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Study on Influencing Factors of Roadway Surrounding Rock Stability of Extremely Weak Coal Seam In Wangxingzhuang Coal Mine

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ABSTRACT

The Er_1 coal seam in Wangxingzhuang Coal Mine is an extremely weak coal seam. In order to explore the influence degree of geological conditions such as tunnel burial depth, seam thickness, mining influence, and support parameters such as bolt cable row spacing and U-shaped steel row spacing on the stability of roadway surrounding rock, this paper adopts the orthogonal test design numerical simulation scheme and evaluates the influence degree of each factor on the test index through range analysis. The results provide the parameter basis for roadway support of extremely weak coal seam in Wangxingzhuang Coal Mine. The research results of this paper have certain theoretical significance and engineering practice value.

KEYWORDS

Extremely weak coal seam; Orthogonal design of experiment; Numerical simulation.

1. INTRODUCTION

At present, with a large number of coal seams with superior occurrence conditions being mined, there are fewer and fewer coal seams with excellent geological conditions, and the mining of extremely weak coal seams with complicated occurrence conditions is imperative[1,2]. The surrounding rock of this kind of coal seam roadway has low strength and poor stability, so it needs to be reinforced repeatedly, which increases the production cost and restricts the production efficiency of the working face, which is a technical problem in the design of roadway support parameters[3,4]. In China's coal measures, mines with soft rock are widely distributed. Among them, extremely weak coal seams occupy a large proportion in the coal producing areas of Henan Province. The extremely weak coal seam has its unique ways in the layout and support of mining roadway and regional outburst prevention.

Wangxingzhuang Coal Mine is a coal and gas outburst mine with an east-west length of 11.2km and a north-south width of 9.0km. The mine covers an area of 71.90km^2 and an exploration area of 48km^2. The designed production capacity of the mine is 1.20Mt/a. Mine shaft development, cage lifting, underground transport to belt conveyor, supplemented by rail transport, mainly mining Er1 coal seam, belongs to the very weak coal seam. Central parallel ventilation mode, auxiliary shaft into the air, air shaft return air.

In this paper, UDEC numerical simulation software based on discrete element method is used to establish a numerical simulation model of coal seam roadway Er1, and orthogonal test design method is used to compare and analyze the displacement of roadway surrounding rock under different simulation results and the sensitivity of each factor to the stability control of surrounding rock, and finally evaluate the impact of each factor on the test index.

2. ORTHOGONAL EXPERIMENTAL SCHEME DESIGN AND NUMERICAL SIMULATION MODEL

2.1. Orthogonal Experimental Design Scheme

In the process of support design of roadway surrounding rock in extremely weak coal seam, the design is usually based on engineering analogy of similar conditions or technical experience, and then according to the law of mine pressure development, the scheme is optimized to ensure construction quality and safety. Due to the diversity of geological conditions such as depth of mining roadway, thickness of coal seam, influence of mining, and supporting parameters such as row spacing between bolt cables and row spacing of U-shaped steel in extremely weak coal seam, there are obvious differences between these factors on the stability of surrounding rock support. In order to effectively explore the influence of the above factors on the stability of roadway surrounding rock, orthogonal test design provides a scientific method to analyze multi-factor tests, and achieve a large number of comprehensive tests with the least number of tests, so as to obtain more accurate results. Moreover, the influence degree of each factor on the test index can be accurately evaluated through the analysis methods such as range, so as to better grasp the test results.

In the design of orthogonal experiment, the main factors should be grasped and the secondary factors should be considered, while the interrelated factors should be avoided, and the selection of factors should also be carried out according to the actual situation of the site. According to the above theoretical analysis, 5 factors were determined as burial depth, coal seam thickness, row distance between bolt cables, U-shaped steel row distance and mining influence coefficient, and 4 levels were set for each factor. The test was a multi-factor combination test at different levels, so the orthogonal table L_{16} (5^4) was selected, and the horizontal parameters of each factor were selected in Table 1, where the row distance between anchor cables was designed to be twice the row distance between anchor rods.

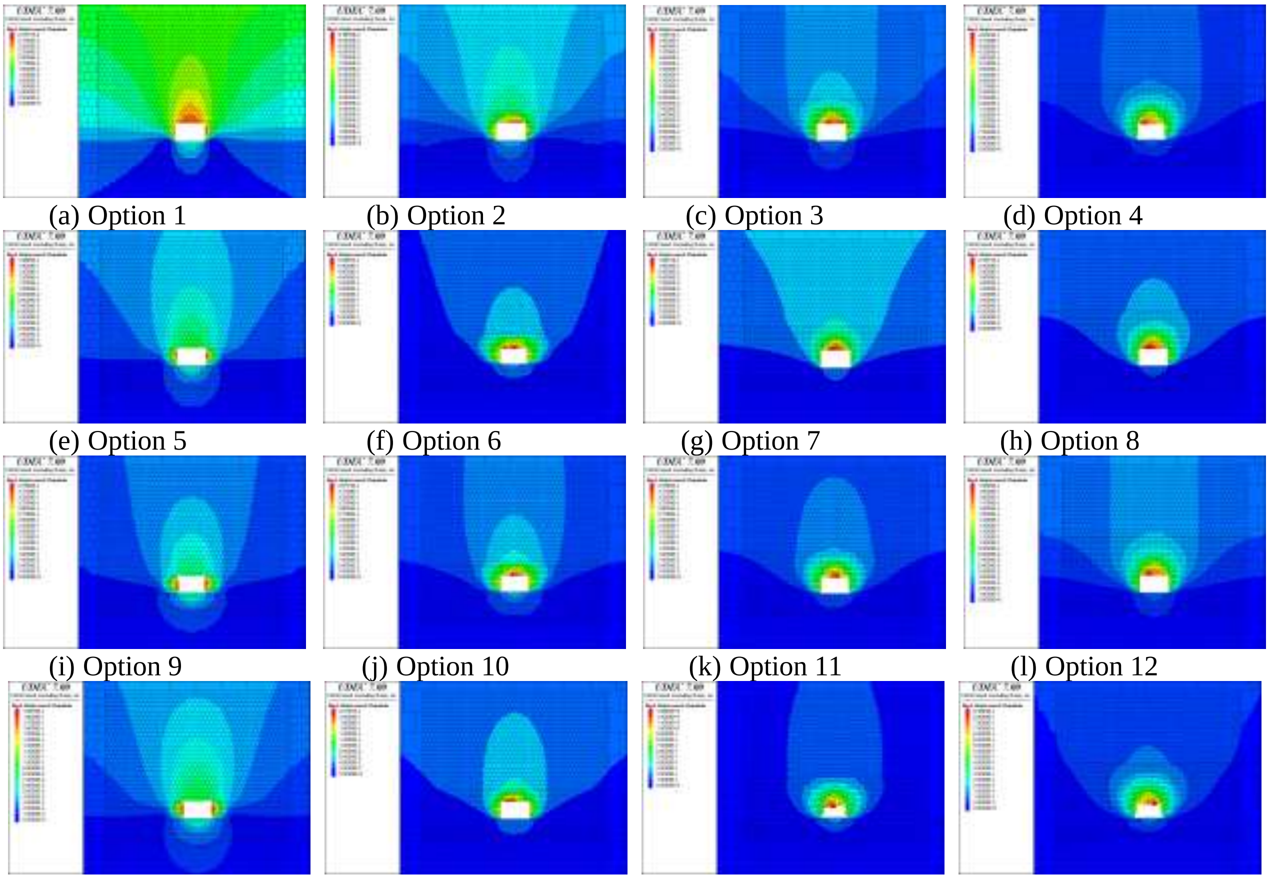
Table 1. Orthogonal Test Table

Test scheme	Roadway depth [m]	Seam thickness [m]	U-shaped steel row spacing[m]	Mining influence coefficient	Spacing between bolts [m]
1	500	3.0	1.4	1.0	0.7
2	500	5.0	1.6	1.5	0.8
3	500	7.0	1.8	2.0	0.9
4	500	9.0	2.0	3.0	1.0
5	700	3.0	1.6	2.0	1.0
6	700	5.0	1.4	3.0	0.9
7	700	7.0	2.0	1.0	0.8
8	700	9.0	1.8	1.5	0.7
9	900	3.0	1.8	3.0	0.8
10	900	5.0	2.0	2.0	0.7
11	900	7.0	1.4	1.5	1.0
12	900	9.0	1.6	1.0	0.9
13	1100	3.0	2.0	1.5	0.9
14	1100	5.0	1.8	1.0	1.0
15	1100	7.0	1.6	3.0	0.7
16	1100	9.0	1.4	2.0	0.8

2.2. Analysis of Numerical Simulation Results

Through numerical simulation, according to the orthogonal test scheme, the deformation of roadway surrounding rock was analyzed as the evaluation index, and the convergence coefficient of roadway was calculated to obtain the influence degree of each factor on roadway deformation, so as to control the effect of roadway surrounding rock support more effectively.

The deformation of roadway surrounding rock varies greatly under different stress, seam thickness and mining influence coefficient. This is directly related to the row spacing of U-shaped steel, the row spacing and number of anchors and cables. The displacement characteristics of tunnel roof and floor in each scheme of orthogonal numerical simulation are shown in Figure 1.



(a) Option 1 (b) Option 2 (c) Option 3 (d) Option 4

(e) Option 5 (f) Option 6 (g) Option 7 (h) Option 8

(i) Option 9 (j) Option 10 (k) Option 11 (l) Option 12

(m) Option 13 (n) Option 14 (o) Option 15 (p) Option 16

Figure 1. Orthogonal Numerical Simulation Results

It can be seen from the numerical simulation results that the roof deformation of the roadway is larger than that of the floor as a whole, and the roof deformation ranges from 27 to 1249mm, while the floor deformation ranges from 0 to 229mm. The deformation of the two sides is more balanced, and the size is between 23-890mm. Among them, scheme 15 has the largest deformation, the roof subsidence is 1269mm, the floor deformation is 229mm, the left side deformation is 806mm, the right side deformation is 890mm, the corresponding test scheme is buried depth of 1100m, coal seam thickness of 7m, U-shaped steel row spacing of 1.8m, mining influence coefficient of 3.0, and the row spacing of anchor cable is 0.7m. Scheme 1 has the smallest deformation, the top deformation is 27mm, the bottom deformation is about 9mm, the left side deformation is 24mm, and the right side deformation is 27mm. The corresponding test scheme is buried 500m, the seam thickness is 3m, the U-shaped steel row distance is 1.4m, the mining influence coefficient is 1.0, and the row distance between the anchor cables is 0.7m.

3. ANALYSIS OF TUNNEL CONVERGENCE INDEX RANGE

In orthogonal experimental design, range is an important index used to evaluate the impact of various factors on experimental results. In order to better analyze the performance of various factors at different levels, the sum of the convergence coefficient of the roadway at each combination level is called K_i, K_i divided by the number of occurrences of this level is called k_j, and range R refers to the value in the same column. The difference between the maximum and minimum k_j. The range R reflects the change amplitude of the test index when each factor changes.

The convergence area of the roadway is set as S_1, the original area of the roadway is S_0, and the deformation index of the roadway is defined as λ.

$$\lambda = \frac{S_1}{S_0} \quad (1)$$

The deformation of roadway surrounding rock in each scheme is shown in Table 2, and the convergence index of roadway is reserved for two decimal places.

Table 2. Orthogonal Test Result Table

Test scheme	$S_0[m^2]$	$S_1/[m^2]$	λ
1	15	0.32	0.02
2	15	0.74	0.05
3	15	1.58	0.11
4	15	3.49	0.23
5	15	1.10	0.07
6	15	4.21	0.28
7	15	0.80	0.05
8	15	1.77	0.12
9	15	2.97	0.20
10	15	3.33	0.22
11	15	2.76	0.18
12	15	1.56	0.10
13	15	1.58	0.11
14	15	1.61	0.11
15	15	8.65	0.58
16	15	5.85	0.39

It can be seen from Table 2 that the convergence coefficient of roadway forms a positive correlation with roadway transformation. The results of range analysis are shown in Table 3.

Table 3. Range Analysis Table

Index	Roadway depth	Seam thickness	U-shaped steel row spacing	Mining influence coefficient	Spacing between bolts
K_1	0.41	0.40	0.87	0.28	0.94
K_2	0.52	0.66	0.80	0.46	0.69
K_3	0.70	0.92	0.54	0.84	0.60
K_4	1.19	0.84	0.61	1.29	0.59
k_1	0.10	0.10	0.22	0.07	0.24
k_2	0.13	0.17	0.20	0.12	0.17
k_3	0.18	0.23	0.14	0.21	0.15
k_4	0.30	0.21	0.15	0.32	0.15
R	0.20	0.13	0.08	0.25	0.09

The size of range R reflects the change amplitude of the roadway convergence index when the factors change. Comparing the range under each factor can determine the strength of the influence of each factor on the roadway convergence index. The larger the range, the more significant the influence of different level changes of the factor on the experimental results, and the more important the factor. On the contrary, the factors with smaller range have less influence on the results. Through the analysis of tunnel convergence index in Table 3, it can be concluded that the influence degree of each factor on the stability of roadway surrounding rock is 0.20, 0.13, 0.08, 0.25 and 0.09, respectively. It can be seen that the order of influence degree on the deformation degree of roadway surrounding rock is mining influence coefficient, tunnel buried depth, coal seam thickness, bolt cable row spacing and U-shaped steel row spacing.

4. SUMMARY

According to the above analysis, the influence degree of roadway buried depth on the stability of roadway surrounding rock is 0.20. The influence degree of coal seam thickness on the stability of roadway surrounding rock is 0.13. The influence degree of U-shaped steel row spacing on the stability of roadway surrounding rock is 0.08. The influence degree of mining influence coefficient on the stability of roadway surrounding rock is 0.25. The influence degree of the distance between bolt cables on the stability of roadway surrounding rock is 0.09. The research results have certain theoretical significance and engineering practice value, and can provide parameter basis for roadway support of extremely weak coal seam in Wangxingzhuang Coal Mine.

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