Stress Mapping for Preferred Orientation of Galleries in Underground Coal Mines

Dr.D.N.Sharma
U.Shivnarayana
Pankaj Kulshrestha

The Singareni Collieries Co. Ltd,
Kothagudem-507101, A.P., India
Ph.: 08744 242418
Fax: 08744 245968
E mail: drdn_sharma@yahoo.co.in

ABSTRACT

In the Singareni Collieries Company Limited, 5 Shaft mine is situated in the South Central part of Kothagudem coalbelt. In this block, Queen seam and King seam are under exploitation. In Queen seam, dip side working districts are approaching a depth of 350 m below the surface, it is reported that the most unstable roof conditions are experienced. To ascertain the reasons for the unstable roof rock conditions, a detailed underground stress mapping was taken up by conducting different studies. Based on these studies, it is found that the most prominent Joint set J_1, aligned to the major principal stress direction σ_1, is responsible for the roof instability, confined to level galleries. Conversely as J_3 joint set is parallel to the minor stress axis σ_3, it is contributing to stable roof conditions in dip galleries. Further, gutter roof, geographic features and low RMR are also contributing to unstable roof conditions.

Key words: Joint, Gallery, Principal Stress, Gutter Roof, Rock Mass Rating

1. INTRODUCTION

Five shaft mines is situated in the South Central part of Kothagudem coalbelt (Fig. 1). The block covers an area of about 6.51 km^2 and is enclosed between N. Latitude 17^0 29' 23" to 17^0 30' 35" and E. Longitudes 80^0 30' 28" to 80^0 41' 00". In this block, total two seams viz; Queen (Top) seam and King seam are under exploitation. General trend of the coal measures is NW-SE correspondingly dipping towards northeast with 7^0 to 9^0. Queen seam is the topmost workable seam with an average thickness of 6.0 to 8.0 m. In this seam, middle section is being worked leaving part of the seam in roof as well in floor. Height of extraction is 3.0m. The workings have crossed the 340 m depth. Average width of gallery in study area is 3.60 m. Size of the pillar is 40 m X 40 m. Underlying the Queen seam, with a parting variation of 45m to 50m, King seam is also extensively developed. The thickness of King seam varies from 6m to 8m.

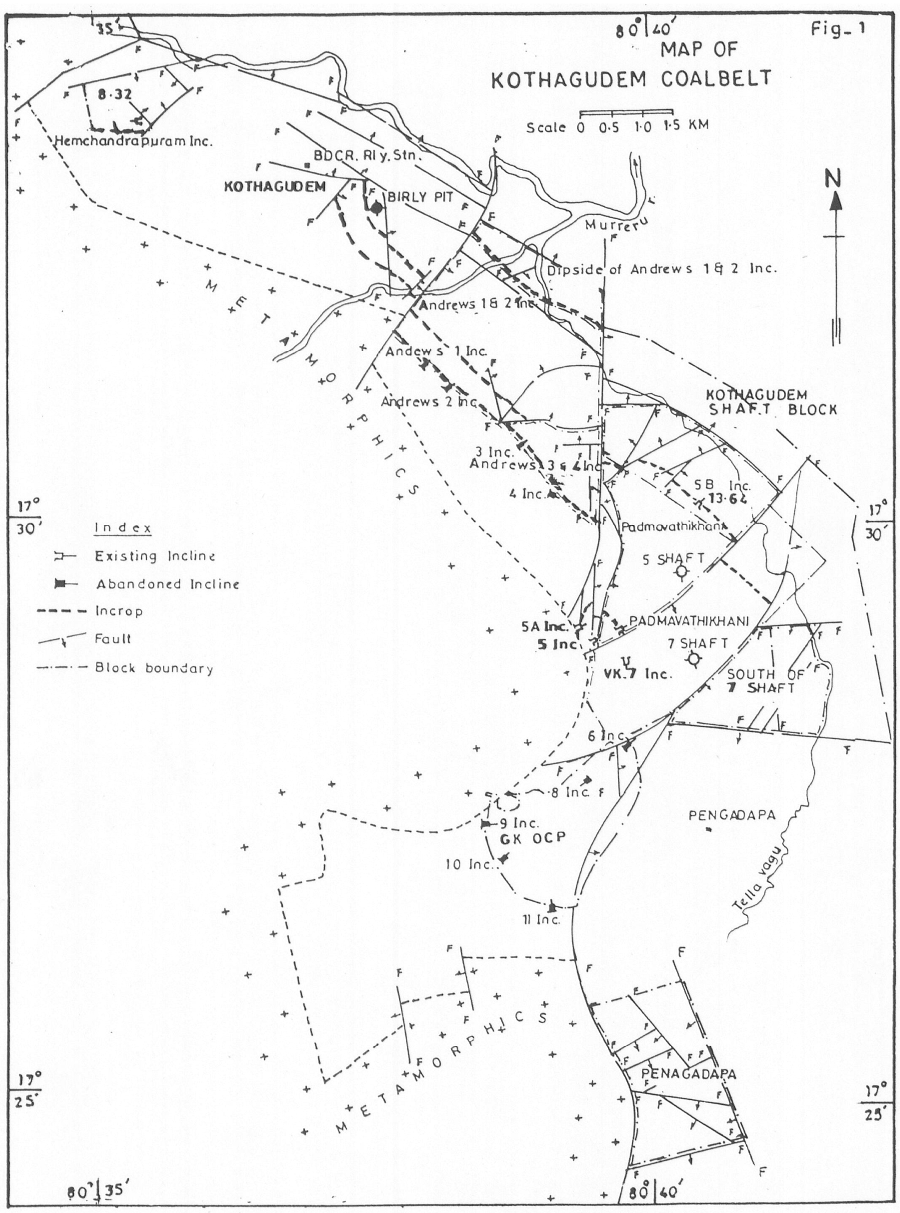

Fig. 1- Map of Kothagudem coal belt

2. DETAILED UNDERGROUND GEOTECHNICAL MAPPING

A detailed underground geotechnical mapping has been carried out in the study area to pickup the trends of joints, cleats, locating "gutter roof" and their impact on roof rock stability. All these features are demarcated on underground working plan of Queen seam. Unstable roof conditions are observed beyond 110 level workings and confined to level galleries alone where the dip galleries are stable. On detailed mapping of the study area, where middle section is under development by leaving about 2.50 m of seam portion in the roof, comprising coal, shale and clay, the following observations have been made.

(i) From 110L to 120L, roof instability is noticed only in level galleries and the dip galleries are stable.

(ii) Based on the experience of unstable roof conditions in level galleries, they were re-oriented and attained the stability. The details are furnished hereunder.

	Level Gallery	*Dip Gallery*
Original orientation	N 55^0 W	N 48^0 E
After re-orientation	N 30^0 W	N 50^0 E

(i) The workings have crossed 340 m depth line and approaching the fault in the dip side of the block. From the perusal of floor contour plan, the seam gradient varies from 1 in 6 to 1 in 13. Because of the fault also, roof conditions have deteriorated (Fig. 2).

(ii) Among the most troublesome obstacles found within a coal mine are those partial or complete removals of a seam known as ‘washouts’, which is the result of erosion at some period during or soon after the formation of the seam or seams. In its simplest form and on the smallest scale, a washout may be defined as a channel cut into or through a coal seam and filled generally with sandstone. The common feature is that of the ‘stone intrusions’ or ‘stone eye’ (irregular masses of sandstone) that occur within the seam or penetrating into the seam from top or bottom (Raistrick and Marshall, 1939).

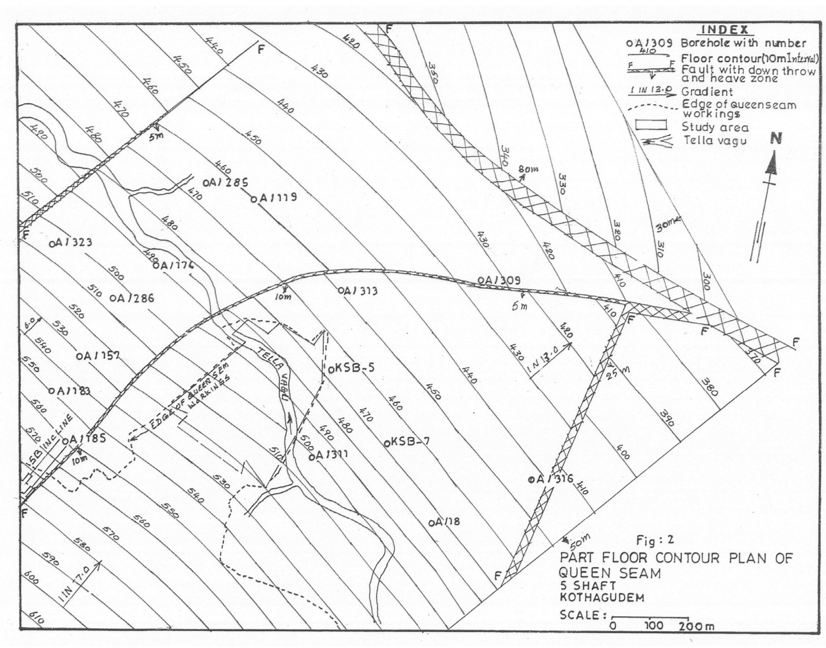

Fig : 2
PART FLOOR CONTOUR PLAN OF QUEEN SEAM
5 SHAFT
KOTHAGUDEM

3. DETERMINATION OF STRESS ORIENTATION

To facilitate the recognition of horizontal stress effects and to easily determine principal stress direction without resorting to cumbersome, expensive and time consuming field measurements, stress mapping methodology was developed. Stress mapping technique has been used in major coal producing countries, most notably UK, Australia, USA etc. and greatly enhanced the safety. Mucho and Mark (1994) explained features like cutter, guttering or kink roof, tensile fractures, roof potting, roof bolt hole offsets, shear planes, rock flour, striations on roof rock etc., in stress mapping, which help to establish the stress orientation in underground coal mines.

Fig. 3 – Location 116 LS-2D: Sagging and compressional crack developed in the roof strata resulted into 'Gutter Roof' in 116 level

Krausse et al. (1979) coined the term 'kink zone' for narrow zone of compressional cracking and sagging which develop in the immediate roof after mining 'kink zone' / 'gutter roof' / 'cutter roof' / 'shear' / 'snap top'/ 'pressure cutting' most commonly develop near the centre line of gallery or one side of the gallery. Lateral stress buckles the roof layers downward and jams their ends together. Some lithologies are more susceptible than others in development of kink zones. Kink zones develop readily in brittle, thinly layered / laminated strata. The number and thickness of layers and inter layer tensile and shear strength are more critical than the strength of the strata between bedding planes (Fig. 3). Local structural features, especially faults / slips joints etc. influence the development of kinks and directional roof falls. In the study area, 6 (Nos.) slips have been mapped with varying throw amount of 0.04 to 0.60 m. Displacements of layers on either side of the slip plane are noticed. Some times, the slips are associated with joints and in some places, the slip planes are filled with sandstone.

These kink zones / gutter roof in study area has been mapped and plotted in the underground working plan. From the exposed section of roof strata of workings in the study area, it is noticed that the strata is thinly layered and failure of the roof is observed in the centre of level galleries (Fig. 3) and some times they develop preferentially on one side of the gallery.

Sharma and Chandra (1988) investigated on the orientation of the joints of roof rocks and its bearing on the roof falls in the level galleries of Queen seam in VK-7 Incline. They found that the most prominent tensional joints J_1 aligned to the greatest principal stress direction (σ_1) are normal to the level galleries. At the same time, compressive in situ stresses also acted perpendicular to the level galleries and hence the roof instability prevailed only in level galleries. Conversely, the dip galleries were very stable. The normal stress is zero when the plane is parallel to the maximum compression direction and increases to a maximum when the plane is perpendicular to the maximum compression (Badgley, 1959). Based on these investigations, they suggested to take advantage of the orientation of J_1 joints by driving only dip galleries and later connect the dip galleries with few level gallery faces in the dip side so as to retreat the panels towards rise. Further they observed that the minor stress axis (σ_3) is favorable for such a method of mining to implement.

Further more, above findings were contemplated to be valid in the practical field operations by Rao, Rao and Reddy (1993). They found in their investigations that the performance of strike face is better than the dip rise face in longwall panels.

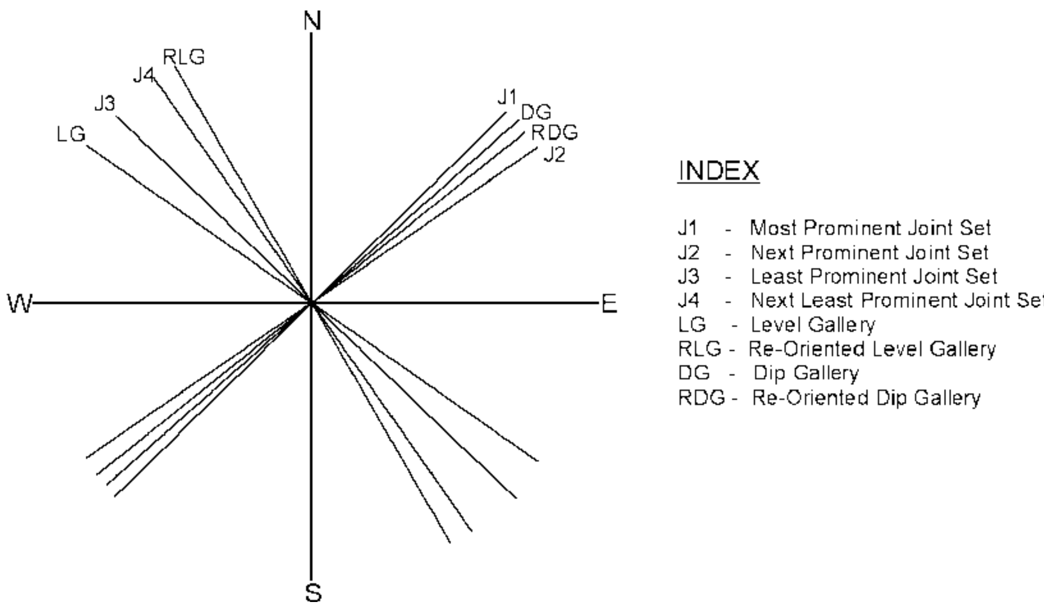

Fig. 4 – Trend of joints and galleries

Similar stress conditions of VK-7 are observed in the area under reference that is 5 shaft, being northern continuity. The rose diagram drawn for 100 readings of joint orientation reveals two distinct directions of joints viz. J1 and J2 (Fig. 4). The most prominent joint set J_1 is in the direction of N45^0 E which is almost perpendicular to level galleries and next prominent joints J2 trends in N 55^0 E. The least prominent sets J3 and J4 fall in the directions N 45^0 W and N 35^0 W respectively. The identification of total number of joints sets and their dips and dip direction is very important in the analysis of stability of underground openings. As such, true dip and dip directions of a large number of joints are measured in the study area. Zhang and Tong (1988) developed a computer program, STEREO, for automatic plotting of pole concentration. Using the software of Singh and Goel (2002), the poles of the joints are plotted on the stereonet and are contoured at 5% interval to infer the major principal stress direction (σ_1) indirectly, as there are no major or minor folds in the study area to derive the σ_1 from the orientation of fold axis (Fig. 5).

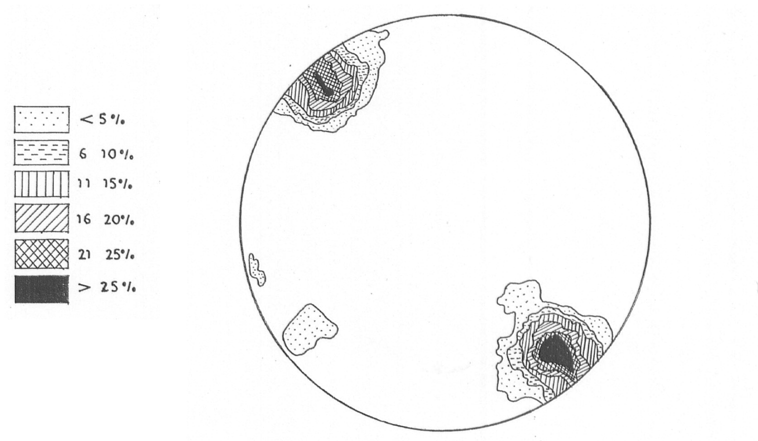

Fig. 5 – Contour diagram of joints plotted on equal area projection, lower hemisphere (100 joint poles)

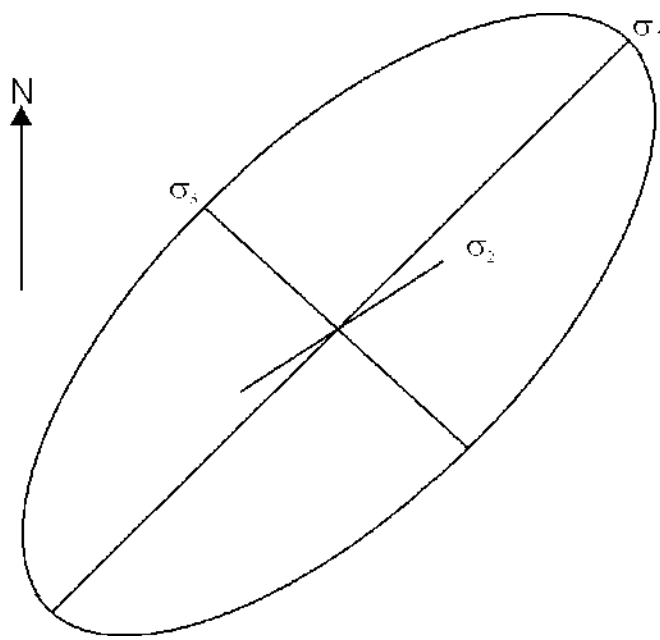

Fig. 6 – Direction of strain ellipsoid developed in the queen seam workings

Using these studies (as it was already established in VK-7 shaft), the most prominent Joint J_1 (N 55^0 E) is inferred to be the tensional joint and develop perpendicular to the minor stress axis (σ_3). In the study area, the major stress axis (σ_1) is parallel to J_1 and accordingly the strain ellipsoid is developed which is depicted in Fig. 6. Further J_1 dips at steeper angles, hence the major principal stress direction σ_1 is oriented parallel to the most prominent joint set J_1, direction of minor principal stress axis σ_3 which develop under compressive stress and contributing the stable roof conditions in dip rise galleries (Fig. 7). It is inferred that the most prominent tensional joints J_1 aligned to the major stress direction are normal to the level galleries, which contribute towards unstable roof conditions resulting into 'gutter roof' (Fig. 8).

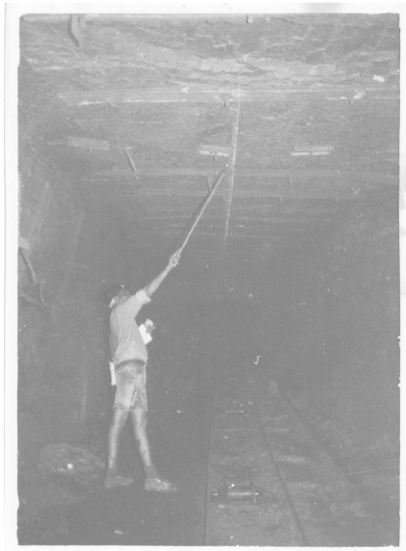

Fig. 7 – A Typical stable roof condition in dip-rise gallery

Fig. 8 – Failure of roof associated with cleats and bend in the W-strap support

Similar stress mapping technique was taken up in GDK-11A incline of Ramagundam and the data was generated by similar geo-engineering studies (SCCL, 2000). Making use of this data, CMRI, Dhanbad has derived the stress direction and advised the re-orientation of the galleries (CMRI, 2001).

Table 1 - Rock mass rating of roof strata of Queen seam

Sl.No	Parameter	Value	Rating
1	Layer thickness (cm)	15.38	19
2	Structural Indices	13	7
3	Slake durability index	86.15*	9
4	Compressive strength (kg/cm^2)	213.55*	5
5	Ground water seepage	Dry	10
Total			50

* Weighted average

4. ROCK MASS RATING (RMR)

Rock Mass Rating (DGMS, 1990) studies have been carried out in the study area considering five parameters viz., layer thickness, structural indices, slake durability index, compressive strength and ground water seepage rate. Accordingly, the total RMR is 50 (Table 1). In the adjustment factor, 10% reduction is given both for depth of workings as the study area falls in 340m depth and for method of excavation since it is solid blasting, respectively. After adjustment, roof strata is classified as ‘fair’ with rating of 40. Subsequently, the rock load is estimated to be 3 to 5 t/m^2. As per the RMR, the rock mass is classified as ‘poor’ for RMR from 20 to 40 and ‘fair’ for RMR from 40 to 60. The RMR of roof strata in the study area (40), which is just in transition, contributed to the unstable roof conditions.

5. TOPOGRAPHIC RELIEF

A stream / channel is generally created by surface run off water that cuts through a weak rock zone or an area of high fracture density. Streams tend to fallow surface fractures. It is generally known that in the coal mines area, the roof rocks immediately under and adjacent to a stream are almost always less stable and much liable to fall once the area is under active mining. Over the study area, tella vagu is passing through the block and contributing for the unstable roof conditions (Fig. 2).

6. SUMMARY AND CONCLUSIONS

The studies conducted in the area under reference in Queen seam (Middle section) are summarised and the following conclusions are drawn:

(i) Based on the underground geotechnical mapping, the causative factors of unstable roof conditions are due to :

  a. The most prominent Joint set J_1, aligned to the major principal stress direction σ_1, is responsible for the roof instability confined to level galleries. Conversely, as J_3 joint set is parallel to the minor principal stress axis σ_3 , it is contributing to the stable roof conditions in dip galleries.

  b. Roof strata is thinly layered and leading to failure that is confined to level galleries with an indication of ‘gutter roof’. Trend of the ‘gutter roof’ largely helped to further confirm the orientation of principal stress σ_1 in the study area.

(ii) The findings of the present investigations are closely matching with that of the stress orientation established in the adjacent block, i.e. VK-7 shaft.

(iii) The workings have crossed 340 m depth and approaching the fault in the dip side of the block. It is believed that because of this fault also the roof conditions have deteriorated. Other wise, roof is stable in the rise side of the study area.

(iv) Tella vagu is passing on the surface through the area under consideration and contributes for bad roof conditions.

(v) The 2 m roof strata of working section as per RMR is classified under ‘fair’ category with RMR value of 40 to 50 and rock load ranges from 3 to 5 tons/m^2 also indicates bad roof conditions for all practical purposes.

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