Influencing factor analysis and control measures for speedy excavation in fully mechanized mining roadway

Tantan Feng*, Xinming Zhu, Xiaohua Xie, Hao Zhang
Xinyi Coal Mine, Linyi Mining Group Co. Ltd, Jining, Shandong, 274700, China.
*Corresponding author’s e-mail: 274158340@qq.com

Abstract: To solve the existing problems, such as low mining rate of coal and tension mining replacement triggered by slow roadway excavation in Linyi Mining, this paper analyzed the main influenced factors and control methods of the speedy excavation of tunnel via comprehensive investigation method, taking the transportation roadway in the second mining area as an example of specific engineering geological conditions. The research shows that the main influencing factors include complex geological structure, unreasonable support of design scheme and working procedure, complex transportation system and defective personnel and equipment management. Based on those factors, the control measures, such as strengthening geological prediction, optimizing the construction process and auxiliary transportation system as well as innovating management concepts, were proposed, which has effectively solved the current problems and provided guidance and reference for the similar speedy excavation projects.

1. Introduction

In recent years, with the great improvement of the degree of informatization and automation in coal mine, the requirements concerning work face mining and excavation speed of roadway are higher and the speedy excavation of roadway has become the key part to ensure high yield and efficiency of coal mining. Presently, many experts and scholars in China and foreign countries have made a large amount of useful research on the technology and equipment of the speedy excavation of roadway. For example, Zhang had designed, operated and managed the concept of speedy excavation from the aspect of mechanized excavation system [1]. Professor Zhao put forwards the measures for the excavation of roadway by using high power heavy cantilever road-header [2]. Ma et al. proposed the measures to change the temporary support of roof and optimize the construction technology of excavation [3]. The above researches have significant meaning in promoting the development and evolution of speedy excavation of roadway. Xinyi Mining is one of the main mines in Shandong Energy Linkuang Group. Since the mining depth of coal mine increases, the geological conditions become complex and the production of coal mine is modernized, the slow excavation speed in roadways has become a major factor limiting safe and efficient coal mining.

Taking transportation roadway in second mining area of Xinyi Mining as an example, this paper analyzed the main factors affecting the speedy excavation of roadways, combined with testing the geological production conditions of roadway. Additionally, this paper carried out management and innovation in the technology of speedy excavation of roadways from the aspects of production engineering, technical management and labor organization, thus effectively solving the problems of continuous tension in mining faced by mine and low production efficiency and rendering the reference for the similar speedy excavation projects.
2. Engineering background
Transportation roadway in second mining area in this paper was selected as the testing roadway in the paper, whose west side was solid coal seam, south side was Six picks, north side was -670m horizontal orbit uphill. The depth of testing roadway is in the range of 713.8~829.1m, excavation along the floor of No. 3 coal seam, whose thickness is 1.95~3.49m, average thickness is 2.72m and stratification of coal rake is developed. The false roof of testing roadway is carbon mudstone with plant root fossil, whose average thickness is 0.5m. With an average thickness of 1.88m, the immediate roof testing roadway is light grey interbedded fine sandstone with multiple coal interlayer. Its basic top is deep grey siltstone with parallel joint and 1.8m average thickness, which intercalates with fine sandstone. The direct bottom is dark grey siltite with an average thickness of 1.05m, medium and thick layer, horizontal texture and brittleness. The basic bottom is fine sandstone with an average thickness of 0.9m, olloidal layered siltstone and great integrity, whose main component is thin sandstone.

The designed length of transportation roadway in second mining area is 3450m and its design section is rectangular with a net width of 4.8m and net height of 4.2m. The height of baseboard coal seam is 3.0m and the height of rock formation is 1.2m. The EBZ160S roadheader was used for cutting, the belt conveyor was applied for transporting coal and gangue and rail transportation was employed as the auxiliary transportation mode.

Combined support mode of anchor, mesh and cable was selected in the roadway. The roof adopted φ20×2400mm high strength threaded steel anchor rod and two sides used φ20×2400mm common threaded steel anchor rod, whose average distance between rows was 900×900mm. The roof was reinforced by using φ22×6000mm anchor wire based on the 3-1-3 mode, whose row distance between anchor cables was 1800×900mm.

3. Analysis of influenced factors of speedy excavation of fully mechanized drive
According to the geological production conditions of the transportation roadway in the second Mining area of Xinyi Mining and the research, it is found that the main factors affecting speedy excavation of roadway include complex geological structure, unreasonable design scheme and working procedure of support, complex transportation system and chaotic personnel management mode.

Complex geological structure. Geological structural factors play an important role in speedy excavation in fully mechanized working face. During the process of excavation, the roadway goes through lots of small structures and faults, causing fragmentation of coal rock mass. The poor integrity of roadway and shaping of excavation makes the speed of roadway supporting slow and its quality low, thus influencing the excavation speed of roadway.

1) Unreasonable design scheme and working procedure of support. Safe and high-efficient design scheme of support and reasonable construction procedure are the important premises for the speedy excavation of roadway [4]. On one hand, the poor integrity of roadway and shaping of excavation reduce the speed of support of roadway. On the other hand, the scale design and working procedure do not consider some situations, such as on-site personnel, material consumption and examination and repair, which makes process connection loose, man-hour utilization rate low and scale of cyclic scale small, thus greatly influencing the excavation speed of roadway.

2) Complex transportation system. Reasonable and developed transportation system is the important guarantee for the speedy excavation of roadway, which could avoid the low excavation efficiency caused by the slow transportation of bastard coal. In the excavation period, transportation roadway in second mining area has not set the coal bunker and coal needs transporting over a long distance before being shipping out. Moreover, the poor transport continuity of belt, large influence of main transporting belt, low operational efficiency limits the speedy excavation of roadways.

3) Single form of auxiliary transportation and low transporting efficiency. Ensuring the timely supply of materials in working face is the key step to realize the speedy excavation of roadway [5]. With the length of 3450m in two-level transport tunnel, the transporting distances of pipeline, track, supporting material are long. Due to slow rail transportation, the time of material transportation is long and the supply of material late, thereby affecting the excavation speed of roadways.
4) Immature management mode. The effective management mode could improve the efficiency of excavation. The management concept of the roadway excavation team is poor and it has some problems in its workers, such as idle work, litter work, poor enthusiasm. The faults of the fully mechanized roadheader, belt machine and other equipment are many. The chaotic management as well as insufficient maintenance of accessories, the excavation work is forced to stagnate, thus influencing the production progress of speedy excavation of the fully mechanized roadway.

4. Control measures for speedy excavation of mechanized mining roadway

Aimed at the main significant influence factors of the speedy excavation of transportation in the second mining area in Xinyi Mining, the methods to improve speedy excavation of roadway were proposed by combining the current economic and technical force of the mine.

1) Enhancing geological prediction and laying the foundation. Making full of the comprehensive exploration means, such as three-dimensional geophysical exploration, geological drilling and lane probe, the geological situations could be explored in advance, thus controlling the influence of geological structure on the production. The geological dynamics is analyzed at any time to accurately master the situations of the structure and obtain more time for continuous construction of roadway, which has laid a good foundation for the speedy excavation of roadway.

2) Optimizing the design of support and reasonably determining the construction procedure [6]. Based on the variation of site conditions, the design parameters of support are changed timely to realize the implementation of differential support. The spacing between anchors is adjusted timely, the time for punching a hole is shortened. The footage excavation cycle in the better area of the roof is raised to 2.7 m, and the local lift is 3.6 m, which has saved the time for process connection. The footstep is used as the support and each cycle has one supporting footstep, which has expanded the parallel operation space to the greatest extent. At the same time, the examination and repair are arranged flexibly, the production time is increased, thus ensuring the continuous construction and parallel operations among the roadway excavation, laying of wind and water management, cable hanging, trench masonry and material transportation. In addition, the posterior auxiliary process is canceled and the worker efficiency is improved, thus realizing the linear management.

3) Optimizing transportation system. The influence of belt is reduced and the transportation efficiency is improved. The allocation of mining area double warehouse is set quickly and the transportation system is upgraded. The No. 1 coal bunker of South Wing is used and belt transportation system is reformed after the construction of coal bunker. Three belts are lessened, thus reducing the working load of repair belt and shortening the shipping distance. Via three belts, bastard coal is shipped to the No. 1 coal bunker of South Wing. Without the restriction of maintain time of strong belt, the influence of main belt maintenance is reduced, thus effectively increasing the production time and flexibility of head-on excavation.

4) Optimizing auxiliary transportation system and ensuring the material supply timely [7]. To solve problems, such as long distance of material shipping and consuming time, the continuous rope is used to replace haulage winch and several ring-shaped stations are established, thus guaranteeing the continuity of auxiliary haulage. Moreover, the overhead trolley is adopted to replace rail haulage, which would reduce the transportation link, decrease the labor intensity of workers and effectively improve the efficiency of excavation.

5) Optimizing the construction process and improving the efficiency of working hours [8]. The temporary support is transformed from ring front canopy to machine-mounted front canopy, two punch-pliers are added and the construction is proceeding at the same time. All of those greatly save the cycle support time, improve artificial efficiency. The special material rack and moving water bin are set in the head-on excavation, ensuring that the distances among materials is appropriate and the head-on water could be discharged timely.

6) Innovating management concept and mobilizing people and equipment. By using system engineering thinking, the labor organization is optimized and the personnel is allocated reasonably. The cross operation is made parallel and the traditional scoring model is changed, thus implementing
the fine award and the bad punishment. Step division mode is made and the distribution according to work is implemented to inspire the enthusiasm of the staffs. The daily maintenance quality management of the electromechanical equipment is strengthened. The repair staffs, projects as well as the requirement of quality are determined. The contract maintenance system and accountability system are adopted so that the individual will be investigated if the maintenance is lacked and the construction is influenced, thus improving the quality of examination and repair.

5. Engineering effect
The management rules of speedy excavation of transportation roadway in the second mining area is successfully applied. Due to changeable geological conditions, the roadway is influenced by fault, drenching, pseudo roof, floor hard rock, long transportation distance, but it still could create the best record of the monthly advance of 350m in roadway construction under the same condition. Before implementing speedy excavation, the average monthly excavation length of the transportation roadway in second mining area is 240 m and the average work efficiency is 0.19m per individual per day. After implementing speedy excavation, the average monthly excavation length reaches 325m and the average work efficiency is 0.257m per individual per day. The average excavation length is increased by 85m and the average work efficiency is increased by 0.067m per person per day.

Presently, based on continuous adjustment plan for mine production, the 1314 working face becomes the following important point. To quicken the excavation speed of working face, the management method of speedy excavation fully mechanized drive is successfully applied in 1314 tape slot and track slot. For three continuous three months, the one-side excavation length exceeded 350m, which had relieved the continuing tension and obtained good results.

6. Conclusions
1) Via research, it is found that the main influenced factors of speedy excavation of transportation roadway in No.2 mining area in Xinyi Mining include complex geological structure, unreasonable design scheme and working procedure of support, complex transportation system, single auxiliary haulage and chaotic personnel management mode.

2) Aimed at the main affecting factors, the control methods, such as strengthening geological prediction, optimizing roadway support design scheme, construction technology, transportation system and auxiliary transportation system, as well as innovating management concept were proposed.

3) The control methods not only improve the efficiency of excavation of roadways in Xinyi Mining and alleviate the problem of mining succession, but also improve the productivity, thereby providing guidance and reference for the similar speedy excavation projects.

References
[1] Zhong GZ. (2016) Development trend and key technology of coal roadway rapid tunneling system [J]. Coal science and technology,44(1):55-60
[2] Zhao XS. (2008) Current status and development trend of efficient mining technology in coal mines [J]. China coal society, 35(4):5-14.
[3] Ma CL, Yuan LF, Zhang Y et al. (2013) Rapid tunneling technology for roadway with large section [J]. Coal mine safety,(05):98-100
[4] Tian L. (2013) Application research of rapid tunneling technology of coal roadway [J]. Modernization of coal mine, (06):87-89.
[5] Li G, Niu L, Li WL (2018) Research on fast tunneling technology of hard rock roadway in coal mine [J]. Coal science and technology, 46(11):18-25.
[6] Liu YD, Lin J, Yang JW et al. (2017) Rapid tunneling and support technology based on integration of excavation and anchor for extra-thick top coal roadway [J]. Coal science and technology, 45(10):60-65.
[7] Yang RS. (2013) Status and prospect of safe and efficient tunneling technology in coal mine roadway in China [J]. Coal science and technology, 41(9) : 18－23.
[8] Nie XF, Yan GF, Song YG et al. (2013) Rapid tunneling technology of large section coal roadway [J]. Coal science and technology, (s2):141-142.