Study on the Mechanism and Control Technologyof Floor Heave in the Laneway

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Abstract: Floor heave is one of primary forms of failure of laneway, and also one difficulty points of maintenance of laneway. In order to promote the uninterrupted growth of the research field . On the basis of Chinese and foreign present situation of research, author comprehensively expounds formation reasons, basic types and control approaches of floor heave of laneway. Not only may to make full use of important role in stratum control of mine, but also to possess generally meaning to tunnel engineering of highway, railway and various underground engineering.

Key words: stratum control; floor heave of laneway; mechanism of floor heave; control of floor heave

1 Introduction

The effective control of the Rocks exposed on the face is an important issue in the field of engineering and mining, and the control of floor control is an important and difficult problem during the course of strata control [1]. The Chinese mines such as Shulan, Shenbei, Liaoyuan, Longkou, Jinchuan, Nalong as well as Meihe have been seriously troubled by floor heave over a long period of time (Fig.1).

(a) The floor heave in medical underground chamber **(b)The floor heave in underground charging chamber**

Figure 1. The severe floor heaves in mine

The study shows that about two thirds of the closer between the roofs and bottoms of the laneways were caused by floor heaves. The influences that the floor heave brings to the mine's production and security are as follows: First, The cross-section of the laneway becomes narrow, which causes the laneway loses the function of sidewalk, ventilation and transportation; Secondly, the expense of the maintenance of the laneway increases largely; Thirdly, influence the deployment of manpower and the formal circulation work are disturbed, which prolongs duration of the project; Finally,the workers' emotions were extremely suffered from the floor heave which results in a reduction of work efficiency.

The influence of the floor heave on the laneways varies from different types of laneways. Laneways are divided into two kinds according to their arrangement: One is the main laneways which are laid out in the rock; the other is the accessory laneways which are extended to the working surface. The floor heave of the former usually occurs in the mine whose depth is more than 750 meters, but the floor heave can even appears in the laneways which are buried about 500 meters when the bottom is very soft. Most of the accessory laneways, especially the trough of the long wall face, may be affected by the floor heave. The ideal control model of floor heave in trough includes appropriate support and construction method which needs regular cross-section, high-quality support and backfilling as well as appropriate and adequate roadside packing.

2 Conformation of Floor Heave

A large number of theoretical studies and underground observations show that, the appearance of floor heave may be derived from the followed causes[2-6]:

2.1 Direct Causes

The floor heave comes into being when the bottom of the laneway is soft and its bearing capacity is insufficient, which was induced to the geological structure of the coal floor: first of all, the capillary roots of coal plant have been widely distributed in the carbon layer of the floor; Secondly, a lot of frictional slip happens between the clay in the bottom of coal and adjacent rock; Thirdly, the strength of the clay in the underground of coal reduced greatly when it encounters water and swells. With the effect of rock stress, the bottom rock give rise to plastic and rheological deformation easily.

2.2 Indirect Causes

The high support pressure is an important factor of

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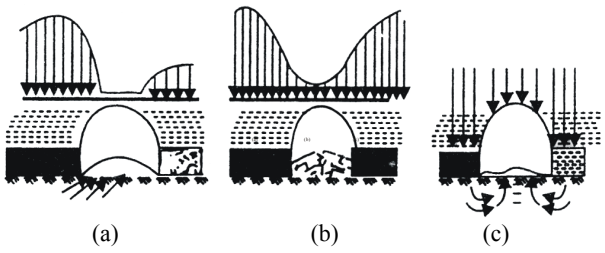
the floor heave. Practice shows that the floor heave in deep mine is worse than that in shallow mine which is due to the high support pressure of the deep mine. Under the ordinary coal conditions, ground pressure increases at the rate of 0.23 kg/cm2×m-1. The bottom displacement calculated by the mechanic model based on elasticity theory shows that the floor heave owing to the high support pressure of the lateral coal in the laneway.

Under the mining environment, common existence of groundwater can change the intensity and volume of soft rock layer, which contributes to the reduction of the rock mass bearing capacity until being zero and accelerates the rock mass plastic deformation and swelling deformation at the same time. The next, the wide laneway is easier to suffer from floor heave than the narrow laneway.Therefore, under the precondition of meeting the need of mining work, it's feasible to increase the height and decrease the width of the laneway correspondingly to maintain the size of its cross section. Furthermore, the effect of strata control is major factor in the formation of floor heave. The formation mechanism of a floor heave can be summarized as: under the high bearing, all the soft bottom rock of the laneway begins to shear failure and swell after absorbing some water. Finally, the floor heaves takes shape (Fig.2).



(a)Extrusion under the coal wall (b)Warpage deformation of the floor without constraint (c)Cutting effect of the arch support

Figure 2. Three elemental types of floor heave

3 Experimental Study

3.1 Study Purpose

The support style depends on the intensity condition of the laneway floor. In most cases, roof subsidence is due to the destruction of the laneway floor which makes the support lose balance. As a result, one of the most important tasks about the research is to obtain the integral information about the characteristics of the laneway floor. So it's necessary to make a comprehensive analysis of laneway floors. In addition, the stability of the laneway is also decided by the states of the raw rock and the direct displacement of the surrounding rock.However, to obtain the materials about how to improve laneway stability, it's imperative to observe the type and extent of the surrounding rock deformation. So far, although there are some limitations in the field of measurement about strata control and lots of problems have not been solved in theory basically, the survey is very beneficial and feasible in some respects.

3.2 Lithology Analysis Test

In order to obtain a more comprehensive understanding about the floor heave, it's essential to survey and evaluate the mechanical characteristics of the clay under the laneway floor, which is the first task of all experiment study. The outcome shows that the mineral is obvious, especially mineral affinity to water is rather significant. The rock bottom contains montmorillonite is especially subject to the water. The impact of water on rock strength can be expressed by empirical formula:

$$s_c = k s_0 e^2 \quad (1)$$

Where k is a experience coefficient; s_0 is the uniaxial compressive strength of rock; e is the saturated rate of water.

The specific way is that certain number of clay under coal which collects from different site is used to make shear strength test and uniaxial compressive strength test. In the process of collecting sample of clay. Some related material which is required for the experiment should be collect, such as the clay's thickness, humidity, depth, coal's cutting height as well as total area of mining area.

3.3 Determination of Floor Heave

The best practicable technology of measuring floor heave is multitier borehole extensometer technique. The principle is that a 3~5m deep hole is drilled in the bottom and several of sticks with iron wire are inserted into the hole. Next, iron wire should be tightening up and the mark tied up on every iron wire would be measured regularly. By this way, less skilled operating personnel can achieve the measurement results whose deviation is not more than 0.5~1.0mm and skilled operators can make it less than 0.01mm. The key to ensure the accuracy of measurement result is a stick should be sufficient to achieve the insertion depth of the original rock.

4 Adaptability of Control Measures[7-9]

Over the years, many scholars have been concentrated on the research and exploration of floor heave control and have made continuous progresses. So far, the proposed control method can be summarized into two main categories: strengthening method and stress-relief method. In practice, a number of ways are applied to control the serious floor heave simultaneously. The common features and applicability of several methods were compared as follows.

4.1 Roadside Packing

Roadside packing method, filling between laneway and coal, that is a traditional way of control method of floor heave. It improves the resistance of the clay in the

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coal bottom sliding to the laneway by moving the rock lateral pressure to change the pressure distribution. British scholar verified the support principle through the ratio of this principle was further confirmed support whose length of filling packing is about 3 meter. It is worth pointing out that the strip packing has sufficient bearing capacity, otherwise it will break down because of the sank of the roof.

4.2 Roadside Slotting

Opening trench on the coal next to roadside, which is an effective method of lowering rock pressure by removing the lateral bearing pressure to the coal far from the laneway. However, this method has some limitations because there are some difficulties to set up support in the limited space of the gate road.

4.3 Closed Support

A closed support is applicable to the laneway which is round or elliptical. It can make a larger restriction to the floor. But such support is used only under special occasions in the main laneway because of its high cost and forbidden to be applied in the gate road. So closed support is not used widely.

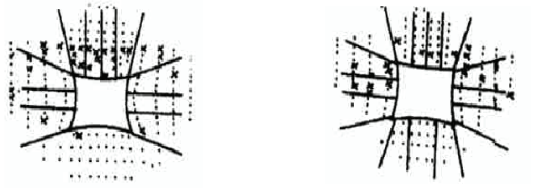
5 Mechanism of Anchor Reinforcement

So far, domestic and foreign scholars have studied the mechanical principle of the anchorage reinforcement of the laneway floor from multi-angle and multichannel. This paper, according to the rock beam theory in the Mechanics of Materials, analyzes the deformation and destruction of the laneway floor on the basis of fixed beam. According to the Materials Mechanics, the maximum bending moment is in proportion to the square of the span, and the total deflection is proportional to the fourth power of the span. The high support pressure of the two sidewalls is vital to lead to the floor heave if the laneway is treated as a rectangular beam, which is similar to the mechanical phenomenon of upward deflection. It's obvious that the inertia moment of a rectangular beam:

$$I = \frac{bd^3}{2} \quad (2)$$

Where b is the beam width; d is the thickness of beam.

After the lane has been excavated, two-lane and basic angle plastic zone appears in the two sidewalls and base angles easily under the function of centralized stress. With the development of plastic zone, the floor heave of the laneway is more serious because of the plastic deformation.The distribution of plastic zone of surrounding rock with or without bottom anchor is diagramed as follows (Fig.3) [10]. Firstly, the anchor reduces the stress concentration in the corner of the laneway, and the high bearing capacity arch appears on the two sides which helps to control the expansion of plastic zone; Secondly, the self-supporting ability of the rock on the two sidewalls and corners is improved.



(a) (b)

(a) Distribution of plastic zone without bolting

(b) Distribution of plastic zone with bolting

Figure 3. Distribution of plastic zone in floor rock

6 Experiment of Anchor Reinforcement

The underground experiments are necessary to draw up a right scheme. The following are the anchor reinforcements under different conditions as well as the test results.

6.1 In Middle Depth and High Pressure Areas

The tested laneway is located in the coal seams whose depth is about 500m. The constringency between the roof and floor of the two gats in the heading face comes to 1.2～1.5m which is mainly taken on the floor heave. The gate road must be maintained by four people every day. The two gates all were strengthened with wood metal anchor. Along the main gate, wood anchor were laid out in the way of 3m × 4m, which is fixed perpendicularly to the floor. A row of wood anchors need to be installed between two arch supports whose spacing is 0.9m. However, four metal anchors are arranged between each pair of arch support , two anchors on each road, installed by the angle of 45° below the every sideway of the laneway. The wood anchors are arranged by 2m ×3m and two metal anchors are fixed between each pair of arch support, which avoids the undercover operations and laneway maintenance of the two gate roads. Then a few hundred meters of the laneway has been reinforced.

6.2 In Mining Area Where the Heave Is Serious

When the depth of the laneway with all kinds of the surrounding rock comes to or exceeds the limited depth, the convergence of the surrounding rock steps up with increasing depth of the laneway (Table 1).

Table 1.The limited depth and incremental displacement of rock

The type of the Surrounding Rock	Bounding Depth(m)	Displacement Increment Per Additional 100m(mm)
Soft Rock	150	400
unstable rock	300～400	134
Secondary stable rock	650～750	80
comparative stable rock	＞1000	50

The connection between the depth of the laneway and the convergence of the surrounding rock is showed in Fig.4[11]. The test site is a downward gate that lies in the approximately 850m deep advancing working face. The anchor is arranged by 3m × 4m, and two metal anchors are installed vertically and the two angle of inclination of the anchors below the two sidewalls is about 45°. The roof-to-floor convergence of the gate road before the floor rock was reinforced is about 1.2m, while that in the laneway which is strengthened with anchor is decreased by a half of the former.

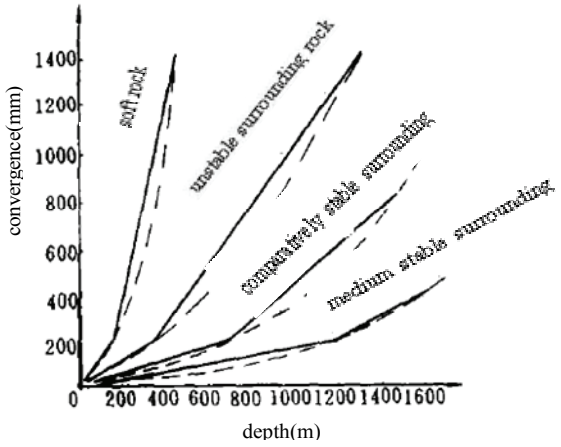


Figure4. The connection between the depth and the convergence

6.3 Under Rather Soft Bottom Conditions

The floor heaves results in the repeated undercover in the laneway if secondary top pick is lacking. The test site is located about 400m deep in the downward gate road of the advancing working face. The gate road is supported with metal arch support which is made of 10cm×10cm steel whose size is 2.4m×2.7m and the spacing is 0.9 m.The approach of the roof and floor came up to 1.5m which made it difficult to operate undercover before the reinforcement. But the laneway does not need to repair after being strengthened by anchor. In the area of anchor reinforcement, the average height and minimum height is 2.25m and 1.8m respectively, while the height is only 1.0m before the laneway was reinforced. Although the bottom board of coal layer is so soft that it becomes deformed as a form of sliding away without warpage. But this experiment indicates that effective contronl of the floor heave can be achieved as long as the floor of the laneway is approporately strengthened with anchor. Subsequently a series of these observing results are justified by the experiments on anchor floor- reinforcement in other mines.

7 Conclusions

The anchor reinforcement is the most cost-effective method of the floor heave control. Therefore, it's widely throughout the world. A lot of work on the theoretical research and practical test is carried out continuously. The mechanism of the anchor reinforcement should be fully disclosed based on the multidisciplinary and multi-angle theoretical study. Simultaneously, it's applicability under different geological conditions still needs to test in order to broaden the scope of its application.

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