A Theoretical Study on Strata Behaviour and Ground Control in Coal Mines

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Abstract – *The mining activities are one of the main causes to strata movement and lack of its knowledge leads to various mining hazards such as roof fall, inrush of ground water, rock burst, coal bump, sub surface deformation and damages to the buildings or structures on the surface. The movement of strata affects the life of men, material, and machines during the course of mining operations. Therefore, a detailed study on the investigation and monitoring of strata behaviour and its control is becomes one of the key concern in the field of mining. In this paper a theoretical attempt has been made to understand the mechanics of the ground movement that occurred during any mining operations. The behaviour of the ground movement can be predicted by measuring the intensity of load on the strata. Thus, the paper focused on the application of geotechnical instruments such as vibrating-wire type stress cells, load cells, Tell– Tale type borehole extensometers and convergence stations on the measurement of load*

***Key Words*: Strata behaviour, Ground control, Roof fall, Borehole extensometer**

1. INTRODUCTION

The progress in the state of the art, technology in many branches of engineering is quite rapidly in recent years (Adomavicius et. al.2005). In the case of underground coal mining industry, a slow progress was observed during the last one decade, due to its complex and hazardous environment. Nevertheless, a few advancements in the availability and adaptability of the modern mining machinery was observed. These advancements in the underground coal mining are also limited due to the inadequate technology of strata control (suitable designs of workings and support systems) (Minggao et. al. 1994). The Board and Pillar mining method is the most widely used technology in the scenario of Indian coal mining industry. This method of coal winning has the negative impact on roof maintenance. During the operation of this method a large portion of roof is exposed to the external load which degrades the strength of the roof. Roof fractures and roof fall occur in this method of workings when the roadways are being driven due to time dependent deformation or during the extraction of pillars. This reduces the safety and increase the probability of roof fall. Therefore, it is required to implement various innovative technologies for the extraction process by this method (Rogers M. et. al. 1995).

The factors influencing coal mining involves geological distribution in ore blocks, depth of deposit, and geology of deposits, and sustainable mining operation which improves the support system installation which is originated by the study of strata mechanics (Kang et. al. 2010). In earlier days of mining, due to less investment in mining equipment and technology there was limited possibility of quantification coal with good qualitative possible.

However, now-days, with improved technology of mining and instrumentation, such as numerical models and computer applications analysis of data, investigators gained enhanced satisfaction through observational approaches (Von Kimmelmann et. al. 1984). The mining industry in the recent scenario requires more innovative changes in the instrumentation adopts for their safer and appropriate extraction. India has large resources of coal deposits of underground mining and lots of coal was blocked in existing underground mines. These blocked coal needs to be extracted by the installation of proper strata reading instruments (Zhang J et. al. 2010). Moreover, the accidents which mainly occurred in the underground mines are due to the strata deformation and it is the one of the important factors for these accidents.

2. MATERIAL AND METHODS

Generally, the problem of ventilation and strata control poses a very big challenge to the mining employees to work coal at greater depths at 450-600m (Noack K et. al. 1998). Obviously, the strata on the face, and in the adjoining areas (in front and behind), must require attention so that no uncontrolled failure of ground takes place.

In order to understand proper strata control measures, it is important to understand the mechanics of the movement of ground, which usually occurs as a result of mining operations. 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 (Guo H et. al. 2008). 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. The figure 1 shows a significant increment in stress concentration and bump potential at the tailgate of mines usually at greater depth.

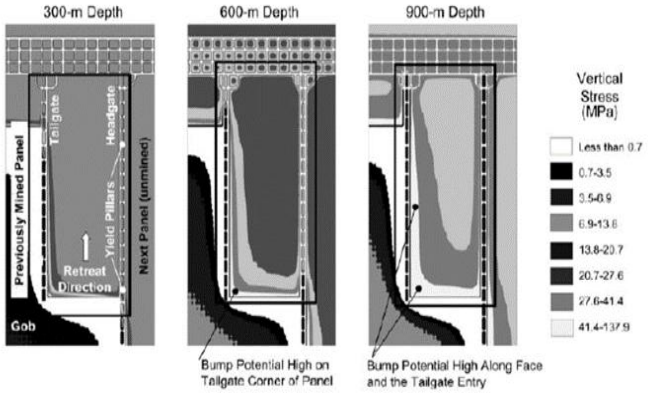

Fig 1: Modelled Vertical Stress, Increase with Depth Acting on a Longwall Panel Using a Two-entry Yield Pillar Gate road System

Abutment Stress Distribution:

These stress distributions have been proposed on the basis of mechanics of strata behavior. Various theories for this study are discussed below:

Dome or Arch Theory

During the drivage of headings in the advance of longwall face, it is observed that the roof strata gets fractured to a certain distance ahead of the coal faces at a considerable distance stratum movement takes place ahead of fracturing. The abutment load ahead of the face creates some bumps, tightening, minor sinking and some bulging. The formation of acute angles with the coal face side with coal ribs left, the face abutment pressure gets invaded at a greater distance at coal ribs. When the angle becomes greater than 900, this gets displaced near to the coal ribs. The position of back abutment and even their existence is a point of controversy, some researchers believes the existence of back abutment while others in the presence of pressure arch. The different roof beds bends by different amounts because of having the properties of young's modulus of elasticity and the formation of cavities takes place, known as Weber's cavity. The line of increased pressure in this theory is known as Pressure Arch, pressure dome, or Pressure ellipse.

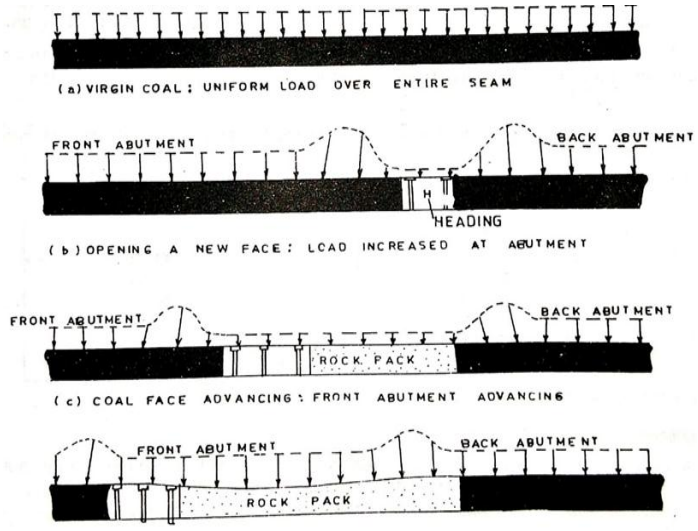

Fig 2 Distribution of rock load in vicinity of Longwall face

Soil Mechanics theory

The coal measure rocks found in India are full of geotechnical disturbances like joints, faults, originally formed due to the occurrence of orogenic force in the vicinity of their area. Whenever, an excavation is made in such rocks, the strata around the excavation tends to expand towards it toward it and as a result are gets fractured under the action of new stresses arising out of the disturbances. This theory has many limitations which are discussed below:

- It cannot be logically applied to the coal measure strata since the symmetrical arrangement of the beds, bears no resemblance with beds.
- No consideration of time and dip of strata.
- Load on support will be more than the load on broken debris.

Dynamic Rock Pressure theory

In general, the roads driven in longwall method of mining should have four characteristics: a) The boundary surface of influence; b) The surface of fracture; c) The surface of aspiration; d) the surface envelope of separate beds. This theory relies on the dynamic working of the faces and cope up with various stresses involved. This takes into account the time factor and the properties of the supports and the theory accords well within the observation made in actual practice.

Mining Options in Indian Coalfields

The coal measure strata of Indian coal fields consists mainly of sandstone, shale and an alluvium cap of varying thickness at the surface. 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. The type and radial extent of coal measure strata are influenced by tectonic setting. 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) Numerical modelling with computerization

Mechanical properties of Indian coal measure rocks varies from place to place in respect of volatile matter, depth of Burial, their compaction, Moisture content etc. The compressive strength of these strata generally lies between 56 kg/cm2 and 396 kg/cm2. On the basis of the behavior of coal seams, the roof is categorized into three:

- Thick strong roofs;
- Fragile roof:
- Stratified competent roof.

Proper Investigations were conducted at the mine to understand the behavior of the strata in the longwall panel. The main aim of these investigations is to measure the front abutment, and the deformation of the strata surrounding the gate roads ahead of the longwall face. The measurement of these parameters is done with the help of geotechnical instruments such as vibrating- wire type stress cells, load cells, Tell– Tale type borehole extensometers, and convergence stations. The bore hole sections for the study of strata control of some Indian underground coalfields is shown in Figure 3.

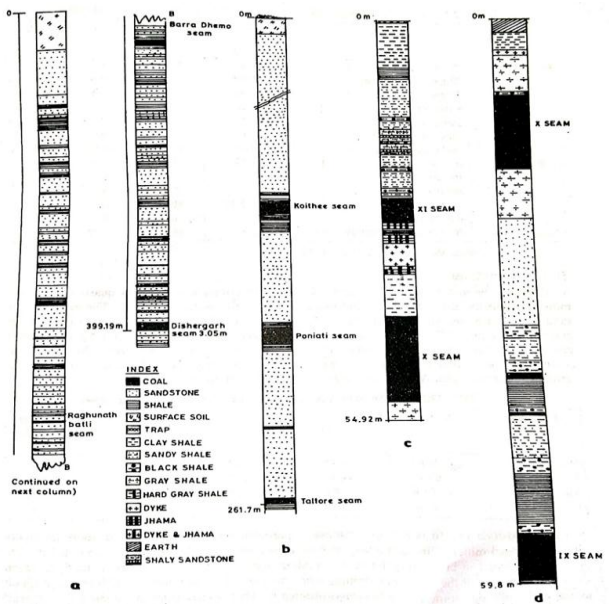

Fig 3 Bore-hole section in Indian coal fields

Strata Control Observations

Aim is to understand the geo-mechanical behavior 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 4.

Monitoring

The telescopic convergence indicator is used to determine the convergence at the main and tail road of longwall mines. The efficiency of the supports is monitored by measuring load variation on the OC props by installing load cells and convergence of Gate road ways. The abutment load on the pillars during the extraction can be monitored by installing four vibrating-wire type stress cells. Two stress cells were installed in main gate and two in tail gate.

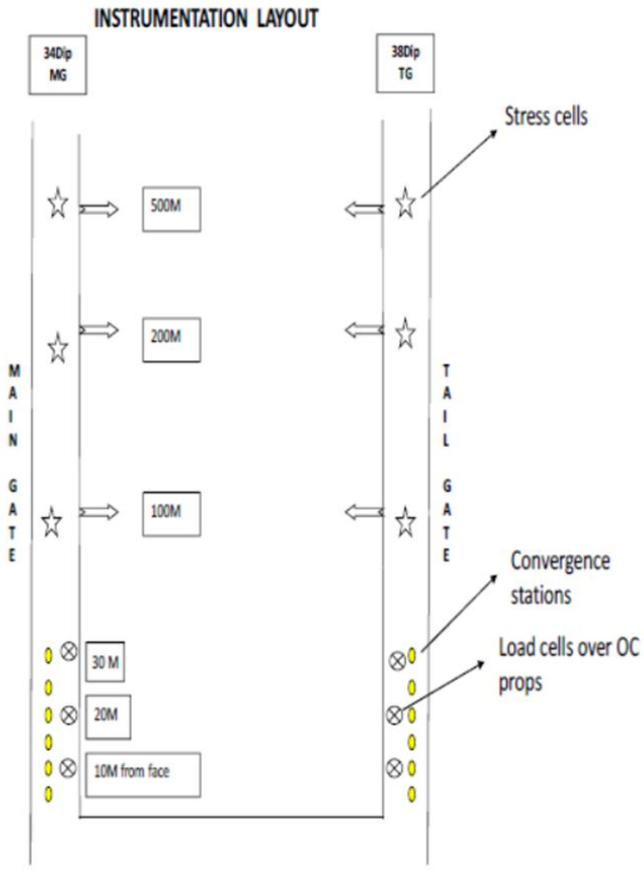

Fig 4 location of instrument in longwall panel.

Strata and support behavior monitoring is required for understanding the performance of support system. To minimize the dangers from weighting on the pillar due to overhanging of roof in the goaf and to ensure that as small an area of un-collapsed roof as possible is allowed in the goaf, a suitable code of practice for induced blasting shall be evolved in consultation with a scientific organization keeping in view the depth of induce shot holes being not less than 2.7 m, direction & spacing of shot-holes, explosives used etc. so as to limit the rate of convergence [i.e., the ratio of C1/C2 is equal or less than 2, where C1 is daily convergence at a site in a day "n" and C2 is the average daily convergence at the site up to the previous day i.e. day (n-1)] and also to ensure complete filling of the goaf and release of any abutment pressures.

Support and Strata Interaction

In general, roof supporting is done to create a stable rock structure. The factors governing the installation of roof support involves the properties of rock, and the magnitude of stress distribution. To study the strata behavior in underground longwall mines, a concepts of Ground reaction curve is established. This curve is defined as the requirement of all possible set of loads to achieve maximum stability. The ground reaction curve depends on the rock mass quality, the span, the in situ stress, and the mining-induced stress. The schematic ground reaction curve is shown in figure 5.

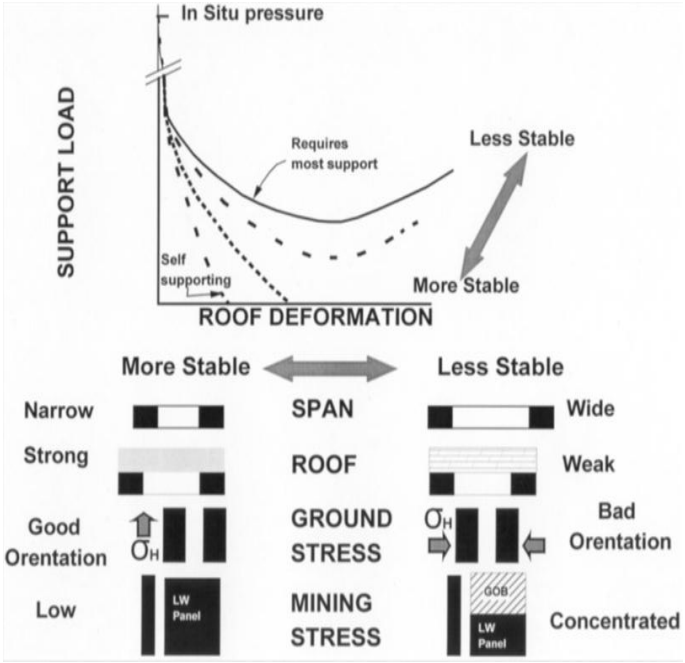

Fig 5 Schematic diagram of Ground reaction curve

As illustrated by the ground reaction curve, the "ideal" roof support has the following properties:

- High initial stiffness, so that only small ground movements are needed to mobilize the capacity of the support;
- Large load-bearing capacity; and
- High residual strength over a large range of displacement

Over-break and rock load

This is the case where overloading and pressure on the coal seam roof is atudies in conjunction with strata behavior and ground control. The main factors governing the over-break and rock are given below:

- Spacing between the joints.
- Shattering effect of blasting on the rock located beyond the pay-line.
- Distance between the working phase and roof support.
- Length of time which elapses between the removal of the natural support of the roof by blasting and the installation of the artificial support

Figure 5 and Figure 6 shows the how the working phase and the supported roof is influenced by the distance on the over-break in closely jointed, horizontally stratified rock. The smaller this distance, the smaller is the quantity of rock which is likely to drop out of the roof when the round is fired.

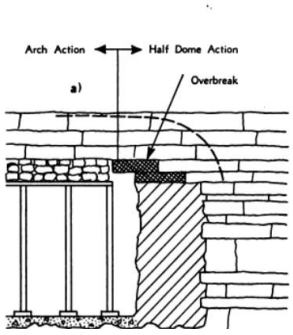

Fig 5 unsupported action

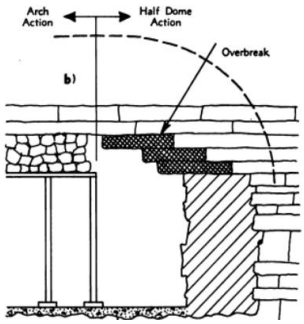

Fig 6 Unsupported action long very short

If the mine support is installed and wedged soon after blasting, the friction forces on the sides of the rock fragments occupying the space between the roof support and the vault transfer part of the weight of this rock on to the rock located beyond the sides of the vault.

In the folded mass of rock, the dip of the strata may range anywhere between 00 and 900, and the strike may intersect the centre line of tunnel at any angle between 00 and 900. The angle of friction ϕ depends not only on the nature of the surface of contact but also on the hydrostatic pressure in the water which percolates into the space between the two surfaces.

3. CONCLUSION

The strata behavior and ground control is an important concern in the view of safety aspect and the proposed stress distribution theories also help to understand the basics of strata behavior. The telescopic convergence indicator is used to determine the convergence at the main and tail road of longwall mines. The efficiency of the supports is monitored by measuring load variation on the OC props by installing load cells and convergence of Gate road ways. Strata and support behaviour monitoring is required for understanding the performance of support system. To minimize the dangers from weighting on the pillar due to overhanging of roof in the goaf and to ensure that as small an area of un-collapsed roof as possible is allowed in the goaf, a suitable code of practice for induced blasting shall be evolved in consultation with a scientific organization.

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