Failure mechanism and control technology of water-immersed roadway in high-stress and soft rock in a deep mine

Yang Renshu, Li Yongliang, Guo Dongming, Yao Lan, Yang Tongmao, Li Taotao

Aiming at soft rock ground support issues under conditions of high stress and long-term water immersion, the ground failure mechanism is revealed by taking the deep-water sumps of Jiulong Mine as the engineering background and employing field investigation, tests of rock structure, mechanical properties and mineral composition. The main factors leading to the surrounding rock failure include the high and complex stress state of the water sumps, high-clay content and water-weakened rock, and the unreasonable support design. In this paper, the broken and fractured rock mass near roadway opening is considered as ground small-structure, and deep stable rock mass as ground large-structure. A support technology focusing on cutting off the water, strengthening the small structure of the rock and transferring the large structure of the rock is proposed. The proposed support technology of interconnecting the large and small structures, based on high-strength bolts, high-stiffness shotcrete layer plugging water, strengthening the small structure with deep-hole grouting and shallow-hole grouting, high-pretensioned cables tensioned twice to make the large and small structures bearing the pressure evenly, channel-steel and high-pretensioned cables are used to control floor heave. The numerical simulation and field test show that this support system can control the rock deformation of the water sumps and provide technical support to similar roadway support designs.

© 2017 Published by Elsevier B.V. on behalf of China University of Mining & Technology. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction

With the continuous increase of the strength and scale of coal mining in China, many mining areas have gradually turned to deep mining. The problems of high stress and soft rock roadway support have become a major concern and repair after excavation commonly occurs [1,2]. After the above-mentioned types of roadway undergo water issues, the nonlinear large deformation and rheological characteristics of the surrounding rock become more significant and the extent of fragmentation and damage of the surrounding rock experience a substantial increase under the influence of water-rock interaction [3–5]. This also results in support failure and weakening of rock bearing capacity, which can easily lead to roof caving, rib spalling and floor heave. It is difficult to guarantee the stability of the surrounding rock of a roadway with single support method. Numerous scholars have carried out beneficial exploration of the deep soft rock roadway support issue and achieved good results. He [6] proposed that the soft rock tunnel has many kinds of deformation mechanism, which transforms the mechanical mechanism of the compound deformation into a single one and is the key to the success of the support system. Kang [7], aiming at deep and complicated difficult roadways, proposed the high-prestress and strong support theory, by improving the initial stiffness and strength of the supporting system, which can effectively control the deformation of the surrounding rock. It emphasizes the importance of first support to avoid the second support and roadway repair. Wang [8], aiming at high stress and extremely soft broken rock roadways, proposed the use of high-strength rock bolts and cables, and the technology of high-resistance and intensive support by grouting, to reinforce the surrounding rocks. Liu [9] proposed that, using ultrahigh anchor bolt with high initial anchorage force and grouting, energy-releasing measures as subsidiary can keep the deep roadway stable. Guo [10] proposed the employment of the combined supporting technology of constant-resistance and large deformed anchor bolt, steel belt and grouted anchor pipe to prevent deep soft rock roadway from deformation on a large scale. This technology shows obvious on-site effects. Meng [11] analyzed the different failure courses of deep soft rock
roadway under the influence of different factors with numerical simulation, and put forward five different failure modes.

The influence of water on the stability of the surrounding rock of a roadway has been a long-lasting issue of the research of mining workers [12–15], but previous studies mainly concentrated on the effects of gushing water in the aquifer on the surrounding rock of the roadway; research into deep high-stress soft rock roadways enduring prolonged water immersion is rarely discussed. The main mining area of JiuLong Mine in the Fengfeng area is the second level of ~850 m, the hydrogeological condition is complex, and the mine inflow is large. Both the internal and external water sumps serving this level are arranged in high stress soft rock. Coupled with the effects of prolonged water immersion on the surrounding rock in the process of impounding water, the water sumps appear to suffer serious deformation, and their storage capacity cannot meet the needs of safe production. Repeated repair has a limited effect, which has affected the regular production of the mine. The key to safe production is to choose reasonable repair-control technology, ensure the long-term stability of surrounding rock in the roadway; research into deep high-stress soft rock roadways under the influence of different factors with numerical simulation, and put forward five different failure modes.

2. Field overview

The internal and external water sumps in JiuLong Mine second level are at a depth of 980 m; the horizontal distance of the internal water sump is 89 m and the external water sump is 159 m. The horizontal distance between them is 20 m. The internal and external water sumps have the same shape and size, with a straight wall semicircle section, excavated section height is 3250 mm and the horizontal distance between them is 20 m. The internal and external water sump is 89 m and the external water sump is 159 m. The level are at a depth of 980 m; the horizontal distance of the internal water sump and external water sump is large. Both the internal and external water sumps serving this level are arranged in high stress soft rock. Based on previous research and effective control measures are proposed to provide reference for the design and construction of roadway support under similar conditions.

3. Failure mechanism of surrounding rock of roadway

3.1. Failure characteristics of surrounding rock

3.1.1. Failure modes of surrounding rock

The capacity of water sumps gradually reduced with time, resulting in a serious shortage of water storage capacity. By investigation into the internal and external water sumps after pumping water, it was found that the water sumps had been severely deformed, as shown in Figs. 2 and 3. The whole section converged, basically closed in some sections of the internal water sump, the concrete spray layer appeared to have a large area cracking and peeling, steel mesh was badly torn, many bolts had bending and breaking failure, the floor was seriously heaved and the concrete spray layer had flexed on the roof and rib of both internal and external water sumps. Both internal and external water sumps appear to have different degrees of roof caving and spalling, exposed rock was broken and argillization phenomenon was serious. The characteristics of deformation and failure of the water sumps surrounding rock are mainly reflected in the following aspects: large deformation, long duration, sever damage and high repair rate.

3.1.2. Failure depth of surrounding rock

The extent and scope of damage of the surrounding rock of the water sumps are the basis for selecting the reasonable support method and parameter. For this reason, the TS-C0601 multifunctional borehole imaging analyzer has been used to drill holes in the roof and ribs of the internal and external water sumps. According to the result, it can be seen that the damage extent and scope of the surrounding rock are roughly the same in both internal and external water sumps under the condition of long-time water immersion and bulking. Rock in the shallow area is broken, while the deep surrounding rock is fracture. Fig. 4 is the result of the internal water sump surrounding rock. The surrounding rock
دریافت فوری
متن کامل مقاله
امکان دانلود نسخه تمام متن مقالات انگلیسی
امکان دانلود نسخه ترجمه شده مقالات
پذیرش سفارش ترجمه تخصصی
امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
امکان دانلود رایگان ۲ صفحه اول هر مقاله
امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
دانلود فوری مقاله پس از پرداخت آنلاین
پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات