A STUDY ON THE HIGH-WATER SOLIDIFYING MATERIALS FOR GOb-ALONG ROADSIDE INSTEAD OF COAL PILLARS

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ABSTRACT
A new technology has been introduced - the use of the High-Water Solidifying Material for providing pumped roadside supports to maintain a roadway for re-use in longwallRetreating. As a gob edge support, its initial use at Heji No. 1 Colliery was successful, providing acceptable performance in support and control of convergences and lateral closures of the gob-edge roadways. This acceptability applied to both first use and re-use when the roadway became a gateroad for the adjoining longwall, remaining stable throughout the associated loadings and convergences. The technology promises economic and social benefits.

INTRODUCTION
In modern longwall mining operations, problems between coal extraction and panel preparation and coal loss and spontaneous combustion are becoming more conflicting as mining depths increase and with higher mine mechanization. To leave and maintain a road along the gob edge without coal pillars is one of the most effective means of comprehensively solving these problems.

Theoretical and practical researchers have concluded that the key to the success of leaving a road along the gob is support. In seeking an effective means of support for such a roadway, Beijing Graduate School of China University of Mining and Technology has expanded great effort and successfully developed a new type of material, the High-Water Solidifying Material. This material has been used with satisfactory results in roadside stowing to maintain a roadway along the gob edge in coal mining.

THE MATERIAL
The High-Water Solidifying Material has the following properties and uses:
1. Ingredients: two kinds of solid powder materials, substance A and substance B. They must not be mixed before use.
2. Strong water-solidifying capability. When these two substances are mixed with 90 percent of water to form a slurry, they quickly become a high-strength solid - artificial stone.
3. Fine pumpability and pumpable for a long time. The slurry mixture flows and sets well. Slurry A and slurry B, if kept separately, can both remain liquid without solidification, for one to three days.
4. Quick setting and with early developed strength. When slurry A and slurry B are mixed in 1:1 ratio, they will set into a type of strong artificial stone in between 5 and 30 minutes. The strength increases very quickly. Normally it will reach 0.5MPa in strength within an hour of mixing, 1.5 in two hours, 3.0 in one day, 4.0 in three days, and 5.0 in seven days. Moreover, the artificial stone has high residual strength after being cracked.
5. The material is weakly alkaline, slightly corrosive, and harmless.
6. Although its major use is in stowing, also it is incombustible and useful in sealing goaves and firefighting, is a substitute for low strength concrete, is useful for solidifying industrial wastes and it has uses as an urgent construction material.

CASE STUDY
GEOLOGICAL AND MINING CONDITIONS
The experiment was conducted in Panel 1807, Heji No.1 Mine. The purpose was to maintain the transport roadway of Panel 1807 for Panel 1808 use.

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Both Panel 1807 and Panel 1808 are retreat longwall mining faces. Coal winning is done by blasting, and faces are supported by means of frictional steel beams and props. The trapezoidal road has a cross section of trapezoid, 5.61 m², and is supported by flexible and rigid I-shape steel (Fig.1). The panel is 400m and 80 m wide as shown in Fig. 1. The area is complicated with geological disturbances. The transport roadway encountered four faults, with a maximum displacement of 2.2 m.

The working seam No.8, is about 2.0 to 2.4 m thick, has 4 to 10° dip and lies about 210 m below the surface. The roof of the seam is composite, with 2.76 m thick mudstone with well-developed fissures and cracks which is very easy to cave. The floor is sandy mudstone, 3 m thick.

The return airway of Panel 1807 is abandoned as the face proceeds, while the transport road is maintained along the gob. While Panel 1807 is mined out, the east, south and west sides of Panel 1808 will become gob areas.

THE STOWING SYSTEM
The High-Water Solidifying Material stowing involves building a certain width of continuous wall along the gob edge by pumping in the High-Water Solidifying Material as the face proceeds. Its role is to replace coal pillars that are conventionally used to protect the roadway. This stowing wall is made by placing bags of stowing material closely aligned so that the wall will be continuous and compact. The stowing system consists of several subsystems:

1. Slurry-preparing sub-system, consisting of two identical sets of stirrers with water and material feeders.
2. Delivery sub-system, having two identical sets of stowing pumps and pipelines.
3. Mixing and shaping sub-system, comprising a mixer, a mould frame and stowing bag. Fig. 2 is a flowchart of the stowing system. Slurry-preparing equipment and pumps are placed in a chamber that is far from the face. The in-mine layout of the stowing system is shown in Fig. 1.

Fig. 2 Flowchart of the stowing system

THE STOWING PARAMETERS
Width and Strength
These two parameters are highly dependent on roadside supporting resistance, a key factor to the maintaining of gob along roadway. According to Henghu Sun (1988)

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11th International Conference on Ground Control in Mining. The University of Wollongong, N.S.W., July 1992. 372
The roadway may be estimated:

\[ P = \frac{1}{m} \left( a + \frac{n-1}{2} \right) + \frac{2}{\tan \alpha} \left[ n \cdot (n+1) \cdot a \cdot h \cdot g + \frac{1}{b} \right]
\]

where
- \( P \) = supporting resistance of roadside supporting body, MN/m,
- \( a \) = road width to be maintained, m,
- \( n \) = number of caving layers of the roof,
- \( r \) = average density of caving strata, MN/m³,
- \( h \) = average layer thickness of caving strata, m,
- \( \alpha \) = supplementary angle of strata cut-off angle,
- \( \beta \) = cut-off rock length of the \( n \)-th layer, m,
- \( R \) = tensile strength of the \( n \)-th layer, MPa.

In Hebi No. 1 Mine, the values of the above parameters are:
- \( n = 9 \), \( h = 0.8 \) m, \( a = 4.5 \) m, \( l_{\beta} = 5 \) m,
- \( r = 0.025 \) MN/m³, \( R = 5 \) MPa, \( a_{\beta} = 3.5 \) m.
Then \( P = 1.7 \) MN per meter of roadway. In other words, the carrying capacity of the stowing body shall be no less than 1.7 MN/m.

For operational convenience, stability of the stowing wall, and safe production and economics, a 1 m wide stowing wall was adopted. The stowing material was required to reach 1.7 MPa or more within a day. The authors chose No. 2 solidifying material, which had a strength of 0.5 MPa in an hour, over 2.0 MPa in a day and higher than 3.0 MPa in three days.

**Height and length**

Stowing height means the height of the space to be stowed. In Hebi No. 1 Mine, it is seam height 2.0 to 2.4 m. Based on the advance rate of Panel 1807, the length of each stowing was chosen as 2.0 m. Therefore, the dimensions of stowing bags should be 2.0x1.0x2.4 m.

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One and a half years of site observations and measurements, have resulted in approximately 60,000 items of data being gathered. Analysing this data has helped reach the following conclusions about strata behaviour. Curves of deformation of the surrounding strata are shown in Fig. 3.

**Fig. 3 Curves of the strata deformation**

**WHEN THE ROADWAY IS USED THE FIRST TIME**

From Fig. 3, it can be seen that the convergence rate between the roof and floor increases rapidly up to 10 m from the face line, reaching 19 mm/day at maximum. In other words, the area that is significantly affected by mining operations is within a range of 10 m from the face line. When mine operations have passed by, the convergence rate between roof and floor increases markedly, and reaches the peak value of 85 mm/day 2 m behind the face line. 5 to 30 m behind the face, the convergence rate varies between 2 and 12 mm/day, then it declines considerably, normally less than 4 mm/day at 30 m or more behind the face. At 80 m or more from the face line, the convergence rate reduces to 0 to 2 mm/day; in other words, the strata becomes stable. From these observations, it is assumed that the influential zone of mining operations is up to 80 m behind the face, with the area severely affected being up to 30 m behind the face.

At the point of 130 m behind the face line, the average total convergence between roof and floor is 345 mm or about 15.7% of the extraction height. Of this
345mm, after the gob edge support has been filled, the convergence between roof and floor is only 166mm which represents 48.1% of the total convergence.

In the conventional gob-edge roadway, not stowed along the gob edge, the roof-to-floor convergence on the gob side is twice as much as that on the solid coal side. Site measurements have shown that when the High-Water Solidifing Material is used to stow the gob side, the convergence in the gob side and the solid coal side are basically the same. This means shows that the stowing of the High-Water Solidifying Material controls the roof effectively.

The horizontal contraction of the two sides of the roadway in relation to the advance of mining operations is similar to that of the roof-to-floor convergence. From the point 40 m ahead of the face line to 130 m behind the face line, the total movement of the two sides towards the centre was 176 mm, or 8% of the extraction height. Of the 176 mm, the movement occurring after the face line passed by is nearly 124 mm, about 70.5%. Thus, most of the movement happens after the face line has passed by.

《WHEN THE ROADWAY IS USED THE SECOND TIME》

From Fig. 5, it is clear that the roof-to-floor convergence rate increases significantly from the point 13 m ahead of the face line, and reaches the peak value near the face line. Observations show this to be 15 mm/day on the stowing side, and 8 mm/day on the other. During re-use of the roadway, the total roof-to-floor convergence averages 62 mm.

From Fig. 3, it can be deduced that the variation in rate of displacement between the two sides of a roadway is similar to that of roof-to-floor convergence. The peak value is 12 mm/day. The total displacement between the two sides is 80 mm, which is larger than the total convergence between roof and floor.

《LOAD OF ROADWAY SUPPORT》

During the mining of Panel 1807, the vertical load on roadway supports reached the peak value of 129.4KN/support at 43 m behind the face line, and at 52 m behind the face line, the lateral load reached its maximum of 96KN.

During re-use of the roadway, vertical and lateral loads on roadway supports reached a peak value of 208.2KN and 72KN respectively, when the face line of Panel 1808 was in the vicinity of the supports.

《BEHAVIOUR OF THE STOWING BODY》

The load variation on the gob-edge stowing body is presented in Fig. 4. It can be seen that the load increase was rapid from when the stowing body was formed to when the face line was 60 m away. At 60 m behind the face line, the load on the stowing body rose to 2.2 MPa. Such a large load bearing capacity and increasing rate of resistance during this initial period can effectively stop the separation of roof beds thus greatly reducing the roof convergence and timely breaking the gob roof to protect the roadway supports.

When the face line was 78 m away, further incremental loading on the stowing body slowed down as the face advanced. At 85 m or more behind the face line, the load on the stowing body became basically stable, and stayed around 2.5MPa.

The vertical deformation of the stowing body developed rapidly from 20 m to 60 m behind the face line. Then it became virtually static. The maximum vertical contraction was 64 mm, or 2.8% of the height of the stowing body.

《TECHNOC-DYNAMIC EFFECTS》

In Panel 1807, about 400 m of roadway were maintained by stowing the gob edge. Tests in mines have shown that competitive techno-economic results can obtained by the application of the High-Water Solidifying Material to stow the gob-edge of the roadway, and the roadway can fully meet the requirements as a second-time use roadway.
CROSS SECTION

Site measurements indicated that the overall conditions of the re-use roadway is satisfactory. Its height reduces slightly from 2.2 m to 1.9 m, the contraction ratio being about 15.5%.

ROADWAY SUPPORTS

According to statistics, roadway supports remained in good condition, with a support failure rate of 4.1%, which is far better than that of other types of re-use roadways.

THE GOB-SIDE STOWING BODY

According to statistics, 75.7% of gob-side stowing bodies remained in good condition, 16.2% had slight deformation, and only 8.1% had serious deformation.

SEALING PROPERTY

Site measurements have shown that from 10 meters behind the face line, air leakage is 1.34% per 100 meters of roadway. This implies that the stowing body has a good sealing property.

ECONOMICS

Calculations show that the cost for using the High-Water Solidifying Material to stow gob-edge roadsides, in replacement of coal pillars, is RMB348 per meter of roadway, which is roughly equal to the cost of opening a new roadway. However, in using the gob-edge stowing roadside technology, no coal pillars are required, so the coal recovery rate is greatly increased and the time to prepare a new panel is shortened. Thus, costs of moving machines from one panel to another are saved. Therefore, the overall economic efficiency of the gob-edge roadway stowing technology is significant.

CONCLUSIONS

1. The use of the High-Water Solidifying Material developed by Beijing Graduate School of China University of Mining and Technology to support the gob side of roadways in place of coal pillars is technically and economically feasible. This technology, the first of its kind in China, can achieve the expected results.

2. The contraction rate of the road section area is only 15.5% which fully meets the requirements of a re-use roadway.

3. The High-Water Solidifying Material chosen for the gob is appropriate. All its properties are rational, and the stowing wall has proven effective in breaking off the gob roof, controlling the roof and floor convergence and sealing off the gob.

4. The parameters designed for Hebi No.1 Mine are sound and rational. Under those geological conditions, the stowing body of less than 3.0 MPa in strength and 1 m in width is practically viable.

5. The stowing system is simple and easy in construction, and low in capital investment. The stowing technology is advanced and convenient in operation, and can easily be transferred to other mines.

6. Stowing the gob-side of a roadway with the High-Water Solidifying Material is results in significant economic and social benefits, thus the procedure has great application in the mining industry.