STUDY OF THE IMPACT OF MINING UNDER MASSIVE ROOF AT DATONG COAL MINES, CHINA

By

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ABSTRACT

The Jurassic coals at Datong are characterised by their strong, massive sandstone and conglomerate roofs which fail suddenly over large areas, crushing pillars and creating destructive windblasts. Collapsed areas have exceeded 180,000m² and windblasts have extended over one km underground and 200m on the surface and have been accompanied by subsidence troughs on the surface. Scientific analysis has researched premonitory signs of caving and the nature of windblasts leading to considerations of alternative mining methods and ways of dissipating the energy of windblasts to reduce their damage and danger.

INTRODUCTION

The immediate hard roof in a coal mine is directly in touch with the coal seam, and, having great strength, does not cave immediately after mining. The difficulty in caving is due to roof strength, thickness and hardness. It is structurally massive with only a few joints, fissures, bedding planes and cracks. Not only is the roof thick bedded, but it caves in large blocks. The rocks are not only strong, but hard and give problems in drilling and breaking. The coal seams mined at Datong coal mine belong to the Jurassic period of the Mesozoic Era. Except for the less important thinner fine grain sandstone and siltstone with smaller fractures, the more usual roofs of sandstone conglomerates with low frequency of joints and bedding planes and particularly the conglomerate is difficult to cave. Generally the roof is formed entirely of thick strata with a few weak planes. The average thickness of the strata is 5 to 10 m, with a few up to 40m. The compressive strength of the samples of roof strata is high, being over 100MPa. According to the Coal Administration of China, its classification is of low working face, with a hard and difficult caving roof, not unlike similar European and Soviet Union classification.

The characteristics of roof action and breakdown depend on the structure and properties of hard caving roof. Often, the roof caving taking place with great force and destruction which is the greatest danger to safety and production. This study of the characteristics of the entire caving of the hard difficult caving roof examines control of the damage it produces.

Aspects of these problems were addressed by Song(1977, 1988).

THE TYPICAL SITUATION OF A SUDDEN CAVING OF THE ENTIRE ROOF

Typically in a hard roof coal mine, after an area of coal seam has been mined, a corresponding area of roof is exposed and the mining stress produces an entire caving. Many such occurrences take place in the Datong Coal Mine of China. The large area of total caving takes place with a hard difficult caving roof and is a strong dynamic phenomenon. Not only is there the destructive impact but the air in the gob is squeezed out to cause an air blast with strong destructive action. The formation of the air blast is typified in two examples from practice.

1 Datong Coal Mining Administration, ShanXi, China

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1. The Roof Entire Caving Once in a Small Area at Yungang Mine

Yungang Mine is a large mine, with productivity of 4Mtonne/yr. The mine is fully mechanised including at the working face, but in some seams with poor geological conditions, the method of mining is by bore and pillar, as in Panel 8 South with Seam No. 3.

On the 8416 face, the average thickness of the seam is 2 m, the length of the face is 127 m, and the roof consists of medium grain stone. The distance between the pillars is 25 m and the width of the roadways between pillars is 5 m. These are connected with crosstabs above and below for mine equipment transportation, as shown in Fig. 1. The crosstabs are 2 m wide.

After the first row of pillars was mined the roof remained intact, and all the supports and other mining equipment were moved over to the second panel pillars. When the mined-out area, which was 127×9 m², combined with the mining of the second panel pillar, the mined-out area of the first panel pillar, consisting of medium grain stone of 70×25 m², suddenly fell completely creating a large windblast.

The upper crosstab in the coal face filled up with the larger caving blocks, so the roof beneath the lower crosstab formed an incline of about 40°. At this sudden roof fall, an operator in the lower crosstab was sucked into the gob of an adjacent pillar panel for a distance of 2 m by the reversed return air current. The pusher jack in the lower crosstabs adit was drawn to the gob for 5 m, the cowl was drawn to the gob for 3 m. With the roof caving, the lower pressure space between areas of caved and stable roof built up pressure and produced the air current. The air flowed out from the gob as the roof collapsed. The current reversed and the negative air pressure sucked a pusher jack and operator into the gob.

2. The Entire Roof Caving in Qing Yangwan Shaft

In the 832 mining area of 402 panel at Qing Yangwan shaft of Wu Jing Wang Colliery, the thickness of the seam was 4.0 to 4.3 m and the seam was mined between the roof and the floor in a single pass with the room and pillar method. The width of the rooms was between 8 and 10 m, the number of pillars between rooms was between 6 and 8, the length of room was between 200 and 500 m, and the depth below ground was 84 to 104 m. When the mined-out area was 163,000 m² at 10/22/1961, the roof caved entirely. The area of roof caving was 12,400 m², and a circular basin of 124,300 m² was formed by ground subsidence of 0.5 to 1.0 m with a large number of cracks appearing around it (Fig.2). When the area of gob was up to 163,000 m² in May, 1961, the area of pillars was about 33,200 m². The pillars in the panel were recovered from 25th October. The movement appearing in the roof, accompanied by noise, gradually extended and intensified, the pillars spalled, the floor heaved and the roof suddenly collapsed near the fault. The rate of roof downward movement had been measured and the highest was about 100 mm/min.

The large area of roof caving produced a strong widespread dynamic air movement which caused damage. The shaft was sucked by the air current, and along with it over 90 supports were damaged.

The ventilation system was also damaged including two air crossings, and thirty air stoppings blown down. Two minecars filled with one tonne of coal and were blown down, and a switch weighing about 50 kg was thrown 150 m including through three right angle bends.

THE ANALYSIS OF OF HARD ROOF MOVEMENT

Through analysis of strata pressure behaviour in large caving of the hard roof at Datong Mining Administration, the following can be inferred:
Roof caving over a large area takes place mostly at the face where the roof is supported with pillars. A number of pillars are left in the mined-out area to provide support to the difficult to cave hard roof. The strata pressure acts on the pillars continuously, each pillar sustaining its own pressure field, and eventually the pillars are damaged and their supporting capacity is reduced. The balance between the roof and pillars is broken, and the entire roof caves rapidly.

Before an entire roof cave occurs over a large area, normally the pressure build-up becomes evident. The collective pressure acts on the pillars, the roof strata moves and cracks, the pillars spall and roadways around the perimeter come under pressure. Deformation of boreholes in the seam, drillholes jamming in the borehole, and cracks in the roof and water flow from the roof are typical manifestations. The onset of caving can be anticipated from:

1. pillar spalling or bursting in the working face, accompanied by the noise of movement,
2. increased rate of roof sag,
3. roof and floor cracking and rupturing of roof with thunderous noises, areas of floor heave, and cracking of floor along pillars,
4. cracks and infiltrating water appearing in the roof, and
5. vibrations due to the cracking of the roof of various wave shapes according to the rock types and measurable by vibroscope.

Roof caving of large areas can be of two types, complete and separated areas, which are due to the following factors:

1. Rock Properties and Structures of the Roof

If the roof strata have many bedding planes, joints, and weak partings, separated caving takes place mostly. Conversely, if the rock is hard and strong, the strata is massive, the integrity is high and entire caving mostly occurs.

2. Geological Structure

Separated caving takes place mostly in areas with many small geological structures or where the roof conditions change quickly. With the converse, entire caving takes place.

According to the analysis, the stability of roof depends on the stability of pillars. This is because:

a. The stability of pillars is related to the ratio of the pillar's width to height of the pillar and its size, form and distribution. The pillars at Datong have a width to height ratio of 3 to 4, which is satisfactory for the needs of roof control.

b. The stability of pillars is also related to their horizontal size and their distribution of pillars. A single pillar left in the mined-out area and irregularly distributed pillars are easily destroyed by the roof strata pressure.

Both practice and model examinations showed that the ratio of the total area of the pillars in the gob (b) compared with the total area of the gob (a+b) is:

\[ S=b/(a+b) \]

This is an important parameter for roof stability as the ratio of pillar area approaches a constant value. Where the roof is supported by damaged pillars, the value of S could be greater than 35% for a thick seam. For thin and medium seams, the value of S should be greater than 50% for increased stability.

**IMPACT OF AIR PRESSURE WHEN CAVING OCCURS**

As hard roof is difficult to cave, there will therefore be a considerable amount of uncaved roof in the gob. A sudden collapse of the roof would produce an air blast which is a key problem in mine safety.
A gob is virtually an air container; the entire roof, in caving, compresses the air in the gob. The energy of the compressed air due to air blast acts any air stoppings and spreads to the adjacent roadways. The impact of the air blast along the roadways represents the biggest danger to safety and productivity.

According to Boyle's law, the relationship between the volume of air and pressure at constant temperature is

\[ P = \frac{P_0 V_0}{V} \]  

(1)

where: \( P_0 \) is the air pressure before roof caving

\( V_0 \) is the volume of air in the gob before roof caving

\( V \) is volume as the result of rapid roof caving

\( P \) is the new air pressure due to roof caving

Thus, the air pressure in the gob following roof caving depends on the changes of the volume of the gob and the area of roof caving. Formula (1) can therefore be simplified as:

\[ P = \left(1 - \frac{n}{100}\right) P_0 \]  

(2)

where \( P \) is the air impact pressure, \( P_0 \);

\( n \) is the "area change coefficient," that is the comparison of the gob area and the roof caving area.

Formula 2 is a double curve function, pressure \( P \) being the function of \( n \) as shown in Fig. 3.

For better understanding, the effect of air pressure impact, the components of Formula 2 can be analysed as follows:

A number of pillars remaining in the mined-out area and carrying a large portion of the still hanging roof will be seriously damaged due to roof weighting. Hard competent roof normally caves as a large block. The size of the caved rock can vary from ten to tens of meters. The thickness of the strata caving near the gob perimeter will be rather thin, in comparison with thicker roof failures at the centre of the gob. The gob area would not usually be filled up with caved material.

The formula is inferred from the condition of ideal air pressure. In practice, the pressure greatly changes at different locations in the mine, and the influence coefficient of air pressure (K) should be increased as the situation dictates.

\[ K = \text{air pressure in shaft/ideal air pressure, then} \]

Formula 2 becomes:

\[ P = K \left(1 - \frac{n}{100}\right) P_0 \]  

(3)

The pressure produced by a caving of a large area of roof caving at Datong coal mine, China, is calculated as shown in Table 1.

The energy of the compressed air is applied in the mined-out area. To maintain a balance, the air will be discharged from the gob to the outside at high speed, and the surrounding coal perimeters and the stoppings are thus subjected to the air pressure given as:

\[ P = \left(\frac{V^2}{2gr}\right) \]  

(4)

where

\( V \) is primary speed of compressed air current, m/s;

\( r \) is the density of air, \( \text{kg/m}^3 \);

\( g \) is the gravitational acceleration 9.81 m/s².

Based upon the ventilation resistance law, when the air flows in the roadway, the increase of pressure relates to the resistance of the roadway, which consists of three parts, that is friction, front resistance and partial resistance.

The air blast pressure is extra strong when the large area of roof caving takes place rapidly and its movement along the roadways out of the gob mainly appears as friction. This can be expressed as follows:

\[ R = a(LP/S) V \]  

or \[ R = a(LP/S) Q \]  

(5)

where:

\( L \) is the length of roadway, m

\( P \) is the surrounding length of roadway, m

\( S \) is the cross-section area of roadway, \( \text{m}^2 \)
\[ Q = \frac{R \cdot S}{a \cdot L} \cdot P \]

\[ Q = \frac{(R - S) \cdot a \cdot L}{P} \]

\[ Q = \frac{R \cdot S}{a \cdot L} \cdot P \]

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The key problem of using the blocking air to deal with the air impact damage produced by the large area entire roof caving in the gob is isolating a large area with roof which refuses to cave by pillars into separate smaller areas. An air stopping which can withstand the impact of 10 atmospheres of air pressure, is built in each of the separated areas to prevent the destruction by windblast. Thus, the pressure decrease of the air pressure front from the caving roof will balance the frictional resistance of the roadway.

The blocking air barrage consisted of an "A" block stopping and buffering strip. The "A" stopping can be designed for conditions below 10 atmospheres air pressure. The "A" and circle theories are the way to calculate the water-proof dam. The buffering strip applies to both the actions of active and static pressure.

CONCLUSION

The rapid caving of large areas of hard roof has several characteristics. The damage produced by windblast from the gob is a serious accident, therefore the study of the subject is very important in the mining of this kind of coal seam.

Because of this and because prevention is difficult to achieve, the buffering stopping wall provides an efficient way in preventing the damage of windblast. But these special procedures involve expense and involve lower recovery.

To prevent the damage of the windblast produced by rapid hard roof collapse, the source of the windblast must be removed beginning with changing the mining methods, such as by softening massive roof strata by water infusion and inducing caving by blasting in boreholes.

REFERENCES


Fig. 1 Plan of Panel 404 in Yungyang Coal Mine showing fissures formed on the surface after the great roof collapse.

Fig. 2 Some surface cracks after gob roof collapse at Qing Yangwan Shaft.
Fig. 3. The relation of air pressure and "Area Changing Co-efficient".

(a) Plan

(b) Detail

(c) Section AA

Fig. 4. Details of special thin stoppings and leakage roadways for dissipating windblast pressures.

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**TABLE 1  DAMAGES DUE TO LARGE GOAF FALLS IN DATONG COAL MINES**

<table>
<thead>
<tr>
<th>Mine name</th>
<th>Panel</th>
<th>Date</th>
<th>Area of overhanging roof in mining area</th>
<th>Area of roof entire caving instantaneously</th>
<th>Calculation in theory of air blast pressure</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wa Jing Wan Qing Yang Wan Shaft 14:402</td>
<td>July, 1960</td>
<td>63010</td>
<td>22810</td>
<td>35.41</td>
<td>0.86</td>
<td>1.33 x 10⁴</td>
</tr>
<tr>
<td>Wa Jing Wan Qing Yang Wan Shaft 14:832</td>
<td>Oct, 1961</td>
<td>184047</td>
<td>163000</td>
<td>76.1</td>
<td>0.86</td>
<td>3.6 x 10⁵</td>
</tr>
<tr>
<td>Yan Ya</td>
<td>11' 301</td>
<td>Oct, 1964</td>
<td>30001</td>
<td>17370</td>
<td>57.9</td>
<td>0.88</td>
</tr>
<tr>
<td>Ma Fa Liang</td>
<td>2' 402</td>
<td>June, 1975</td>
<td>151280</td>
<td>125202</td>
<td>82.83</td>
<td>0.87</td>
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</tbody>
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