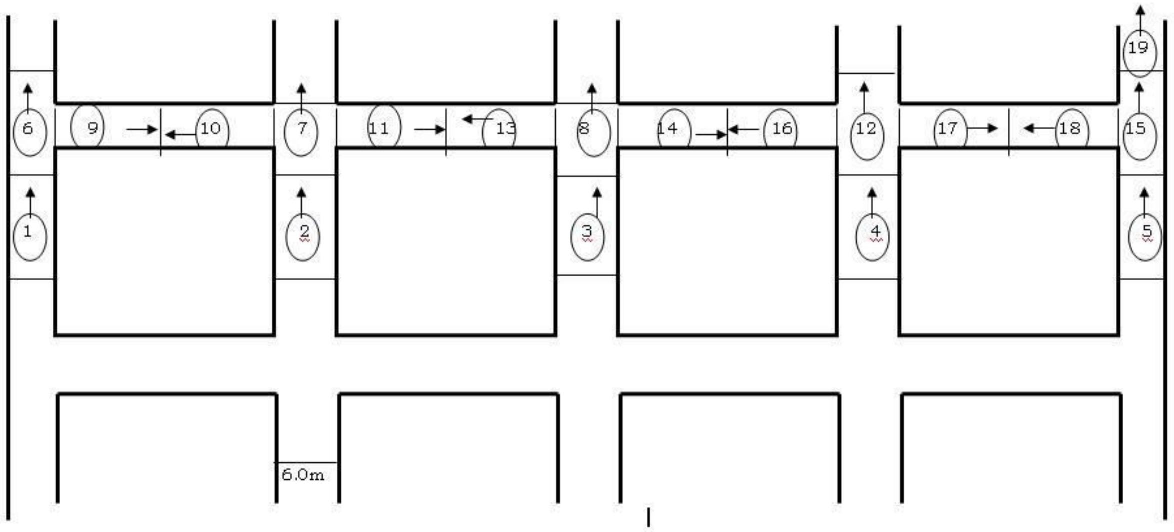
(Cut out distance – Continuous Miner cut maximum 12 mtrs from the last line of support)

4. Support system – There was four rows of non-retractable roof bolts of 1.8 mtrs in length and bolt dia 22mm in dia, the distance between the two adjacent rows of roof bolts should not be more than 1.5m and that between two adjacent bolts in a row should not be more than 1.2m.

5. Formation of pillars should be commenced from left to right in the panel.

6. The Continuous Miner should cut the left gallery as shown as (1) in sketch. After cutting 12 mtrs it should be trammed to position as shown as (2) in the sketch.

LAYOUT FOR CUTTING SEQUENCE



Cutting sequence continuous miner working during development

7. While continuous miner cut the position at (2), quadbolter supported the face already cut by the continuous miner shown as (1).

8. After cutting position no. (2), the continuous miner trammed to position no. (3), and the quadbolter supported the position no. (2).

9. Likewise Continuous Miner cuts and the quadbolter supports and follows the sequence of cutting & supporting as shown in the layout plan that all the headings were advanced simultaneously.

10. One cut of the Continuous Miner was of 12 mtrs in length.

B.) Depillaring with Continuous Miner: After successful development of the seam it wasconsidered for extraction of the pillar. There were two alternatives for depillaring the panel S-1. The two alternatives were –

I. Splitting and Fender method.

II.Diagonal Slicing.

II. Diagonal Slicing

In this method cutting the pillar was done in diagonal fashion from the original gallery without splitting.

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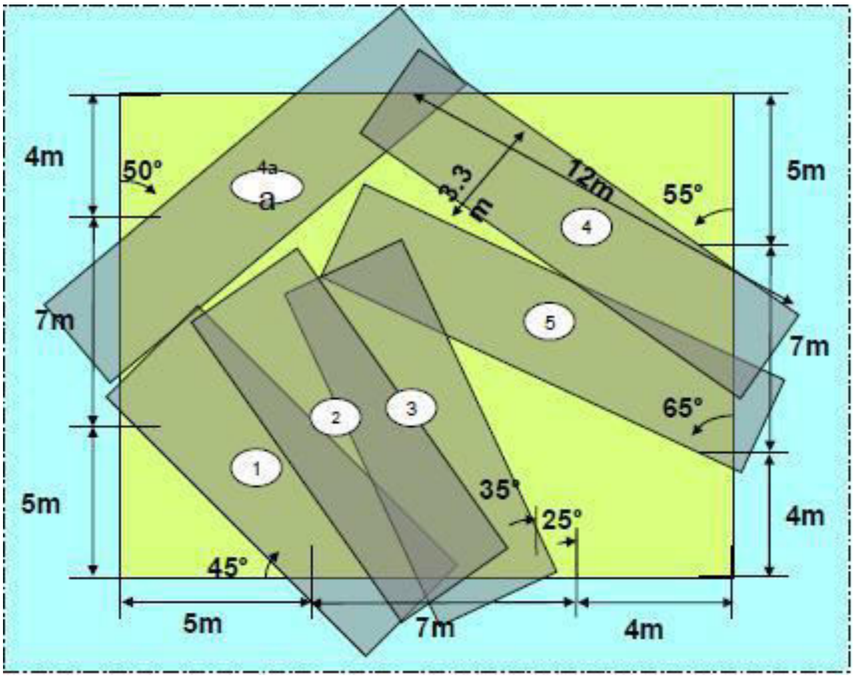
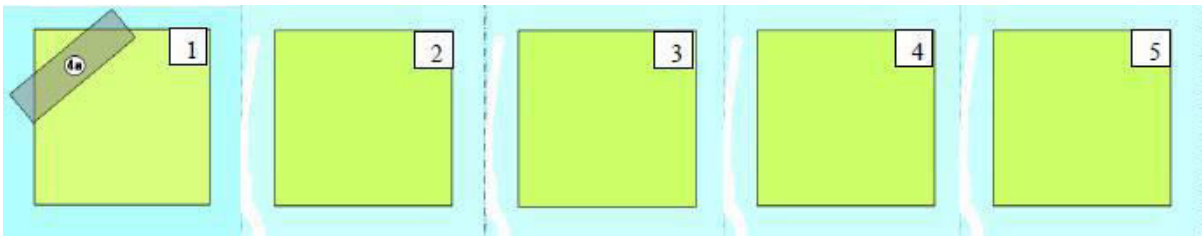


Pillar Extraction-Slicing Sequence with dimensions

In diagonal slicing method, cutting the pillar was done in a diagonal fashion. It was to ensure that the Continuous Miner did not go too deep into the pillar. It required that a cut should be taken from the side or back of the pillar some time before it was finally extracted. The cuts were of 12 meters in length. In this method it was possible to extract these pillars without splitting the pillar. As this method did not require split that needed supporting. It speeded the rate of extraction and was significantly safer as less time was spent in the pillar. The split method had an additional risk as this required to place the support personnel within the split.

So for the above reasons it was recommended that diagonal slicing method should be adopted for pillar extraction in S1 Panel.

Extraction Method of coal by diagonal slicing: In panel straight line of extraction hadbeen adopted. In the first step a diagonal slice of 3.3 meters width and 12 meters of cutout distance were commenced from the original gallery. The angle was about 45o to 50o from the original gallery. It is shown in the below picture. After taking diagonal slice, bottom coal of the diagonal slice was taken out. Height of extraction should not exceed 6.5 meters. This was done by Continuous Miner by making a gradient from the original gallery to the diagonal slice.



Step-I, Pillar Extraction-Slicing Sequence with dimensions

After completion of no. 4a diagonal slice (as shown in the picture below) from the original gallery, shifting of the continuous miner (as shown in the picture below) was done and the diagonal slices of no. 1, no.2 & no.3 was driven. The cutout distance was 12 meters. The

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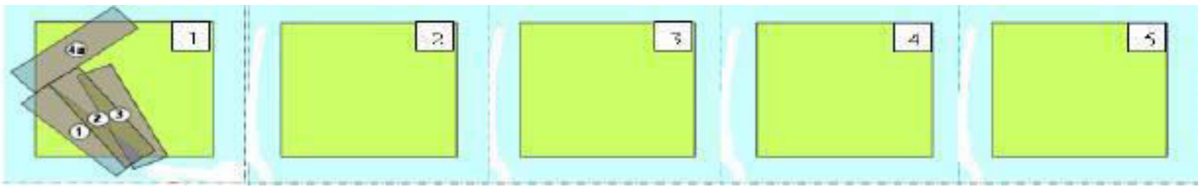
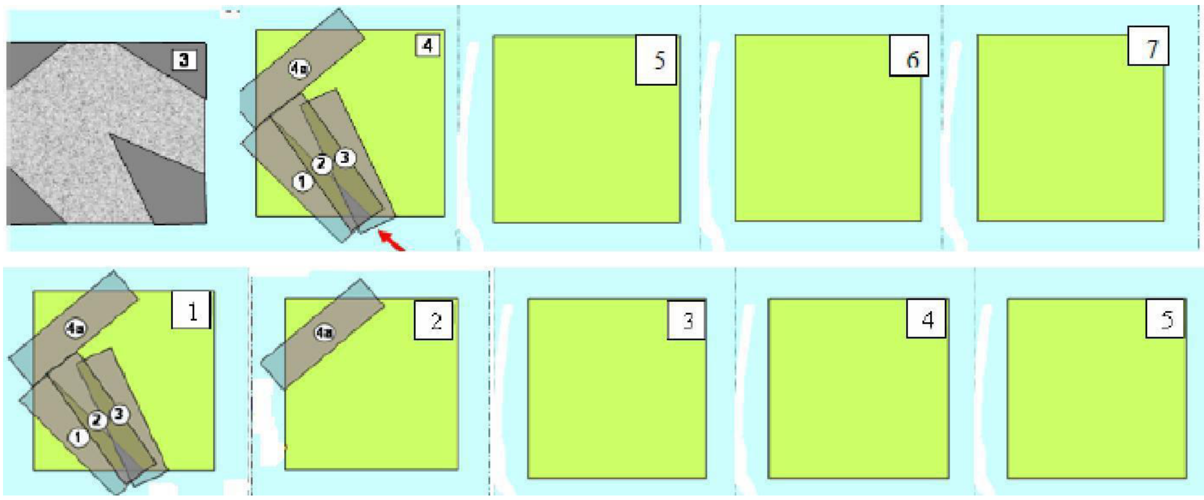
angle was 40o to 50o from the original gallery of the diagonal slicing. After driving slice no.1, no.2 & no.3 bottom coal was extracted. Height of extraction did not exceed 6.5 meters.

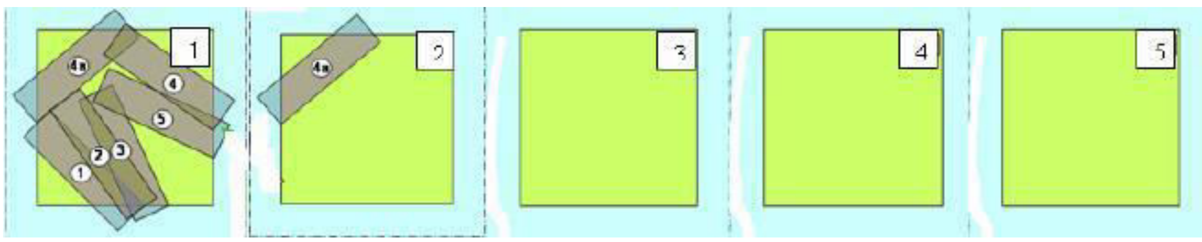


After completion of no. 1, no.2 & no. 3 slice of pillar no. 1 a diagonal slice of no. 4a of next pillar (as shown in the picture given below) was driven. The cutout distance was 12 meters. The angle was 45o to 50o from the original gallery of the diagonal slicing. After driving slice 4a of next pillar, bottom coal of the diagonal slice was taken out. Height of extraction was not more than 6.5 mtrs.



Step-III, Pillar Extraction-Slicing Sequence with dimensions

After completion of no. 4a diagonal slice of the next pillar, the diagonal slices of no. 4 & no. 5 of the first pillar were driven. The angle was 55o to 65o from the original gallery of the diagonal slicing. After driving slice no. 4 & no. 5 bottom coal of the diagonal slicing was taken out. Height of extraction was not more than 6.5 meters.



Step-IV, Pillar Extraction-Slicing Sequence with dimensions

In this fashion extraction of the coal of pillar no. 1 was done and the same above sequence for driving the slices no.1, no.2 & no.3 of the next pillar was repeated. Driving the slice no. 4, no.5 & no. 4a of the above said sequence was also followed.

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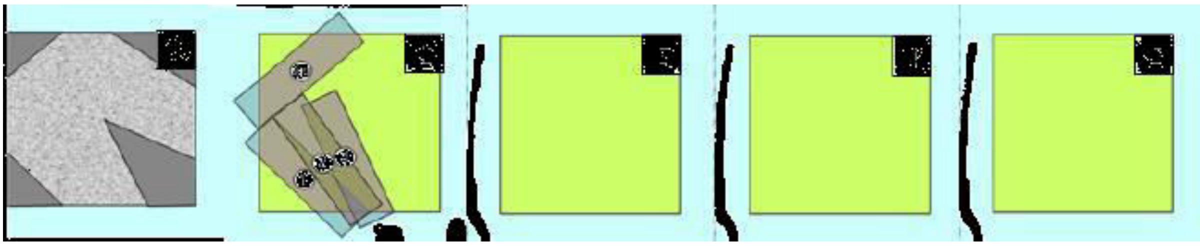

Step-V, Pillar Extraction-Slicing Sequence with dimensions

The speed of the rate of extraction by driving the diagonal slicing was maintained. The width of the slice was not more than 3.3 meters at a time. There was no bolting during the extraction of pillar. Before commencing of extraction of pillar, only breaker lines of roof bolts was erected. Roof bolt breaker lines were consisting of two rows (6 bolts in a row) of rock bolts having 2.4 meter long, 22 mm diameter, and full column resin. The spacing between two bolts in row and between rows was 1 mtr.

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