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Research on Blasting Technology in Large Cross Section Roadway Heading in Hard Rock at Depth

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Abstract: According to the high hardness rock in Xinji 2nd Mine, the problem of low utilization of blasthole, an undesirable effect of blasting, and low circulating footage in the roadway construction has arisen. By analyzing the factors of the blasting effect in large section hard rock roadway excavation, it is to optimize the blasthole diameter, charge diameter, cutting modes, and other parameters of blasting. The results show that the improvement ensures good formation of large cross section roadway in hard rock while the heading speed and blasting efficiency are greatly enhanced by occupying the double wedge cut, increasing the number of ultra-deep middle cut, and expanding the diameter of the blasthole.

Keywords: Large Cross Section; Hard Rock Roadway; Double Wedge Cut; Excavating Blasting; Blasting Parameter; Influencing Factors

Introduction

At present, the method of borehole blasting is adopted to carry out roadway excavation in many domestic mines. The theory and technology of drilling and blasting in deep rock roadway are facing some new problems with the deep development of coal mining. The low efficiency of coal mine roadway excavation greatly affects the sustainability of production [1]. The main problem of roadway excavation is to realize the high quality of the production. Therefore, domestic scholars have done a lot of experimental researches on the optimization of blasting parameter and obtained some research results [2-4].

There are many problems in the roadway excavation of Xinji No.2 Mine, such as large rock hardness, low utilization rate of blasthole, blasting effect is poor, and low advance of working cycle. Based on the analysis of rock physical and mechanical properties and the study of blasting mechanism under high stress conditions, the blasting parameters of roadway excavation are optimized to solve above problems. Compared with old blasting scheme, the utilization rate of the borehole is increased from 80% to 93%, and the single-cycle footage is also increased from 1.6m to 2.0m.

1. Influence factors of blasting excavation efficiency

With the increase of mining depth, crustal stress, temperature and osmotic pressure of groundwater were also increased by conditions of three highs, such as the high stress, the high temperature, and the high osmotic pressure. Coal outburst, disasters are becoming more and more serious, which contains the gas outburst, the rock burst, and the rock blasting. the difficulty of blasting is increased by deep rock under the influence of high crustal stress. The factors affecting the blasting efficiency mainly include the physical and mechanical properties of rock and the selection of blasting parameters, such as cutting mode, hole depth, loaded constitution, initiation way) [5].

1.1 Physical properties of rock mass

In the roadway excavation, the physical and mechanical properties of the rock and the geological structure are the important factors to affect the blasting efficiency. Low blasting efficiency will happen for rock mass with high hardness, poor

drillability and explosiveness, and undeveloped joints. On the contrary, drilling and blasting are easier and the blasting efficiency is higher.

1.2 Cutting blasting

Cutting blasting is an important technical content in tunnel blasting engineering, and it is the main factor to determine the blasting footage and the utilization rate of borehole. The current roadway excavation cutting method and blasting parameters are basically according to past experience, and far from ideal cutting blasting effect. The current mode of cutting and the blasting parameters of roadway excavation are basically determined by the experience, which is far from the ideal cutting blasting effect. Therefore, it is necessary to choose reasonable mode of cutting and charge quantity to improve the utilization rate of borehole [6].

1.3 Borehole depth

The size of the hole depth affects the excavation work procedure of the workload and the blasting effect [7]. It is to determine the main factors of driving cycle in each shift. In general, it should increase the depth of the borehole to achieve rapid excavation, but the restriction of rock on borehole will increase, the utilization rate of borehole and the cutting effects will decrease obviously. So, it is necessary to choose the reasonable hole depth can improve the progress of the whole roadway excavation, and blasting effect.

1.4 Charge structure

Because this part of rock should not only be broken but also thrown out during blasting, it needs to consume more explosive energy. In order to improve blasting efficiency, cutting hole, satellite hole and bottom hole is given priority with continuous charging especially in solid rock, cutting hole of charge quantity of the need to improve; it can increase peripheral hole non-coupling coefficient to achieve smooth blasting [8].

1.5 Initiation mode

The practice shows that on, indirect initiation is safe and reliable under the premise of good jam and the gas in the mine. Indirect detonation can not only prolong the role of explosion products in hole, it also can reduce the harmful effect of blasting. Therefore, indirect initiation can be used to improve the effect of blasting in the roadway with no gas or less gas.

2.Test conditions and equipment selection

2.1 Test conditions

Field test is carried out in xinji 2nd coal electricity group company, the roadway excavation in this mine has large cross section and high hardness of rock. The rock is mainly coarse sandstone and medium coarse sandstone, which brings great difficulties to roadway construction. In excavating rock are coarse grained sandstone, rock coefficient is f = 10 ~ 12, the bedding is clear, and the joints are well developed. The buried depth of tunnel is – 650 m, the section is a straight wall semicircle arch, the excavation width is 4.2 m, the height of tunnel is 3.6 m, the excavation area is 13.23 m^2 . Using spray the anchor net supporting form, the thick of uneven paint coverage is 150 mm, row spacing between bolt of φ 18 is 800 × 800 mm.

2.2 Equipment selection

The air leg drill is used to drill in hard rock tunnel, but the drill stuck seriously and the drilling speed is slow. According to the quick roadway excavation requirements, the type 7655 air-rider jack hammer is chosen. The drilling is suitable on hard rock of horizontal drilling or inclined horizontal hole, and the drilling depth can be up to 5 m. In order to shorten the drilling time and the number of drilling machines at the same time, at least 4 drilling machines should be used at

the same time on the working face, and another one should be reserved. Hollow hexagonal steel drills with lengths of 2m, 2.5m and 3m and diameters of 22mm should be used for each drilling machine.

3.Excavation blasting technology research

3.1 Rock physical and mechanical performance test

Rocks from the construction of the working face, and carries on the physical and mechanical properties test, and provide the basis for the design of blasting scheme and improve. Mining area substation in excavating rock processed into standard specimens in the laboratory is to test, and the results are as follows: the density of rock is 2.47 ~ 2.57 g/cm3, Poisson's ratio is 0.25, elastic modulus is (1.6 ~ 3.0)×104 MPa, compressive strength is 75.0～121.0 MPa, tensile strength is 5.7 ~ 8.9 MPa, and longitudinal wave velocity is 3.5 ~ 4.2 km/s.

3.2 The depth of the borehole

Borehole depth is decided by the test requirements, the drilling machine drilling ability, workers operating level, security requirements of unsupported roof distance. Borehole depth should be adopted according to the on-site construction level by 1.8 ~ 2.3 m, circulating footage is expected to be 1.8 ~ 2.1 m. The vertical depth of cut eye, auxiliary cut eye and center eye is 100~200mm deeper than that of peripheral eye, two circle eye and three circle eyes.

3.3 Hole diameter and charge diameter

In construction of rock drilling and blasting method, the explosive is one of the important factors to determine blasting effect. According to the actual situation, USES the level 3 coal mine water gel explosive is used. The low utilization rate of borehole was considered in the implementation of medium-deep hole blasting and 27mm charge diameter. In order to improve the explosive energy and explosive transmission effect, the diameter of cut holes, auxiliary cut holes and center holes (12 holes) was changed from 32mm to 42mm, and the diameter of charge bag was changed from 27mm to 35mm. With the increase of charge diameter and uncoupling coefficient and the extension of stress wave action time, rock can be broken to a greater extent and blasting effect can be improved.

3.4 Cutting method and blasting parameter optimization

（1）The scheme determination of cutting

When the medium-deep hole blasting of about 2m is implemented, the cutting mode and borehole layout should be changed. The cutting way depends on lithology, equipment preparation and so on. Three pairs of wedge cut can be used for tunneling in broken rock of soft and hard rock with circulation progress less than 2.0m. The drilling rod with 2.2m specification is adopted, and the hole depth is about 2m. Double wedge cut was adopted, three pairs of wedge cut holes and two pairs of auxiliary wedge cut holes were arranged, with two central holes in the middle. The hole depth of cut hole is 100mm deeper than other holes, and the depth of center hole is 100mm ~ 200mm larger than cut hole. The Angle of cut hole should ensure that the distance between hole mouth and hole bottom strictly meets the design requirements. Drilling of soft and hard rock with circulation progress greater than 2.0m shall be carried out with drill rod with specifications above 2.0m. Cut mode and cut borehole layout including hole distance shall be carried out strictly in accordance with medium-deep hole blasting instruction to ensure blasting circulation footage.

（2）Determination of auxiliary hole and surrounding hole

Depending on the size of the section, there are two kinds of auxiliary holes, namely three circle holes and two circle holes, which are mainly used to continue to expand the cut. The spacing of the auxiliary holes is 600mm, and the auxiliary holes are arranged between the cut hole and the surrounding holes, and the direction is basically perpendicular to the working face, so as to ensure the uniformity of rock blocks falling by explosion and create favorable conditions for rock loading. The surrounding holes directly determine the forming quality of the roadway contour. Generally, the surrounding holes are

100mm away from the roadway periphery, and the stronger the rock is, the closer it should be to the periphery, and the spacing between the surrounding holes should not be too large, generally 400mm, in order to ensure the section contour of the roadway and minimize the amount of brushing or the quantity the sprayed cement liquid. The fundus of the auxiliary hole and surrounding holes should fall as far as possible on the plane of the same depth, so that the working surface of the explosion is relatively flat, which is conducive to the next drilling, and the residual hole left after the explosion is shallow.

（3）The arrangement of detonating sequence

In order to make cutting thoroughly, a free surface is provided for other explosive charge firstly. Three pairs of cutting holes are primed with one-stage detonator, two pairs of the auxiliary cutting holes and central holes are used with two-stage detonator, and the number of other holes is arranged from inside to outside with increasing delay detonator. The depth of the central hole is 100 ~ 200mm, which is larger than the cut hole, and a certain amount of explosive is properly loaded. The central hole plays the role of follow-up slag throwing, it improves the molding quality of the cavity and the rock-breaking ability at the bottom, expands the volume of the cavity, effectively breaks the bottom rock, makes the cavity more fully broken, deepens the effective depth of the cut, and strengthens the throw dregs effect. The section blast hole layout of the body is shown in Figure 1, and the selection of cutting blasting parameters is shown in Table 1.

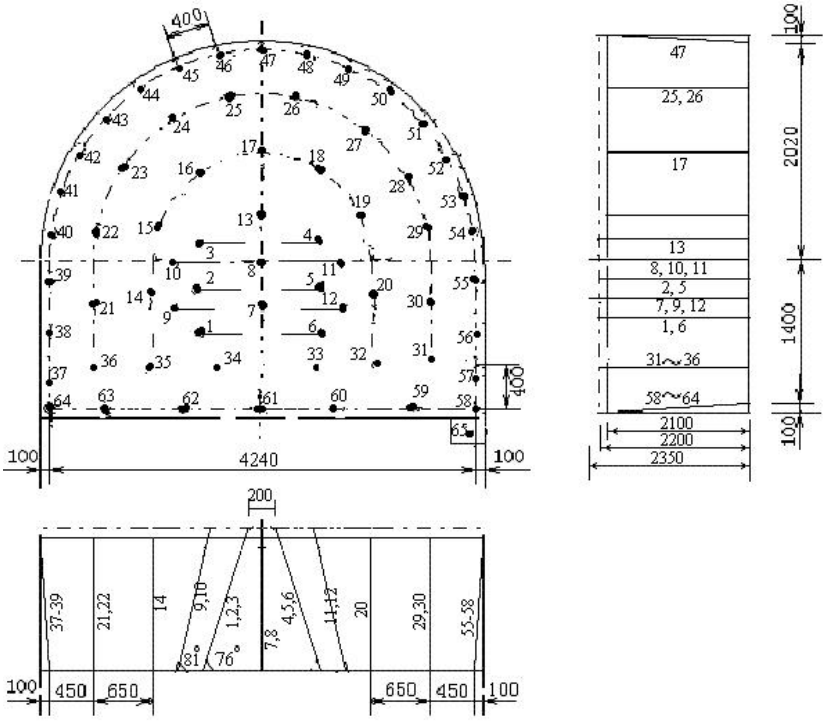

Figure 1 The layout of optimized blast hole

4.Test results analysis

Before the test, the cutting blasting method is six-hole wedge cutting, the diameter of all the holes is 32mm, the diameter of charge is 27mm, and the three-level water gel explosive permitted in coal mine is adopted. Before the test, the single circulating drilling footage is 1.6m, and the utilization rate of borehole is about 80%. After optimization, the new scheme adopts double wedge cut and a pair of central holes, the diameter of the hole is 42mm, and the diameter of the coal mine allowable secondary water gel explosive is 35mm.After blasting, the section forming and surrounding rock stability is better, and throw dregs is more reasonable. The borehole utilization rate is increased from 80% to 93%, and the single circulating drilling footage is increased from 1.6m to 2.0m. Statistical data of blasting effect measured on site are shown in Table 2.

Table 1 The optimized blasting parameters

Designation	Serial number	Hole depth	Pitch	Burden	The Angle		Charge quantity			Firing order	Connecting wat
					vertical	level	Number of holes	Single hole	Total		
Cut hole	1-6	2.2	400	1000	90°	73°	6	0.75	4.5	1	In series
Central hole	7,8	2.3	400	400	90 °	90 °	2	0.45	0.9	2	
Talus hole	9-13	2.3	500	200	90 °	81 °	5	0.75	3.75	2	
Three circles hole	14-20	2.1	650	650	90 °	90 °	7	0.50	3.5	3	
Two circles hole	21-30	2.1	650	650	90 °	90 °	10	0.50	5.0	4	
Bottom hole	31-36	2.1	600	400	87 °	90 °	6	0.60	3.6	4	
Surrounding hole	37-57	2.1	450	450	87 °	90 °	21	0.30	6.3	5	
Bottom hole	58-65	2.1	700	450	87 °	90 °	8	0.60	4.8	5	

Table 2 The optimized blasting effect of statistical data

Serial number	Project name	Unit	Quantity	Serial number	Project name	Unit	Quantity
1	Blast hole utilization factor	%	93	5	Loop detonator consumption	Unit	65
2	Circulating footage	m	2.0	6	The unit consumption of explosive	kg/m^3	1.21
3	Circulating solid rock volume	m^3	26.8	7	The unit consumption of detonator	$block/m^3$	2.43
4	Circulation explosive consumption	kg	32.35	8	Circulation blasthole length	m	138.0

5. Conclusion

From the actual blasting performance of explosive site, the performance of two-level coal mine permissible water gel explosive is better than that of three-level coal mine permissible water gel explosive. The performance of large diameter coal mine permissible water gel explosive is better than that of small diameter coal mine permissible water gel explosive. Therefore, from the point of view of blasting, large diameter two-level coal mine permissible gel explosive should be selected as far as possible, especially in the working face with low gas concentration and hard rock. In the soft rock working face can be considered to choose three-level coal mine allowable water gel explosive.

For deep large section hard rock roadway excavation, it is appropriate to adopt double wedge cut to overcome the constricted function, the rock groove holes position is easier to pull out. The depth and charge amount of the central hole

should be appropriately increased in the center of the groove hole, so as to better assist other groove holes to throw out the deep rock.

The test results show that model 7655 air-rider jack hammer is suitable for drilling horizontal or inclined horizontal holes on medium or hard rock, and the drilling efficiency is relatively high, which can be widely used in deep hard rock tunnel.

Aiming at hard rock construction conditions, the blasting design combining large diameter cutting to improve blasting effect and small diameter caving to improve drilling efficiency, not only ensures the forming quality of roadway but also speeds up the driving rate, and achieves the expected blasting effect.

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