

Research on the water-inrush risk of coal floors based on Fisher-evaluation and AHP

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Abstract. There are many factors that influence floor water-inrush. Based on the widely collected data of floor water-inrush in China, the evaluation factors in this paper consist of water pressure, aquifer type, aquiclude thickness, floor failure depth and fault throw. These are used to build a single Fisher evaluation model and a Fisher evaluation with weighting model of an analytic hierarchy process (AHP). By comparison, through AHP weighting value, the inter-class distribution of the data in the Fisher model is relatively more concentrated than the single Fisher evaluation method. It would produce higher reliability and more extensive application value.

1. Introduction

Most of the coal resources in China are underground where hydro-geological conditions in coal seams are complicated. Drilling in coal seam floors has received serious threats from limestone confined water, especially in the north China coal field. With the deepening of coal mining depth, it is dangerous for mining when thick, high water pressure and large amounts of Ordovician limestone aquifer occur. This problem has been a concern for many scholars and a lot of research has been carried out [1-3]. The results play an important role in the prediction of water inrush from floors, such as the water inrush probability index method [4], the vulnerability index method [5], and the water inrush factor analysis method [6]. In addition, the analysis method, namely fuzzy mathematics, the artificial neural network, stochastic theory, information fusion technology, the GIS system, and the expert system also have important theoretical significance to guide mine safety production. Because of the influence of geology and technology conditions, it is difficult to get the full theory and method about what is needed. Thus, the application process is largely affected [7-9].

This article uses water pressure, aquifer type, thickness of water-resisting layer, floor damage depth and fault throw information, which are commonly used in the actual production process. By introducing data weighting to set up a Fisher evaluation model of the working face of mining safety evaluation, we can provide a convenient method to evaluate inrush risk at coal mine production sites [10-13].



2. Determination of Fisher evaluation model

2.1. AHP and Fisher evaluation theory

Analytic hierarchy process (AHP) is an application of the theory of network system and multi-objective comprehensive evaluation method from Professor T L Saaty at the University of Pittsburgh in the early 1970s. The method proposes a way to solve qualitative and multi-objective complex issues, and employs a combination of quantitative level weighted decision analysis approaches. The problem is decomposed into different factors, then the factors correlated with membership can be combined into different levels to build a multi-level analysis structure model. Finally, we can obtain an important schedule in the weights among the lowest layer relative to the utmost layer [14].

The analytic hierarchy process can be roughly divided into the following steps: establishing a hierarchy model, creating a Tectonic evaluation matrix, calculating the charge quantity and doing a consistency check.

The Fisher evaluation function is one of the most influential linear evaluation functions from R. A. Fisher in 1936. In order to maximize variance between classes and minimize variance within classes, the basic theory is to determine the original vector projection direction, make the training sample projection separation and classify all the kinds of sample. Variance between classes measures the amount of difference between the average category, and variance in the class is a measure of the amount around the mean variance. The Fisher evaluation method can be divided into several steps: establishing criterion and the evaluation function, back to the generation of the sample and estimation back to the generation of error rate, and identifying new samples [15-16].

Extracting n_1, n_2 samples of m dimension from overall samples of two kinds is known as the training sample to build a evaluation function. By determining the value of the coefficient by analyzing the basic theory, the value of y can be acquired by generating pending approval samples into the evaluation. Therefore, we can distinguish the samples that belong after comparison with critical value y_0 .

2.2. Determination of two Fisher model parameters

2.2.1. Determination of evaluation index. The choice of evaluation index directly affects the evaluation result. Therefore, there are many factors that can influence the inrush in the process of coal mining. This article uses water pressure, aquifer type, thickness of water-resisting layer, floor damage depth and fault throw to build and judge the model. In addition, numbers 1 and 2 represent good and poor water abundance in aquifer type, respectively.

Table 1. Training sample data of water inrush of coal mine floor.

No	Working Face	Water Pressure	Aquifer type	Thickness of Water-Resisting Layer (m)	Floor Damage Depth (m)	Fault Throw (m)	Actual Condition
1	Face 9901 of Taoyang Mine in Feicheng	0.6	1	17	8.6	8	II
2	Face 9204 of Dafeng Mine in Feicheng	1.08	1	16.5	16.5	3.2	II
3	Face 9906 of Taoyang Mine in Feicheng	1.42	1	25.7	15.2	0	I
4	Face 9903 of Taoyang Mine in Feicheng	0.85	1	23.1	13.9	0.4	I

5	Face 7505 of Chazhuang Mine in Feicheng	1.01	1	18	11.7	0	I
6	Face 106 of Pandong Well of Panxi Mine in Xinwen	1.7	0	10	10.7	5	II
7	Face 31104 East of Xiezhuang Mine in Xinwen	1.3	1	30	18.3	4.9	II
8	Face 1532 of Fengfeng First Mine	2.3	0	7.3	7.3	0	II
9	Face 2682 of Fengfeng Second Mine	2.9	1	40	20.9	0	II
10	Face 2671 of Fengfeng Second Mine	2.8	1	40	15	6	II
11	Face 149 of Longquan Mine in Zibo	4.06	0	65.9	16	10	II
12	Face 12031 of Jiulishan in Jiaozuo	1.8	1	23	12.3	0	II
13	Face 1441 of Wangfeng Mine in Jiaozuo	1.1	1	20	8.5	15	II
14	Floor of 33 mining area of Xieyi Mine in Huainan	2	1	30	12.9	1.5	II
15	Face 1301 of Fengying Mine in Jiaozuo	1.9	1	15	13	65	II
16	Face 2131 of Hanwang in Jiaozuo	1.1	1	23.5	8.5	0	II

2.2.2. Preparation of the assessment grade

Combining the actual mine drainage ability, the sixteen biggest variation range of water inrush training sample data can be collected. For the convenience of the Fisher criterion of classification, according to the largest water inrush, safe mining evaluation of working face is divided into two levels: safety of first-class ($0 \text{ m}^3/\text{h} \leq Q < 600 \text{ m}^3/\text{h}$), I, and safety of second-class ($Q \geq 600 \text{ m}^3/\text{h}$), II, as seen in table 1.

Table 2. Prediction samples of water inrush of coal mine floor and comparison of the results of two determining methods.

No.	Working Face	Water Pressure	Aquifer Type	Thickness of Water-Resisting Layer (m)	Floor Damage Depth (m)	Fault Throw (m)	Actual Condition	A Single Fisher Evaluation Result	AHP Weighting-Fisher Evaluation Result
1	Face 1007 of second well of	5.19	0	55.9	17	7	II	II	II

2	Xiazhuang Mine In Zibo Face 9206 of Dafeng	1.26	1	23.5	8.5	0	I	I	I
3	Face II 617 of Yangzhuang Mine in Huaibei	3.11	1	44.3	14.4	3.5	II	I	II

2.3. Analysis of two Fisher evaluations

2.3.1. Analysis of one single evaluation model. Combined with the collected data sample, MATLAB software programming can be used to construct the single Fisher evaluation model. Using the single Fisher evaluation model to inspect three test samples, we can find only one sample (Face II 617 of Yangzhuang Mine in Huaibei) that did not tally with the actual test results, and the other evaluation results are consistent. The accuracy can reach 66.67%, as shown in table 2.

2.3.2. Analysis of AHP weighting-Fisher evaluation model. (1) Establishing set of evaluation index weight by AHP

Using AHP, we can determine the weights of the evaluation factors. After determining a target and evaluation index, a structure can be built, followed by the judgments matrix and consistency check calculations. Following the hierarchical order sorting method, we can construct judgment matrix [17]:

$$S = \begin{bmatrix} 1 & 4 & \frac{1}{2} & 1 & 2 \\ \frac{1}{4} & 1 & \frac{1}{3} & \frac{1}{4} & \frac{1}{5} \\ 2 & 3 & 1 & \frac{1}{2} & 1 \\ 1 & 4 & 2 & 1 & 2 \\ \frac{1}{2} & 5 & 1 & \frac{1}{2} & 1 \end{bmatrix}$$

The biggest characteristic root $\lambda_{\max} = 5.2859$ of the matrix can be taken from function eig in the Matlab software, and the consistency inspection and indicators can be shown as follows:

$$CI = \frac{\lambda_{\max} - n}{n - 1} = \frac{5.2859 - 5}{5 - 1} = 0.0715$$

According to the different order judgment matrix table, 5 order of judgment matrix and the mean random consistency index $RI = 1.12$, the random consistency of the judgment matrix may be revealed by $CR = \frac{CI}{RI} = \frac{0.0715}{1.12} = 0.0638 < 0.10$.

Thus, AHP satisfactory consistency can be acquired and normalized to:

$$A = (0.2347, 0.0573, 0.2270, 0.2991, 0.1820)$$

2.4. Results analysis

By means of the way that the weights of AHP multiply every evaluation index values, the distribution between two classes can be separated as much as possible, together with the inter-class distribution exhibited as dense as possible. When using the same method to predict test samples by Fisher, we can find out that three test samples are in accord with the actual inspection sample in complete (table 2) and that the established working face safe mining by AHP empowerment-Fisher evaluation model has relatively higher accuracy. Fisher evaluation accuracy after AHP weighting is higher than the single

Fisher evaluation, so this method has relatively broad application prospects in the mining safety inrush risk assessment.

Conclusion

- Based on the information provided, AHP analysis and Fisher evaluation theory can be used to study working face safe mining evaluation. The water pressure, aquifer type, thickness of water-resisting layer, base damage zone depth and fault throw are considered as evaluation indexes.
- Single Fisher evaluation and AHP empowerment Fisher evaluation were both applied to the mining safety mining inrush risk assessment. After comparing the evaluation results, clearly, the AHP empowerment - Fisher evaluation inrush model provided more accurate evaluation results.
- The method provides a more effective prediction method in coal mine working face safe mining, and safe mining can be effectively guaranteed by the proposed research.

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