STRATA BEHAVIOUR IN LONGWALL MINING AT GREATER DEPTHS

A THESIS SUBMITTED IN PARTIAL FULLFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology

In

Mining Engineering

By

DEEPANSHU R. SINGH

108MN051

DEPARTMENT OF MINING ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

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Under the guidance of

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CERTIFICATE

This is to certify that the thesis entitled **“**Strata behavior in longwall mining at greater depths” submitted by Sri DeepanshuRanjan Singh (Roll No. 108MN051) in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Mining Engineering at the National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

Date:10.05.2012

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ACKNOWLEDGEMENT

We wish to express our deep sense of gratitude and indebtedness to Dr. S. Jayanthu, Professor, Department of Mining Engineering, NIT, Rourkela; for introducing the present topic and for his inspiring guidance, constructive and valuable suggestion throughout this work. His able knowledge and expert supervision with unswerving patience fathered our work at every stage, for without his warm affection and encouragement, the fulfillment of the task would have been very difficult.

We would also like to convey our sincere thanks to the faculty and staff members of Department of Mining Engineering, NIT Rourkela, for their help at different times. Apart from these we feel grateful and obliged to all the officials of GDK 10&10A mines of SCCL, for their help and guidance for accomplishing this project.

Last but not least, our special thanks to Hitesh Mishra, AsheshRaghav, and all other friends and family members who have patiently extended all sorts of help for accomplishing this project.

Date: 10.05.2012

Deepanshu R. Singh

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CONTENTS

Abstract:

This thesis presents the overview of problems of underground coal mining at greater depth and reserve position of coal in India. Various strata control issues relate to stress distribution around the longwall panels at depths approaching 900m in different countries was discussed. Extent of abutment loading and need of advance support for more distances away from the longwall faces as compared to conventional practices at shallow depths is emphasized. Innovative design of barrier pillars at high stress conditions with yield pillars is illustrated. Mining options for various coalfields in India are presented.

Issues regarding mining techniques, or need of innovative techniques is critically evaluated based on the experiences of different countries and the design implemented for safe and economically viable mining for the extraction of seams at greater depths. Strata behaviour monitoring of longwall panel at GDK 10A Incline (SCCL) is illustrated along with the instrumentation used for monitoring, convergence, and load over the supports atmain gate and tail gate roads.Increase of load on supports observed between 5Te. to 10Te., the roof to floor convergence of 42mm in tail gate was recorded, and maximum of 88mm in main gate was recorded, and maximum stress over the pillar of16.45 kg/cm2 was recorded in the main gate, and maximum of 7.1 kg/cm2 in tail gate was recorded.

LIST OF FIGURES

Chapter 01: Introduction

1. Introduction

The progress of the technology in many branches of engineering is quite rapid in recent years. However, in case of underground coal mining, the progress is not as expected. It remained a lot with traditional systems, and only a few attempts were made to adopt/absorb recent trends. Although it could be attributed partly to availability and adoptability of the modern mining machinery, but also mainly due to limitations of available strata control technology, be in underground (suitable designs of workings and support systems).

More than, 18000 Million tons of coal out of 200 billion tons of coal reserve is at a depth of 600-1200 m in India. In view of the limitation of conventional board and pillar method in India, it is required to explore the possibility of application of various innovative techniques for its extraction. Longwall method is one such feasible option, however, it needs modifications in terms of barrier pillar design, support design at the face and in abutment zones as advance supports in the gate roads. In future, various coalfields may have to venture into greater depths of about 600 m and more. Experiences gained in some studies abroad (Dolinear, 2000)can be utilized effectively for design of yield pillar s in barriers , and for understanding the extent of abutment loading trend and design of support in gate roads. Prospects of coal mining depends upon the quantity and qualitywise demand, heat energy, ash content, caking index, economics of mining, market pricing structure for the available produce and scope of value addition by way of washing or processing of ROM (Singh, 2007).The factors are influenced by geographical distribution with quality wise abundance, depth wise availability, geomorphology of coal complexity of the deposits and amenability to economic mining options. The factors are influenced by geographical distribution with quality wise abundance, depth wise availability, geomorphology of coal complexity of the deposits and amenability to economic mining options. The distribution of the coal resources are geographically imbalanced .In olden days, due to lack of proper instruments, qualitative observations with limited possibility of quantification lead to some empirical relations/thumb rules. However, now-days, with improved technology of mining/instrumentation, numerical models - computer applications for analysis of data; investigators gained enhanced satisfaction through observational approaches. There is a need to be more innovative in application of the existing instrumentation.India has large resources of coal deposits for underground mining and lot of coal was blocked in existing underground mines. Safe extraction of these can be made possible by effective strata management. Accidents due to movement of strata in underground coal mines had been a major concern for the mining industry and it is largest contributing factor of underground coal mine accidents. Continuous efforts were being made by all concerned to reduce the hazard of strata movement. The analysis of the accidents due to strata movement for last 12 years (1997-2008) revealed that:

1. The roof fall and side fall accidents accounted for 59% of all below ground fatal accidents in coal mines.
2. All types of strata were involved in roof and side fall accidents (shale, coal, sand stone, shale coal, shale sand stone etc.)
3. Accidents due to fall of roof occurred in almost same proportion in board & pillar development as well as depillaring districts.

The condition of strata and the stress environment around any working place is always dynamic in nature. No two working place are having identical strata condition. It is therefore essential to assess the roof condition of the working places at regular intervals by scientific methods. Strata problems include roof sagging, floor heaving, presence of shale or clay bands, heavy water seepage, faults, cleavage planes, cracks, joints etc. State of art of monitoring system through instrumented rock bolts, tell-tales, multiple point bore hole extensometers, convergence indicators, local cells etc. are available for continuous monitoring the strata movement. Strata control instruments are helpful in analyzing the deterioration in the roof and indicates roof movement.

1.1.Background

The resource position of coal shows nearly 37% within 300-700m depth cover and a small portion (7 %) below 600m depth cover (Singh 2007). Quality coal below 300m depth cover in Raniganj, Jharia, East and West Bokaro, North and South Karanpura, Sohagpur, etc should be the main targets for underground mining. The coals of Godavari and Wardha Valleys may also be included in this category because of preferential pricing structure. The options world over for such deposits are pillar mining- pillar mining using continuous miner, longwall mining and sublevel or integral caving with special support system.

Longwall technology should be adopted with due consideration of coal seam parameters, panel geometry and coal quality in seams below 300m depth cover in Jharia, Raniganj, Godavari Valley, Sohagpur, E Bokaro and S Karanpura where bulk of coking and superior grade non coking coals within 300-600m and below 600m depth are estimated. High supports suitable for 3-5m seam thickness should be used in areas where 12 - 15km long panels could be formed, each of 2 to 3km length and face length of 250 to 300m. In India, we have mined upto 450m, and the extraction of seams up to 600m, is to be carried out in near future, some of the mines in other countries have mined up to 900m mark with safe and viably economical technique. Hence critical analysis is done on barrier pillar design, abutment loading.

1.2. Objective

To understand the strata behaviour in longwall mining at greater depths, literature survey and field investigations were conducted with the following objective:

1.To critically evaluate the strata behaviour during longwall mining at greater depths about900m with barrier pillar of 250m causing, ground problems and implementation of alternative innovative design.

2.To conduct the strata behaviour observations in longwall panel at GDK 10A Incline vis-à-vis stress over the pillars, convergence gate roads, and the load coming on the OC props at gate roads.

Chapter 02: Literature Review

2.1. Challenges of Mining at Greater Depth vis-a-vis Strata Control

In general, strata control and ventilation poses a stern challenge to mining engineers in working of coal deposits at greater depths exceeding 450 m in India. Till now, it was observed that in some of the Indian coalfields, pillar mining at depths exceeding 250 m also posed serious strata control problems due to horizontal stresses, geological disturbances etc. Thus, longwall mining has been proposed as a feasible solution for deep seam mining in the years to come. At present, various coalfields such as Church mine of SECL experienced failure of longwall mining due to hard roof conditions. Although, some longwall faces are highly successful, it requires modifications in terms of extent of abutment loading and associated need of providing more advance support in the gate roads, design of barrier pillars etc while going to deeper horizons. Some of the studies conducted in different countries showed that Panel width affects normalized peak stress, whereas overburden depth affects the stress transfer distance (only). In addition to strata control problems, ventilation also poses a great challenge to the mining fraternity for designing innovative methodologies of implementation of environmental control measures in mines.

The yield-pillar gate road system provides no significant protection to the tailgate corner of the active longwall face from side-abutment stresses (Gilbride and Hardy, 2004). Yield pillar systems succeed when abutment loads are shifted off gate road pillars, thereby avoiding potentially hazardous stress concentrations, and onto the panel edge where loads can be distributed over a broader area. As a consequence, the risk of pillar bumping is virtually eliminated, but the risk of face bumping is somewhat elevated. In most cases, the net improvement justifies the use of yield pillars. The risk of bumping at the tailgate corner of the panel is almost always directly related to the severity of abutment loading. Mining depth is the principal factor affecting abutment loads. Cave quality and massive strata in the overburden are also recognized to affect abutment loading. The sequence of numerical models in Figure 1 illustrates the rise in abutment stress acting on a panel as the mining depth increases from 300 to 900 m The figure shows a significant rise in stress concentration and bump potential at the tailgate corner of the panel with depth. Experience suggests that abutment stresses reach bump-prone levels at depths on the order of 600 to 750 m with multiple side-by-side panels in the Wasatch Plateau-Book Cliffs coal fields, depending upon the local geologic conditions. Severe longwall bumps have been known to occur as shallow as 365 m in the region.

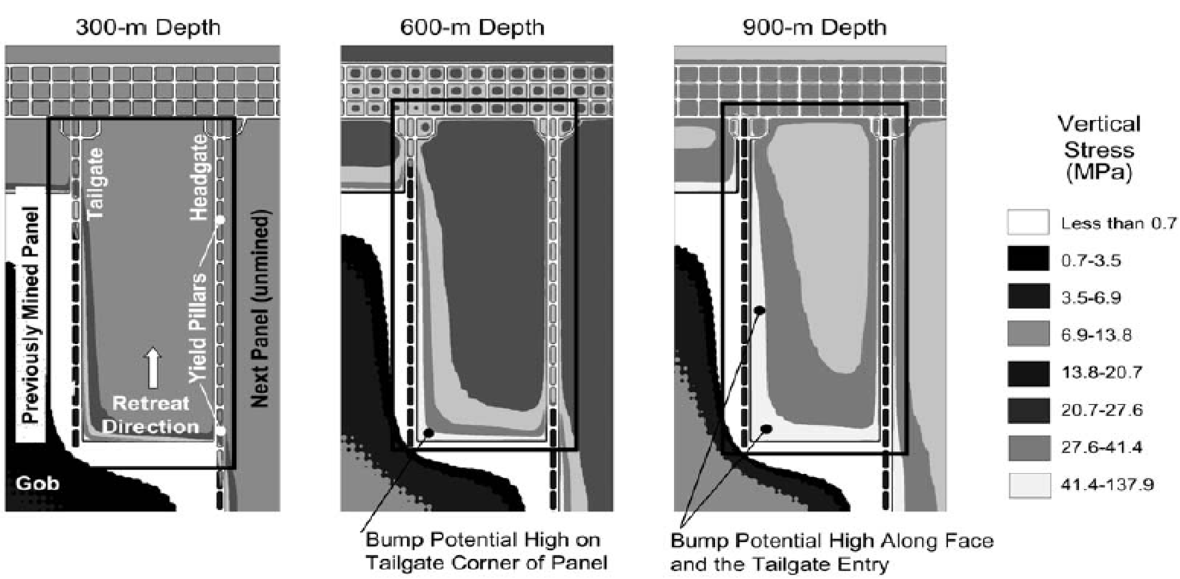

Figure 1:.Modelled Vertical Stress Increase with Depth Acting on a Longwall Panel Using a Two-entry Yield Pillar Gate road System (Gilbride and Hardy, 2004)

In the past, face bursting has caused three separate mines to prematurely abandon panels during retreat. All three utilized fully-yielding gate road systems. One of the three operators elected to continue mining in the same seam using a conservative panel-barrier layout, where a complete barrier was left between every panel. At the other mines, operations were terminated after each retreated a final panel adjacent to the abandoned panel. The panel-barrier option and other layouts are being considered for another 800-m-deep mine presently at the planning stage.

The studies by the National Institute for Occupational Safety and Health (NIOSH) and the Mine Safety and Health Administration (MSHA) at Sargent Hollow Mine, in Wise County, VA, indicated that the weak floor strata was being subjected to, and damaged by, high horizontal stresses. After the 'advance and relieve mining method' was implemented, the overall mining conditions at the mine improved, and the roof control plan was approved for further use.

Roof falls have been usually attributed to bad roof strata and high vertical stresses related to the overburden depth. However, for shallow depth conditions, roof falls in recent studies have been attributed to high horizontal stresses (Yajie and John, 1998). About 73 roof falls analyzed in USA, 37 occurred in the entries with 52^{o} angle with the major horizontal stress. Through the horizontal stress recognition features, some of the following control techniques can be effectively implemented:

- reorienting the drivage direction of the mine openings
- panel orientation and retreat direction
- stress shadowing through key openings
- altering mining cut sequences

2.2.Experiences of Longwall at Greater Depths

Panel mining methods, both pillar and longwall, rely on caving to limit stress transfer to neighbouring pillars and abutments. The critical width is the span at which arching or bridging has failed to the surface and maximum subsidence obtained. It can be described as the panel width, when the lines extending upward from each rib at angle β intersect at the surface; it represents the vertical section geometry where caving and abutment loading conditions that form the boundary between subcritical and super-critical conditions. Crushing of yield pillars, where they are used, more gradually transfers stress across the entries to the solid abutment. Thus, the effective span in these cases includes the entries and can span multiple panels if they are separated only by yield pillars. Indeed, due to the greater mining depth, the critical width in deep western coal mines is often several panels. For example, the critical width at the Deer Creek mine occurred with mining of the third panel.

The distance at which neighbouring openings are impacted by shifting of stress is a practical quantity, but that quantity may vary according to site conditions. Therefore, for purposes of comparison, the distance at which the calculated vertical stress on the seam returns to 50% of the pre mining stress will be used as a measure. This level is arbitrary, but is equivalent to a 50% increase in overburden, an increase that will certainly be evident in driving of an entry. Observations in the literature refer to a “detectable” increase in stress, when determining as the stress transfer distance.

Observations of stress transfer distances are often remarked upon in discussions of ground behaviour in deep western coal mines. Generally, distances are considered notable because of their long length. These observations also hint at the importance of anticipating these distances.

These observations include: • DeMarco et al. discuss western U.S. longwall operations and report that units of strong, competent strata transfer "considerable abutment loads over relatively large distances." • Koehler observed stresses overriding a 46-m- (150-ft-) wide barrier pillar to cause bump events at the Sunnyside No. 1 mine (discussed by Chen et al.). The mine was under 610 m (2000 ft) of overburden with 55-m-thick (180-ft-thick) sandstone about 46 m (150 ft) above the coal seam.

• Barron described stress transferring from the longwall face in a Book Cliffs mine in strong strata. Stresses induced by a 150-m- (500-ft-) wide face caused tailgate pillars to "explode without warning" 90 to 150 m (300 to 500 ft) out by the face. • Gilbride and Hardy found barrier pillars "as wide as 120 m (390 ft) or more may be necessary for pillar stability and abutment protection when depths reach 900 m (3000 ft) or more."

• Maleki found good performance for a 150-m-wide (490-ft-wide) barrier in the Rock Canyon and Gilson seams with 580 m [1900 ft] maximum overburden . • Goodrich et al. [13] found load transfer distances greater than 230 m (750 ft) at the Deer Creek Mine. A pillar burst and other stress-induced ground conditions were apparent in a developed gate road as mining passed in the previous panel, with a full panel of intact coal seam serving as a barrier. Stress measurements suggested a 13% increase in stress was transferred over the panel.

2.3. Abutment Stress Distribution

The generic site model was designed to be a simple but representative geologic column typical of deep western coal mines. Any massive stratum with bridging potential is labeled "sandstone" while weaker strata are labelled "shale" or "soft shale" (including mudstones, siltstones and even thinly bedded sandstone). Typically, floor and overburden include strong, stiff and massive sandstone members. The immediate roof can be sandstone or shale. An idealized geologic column was formulated with a sandstone floor overlain by coal, an immediate roof of shale, a sandstone layer and then soft shale to the surface. Panel width was set at 240 m (800 ft). A 610 m (2000 ft) thick sandstone floor was defined in volume-element models (the floor of a boundary element model is infinitely thick).

The distribution of stress shifted to the abutment is another important result. Stress shifted to the immediate rib can drive yielding and, possibly, out bursting of coal. Stress carried deeper in the abutment may impact neighbouring excavations and is a particular concern for excavation of new entries, etc.. In the figure, overburden elastic properties were determined by the weighted thickness method. Results calculated with overburden properties determined by the equivalent stiffness method were similar and, therefore, not included in the figure. One of the most powerful FLAC results is the contrast between an immediate thick sandstone roof and a shale interval in the immediate roof. The shale limits peak stress in the coal and increases depth of yielding, moving stress away from the abutment rib. The assumed stress distribution used in the ALPS method predicts a much lower peak stress, but this peak is located at the rib line. Fig.2 and Fig.3 shows the variation of abutment loading as the panel width, height, and angle of contact varies.

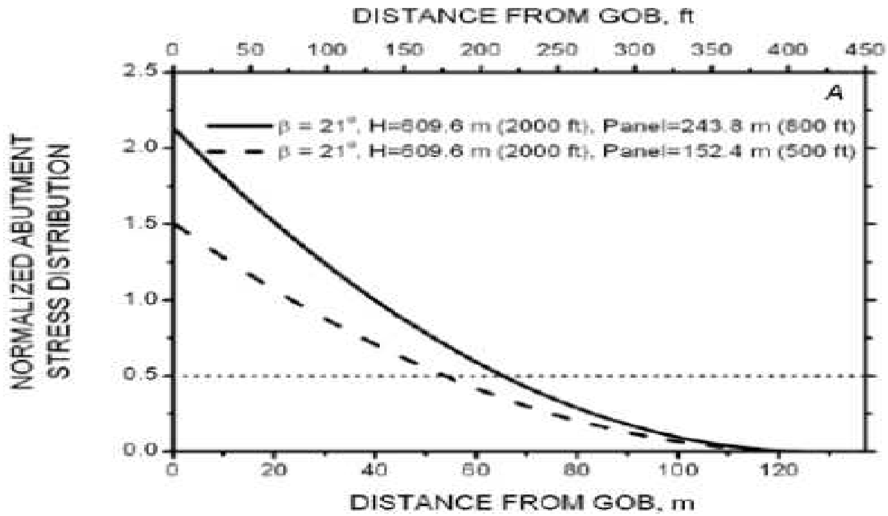

Figure 2: Normalized abutment stress distribution curves (stress/ pre-mining stress - 1). A, Variation of panel width (Gilbride and Hardy, 2004)

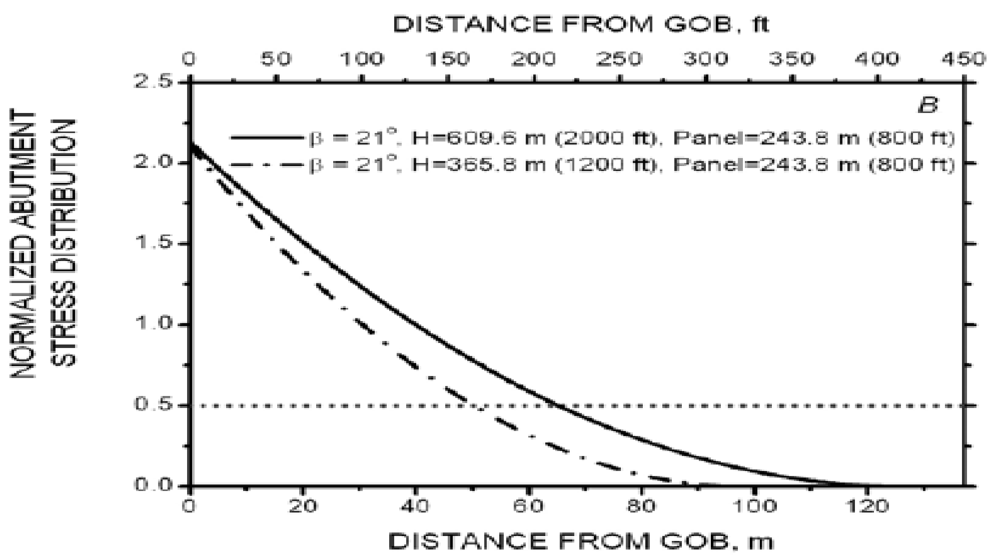

Figure 3: Normalized abutment stress distribution curves (stress/ pre-mining stress B, variation of overburden thickness. The closely dotted line near the bottom of each graph indicates a 50% increase in vertical stress over pre mining stress.

The most important consideration is whether a design project considers all possible modes of ground response to mining. For empirical methods, this concern is best addressed by comparing conditions at underlying cases with those for the application. A mismatch may compromise empirical method results. It is also important to recognize and, if necessary, compensate for the fact that the boundary element program, LaModel, does not consider the effects of horizontal stresses and failure of the overburden. This work also showed that the assumptions and features of these volume and boundary element programs differ too markedly for a model constructed in one to be "converted" into the other through application of the same input parameters. Thus, care must be taken when taking input parameters from past analyses using different modeling programs. New models should be calibrated to field observations and, ideally, measurements of critical behavior.

2.4.Barrier Pillar Design

Western U.S. longwall operators face increasing challenges with optimizing ground control and productivity as mines reach greater depths and coal bursting hazards increase. Some western U.S. mines, many known to be bump-prone, achieved a successful balance between ground control and productivity by transitioning to side-by-side longwall panel mining combined with a yield pillar gate road system. With this design, development footages could be minimized and pillar bumping averted by controlled yielding at moderate depths, generally in the range of 450 to 600 m.

Over the past four decades, the yield pillar system has won wide acceptance among western mines facing pillar bursting hazards, particularly those in the Wasatch Plateau and Book Cliff coal fields of central Utah. However, recent attempts among the deepest Utah operators to mine side-by- side panels with yield pillars at depths in excess of 600 m have been met with mixed success and, in some circumstances, with serious difficulty. Challenges include violent face bursting and excessive tailgate convergence out by the face, which can be crippling to ventilation. The use of inter panel barriers, i.e., barriers left between longwall panels, offers one possible solution to mining under deep cover with bump-prone geology.

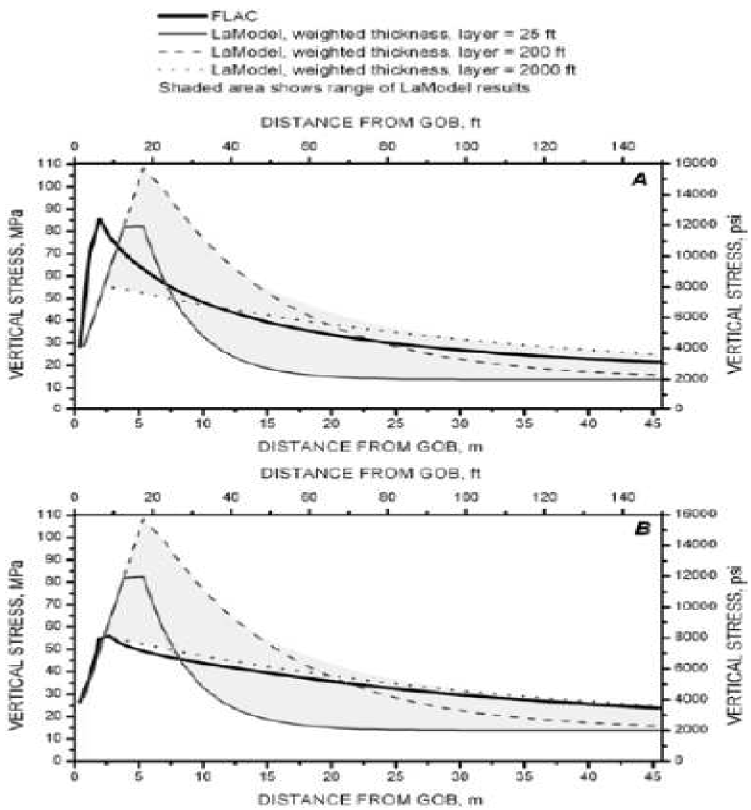

Figure 4: Vertical stress profile on abutment for the generic model case of 61 m (200 ft) of roof sandstone. Gob is modeled. A, No immediate roof shale; B, Immediate roof shale thickness is 15 m.

Inter panel barriers have already been adopted by Utah's deepest longwall mine, and others are considering their use. The geomechanical implications of mining with and without inter panel barriers, and the competing trade-offs between ground control and ventilation are discussed.

2.4.1 Alternative Designs

Alternatives to the two-entry yield pillar system require two key components:

(1) improved protection from side-abutment stresses, and

(2) lower ventilation resistance.

Yield-Abutment Pillar Gate road Systems The three-entry, yield-abutment pillar gate road layout can provide adequate protection if the abutment (rigid) pillar is properly sized. This system is widely used in other districts, generally under shallower cover and less bump-prone conditions. The yield-abutment-yield system, common to Alabama, represents a four-entry variant.

In Utah, abutment pillars as wide as 120 m or more may be necessary for pillar stability and abutment protection when depths reach 900 m or more. Primary disadvantages are the substantial increase in development footages, requirements for supporting four-way intersections, and some risk of rib bumping with the re-introduction of non-yielding pillars. The row of tailgate yield pillars can serve as a protective "curtain" in the event of abutment pillar bumping.

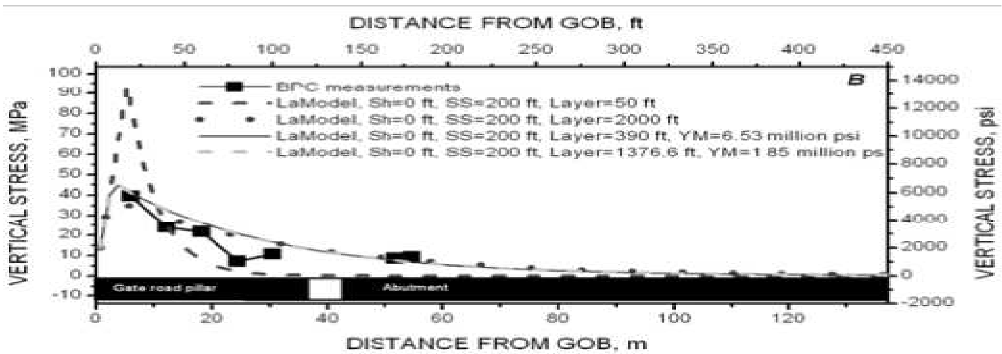

Figure 5:laModel showing stress around gate roads

Panel-Barrier Gate road Systems the panel-barrier option becomes an attractive alternative when crosscuts become too long for economic development. Presently, only one operator is regularly using the panel-barrier system in Utah. Good overall performance is reported with 152- m-wide barriers at depths approaching 800 m. Key advantages include the ability-

(1) to mine safely under extremely bump prone conditions,

(2) the flexibility to seal individual panels after mining, and

(3) multiple entries for improved ventilation.

Disadvantages include a doubling of gate road footages, increased mains and bleeder development, and the sterilization of large amounts of longwall reserves.Hazardous roof conditions identified in some mines of other countries were positively correlated with mining activities beneath stream valleys (Mucho and Mark, 1994). Evidence of valley stress relief was found beneath several valleys in the form of bedding plane faults and low-angle thrust faults. At many places the ratio of horizontal to vertical stress was in the range of 2 to 3. This type of failure, previously believed to be only a shallow phenomenon, was also found at increased mining depths.

'Advance mining method' was employed for pillar extraction in Australia at Oakdale colliery, to combat ground control problems associated with high horizontal stresses. In this method, pillars on one side of the panel were extracted as the panel was developed. The intention was to stress shadow the advancing faces and out-bye workings in order to reduce the occurrence of roof falls. The basic concept is that, some mines experience difficult ground conditions when advancing and retreating the first panel in a new reserve. However, conditions dramatically improved in subsequent panels. Once a panel is caved then extractions of adjoining panels become easy due to stress relief.

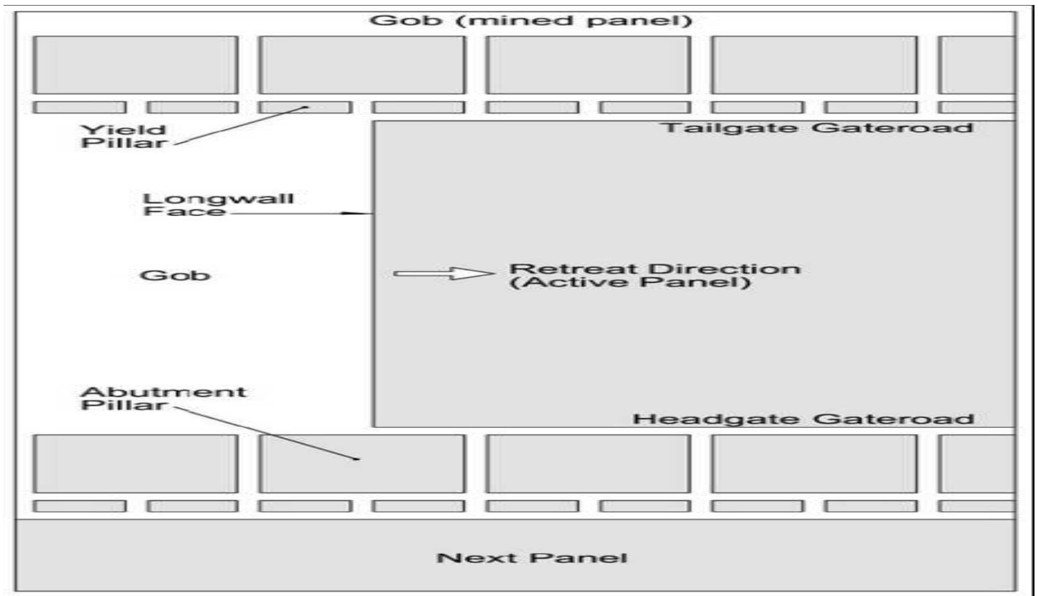

Figure 6.Plan of Three-entry Yield-abutment Pillar Gate roadSystem with Side-by-side Longwall Panels. (Gilbride and Hardy, 2004)

Horizontal stresses affect a number of US coal mines (Mucho, et al., 1995). To address the effects of the stress field and to control its potentially damaging effects, a number of control strategies have been developed, such as reorientation of the retreat direction, stress shadowing of the key openings, and altering the mining cut sequence. However, many of these techniques are direction dependent, and to be effective, they require precise determination of the major (maximum) principal horizontal stress direction. For these types of typical geo-mining condition associated with high horizontal stress, a system of roof truss was used successfully. Cable bolts were effectively utilized for strata control in thick seams and adverse roof conditions in Indian coal mines (Jayanthu and Gupta, 2001). Roof slotting is one tactic to stress shadow the adjacent workings (Frank et al., 1999).

2.5.Mining Options in Indian Coalfields

In the light of limited coal reserve in Indian Territory, limited quality coal reserve, quality coal reserve within 300m depth cover extensively disturbed by pillar mining and poor recovery with pillar mining, it is recommended to go for extensive surface mining in all the major coal basins up to the stripping ratio of 1:10. The coal seams below in selected basins of quality coals – Sohagpur, E&W Bokaro, N&S Karanpura, Jharia, Raniganj, Wardha and Godavari valleys are recommended to go for underground – longwall, pillar mining with continuous miner and mining with vertical production concentration technology is preferred .

No pillar mining is techno-economically viable below 400m depth cover and therefore in deeper coal basins, longwall is the only technology but with State of Art equipment and annual production guarantee above 2Mt. In view of more than half the share of total coal in seams over 5m thickness, longwall slicing in one or other form is suggested. The future of the mining industry demands more emphasis on meticulous application of rock engineering techniques, support design, modification to the existing guidelines through observational approaches, for cost effective and safe mining operations. Many research and academic institutions initiated many studies to help coal industry for better, efficient and safe extraction of coal through

i) analytical analysis and mathematical models,

ii) empirical analysis and models, and

iii) numericalmodelling with computerization.

In view of the experiences in working up to 900 m in various U S coalfields, it is observed that some experimental studies can be designed in Indian coalfields to work at greater depths with yield pillars in barriers, and also studies for understanding abutment loading trend in various longwall panel conditions proposed to be worked in near future. The steady increase in mining depths in the Wasatch Plateau-Book Cliffs coal fields has placed heavy demands on the historically successful two-entry yield pillar gate road system. Alternative, albeit more costly, designs are likely to replace the two-entry system as mining depths reach and move past the 900-m mark, and more mines confront the challenges of ground control and ventilation in what will be an ultra-high stress and exceedingly gassy environment by today's standards. The panel barrier option is a costly alternative to side-by-side panel mining, but offers the best potential for safe mining at great depth with current technology. The panel-barrier system is a practical solution for a number of the deepest mines already facing the worst conditions in the west.

Chapter 03: Field Investigations

3.1. Geological and Mining Condition

At GDK 10A incline, extraction of coal by the fully mechanized longwall method with powered supports progressed smoothly in the earlier longwall panels 1, 2 and 3. The average daily production was consistently more than 3000 t, with good production records. Currently the mine is using longwall method for the extraction of coal seam successfully, and is working at the depth of around 400m plus. Continues strata monitoring is done by strata monitoring cell, to know the strata behaviour in longwall mining.

The longwall panel no. 10 is situated opposite to the already extracted longwall panel no. 3. While all the three panels extracted till now were in the south side, the present panel is in the north side. The longwall workings are in the 6 m thick no. 1 seam. The seam is dipping at about 1 in 6; the depth of the workings is 187m minimum and 260 m maximum. The longwall face is laid out along the dip-rise. The Tail Gate is the top gate road, and the retreat direction is along the strike.The 6 m thick seam is being worked in the middle section to a height of about 3 m, leaving 2 m thick coal in the immediate roof. It is overlain by a 0.8 m thick clay band, and the thicker and strongermembersof medium grained white sandstone forms the main roof.

The longwall equipment consisted of a double ended ranging drum shearer, with chainless haulage, mounted on armoured face conveyor. The roof is supported by 4 x 750 t Chock Shield type powered supports provided with face sprags.

3.2. Instrumentation

Investigations were conducted at the mine to understand the behaviour ofthe strata in the longwall panel. These investigations were aimed at measuringthe front abutment, and the deformation of the strata surrounding the gate roadsahead of the longwall face. These parameters were measured usinggeotechnical instruments such as vibrating- wire type stress cells, load cells, Tell– Tale type borehole extensometers, and convergence stations.

3.2.1 Vibrating-wire type Stress Cell

This instrument is designed for measuring unidirectional stress change incoal/rock. It consists essentially of a wire ("vibrating-wire") tensioned across asteel cylinder of 38 mm outer diameter. The wire is plucked by an electric pulseof high energy. As the stress within the rock/coal changes, the cylinder deforms,causing tension in the wire to change. The change in stress on the cell results invariation of frequency of vibration of the wire. This frequency is recorded by adigital read-out unit, and is converted into stress using calibration charts. Thetrend of variation of stress over the pillars or stooks indicates the extent ofabutment loading in advance of the line of extraction. A bore hole of 38 mmdiameter is drilled at mid height of the pillar either horizontally or slightlyrising/dipping according to dip of the seam. The stress cell along with wedgeand platen assembly is set in the borehole with the help of special installationtools, at a depth of 5 m.

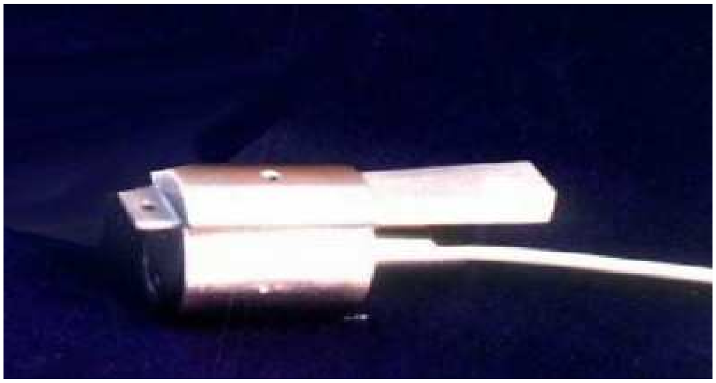

Figure 7: Vibrating-wire type Stress Cell

3.2.2 Vibrating-wire type Load Cell

The load cell is a transducer working on the same vibrating-wire principleas the stress cell. It has three stretched wires housed in a metal cylinder, whichare plucked by an electric pulse of high energy. Changes in the load exerted onthe cell cause changes in the length of the wire, resulting in variation infrequency of vibration of the wire. As the load increases, the frequencydecreases, and vice-versa. This frequency is measured by a digital read-outunit, and is converted into load using calibration charts. Efficacy and adequacyof thesupport system can be inferred on the basis of these load cells.The load cells were installed over the hydraulic props tomonitor the change in load over the props during the extraction. They wereinstalled in the gate roads at an interval of 15 m from the face, and they wereshifted with the retreat of the face line.

Figure 8: Vibrating-wire type Load Cell

3.2.3 Convergence Monitoring

Telescopic convergence indicator is used for monitor the roof-to-floorconvergence in mines. It is a simple instrument consisting of a graduated rod(scale) fitted in a telescopic pipe. It has a least count of 1 mm, and thetelescopic movement is for a length of 2 to 4 m. The measuring points ("reference stations") are metal rods grouted in the roof and floor. Measurements are taken by stretching the telescopic rod between the referencepoints, and reading the graduations on the rod.These indicators are useful for understanding the roof to floor closure inthe gate roads at various stages of extraction.

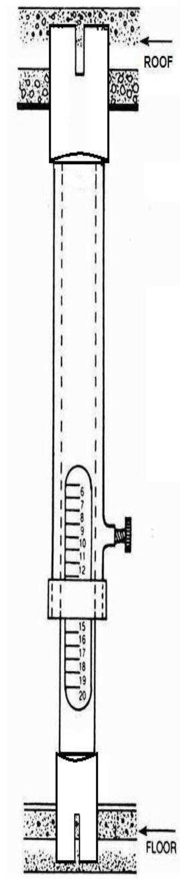

Figure 9: Telescopic Convergence Indicator

3.2.4 List of instruments in longwall panel no. 3c

1. Telescopic convergenceIndicatorsat every 5 m intervalin both the gate roadsRoof to floorconvergence.

2. Vibrating-wire stress cells 260 m – MG, 370 m – MG, 250 m – TG, 340 m – TG, Changein stressover pillar.

3. Vibrating-wire type Loadcellat every 10 m intervalin both gate roads *. Change in load over the supports.

(* shifted with the retreat of the longwall face)

3.2 Strata Control Observations

Aim is to understand the geo-mechanical behaviour of the strata in the gate roads and in the face. These observations were aimed at measuring the location and magnitude of the front abutment, and the deformation of the strata surrounding the gate roads, and load on supports ahead of the longwall face. Four vibrating wire type stress cells were installed, a continuous convergence recorders and convergence points, and load cells were installed in the Tail Gate and Main Gate . The location of these instruments is shown in Figure 10.

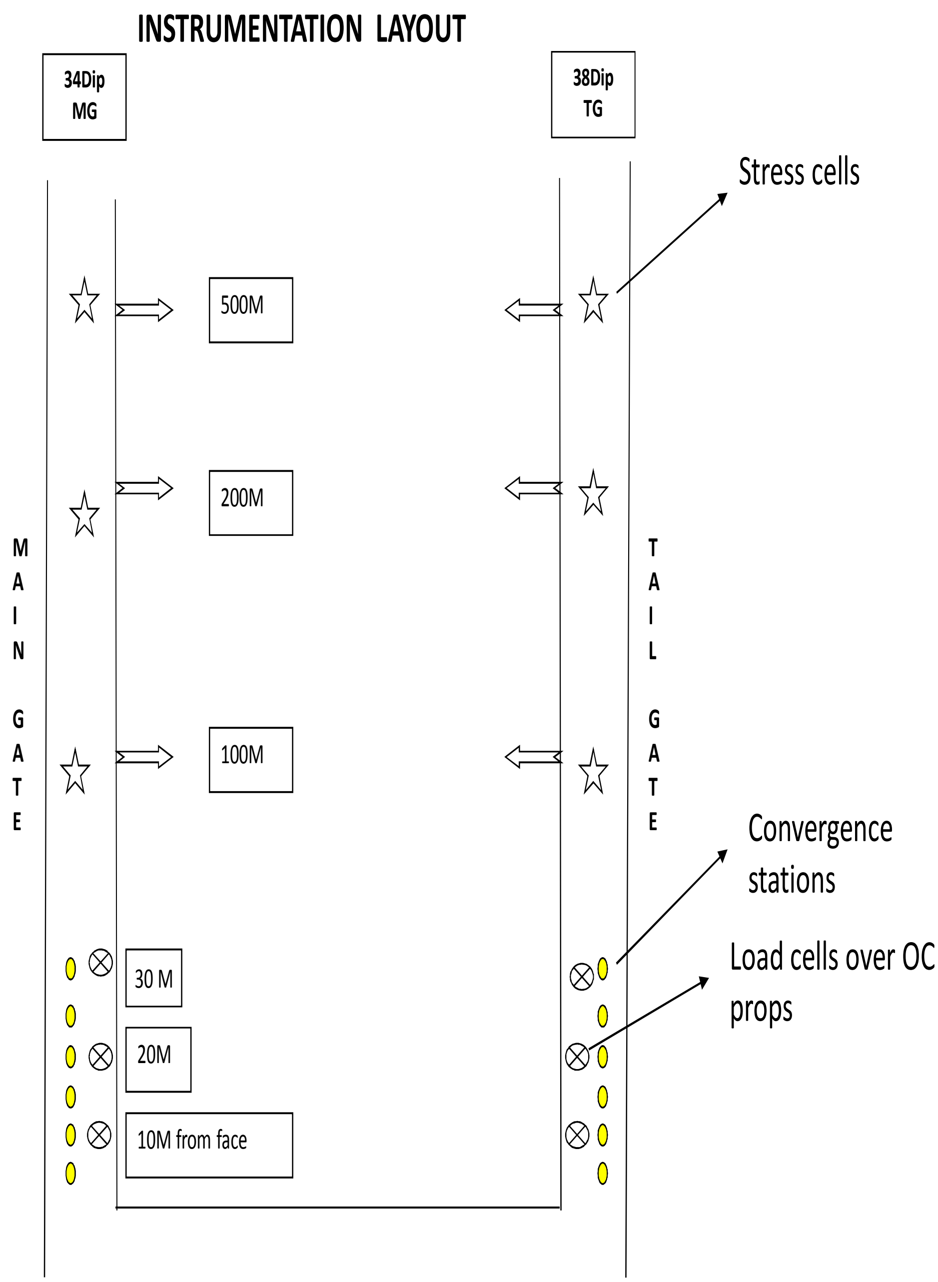

Figure10: location of instrument in longwall panel.

3.4.1 Monitoring

- Convergence at the face and of the gate roads is measured by Telescopic Convergence Indicator.
- The efficacy of the supports is monitored by measuring load variation on the OC props by installing load cells and convergence of Gate road ways.
- For monitoring the abutment load on the pillars during the extraction, four vibrating-wire type stress cells were installed. Two stress cells were installed in main gate and two in tail gate .

Chapter 04:Analysis

4.1. Convergence of the Gate Road ways

Tail gate road way monitored for convergence for 30 M from the face by means of telescopic convergence indicators. The convergence stations are fixed at 5 M interval. Convergence measurements are taken once in every day. Abnormal convergence was not observed during weighting periods and normal periods. Perceivable Convergence in Gate roads starts 18m to 20m ahead of the face and as the face approaches the point convergence increases gradually. Maximum convergence observed at the gate road junctions (When face approaches the station). The maximum value is varies from 4mm to 42mm. It is observed that the maximum convergence of gate roads is decreasing as face retreats in Dip Rise panel. The maximum convergence in Main Gate observed was 88mm during weighting period (roof was disturbed) at 630m convergence point, which is 11m from face.

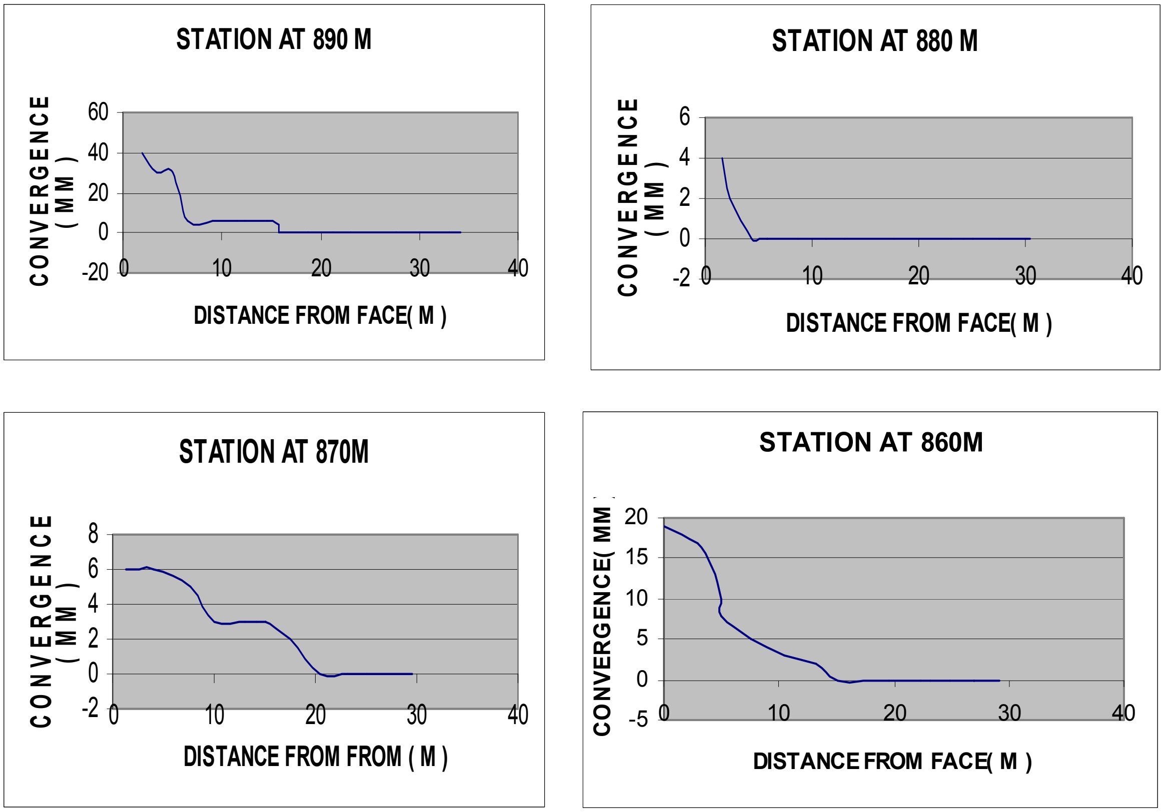

Figure 11: Convergence in Main Gate (34Dip)

4.2. Load over the Supports

Variation of load on OC props is measured by installing load cell on the OC prop. In each gate road way 2 Nos. of load cells are installed at 10 M interval. The load variation in the load cells is measured once in every day as face progresses. Only marginal increment of load on the OC props observed. Increase of load on OC props observed between 5Te. to 10 Te (figure 12-15).

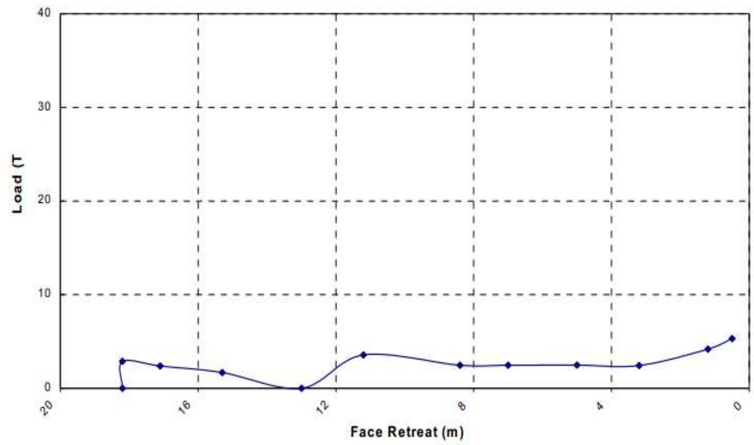

Figure 12: Load over the support at 210 m position in the main gate

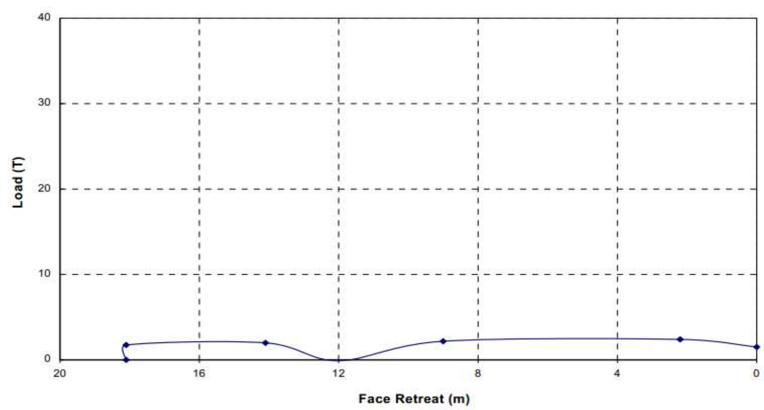

Figure 13: Load over the support at 150 m position in the main gate

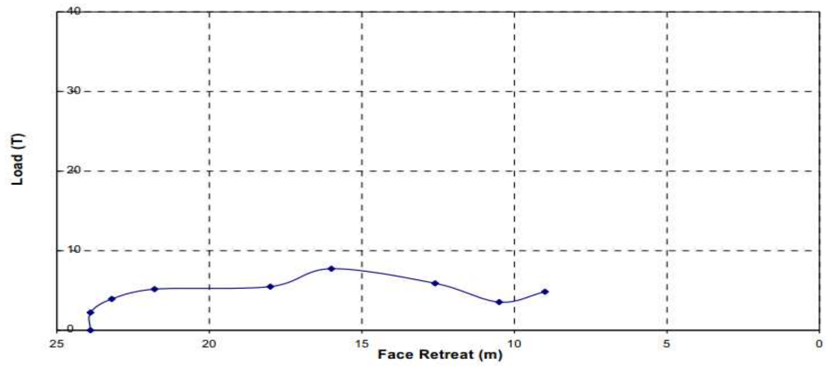

Figure 14: Load over the support at 200 m position in the tail gate

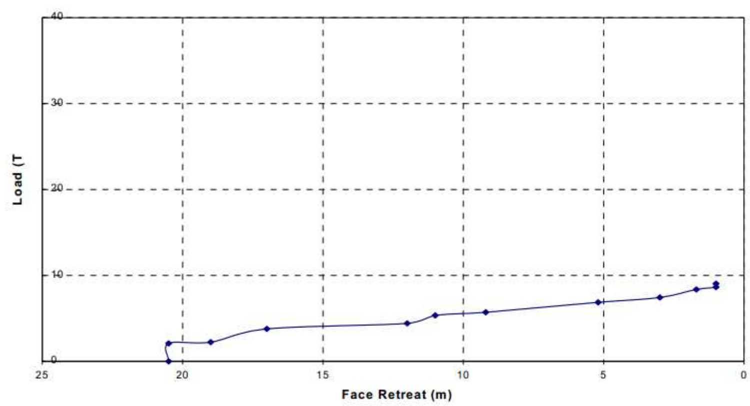

Figure 15: Load over the support at 210 m position in the tail gate

4.3. Stress Over The Pillars

At 260 m position in the main gate, the stress cell was installed with a setting of 7.14 kg/cm2 and max stress recorded is 16.45 kg/cm2 (Figure 16).

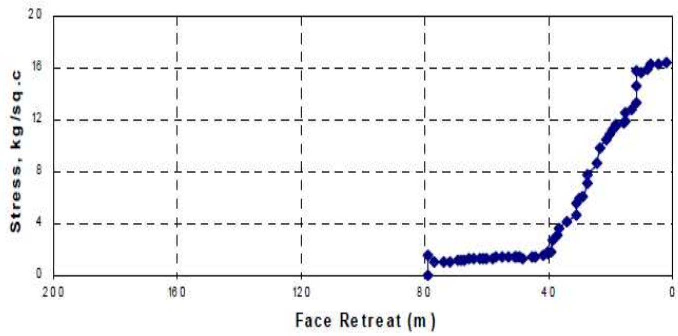

Figure 16: Stress over the barrier pillar at 260 m position in the Main Gate

The other stress cell was installed at 370 m position in the main gate with a setting of 7.14 kg/cm2 and maximum stress of 11.13 kg/cm2 was recorded before the stress cell went inside the goaf (Figure 17).

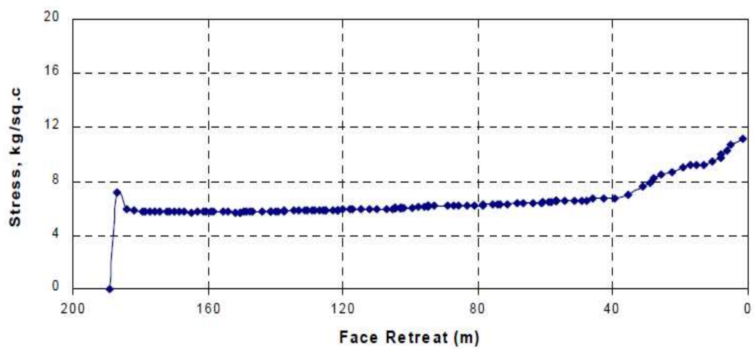

Figure 17: Stress over the barrier pillar at 370 m position in the Main Gate

At 250 m position in the tail gate, the stress cell was installed with a setting of 1.05 kg/cm2, max stress recorded is 2.31 kg/cm2(Figure 18).

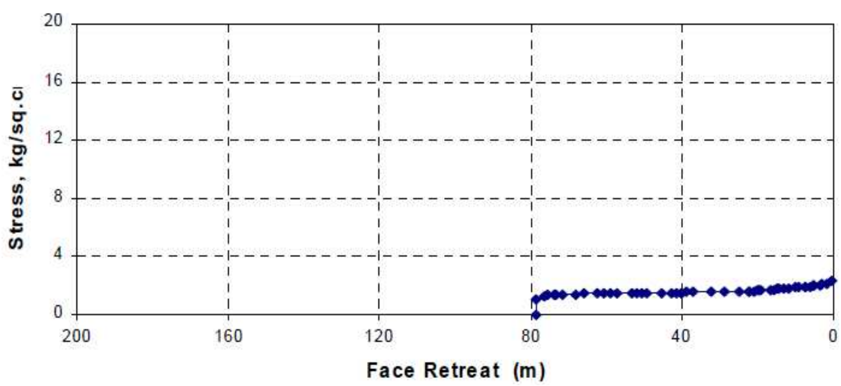

Figure 18: Stress over the barrier pillar at 250 m position in the Tail Gate

The other stress cell was installed at 340 m position in the tail gate with a settingof 4.3 kg/cm2 and maximum stress of 7.1 kg/cm2 was recorded before the stress cell went inside the goaf(Figure 19).

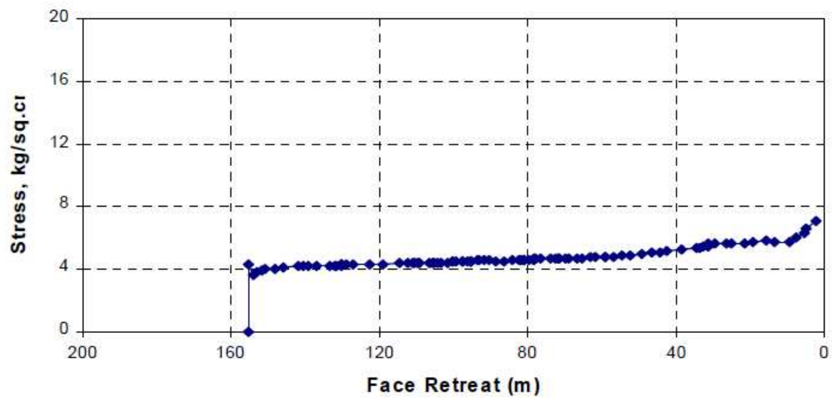

Figure 19: Stress over the barrier pillar at 340 m position in the Tail Gate

5. Conclusion

Based on the critical evaluation and observation of longwall at greater depths in other countries and in GDK 10A Incline following conclusions were drawn:

1. In India, extraction is going on at about 450m depth in various coalfields. Experiences in other countries indicate the vertical stress acting on the 250m wide barrier pillar, at a depth of about 900m can be as high as 137.9Mpa, causing ground control issues, and coal bumps to occur, but can be monitored by knowing strata behaviour, and adapting other innovative design.
2. At GDK 10A Incline at a depth cover of about 400m the maximum roof to floor convergence of 42mm was recorded at the tail gate and 176mm was recorded at main gate, increase of load on OC props observed between 5Te. to 10 Te..Maximum stress of

7.1 kg/cm2 was recordedin tail gate before the stress cell went inside the goaf, and maximum stress recordedin main gate is 16.45 kg/cm2.

3. Due to requirement of mining at greater depths in future in India by longwall method it is suggested to critically evaluate strata behaviour for Indian geo-mining conditions using different approaches and conducting experimental trials, including some innovative strata control/monitoring techniques including advancing and stress relieving technique, and extensive use of innovative strata behaviour monitoring methods.

6.Suggestions

The future of the mining industry demands more emphasis on meticulous applicationof rock engineering techniques, support design, modification to the existing guidelines through observational approaches, for cost effective and safe mining operations.

There is future scope of numerical approach to understand the extent of abutment loading and comparing the value with field data, to conduct experimental trials for designing of barrier pillars by research organization before implementing any design or method.

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