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STRONG WEIGHTING EVENTS IN SHALLOW MULTI-SEAM LONGWALL MINING

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ABSTRACT: When longwalls are operated underneath previously mined-out workings in shallow coal seams in the Shendong Coalfield, China, extremely strong weighting events often occur and sometimes result in the longwall supports becoming ironbound. The occurrence of such events was analysed through characterising the movement of the rock structures formed by the excavation of the upper seam as well as the associated load transfer mechanism. Three typical mining conditions that have caused frequent strong weighting events were identified: (1) when the longwall face is mining underneath the uphill section of a valley terrain; (2) when the longwall face is advancing out of upper coal pillars; and (3) when the longwall face is mining underneath upper chamber coal pillars. The mechanisms caused strong weighting events under each condition and corresponding prevention and management strategies are discussed.

INTRODUCTION

Shallow longwall mining can be regarded as having relatively a low intensity of weighting events in comparison to mining at depths. However, coal mines in the shallow Shendong Coalfield of China have experienced frequent strong weighting events and associated excessive convergence on longwall supports which sometimes resulted in the longwall becoming ironbound, a state of roof supports being fully compressed. Surface cracks with associated scarps w often accompanied such events.

Shendong coalfield in the northern part of China is a typical mining district that produces coals at shallow depth of cover. In recent years, the coalfield has become one of the largest coalfields in the world, producing hundreds of million tons of coal per annum. With the topmost minable seam being mined, some coalmines in the coalfield have extended further to excavate lower seams under previously mined-out workings. Practices so far have showed that the load created on the longwall supports is greater than when mining the upper seam. Sometimes extremely strong weighting events with rapid convergence on longwall supports have occurred. Even with longwall support load capacities as high as 18,000 kN (an intensity of 1.52 MPa) in some coalmines, strong weighting events have still occurred.

The load imposed onto the longwall supports is closely associated with the pattern of overburden strata movement in particular the cantilevered blocks of roof strata hanging over the longwall face (Qian, *et al*., 2010). Generally, when the longwall face advances, the main roof will break at a certain interval, resulting in periodic weighting onto the longwall face. In a single seam-mining scenario, the additional load generated during periodic weighting is mainly associated with the main roof and the overlying strata that breaks together with it. However, such a mechanism is not sufficient to explain the excessive loading events that are being experienced in mining the lower coal seams in the Shendong Coalfield.

The concept of Key Stratum (KS), which is characterised as a strong layer that controls the movement of the strata between it and the next KS above, has been increasingly adopted in China in analysing the process of overburden strata movement as well as longwall weighting events. In the last decade, it has been gradually recognised that the breakage of the second KS from the working seam (the 1st is the main roof) can have a significant effect on the support load (Xu, *et al*., 2009, 2014). Based on the KS concept, the occurrence of strong weighting events in the Shendong Coalfield was analysed. Three typical mining conditions

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were identified that can result in extremely strong weighting and sometimes an iron bound longwall face (Zhu, *et al*., 2010, 2017 and Ju, *et al*., 2015).

These conditions are:

1. When the longwall face is mining underneath the uphill section of a valley terrain Second point,
2. When the longwall face is advancing out of an upper coal pillar,
3. When the longwall face is mining underneath an upper chamber coal pillar.

This paper presents the three typical conditions as well as the mechanisms that cause the events. Corresponding management strategies were also briefly discussed in the paper.

TYPICAL CONDITION 1

A typical case

Valley terrain with a height of 30~70 m is commonly present in the Shendong Coalfield. The geological structure is formed due to flood erosion. In the lower part of the valley, bedrocks are often seen underlying the top loose soil bed.

Daliuta mine is one of the modern coalmines located in the Shendong Coalfield. Abnormal strong weighting events have occurred several times in the mine when the longwall face was advancing underneath the valley terrains. Figure 1 shows the geological conditions along the LW12304 panel, which extracted the 1^{-2} coal seam. The upper 1^{-2} seam, 6~27 m above the mining seam, was previously mined out. The depth of cover of the 1^{-2} seam is 40~120 m. When the lower 12304 face was advancing underneath the valley terrain, excessive loading of the longwall supports which resulted in rapid convergence of the longwall supports occurred twice at the locations shown in Figure 1.

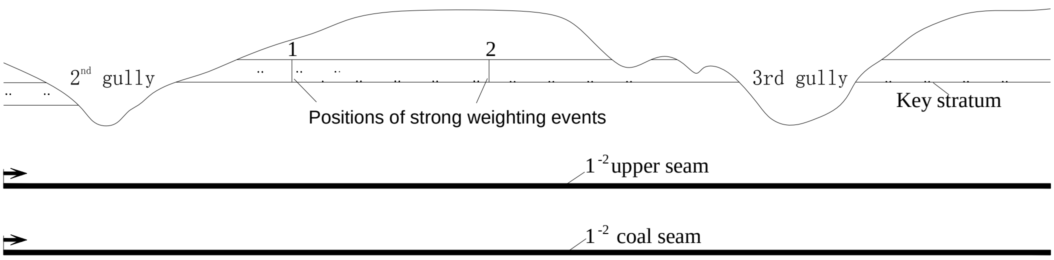


Figure 1: Geological conditions of LW12304 at Daliuta mine

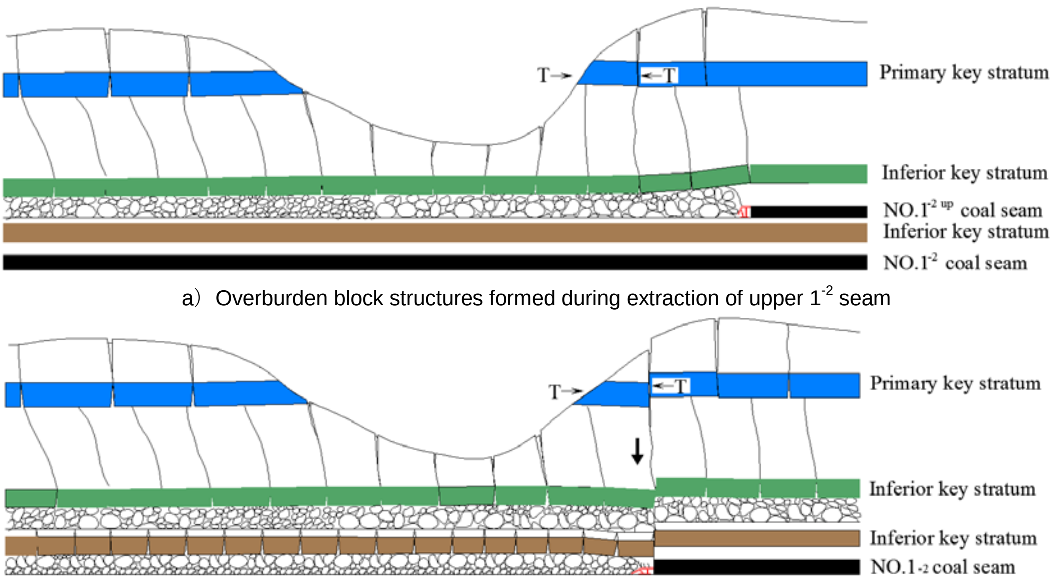
The first event occurred when the longwall face was undermining the middle of the terrain slope, as shown in Figure 1. Consequently, the coalface between supports No.36 and 76 experienced significant spalling with a depth of 1~2 m, and the roof caved about 1.5~2 m. Several supports rapidly converged 200 mm with the yield valves opened completely. On the ground surface, cracks parallel to the longwall face were observed across the valley with a width up to 1.2 m and associated scarps with a height greater than 1.0 m. Figure 2 shows the surface cracks on the slope of the valley.

The second event occurred when the longwall face was undermining the plateau of the terrain. As a consequence, roof falls were observed between supports No.46 and 66, and rapid convergence of 420 mm was observed at the longwall supports. Surface cracks were created with a width up to 4~5 m and associated scarps of 1~2 m high.

Figure 2: Surface cracks with scarps on the slope of the valley

Postulated Failure Mechanism

According to the geological conditions, two KSs were identified in the overburden. The primary KS (PKS), the topmost KS that controls the movement of the entire strata from the layer up to the ground surface, was found missing within the valley area, as shown in Figure 3. In such a condition, the lateral force, which would have served as resistance to the movement of the PKS blocks that were broken during the excavation of the upper 1^{-2} seam, was missing. This would lead to the blocks not being able to maintain stability or provide self-support during extraction of the lower seam. Thus the weight of the PKS and its overlying strata would be transferred down to the main roof of the lower seam and then onto the longwall shields, as shown in Figure 3. As a result, rapid and excessive roof convergence would be inevitable. Meanwhile, large cracks on the ground surface along with associated scarps were created.



a) Overburden block structures formed during extraction of upper 1^{-2} seam

b) Overburden block structures formed during extraction of the 1^{-2} seam

Figure 3: Movement of rock blocks when the coalface was beneath the valley slope

Management

Based on the mechanism discussed above, the risk of abnormal weighting events can be assessed through identifying whether the PKS is present throughout the valley areas. In addition, the risk is also highly associated with the height of the strata overlying the PKS. The detailed stratigraphic information and relevant strata mechanical properties are therefore critical to the risk assessment and management. Clear signs should be placed in underground roadways at corresponding locations that defines the risk zone. In addition, increasing support capacity is an effective and direct control measure. The capacity of the support must be determined in accordance with the detailed stratigraphic condition in the risk zone to ensure that it is sufficient to sustain the load transferred from the PKS and its overlying strata. Taking the LW12304 as an example, the support load capacity should be increased to 13,867 kN based on the stratigraphy present at the strong weighting event sites.

TYPICAL CONDITION 2

A typical case

A number of strong weighting events with rapid convergence have been experienced while the longwall face was advancing out of the coal pillars in the upper mined-out seam. Since 2007, these types of events have occurred about ten times. One such event occurred at LW12304 of Daliuta mine. Figure 4 shows the relative location of LW12304 and the upper coal pillars. A sharp increase of support resistance was observed between supports No.63 and 105 when the longwall face was about 3.4 m outbye the upper coal pillar. Consequentially, the yield valves were activated. The maximum convergence of the supports reached 1200 mm and some of the supports became iron bound. The face spalling was about 1.1 m deep into the coal and the roof caved about 1.2 m high. This event stopped coal production for two days.

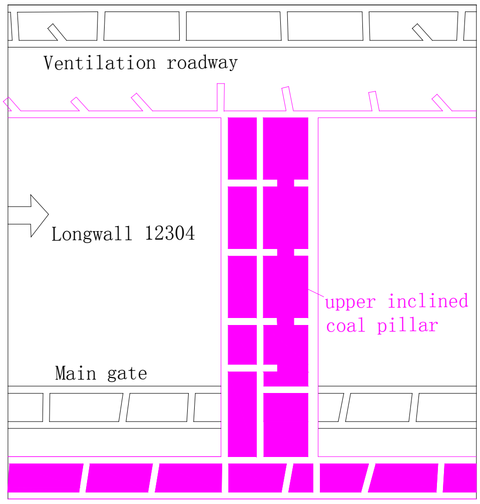


Figure 4: The relative location of LW12304 and upper inclined coal pillars

Postulated Failure Mechanism

Figure 5 shows the structure formed by blocks of roof strata when a coal pillar of the upper seam was undermined. It is clear that the structures of the KS blocks formed during excavation of the upper seam were different between the pillar and goaf zones. Due to the existence of the coal pillars, the KS block over the pillar zone formed a three-hinged structure, as shown in Figure 5. When the lower seam longwall was about to advance out of the coal pillar zone, two blocks C and D rotated towards the coal face along with the subsiding strata below. This rotation caused a repositioning of the middle hinge of the structure (between blocks C and D) thus lowering it relative to the other two, breaching the stability of the three-hinged blocks. In such a situation, the load previously taken by the three-hinged structure would be transferred down to the longwall supports, leading to excessive roof convergence and longwall supports becoming iron bound.

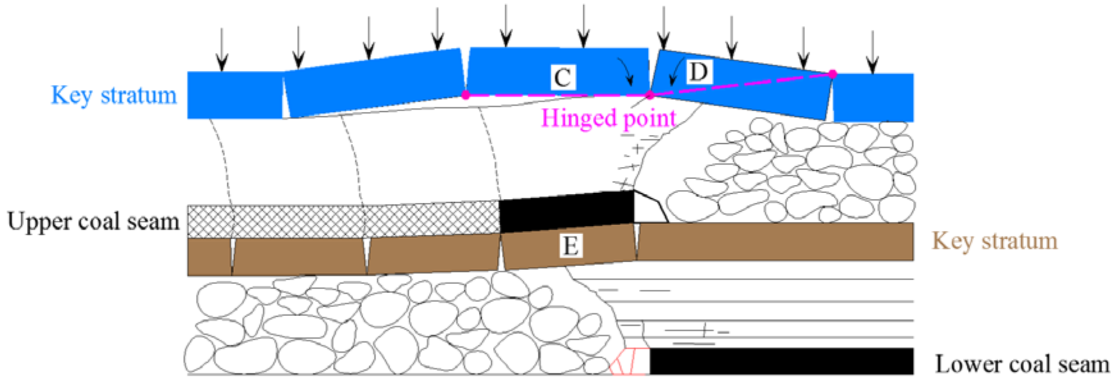


Figure 5: Strata block structures and movements when upper a coal pillar was undermined

Management

To minimize strong weighting events in such a scenario, it is critical to prevent the excessive rotation of the three-hinged blocks that were formed over the coal pillars. In addition to increasing the load capacity of the support, it is possible to take measures to reduce the rotation of the upper blocks. Methods that can be applied include blasting the edge of the upper coal pillars to stimulate the rotation far ahead of the longwall face, and backfilling the goaf area near the pillar zone to prevent excessive rotation of the rock blocks. Moreover, the situation of the longwall loading environment beneath the upper pillar zone needs to be taken into consideration as early as in the planning and design phases of the lower seam excavation. The alignment of longwalls at the two mining horizons can be optimised so as to minimize excessive loading events.

TYPICAL CONDITION 3

A typical case

LW31201 of Shigetai coalmine in the Shendong Coalfield (Figure 6) extracted coal from the 3-1 seam. The longwall was 311.4 m wide and 1,865 m long. The mining seam was 3.0~4.4 m thick and the overlying bedrock was about 48~120 m thick. The depth of cover within the longwall vicinity was 110~140 m. The load capacity of the longwall supports was 18,000 kN. Part of the longwall was overlain by previously mined out chambers in the upper 2-2 seam and remnant coal pillars. The distance between the two seams was 30~41.8 m.

Severe weighting events with rapid roof convergence occurred nine (9) times during the operation of LW31201. The most severe one was on 16 December 2013 after the shearer finished its first cut of the day. The shield supports between No. 22 and 135 converged rapidly from 1.3~1.5 m to 0~0.2 m in about 20 seconds, resulting in the face becoming iron bound. A number of leg supports were crushed and the sealing rings were broken. It took 60 days to repair the damaged supports and recover the longwall face, leading to significant economic loss.

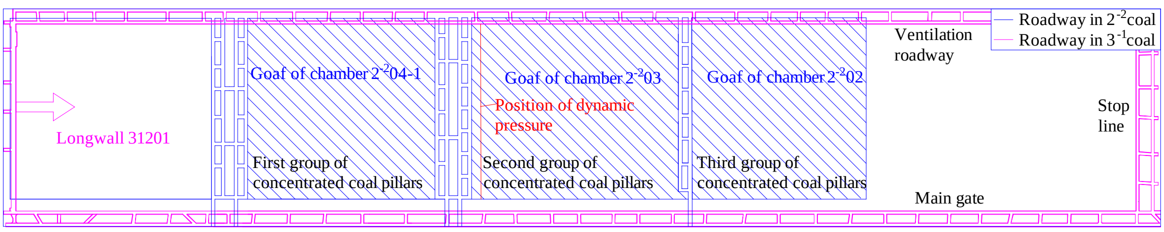


Figure 6: Layout of the longwall 31201 and upper coal seam chambers

Postulated Failure Mechanism

Figure 7 shows the likely structure formed by the blocks of roof strata. When there are chamber pillars in the upper seam, the front abutment load ahead of the longwall face will be concentrated onto these coal pillars. If the coal pillars were strong enough to sustain the abutment load, the overburden movement and the load transfer would be the same as that in other zones of the longwall.

However, if the chamber coal pillars failed due to abutment loading, the load transfer would be different. For example, if the coal pillars 1 to 3, as shown in Figure 7 failed, the upper level KS (highlighted in blue) would possibly break into blocks C and E with the broken point located directly above the longwall face. Different from a normal rotation of a cantilevered block, block C would rotate in the reverse direction towards the longwall face. In such a situation, the majority of the load carried by block C would transfer to the longwall face instead of the caved material in the deep goaf. This additional load would result in rapid and excessive longwall support convergence.

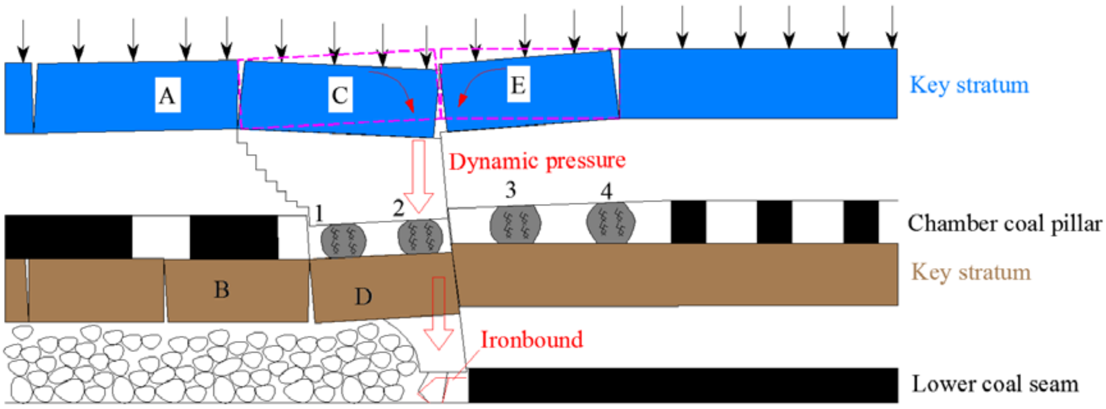


Figure 7: Overburden rock block structure and load transfer when there were chamber coal pillars ahead of the longwall face

Management

The load capacity of the supports used at LW 31201 was 18,000 kN with an intensity of 1.52 MPa. This capacity is already very high leaving limited room to increase the load capacity. Therefore, other measures must be developed.

Based on the mechanism discussed above, the key factor is the rotation of the KS blocks induced by the failure of the upper chamber coal pillars. Therefore, measures that aim to change the patterns of the KS block rotation can be taken. Possible methods include blasting the chamber coal pillars ahead of the longwall face through surface boreholes to make the coal pillars fail prior to being positioned in the abutment zone. This would move the abutment load further ahead of the coal pillar zone and therefore change the KS breaking pattern and rotation levels. Cutting height could also be increased to increase the stroke of legs of the longwall supports to allow more room for convergence.

CONCLUSIONS

Strong weighting events were experienced when longwalls were operated underneath previously mined-out workings in shallow coal seams in Shendong and some other coalfields in China. This sometimes resulted in longwall faces becoming ironbound, significantly threating miners' safety and hindering coal production.

Three typical conditions that can induce strong weighting events were identified from the analysis of the structures of the rock blocks and their movement above both horizons of mining. This characterisation has helped coalmines in the Shendong coalfield assess the risks of strong weighting events for subsequent longwalls. These conditions were:

- When the longwall face was advancing beneath the uphill section of valley terrains,
- When the longwall face was undermining upper inclined coal pillars,
- When the longwall face was undermining upper chamber coal pillars.

The mechanisms of these strong weighting events under various mining conditions were analysed as associated with the movement patterns of the rock blocks that were formed during the excavation of the first seam. It was found that, under the three conditions, it was difficult to keep these blocks maintaining stability or self-supporting during the excavation of the lower seam. Once failed, the load previously sustained by the blocks would be transferred to the lower longwall face, resulting in strong weighting events and excessive convergence causing longwall supports to become iron bound.

Prevention and management measures were suggested based on the postulated mechanisms of the various conditions. In addition to the direct control measure of increasing the load capacity of the shield supports, other practical measures that can change the movement pattern of the rock blocks created by the excavation of the upper seam were suggested.

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