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Study on repair control technology of soft surrounding rock roadway and its application

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ABSTRACT

In order to research the repair control technology of the inclined shaft with soft surrounding rock, the inclined shaft soft roadway of one phosphate mine in Hubei is taken as an example to study the damage characteristics, the deformation mechanism of the surrounding rock and repair control technology of it. The X-ray diffraction was employed to analyze the mineral components of the surrounding rock, also the surrounding rock contains clay minerals, which are easy to swell when in contact with water. The roadway mainly presents the damage characteristics of roof subsidence, two side walls extrusion, U-steel arch set bend or break, etc. The whole section double arch synergy reinforcement technology method of "sprayed concrete + grouting + anchor bolt + anchor cable" is proposed. And the technical parameters of the repair scheme are determined by theoretical analysis, engineering analogy and engineering practice. The numerical simulation is adopted to verify the feasibility of the whole section double arch synergy reinforcement scheme. The application results show that the large deformation roadway can be effectively controlled by the combined support scheme, which can provide certain references significance for similar engineering.

1. Introduction

With the rapid development of China, the demand of minerals in China is increasing rapidly, and many mines have been exploited. The geological condition of the underground engineering is complex, and many mines are facing the deep mining, so the soft roadway is a great challenge for the mines which are threatening the safety of mining [1, 2]. In many cases, the surrounding rock shows the characteristics of obvious soft rock, the compressive stress and shear stress is low, and the joints and cracks are developed [3] As a result, the soft roadway is easy to be damaged [4, 5]. Good practice indicates that more than 40% of soft roadways should be repaired for several times so as to guarantee its stability. Thus, the soft surrounding rock roadway is one of the pressing issues at home and abroad [6].

In order to solve this puzzle of the soft roadway, many theoretical analysis, numerical simulation and engineering practice have been studied. WANG et al. argued that because of the active pressure, low strength of the surrounding rock and improper original support method, the soft roadway is easy to be damaged [7]. HE summarized that the failure of the deep soft rock roadway is mainly

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caused by the following aspects: low strength of the surrounding rock, inadequate support, water effect, and structure stress effect [8]. BAI J.B. discussed the supporting principle of the high stress roadway, which provides the theoretical basis for roadway supporting [9]. LIU C. and HE M.C. used the numerical simulation technology to analyze the stability of the roadway, which can provide scientific guidance for safety production [10, 11]. QI G. and YU W.J studied the theory of stacked arch bearing arch strength, and applied the step by step combination technology to the support [12, 13]. LI proposed the coupling support of yielding shell to the high stress roadway [14]. The comprehensive support method employing bolt, meshes, anchor and lining is applied to repair the main roadway [15]. WANG Q. made an analysis of the deformation mechanism of the roadway, the research results show that the main reason for the soft roadway to be damaged is improper support schemes, the improper support form can't bear the deformation of the soft roadway [16]. All of these research results can solve the problem of soft roadway to some extent, but because of the complexity of the high stress condition and surrounding rock characteristics, the roadways in different conditions showed different failure characteristics. Moreover, the condition of soft surrounding rock roadway is complex [17]. First, the cracks and joints are developed. Second, the strength of surrounding rock is low, so special supporting method should be adopted according to different characteristics of the soft roadway [18, 19].

Based on the research results which have done before, the inclined shaft in China – Heiliangshan phosphate mine is selected as the research object, the inclined shaft is a typical soft roadway. To solve this problem, the support method employing bolt, meshes, anchor and lining is applied to it. Numerical simulation, engineering analogy and engineering practice are adopted to determine the parameters and construction process [20]. The deformation characteristics and failure mechanism of the soft roadway are analyzed, also mechanism of the new supporting method is revealed, the field displacement monitoring is conducted as a means to verify the effect of the repair scheme. The results can provide support for similar projects to achieve its goal.

2. Background

The annual production of the Heiliangshan phosphate mine is 1500 000 tons, and it's located in Hubei province and designed to serve about 20 years. The depth of the inclined shaft is 1200 m while its ingate is between +726 and + 1300 m under pithead. And it is the main transport channel of the whole mining area, which serves the whole life cycle of mine, playing an important role in mine sustainable production. The inclined shaft was to be operational on November 21, 2008. And it was completed on December 10, 2012. The initial support method is U-steel arch set and sprayed concrete. The spacing of the U-steel arch set is 1 m. While the thickness of the reinforced concrete is 100 mm. The sectional shape of the roadway is a three-centered arch, the height and width of the roadway is 3500 mm and 4500 mm, respectively. The dip angle of the roadway is 15°. According to the field investigation, the deformed surrounding rock of the soft roadway which is studied on the level between +758 m to +811 m (as shown in Fig. 1).

According to Fig. 1, the lithology of the soft roadway is mainly composed of muddy shale and argillaceous dolomite. The inclined roadway contains abundant underground water, and the in-situ stress is high, the soft roadway is easy to be damaged. First, the inclined shaft roadway was supported by sprayed concrete after the excavation of it. After the support was finished six months later. The remarkable deformation was occurring, so the inner lining U-steel arch set was taken to deal with the condition, but the deformation and failure of the roadway still could not be stopped. Wood filling was adopted when the surrounding rock of the roadway was damaged on October 2015, but the inclined shaft roadway still had no stopping deformation after repairing for 2 times. In addition, the widths of cracks varied from a few millimeters to several centimeters.

In order to analyze the distribution of plastic zone, the drilling sight instrument is adopted (as shown in Fig. 2) which can reflect the condition of the surrounding rock. The surrounding rock is relatively complete between the two side walls to the ranges of 0–50 cm orifices, while the surrounding rock is severely damaged in the ranges of 50 cm to 205 cm, the fractures are fully developed, so the surrounding rock is broken in this range. In the range of above the 205 cm, the surrounding rock is relative integrity. The results showed that the surrounding rock is complete near the orifice of the roadway, and the plastic zone radius is 2 m. In short, the integrity of the surrounding rock outside the plastic zone is good.

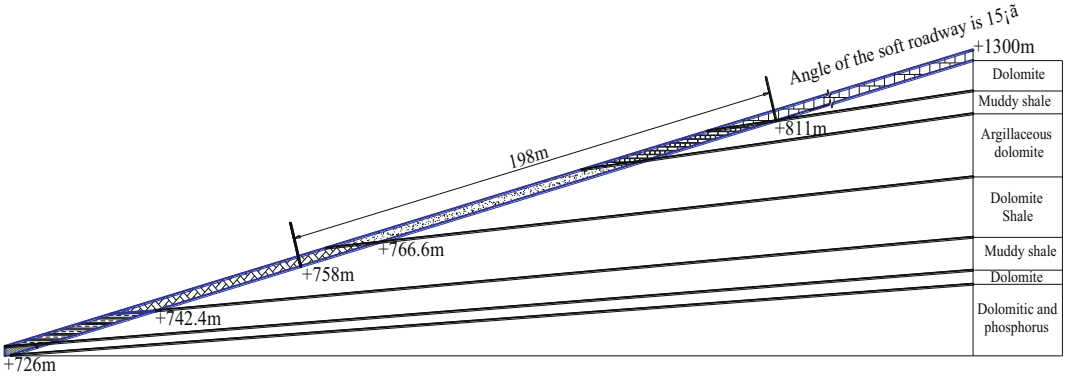

Fig. 1. Arrangement of the inclined roadway engineering.

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