An Interdisciplinary Response to Mine Water Challenges - Sui, Sun & Wang (eds)
©2014 China University of Mining and Technology Press, Xuzhou, ISBN 978-7-5646-2437-8

Watery of Coal-bearing Sandstone Aquifer Analysis and Forecasting with Multi-factor

Youbiao Hu, Qimeng Liu, Wentao Zhang
School of Earth and Evironment , Anhui University of Science and Technology, Huainan, China, ybhu@aust.edu.cn

Abstract Sandstone fracture water of coal seam commonly exists in rock fracture with static reserve. For the water-richness of coal measures sandstone, it is usually classified with specific capacity, because of the heterogeneity of sandstone fracture, this method is proved to be unscientific in mining practice process. By the method of pumping test, the actual observation of water detection and release in the mine, engineering geology test and water properties test, etc., factors including the thickness of sandstone, percentage of sand-shale, cycle liquid leakage of drilling, geophysical data, complexity of fault structure and mine discharge were choosen to evaluate sandstone water-richness comprehensively. It is effective and scientific compared to traditional method. Based on the structure principle of analytic hierarchy process (APH), fitting the above six factors though multivariate information, the sandstone water-richness of coal seam roof was analyzed quantitatively. It provides the basis for coal seam roof sandstone water prevention.
Keywords coal measures sandstone aquifer, water-richness, structure of analytic hierarchy process, multivariative information fitting

Introduction

The coal-bearing strata of north China type is Permo-Carboniferous. Permian coal seam roof with thick sandstone. Water-richness of Sandstone fracture aquifer of coal seam sandstone, as a whole, is weak. Its supply condition is poor, mainly occurrence with static reserve.

The old experience of water control suggests that the water irruption quantity of roof sandstone fracture water is small, the time of water inrush is short and it decay quickly. However, because the fracture of sandstone is complex, it has a clear direction with inhomogeneity distribution, then it can affect the hydraulic connection and water distribution of sandstone fracture water. Therefore the water-richness of sandstone tend to have characteristics of heterogeneity and complexity. Coal measures sandstone often being direct water-filled aquifer for coal mining, particularly in the parts of sandston fracture development, the water inflow is larger which has greater threat to mine production(Wu et al. 2011). Huainan, Huaibei, Xinji and other mines have undergone water inrush with different degree. It develop a layer of K_3 sandstone (fine-grained sandstone or sandstone) at the bottom of 32 coal seam in Huaibei Coalfield, local water-richness is strong, On february 18, 2007, it occurred several water inrush and the largest volume reached 245 m^3/h..In 2005, the 121105 working face airway of East Second mining area 11-2 coal in Liuzhuang Mine of Xinji ccured sandstone floor water inrush, the largest volume reached 280 m^3/h. Huainan Xieqiao 1121(3) working face, had occurred roof sandstone water inrush with a water yield about 200 m^3/h which affect the safety production seriously.

It follows that the water-richness of sandstone has a critical influence on water inrush, accurate judgment and evaluation of sandstone water-richness can guide water detection and release, reduce water inrush accident. At present, for discrimination and evaluation watery of sandstone. It is mainly refer to the pumping test results of specific capacity in "Mine Water Prevention Regulations" to evaluate and judge the water-richness of sandstone. But the accuracy of water-richness evaluation is limited, and it can not grasp the forming water of entire face, falled to guide water detection and release.

On the study of aquifer water-richness, besides the traditional methods of hydrogeological analysis, some scholars have used multiple sources of Geo information to learn superposition principle, according to the hydrogeological characteristics of several physical fields, mutual contrast verify and make up insufficiency each other, making a comprehensive analysis of. water-richness of water bearing aquifer. In addition, it also apply multi-factor analysis, fuzzy clustering analysis and other methods to divide the aquifer′s water-richness, and achieved some results (Ge et al. 2007, Zhang et al. 2000, Shi 2006).

Though analyzing the various factors on sandstone water-richness, using the method of multi-information fitting, this paper provides a new method for quantitative analysis of the sandstone water-richness.

The selection of evaluation factors

The water-richness of coal measures sandstone aquifer is not only related to the characteristics of itself and occurrence conditions, but also affected by factors such as regional structure (Liu et al. 2010). There are many factors that affect the water-richness of sandstone, if the selected factors is too little in comprehensive analysis, it will lead to inaccurate evaluation. However if it has too many factors, then it can lead to the effect cancellation of every factor, so it is suggested to choose 5~8 factors. This paper select the thickness of sandstone, percentage of sand-shale, cycle liquid leakage of drilling, geophysical data, complexity of fault structure and mine discharge to do multivariate information fitting.

The thickness of sandstone

Sandstone thickness is the primary factor that affect the water-richness of sandstone aquifer, of the sandstone thickness is positively correlated to water content in per unit area. The water-richness is strong with the increase of thickness; on the contrary, the water-richness is weak. The mining coal height of water-flowing fractured zone also should be take into consideration in evaluation, Take the total sandstone thickness within this scope as the relative thickness of sandstone aquifer.

The percentage of sand-shale

The water-richness of coal measures sandstone also has close relationship with coal measures strata structure. if the rate of mudstone type is higher, the percentage of sandstone will decrease accordingly with the water-richnss of sandstone reducing.

Specific capacity

Specific capacity is one of the important indicators of aquifer water ability that can be regarded as an important reference of regional sandstone water- richness evaluation.

Complexity of fault structure - fault fractal dimension values

Sandstone water mainly stored in the sandstone fracture, generally in the scope of the fracture development, the sandstone fracture,is also development, water-richness process a water-rich ribbon features. The properties, size and distribution of the fracture structure provide a space for the storage of groundwater, it may also cut through different aquifer to recharge sandstone aquifer. Acorrding to the experience of mine water prevention, it can be known that it prone to occour water inrush.in the place of fault development and larger density. Chose the fracture fractal dimension values as the evaluation index, using the box-counting dimension method to obtain fracture fractal dimension values.

The amount of lost circulation drilling

In the process of drilling, it can occur lost circulation frequently which shows that there are open sex or connective fractures. If the fractured intervals leaking is big, the water-richness is good. In the evaluation process, selecting the maximum of cycle liquid leakage of related drillings to statistic.

Geophysical data

In mine water prevention, electrical prospecting to detect the aquifer water-richness has already very mature, choosing the transient electromagnetic by plane control to evaluate water-richness is more accurate. The basic method of sandstone water governance is to dewatering the abnormal watery areas which were marked byunderground geophysical data interpretation.

Evaluation principle of multivariate information fitting water-richness

The evaluation and prediction of sandstone water-richness process environmental degeneration and fuzziness, sandstone water-richness is complex, all kinds of exploration data also provides some ascertained data, therefore it belongs to Gray problem. Traditional evaluation method of sandstone water-richness such as Fuzzy Mathematics Evaluation, Grey Theory and Analytic Hierarchy Process (AHP), are all belong to subjective values, the cost of the weights determination is high, and it has a strong human empirical. However, the implementation of objective method is convenient, and the cost is low, but the weight can not be recognized. The same factors in different mines should use different weights, some qualitative factors have different weights when quantitative . This paper apply the method that combined the subjective values based on analytic hierarchy process (AHP) with the objective value based on entropy weight method to do multivariate information fitting.

The model of sandstone water-richness evaluation

The three layers evaluation model which is built by the factors that affect the coal measures sandstone water-richness, as shown in fig. 1.

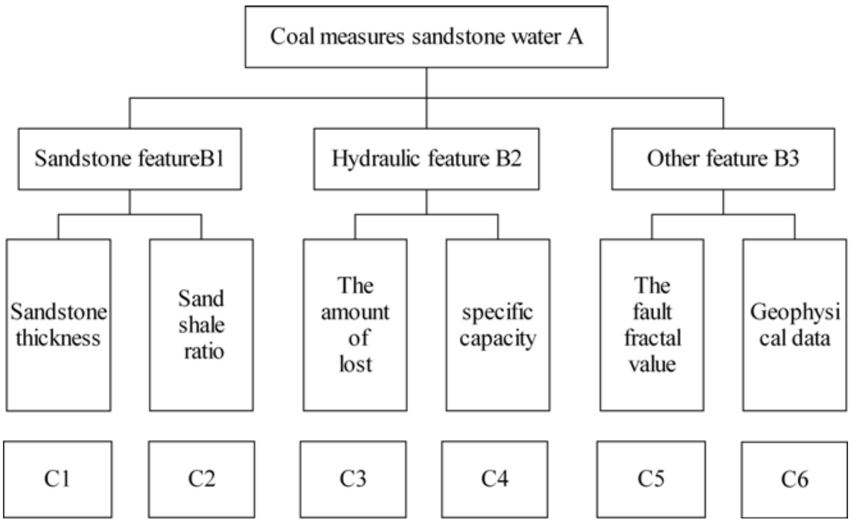

Fig. 1 *Hierarchy structure model of water-richness of aquifer*

The factor , weight and evaluation set

The factor and evaluation set

The factor set is consist of various factors affecting the evaluation object, we built first grade evaluation factors set based on evaluation model: $B=\{B_1, B_2, B_3\}$ ={sandstone character, hydrogeololgy character, other character}; second grade evaluation factors set $C_i\left(j=1,2,3\right)$={B11,B12}, {B21,B22} {B31,B32}.

From the lowest C grade, through middle B grade , finally to evaluate the object layer A in turns, obtained evaluation set of sandstone water-richness which the object layer, $V=\left\{V_1,\ V_2,\ V_3,\ V_4\right\}$ ={worse water-richness, poor water-richness,good water-richness, better water-richness}.

Table 1 *Evaluation index*

evaluation index	worse water-richness	poor water-richness	good water-richness	better water-richness
V value	0~0.25	0.25~0.5	0.5~0.75	0.75~1

The weight set

The degree of importance of various factors in the factor set during evaluation are different and assigned with different weight, as shown below:

$$W_i=\left\{w_1,\ w_2,...,w_n\right\},\sum w_i=1$$

Based on objective weighting method, we adopt the entropy weight method to assign weight, entropy is chaos degree of system. In assigning weight, the bigger the factors of information, the smaller the entropy is. The calculation steps of the entropy weight method is shown below:
(1) Assume with n samples and m evaluation indexs, construct evaluation index matrix:

$$\begin{pmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{pmatrix} \tag{1}$$

(2) Do the positive treatment of x_{ij}, calculate the weight of $j\ th$ scheme under the $i\ th$ index.

$$P_{ij}=\frac{x_{ij}}{\sum_{j=1}^{n}x_{ij}},1\le i\le m,1\le j\le n. \tag{2}$$

(3) Calculate entropy value of $i\ th$ index

$$e_i=-k\sum_{j=1}^{n}P_{ij}\ln P_{ij},1\le i\le m. \tag{3}$$

$k=1/\ln n$.
(4) Calculate weight value of $i\ th$ index

$$w_i=\frac{1-e_i}{\sum_{i=1}^{m}\left(1-e_i\right)},1\le i\le n. \tag{4}$$

Multivariate information fitting

The first grade evaluation

Nondimensionalize and normalize the lowest layer data, construct judgment matrix according to the data after processing $\boldsymbol{R}$ = [R_1,R_2,R_3]$^{\mathrm{T}}$;

Based on R_1, R_2, R_3, according to the type (2) ~ (4), calculate the lowest layer of the weight vector W_i :

$$W_i = (w_{i1}, w_{i2})$$

Vector of the first grade evaluation is:

$$B = (B_1, B_2, B_3)^T = W_i R$$

The second grade evaluation

Take the first grade evaluation as vector of the second grade evaluation, And the use type (2) ~ (4) the middle layer weight vector *W*, $W = (w_1, w_2, w_3)$.
The secondary evaluation vector as follows:

$$A = WB = (A_1, A_2, A_3, A_4)$$

The secondary evaluation vector is multivariate information evaluation vector, based on security first principle, $A_j = \max A$, compare the evaluation sets, obtain the water-richness of evaluation objects.

Examine of water-richness evaluation

With two related data statistics in a coal mining working face in Huainan mining area, table 2 show obtained statistical data:

Table 2 *Statistical data of evaluation area*

evaluation index	C_1 (m)	C_2	C_3 (m^3/h)	C_4 (L/s.m)	C_5	C_6
1	32.97	1.01	0.84	0.52	1.46	1
2	37.79	1.33	0.3	0.52	1.59	3

Using standard method of Nondimensionalize and normalize data, construct the first grade evaluation matrix shown as below:

$$R_1 = \begin{bmatrix} 0.32, 0.27, 0.16, 0.25 \\ 0.35, 0.24, 0.23, 0.18 \end{bmatrix}$$

$$R_2 = \begin{bmatrix} 0.42, 0.21, 0.17, 0.20 \\ 0.11, 0.19, 0.46, 0.24 \end{bmatrix}$$

$$R_3 = \begin{bmatrix} 0.22, 0.26, 0.12, 0.40 \\ 0.28, 0.35, 0.20, 0.17 \end{bmatrix}$$

$$R = \left[R_1, R_2, R_3 \right]^T$$

Using the entropy weight method:

$$W_1 = \left[0.5612, 0.4388 \right]$$

$$W_2 = \left[0.3292, 0.6708 \right]$$

$$W_3 = \left[0.3704, 0.6296 \right]$$

The first grade evaluation vector is $B = W_i R$, construct the first grade evaluation matrix $B = (B_1, B_2, B_3)^T$, using the entropy weight method:

$$W = (w_1, w_2, w_3) = (0.4164, 0.3117, 0.2719)$$

The secondary evaluation vector $A = WB = (A_1, A_2, A_3, A_4)$ =(0.3643, 0.1075, 0.5069, 0.2292).

$V = \max A = 0.5069$, water-richness of sandstone in coal mining working face is good according to the evaluation set *V*. In the actual production, water-richness of sandstone in coal mining working face is good and mine discharge is 142 m^3/h, prove that the evaluation method is reliable.

Conclusion

This paper constructs the evaluation model of fuzzy analytic hierarchy process, using multiple information evaluation for coal measures sandstone water-richness. Using the entropy weight method to assign weights, this method objectively and accurately determines the important degree of each factors in evaluation process, making the quantitative evaluation of coal measures sandstone water-richness. The method is better than the traditional method, providing basis for water prevention of coal measures sandstone.

References

Ge JD, Xiong GH (2007) Analyze of floor water-richness mechanism in northwest mining area in baishan coal mine. Anhui Science and technology 9: 46-47

Liu CE, Wei JC, Guo JB, et al (2010) Evaluation of water diaster in seam roof by using multi-factor complex. ShandongCoal Science and Technology 1: 180-181

Shi XZ (2006) Regularity and application of shanxi group sandstone water-richness. Coal mine engineering 5: 29-31

Wu Q, Fan ZL, Liu SQ, et al (2011) Water-richness evaluation method of water-filled aquifer based on theprinciple of information fusion with GIS: Water-richness index method. Journal of China Coal Society36(7): 1124-1128

Zhang WQ, Li JX, Zhang HR, et al (2000) Study the zone with rich water of the roof rock of 3rd coal seam in xinglongzhaung mine. Coal Geology and exploration 28(4): 53-56

Zhou HR, Zheng P, Zhang Y, et al (2008) Group decision fuzzy comprehensive evaluation based on the entropy weight method. Statistics and Decision making 8: 34-36