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Strata Behaviour in Longwall Retreating -A Comprehensive Comparative Analysis During Production And Salvaging Phases

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Abstract

Understanding the cantilevers formed by thick, massive beds in the near-seam overburden above longwall panels and the associated loads and strata fracturing effects developed during caving (main and periodic weightings) are key elements for the successful implementation of longwalls. Such caving mechanisms rely on the geotechnical conditions within the panel. In India, the majority of longwall downtime and/or roof failures were caused by a lack of knowledge on overburden caveability, in particular when the main and periodic weightings will impact the face and longwall support selection to effectively mitigate such weightings. Godavari Valley Coal Fields is no exception as longwall faces were adversely affected due to the presence of thick, massive beds in the near-seam overburden at both Godavarikhani (GDK) 7 and 9 Incline mines. In contrast, overburden weightings were negotiated successfully in GDK10A and Adriyala Longwall Project (ALP) mines by detailed geotechnical studies, the use of adequate longwall support capacities, and effective operational practices. Thirteen longwall panels with varying face width, at different depths have been extracted under massive sandstone beds of 18 m to 28 m thickness at GDK 10A and ALP mines. This study elucidates that the main roof weighting interval decreases with an increase in face width and attains a constant value with further increases in face width under the same geo- mining conditions. In addition, this study also concludes that with increases in face width, the periodic roof weighting interval decreases and shield loads increase. Similarly with increasing panel width to depth ratio, the main and periodic roof weighting intervals decrease but shield loads again increase. Lastly, the strata behaviour of the longwall face retreated along up-dip direction is demonstrated. The results of this paper improves the mechanistic understanding of the impact of face width, depth and main roof thickness on periodic weighting and associated roof control problems on the longwall face.

Introduction

Mechanized longwall mining in India is 39 years old, since the introduction of first self-advancing powered roof supports in longwall face at Moonidih Colliery in 1978. In spite of 39 years of learning connected with longwall mining, Longwall faces are still affected by strata problems resulting in production delays/failures, causing attritions to infrastructure at face and in worst cases causing structural damage to powered roof supports. Therefore Indian coal operators are not fascinated in adopting longwall mining technology extensively. Whereas in other countries, longwall mining is cited as a mass coal production technology.

The impetus for this paper is the catastrophic roof control problems that have been experienced by Indian longwalls due to the presence of massive beds in the near-seam overburden and the lack of a full mechanistic prescience about the occurrence of roof falls and load imparted on powered roof supports during these roof falls, which depends on the face width and depth of the panel. The designing of powered roof supports for the new site

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remains a question mark, although there are many theories for the prediction of shield loading [1].

In two underground mines in Godavari Valley Coal Fields (GVCF), South India, thirteen longwall panels have been extracted with varying face widths from 98 to 255 m, depth ranging from 154 to 450 m and the face retreated in both strike and up-dip directions. This has provided a rare and unique opportunity in assessing the impact of varying face width, depth and thickness of the main roof (consisting of a massive sandstone unit of varying thickness, known as the SS80 Sandstone) on overburden behavior above the longwall face. Some approaches by foreign and Indian authors based on theoretical analysis, numerical modeling and field experiences to address the impact of increasing face widths, depths and presence of the massive bed in near-seam overburden on main and periodic roof weighting intervals and shield loads during roof weightings, are given below.

Impact of face width

With increase in face width, the value of main roof weighting interval decreases, after a certain face width the value of main weighting interval is unaffected by further increase in face width under same geo-technical conditions and the face width at which constant value attained depends on the thickness of overlying strong bed [2], [3]. The intensity of periodic weighting is observed to be increased from 150 to 200 m width walls [4]. In the narrow faces beneath massive bed, the fracturing arc of strata is formed behind the face, whereas in case of wider faces it moves ahead of face and in middle of the face characterised by strata facturing and instability ahead of the face [5]. Further in narrow longwalls the massive bed will overhang further than in wider panels, due to the formation of a self-supporting arch over the gate roads by which heavy guttering will occur due to transfer of load from spanning roof to gate road pillar [6].

The measure of loads imparted onto the shields is a function of face width [7], [8]. Up to a face width of 213 m the load on the shields increased between 3.5% and 8% per 30 m increment in face width [9]. In narrow longwalls, shield loads were reduced due to the bridging effect of a strong bed [10], [11]. In the case of wider longwalls more load is imparted on the shields moreover, the cycle time will be more which increases yield counts per cycle and subsequent roof degradation [12].

Impact of cover depth

A number of authors have concluded or inferred the need for a greater shield capacity with increasing depth of cover and face width [5], [10], [13]. With the increase of depth, there is a significant increase in vertical abutment on pillar [14], [15]. The influence of depth is very significant in super critical panels (i.e., typically higher panel width to depth of cover values) whereas far less critical in sub-critical panels [16].

1.3. Impact of massive bed in near-seam overburden

Competent beds within 0–40 m of the extraction horizon have the greatest impact on longwall strata behavior and are the main cause of face weightings [17], [18], [19], [20]. Severity of periodic weighting under massive strata in the near-seam overburden is influenced by face width and the thickness of the massive strata [7], [16], [17], [18], [19], [21], [22], [23], [24]. For thin beds, the overhang of roof cantilever beam is short and for thick beds, the overhang of roof cantilever beam is high [18], [25]. The seismic events were observed to be less in longwalls panels under 15 m thick than in 6–12 m thick sandstone units [26]. The shield loading is uniform across the whole panel when the face width is less than 152.4 m [9]. The

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periodic roof weighting interval under massive bed can be 50–100% to the thickness of the bed [27].

A periodic weighting classification was developed which relied on face width and thickness of the competent unit to define controllable (0–10 m thick), operationally controllable (10–23 m thick) and uncontrollable (23–50 m thick) weighting conditions [28]. One of the potential serious consequences of periodic weighting is face instability and the formation of cavities ahead of powered roof supports [3], [29]. Under massive strata, an increase in face width from 150 to 200 m was reported to have had adverse effects on roof weighting and roof control on the longwall face [7].

This paper attempts to extend on similar works by numerous authors cited above on the impact of face width, depth of cover and the presence of massive sandstone beds in the near-seam overburden on important operational mining parameters such as main roof weighting intervals, periodic roof weighting intervals, load impart on shields during main and periodic weightings.

2. Description of the site

There are four workable coal seams namely No.1, 2, 3 and 4 in descending order. The longwall panels were extracted in the bottom section of No. 1 Seam with friable coal and shaly bands as immediate roof and overlying sandstone bed as main roof. A total of thirteen longwall panels with different face widths have been extracted in both mines. During extraction of longwall panels, intensive strata monitoring was done for manifesting the behavior of overlying massive sandstone beds and loads imparted on the shields during weightings.

In GDK 10A mine, six panels (1, 2, 3, 7, 8 and 3A) were extracted on the north side of trunk roadways with gate roads driven in the direction of N26°13′48″W and four panels (10a, 10, 11 and 12) on the South side of trunk roadways with gate roads driven in the direction of S11°15′44″E. In these ten longwall panels (hereafter called as strike panels), the longwall was orientated in dip-rise direction and gate roadways were oriented in strike direction with face widths varying from 98 to 164 m at a depth range from 154 to 355 m. Longwall panels 3B and 3C (hereafter called as dip rise panels) were extracted on the northern most side of trunk roadways at a face width of 154 m, gate roads were driven in the direction of N66°38′4″E and at a depth range from 150 to 360 m with the longwall face oriented in the strike direction and gate roadways oriented in dip-rise direction.

At the Adriyala Longwall Project Mine (ALP), one panel (ALP 1) has been extracted on the north side of the main entries shown in Fig. 1. The longwall was 255 m wide and was accessed via two single entry 2.3 km gate roads developed along strike at a depth range of 360 to 450 m. Second panel extraction is in progress. The layout of longwall panels at GDK-10A and ALP showing their dimensions and numbers is given in Fig. 1.

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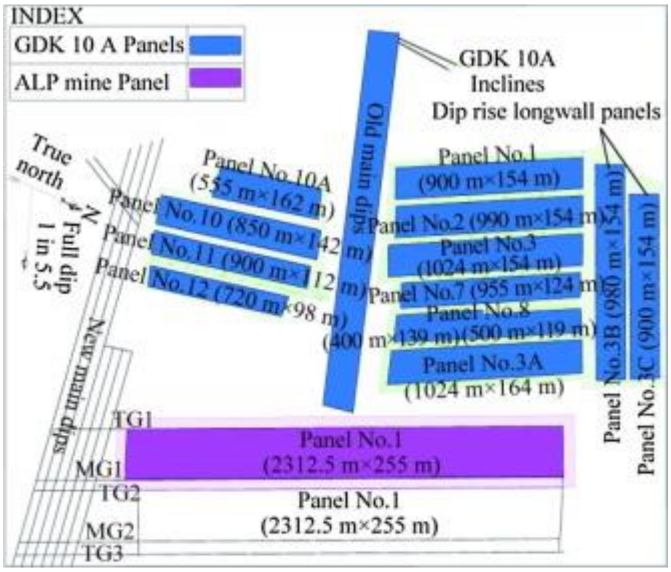

Fig. 1. Layout of longwall panels of GDK-10A and ALP.

Results and discussion

The key outcomes from the study, of the impact of face width, depth of cover and the presence of massive sandstone beds in the near-seam overburden on important operational mining parameters such as main roof weighting intervals, periodic roof weighting intervals, shield loading during main and periodic weightings is summarized as below:

- With an increase in face width, the span of main roof weighting decreases and eventually becomes almost constant beyond a certain face width (i.e., 154 m), unless there is a change in the geological and/or geotechnical conditions.
- For a 98 m face width, the average periodic weighting interval was equal to the thickness of the main roof, for 150 m face width, the periodic weighting interval was 85% of the main roof thickness and for 255 m face width that decreased to 70%.
- With an increase of face width from 98 to 154 m, there was an increase of 6.7% in shield loading and from 154 to 255 m increase in face width there was an increase of 18% shield loading during main weighting. For an increase in face width from 98 to 255 m, there was a 23% increase in shield loading during main weighting. For every 30 m increase in face width there was a 2–5% increase in shield loading during main weighting up to a face width of 164 m. From 164 to 255 m face width, there was an 18% increase in shield loading.
- The main roof weighting interval decreased with increasing width to depth ratio.
- In strike panels, shield loading increases with increasing panel width to depth ratio. Conversely, periodic weighting interval decreases with an increasing panel width to depth ratio.
- In dip rise panels, the periodic weighting interval increased as the cover depth decreased. This was because the magnitude of vertical stress increases with depth thereby causing a more frequent failure and associated weighting of the SS80 sandstone in the main roof.
- On analysis of the data from a dip rise panel, shield loading and cover depth during periodic weightings were largely unaffected by varying cover depth.

7. Conclusions

Panel width, cover depth and the thickness of the main roof above the longwall face play a significant role in overburden weighting and its direct impact on the longwall face and

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therefore, needs to be considered when selecting powered roof supports. The main and periodic roof weighting intervals depend on geotechnical properties of the main roof. Therefore, it is crucial to identify and determine the geotechnical properties of the main roof immediately above the longwall working section.

The empirical data presented in this paper provides valuable and relatively unique insights into the inter-relationships between cover depth, longwall panel width, retreat direction with respect to seam dip and near-seam overburden lithology on main and periodic weighting intervals, powered support loading and roof cavity formation. The application of the resultant knowledge should enable a better insight into the mechanistic understanding of progressive failure of massive roof strata and the direct impact of face width and cover depth on main and periodic weighting intervals. Powered roof support requirements for the safe and productive extraction of longwall faces have been linked to site-specific geo-mining conditions.

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