THE IMPORTANCE ANALYSIS OF EXPERT DIAGNOSIS INDEXES IN THE SAFETY EVALUATION OF CONCRETE DAM

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ABSTRACT

The influencing factors on the evaluation of concrete dam safety are rather complex, which can be divided into quantitative indexes and qualitative indexes and has the characteristic of fuzziness and uncertainty. Expert diagnosis provides positive effect in the comprehensive evaluation of concrete dam safety, and the evaluation result rely on the experiences and wisdom of experts. The importance analysis of experts in the safety evaluation of concrete dams was performed to have fine evaluation result. Subjective expert important analysis model and objective expert importance model were established, and then the interactive objectivity and subjectivity importance analysis model was established. In the end, there proposed models were performed in the safety evaluation of a concrete dam, and the models were verified to be effective in the importance analysis of experts in the evaluation of concrete dam safety.

KEYWORDS

Concrete dam safety, diagnosis indexes, expert diagnosis, objective expert importance, subjective expert importance, interactive expert importance.

INTRODUCTION

The monitoring data and monitoring models are often used to analyze the health status of concrete dams (Zhao 1999; Gu 2008; Zhang 2008; Dai 2014; Li 2015). Due to the complexity of concrete dam, these methods may be not sufficient. Expert diagnosis provides important effect in the comprehensive safety evaluation of concrete dam, and the evaluation result is closely related to the experience and wisdom of experts. Since the experts have different ability, background and experience, the expert weight should be pay attention. The methods to determine expert weight are divided into subjective expert importance analysis and objective expert importance analysis. The subjective expert importance analysis depends on the experts' evaluation, and the objective expert importance analyses relates to their academic status, professional title, practical experience, etc. In this work, subjective expert importance analysis model and objective expert importance analysis model were studied. On this basis, the interactive objective and subjective importance analysis model was obtained. Then the three models were performed in the safety evaluation of a concrete dam, and the models were verified to be effective in the importance analysis of expert diagnosis in the safety evaluation of concrete dam.

THE SUBJECTIVE EXPERT IMPORTANCE ANALYSIS

The influence factors on dam safety include hydrology, geology, design, construction, operation, etc. which make it difficult to determine the importance of the diagnostic indexes (Haiqing 2002; Zhou 2009). By dividing the health diagnosis of concrete dam into several levels and several factors, analytical hierarchy process (Saaty 1980) and fuzzy mathematics (Zhi Jiang 2003) were adopted to quantify the qualitative analysis, and the main procedures were given as follows (Saaty 1980):

（1）Multi influencing factors were decomposed to form the recursive structure.

（2）Set up the judgement matrix

By comparing the diagnosis indexes in one level with that in the upper level, the judgement matrix $R = (r_{ij})_{m\times m}$ was obtained, and r_{ij} is the importance degree which diagnosis index u_i relative to diagnosis index u_j .

Table 1 The improved '0.1-0.9' scale method

Meaning	Index B is more important than index A	Index B is slightly more important than index A	Index B is equally important to index A	Index A is slightly more important than index B	Index A is more important than index B
Value	0.1	0.3	0.5	0.7	0.9

In the monitoring program of concrete dam, if index A is extremely important than index B, there is no need to set index B. The improved '0.1-0.9' scale method shown in Table.1 was adopted to set up the judgement matrix. Element r_{ij} means the importance degree that index u_i relative to index u_j, which is equally to $1-r_{ji}$. Since elements in the judgement matrix R meet the following condition:

$$0<(r_{ij})_{m\times m}<1 \quad (1)$$

Then matrix $R=\left(r_{ij}\right)_{m\times m}$ is the fuzzy complementary judgment matrix.

(3) Consistency check of the judgement matrix

By calculating the largest eigenvalue $\lambda_{\max}$ of matrix R and the corresponding unit eigenvector $L=[l_1,l_2,\cdots,l_m]$, then consistency ratio $C.R$ was calculated as follows:

$$C.R=\frac{C.I}{R.I},C.I=\frac{\lambda_{\max}-m}{m-1} \quad (2)$$

where $C.I$ is the consistency index and $R.I$ is the average random consistency index of the judgement matrix R.

The values of $R.I$ are listed in Table.2.

Table 2 The average random consistency index

m	1	2	3	4	5	6	7	8	9
R.I	0.00	0.00	0.52	0.89	1.12	1.26	1.36	1.41	1.46

If the consistency ratio C.R is smaller than 0.1, judgement matrix R is deemed to have satisfying consistency, otherwise, judgement matrix R was modified according to the following equations to have the satisfying consistency.

$$\bar{r}_i=\sum_{j=1}^{m}r_{ij},\ \bar{r}_{ij}=\frac{\bar{r}_i-\bar{r}_j}{\alpha}+0.5 \quad i,j=1,2,\cdots,m; \quad \alpha\ge 2(m-1) \quad (3)$$

Based on fuzzy mathematics, we demonstrate that matrix $\bar{A}=\left(\bar{r}_{ij}\right)_{m\times m}$ is the fuzzy consistent judgement matrix.

(4) Calculate the importance vector

For the fuzzy consistent judgement matrix, the subjective importance vector of the i th diagnosis index was obtained:

$$w_i^s=\sum_{j=1}^{m}\bar{r}_{ij}\Big/\sum_{i=1}^{m}\sum_{j=1}^{m}\bar{r}_{ij} \quad (4)$$

Considering that the fuzzy consistent matrix meets the following condition:

$$r_{ij}+r_{ji}=1,\sum_{i=1}^{m}\sum_{j=1}^{m}r_{ij}=\frac{m^2}{2} \quad (5)$$

Then

$$w_i^s=\frac{2}{m^2}\sum_{j=1}^{m}\bar{r}_{ij} \quad (6)$$

If the judgement matrix is not the fuzzy consistent matrix, translation was achieved through equation (3), and we obtain:

$$\begin{aligned} w_i^s&=\frac{1}{m}+\frac{2}{\alpha m}\sum_{j=1}^{m}r_{ij}-\frac{2}{\alpha m^2}\sum_{j=1}^{m}\bar{r}_j=\frac{1}{m}+\frac{2}{\alpha m}\sum_{j=1}^{m}r_{ij}-\frac{2}{\alpha m^2}\sum_{i=1}^{m}\bar{r}_i \\ &=\frac{1}{m}+\frac{2}{\alpha m}\sum_{j=1}^{m}r_{ij}-\frac{2}{\alpha m^2}\sum_{i=1}^{m}\sum_{j=1}^{m}r_{ij}=\frac{1}{m}-\frac{1}{\alpha}+\frac{2}{\alpha m}\sum_{j=1}^{m}r_{ij} \end{aligned} \quad (7)$$

THE OBJECTIVE EXPERT IMPORTANCE ANALYSIS

To consider the different social environment, experience, education background and professional familiarity of experts, the objective expert importance was divided into prior expert importance and posterior expert importance. Prior expert importance relates to the experience, education background and professional familiarity of experts, and posterior expert importance relates to the departure degree between the judgement matrix of experts and the comprehensive evaluation matrix.

The Prior Expert Importance

To have more accurate safety evaluation of concrete dam, the experts with great ability or popularity were given greater weight, and the experts with poor ability and low popularity were given small weight. As shown in Fig.1, the prior importance indexes of experts were divided into rigid indexes and soft indexes, and the items such as position, education background, job titles, published papers, citations, prizes, done programs, academic conferences, knowledge structure, practical experience, familiarity degree of the subject were included. Table.3-Table.6 illustrates the evaluation criteria of the prior expert importance. The m evaluation indexes of n experts was given scores, and the scores vector of the i th expert was $x_i = (x_{i1}, x_{i2}, \cdots, x_{im})$, ($i = 1, 2, \cdots, n$). Then the scores evaluation matrix is

$$X = (x_{ij})_{n \times m} \tag{8}$$

where x_{ij} is the score of the j th index given by the i th exper.

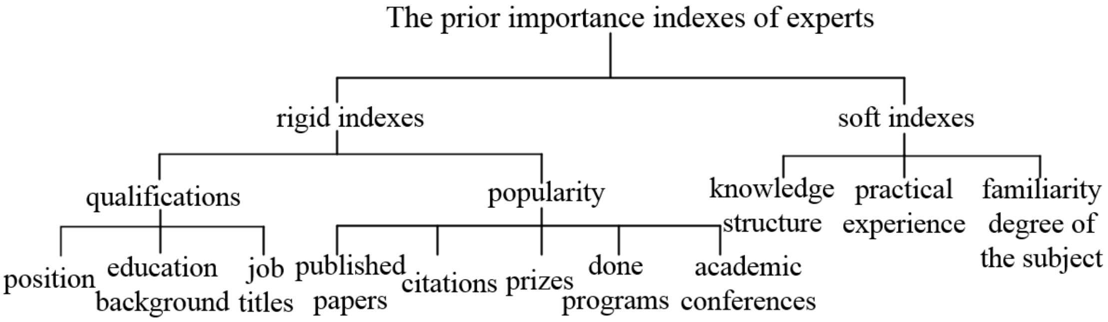

Figure 1 the structure of the prior importance indexes of experts

Table 3 the evaluation criteria of published papers and citations

Published papers			Citations					
Grade	Criterion	Score	Grade	Numbers	Score	Grade	Content criterion	Score
1	international first-rate journal	50	1	More than 20 articles	50	1	Develop the thought	50
2	international second-rate journal	35	2	More than 10 articles	35	2	Cite the achievement	35
3	domestic first-rate journal	20	3	More than 5 articles	20	3	Cite the discussion	20
4	domestic second-rate journal	10	4	More than 1 article	10	4	Only know	10

Table 4 the evaluation criteria of prizes, done programs and academic conferences of the experts

Prizes			Done programs			Academic conferences		
Grade	Criterion	Score	Grade	Criterion	Score	Grade	Criterion	Score
1	national	50	1	national	50	1	national	50
2	provincial	35	2	provincial	35	2	provincial	35
3	Prefectur	20	3	Prefectur	20	3	Prefectur	20

4	al Large company	10	4	al Large company	10	4	al Large company	10

Table 5 the evaluation criteria of prizes, done programs and academic conferences of the experts

Position			Education background			Job titles		
Grade	Criterion	Score	Grade	Criterion	Score	Grade	Criterion	Score
1	central officials	50	1	Doctor	50	1	Professor/senior	50
2	Ministerial /provincial officials	35	2	master	35	2	associate professor/Sub-senior	35
3	Departmental/ city officials	20	3	Bachelor	20	3	lecturer/middle-level titles	20
4	Primary officials	10	4	vocational degree	10	4	primary title	10

Table 6 the evaluation criteria of soft indexes of the experts

Knowledge structure			Practical experience			Familiarity degree of the subject		
Grade	Criterion	Score	Grade	Criterion	Score	Grade	Criterion	Score
1	Very proficient	50	1	Do the health diagnosis frequently	50	1	Very familiar	50
2	Relatively proficient	35	2	Has done the health diagnosis	35	2	Relatively familiar	35
3	General understanding	20	3	Has done the related work	20	3	Generally familiar	20
4	Relatively narrow	10	4	Do not done any work	10	4	Not familiar	10

The scores evaluation matrix was linearly transformed to be the matrix in which the interval of the quantized value is 0~1:

$$r_{ij} = \frac{x_{ij}}{x_{\max j}} \quad (i = 1, 2, \cdots, n;\ j = 1, 2, \cdots, m) \tag{9}$$

where $x_{\max j}$ is the maximum score in the j th index of the experts.

To reflect the normalized scores evaluation matrix $R = (\mathrm{r}_{ij})_{n\times m}$ as much as possible and evaluate the importance degree of the experts, the prior importance analysis model based on the dominance least included angles method was built up, and it was transformed as follows:

$$d_{ij} = r_{ij}^{k} / k^{k-1}, \quad (i = 1, 2, \cdots, n;\ j = 1, 2, \cdots, m;\ 0 \le k \le m) \tag{10}$$

where matrix $D = (d_{ij})_{n\times m}$ is the dominance matrix and d_{ij} is the m-step dominance.

The prior importance vector of n experts was $w = (w_1, w_2, \cdots, w_n)^T$, and the scores vector is $d_j = (d_{1j}, d_{2j}, \cdots, d_{nj})^T$, $(j = 1, 2, \cdots, m)$.

The sum of the included angle cosine $S = \sum_{j=1}^{m} \cos\theta_j$ should be big enough to reflect vector w^1, where θ_j is the included angle between w and d_j. Through the adoption and solution of nonlinear problem as follows:

$$\begin{cases} \max \quad F(w) = \sum_{j=1}^{m} d_j^T w = \sum_{i=1}^{n}\sum_{j=1}^{m} d_{ij} w_i \\ s.t \quad \sum_{i=1}^{n} w_i^2 = 1, \quad w > 0 \end{cases} \tag{11}$$

We obtain $w_i^* = \sum_{j=1}^{m} d_{ij} \Big/ \sqrt{\sum_{i=1}^{n}(\sum_{j=1}^{m} d_{ij})^2}$, and $w^* = (w_1^*, w_2^*, \cdots, w_n^*)$ was normalized as follows:

$$w_i^1 = w_i^* \Big/ \sum_{i=1}^{n} w_i^* , (\mathrm{i} = 1, 2, \cdots, n) \tag{12}$$

where w_i^1 is the prior importance value of the i th expert.

The Posterior Expert Importance

The posterior expert importance relates to the experts' predilection, the consistency of logical judgement of experts and the compatibility between the individual judgement and the comprehensively judgement of the expert groups.

The fuzzy judgement matrix with consistency demonstrates that experts have strong logical thinking ability; rather, the fuzzy judgement matrix without consistency indicates its poor credibility, imprecise logical thinking ability and weak importance, and the judgement matrix R was modified according to equation (3) to be fuzzy consistency matrix.

The consistency of the comprehensive matrix of the expert groups relates to both the consistency of the individual expert and the boundedness of the scale methods of the judgement matrix. If the importance judgement matrix of an expert is highly compatible with the comprehensive matrix, the evaluation of the expert was considered to have high accuracy. Otherwise, the diagnosis of the expert was not compatible with the most experts.

After adjusting the judgement matrix into the fuzzy consistency matrix, the importance judgement which the k th expert evaluates on the diagnosis indexes is $(\mathrm{r}_{ij}^k)_{m\times m}$. The comprehensive fuzzy judgement matrix based on the fuzzy judgement of the experts is $R^* = (r_{ij}^*)_{m\times m}$. The smaller the distance between the fuzzy judgement matrix which the k th expert evaluates and the comprehensive fuzzy judgement matrix is, the judgement of the expert is closer to the comprehensive judgement.

In the norm of matrix theory, the distance between the k th expert and the comprehensive matrix was given as follows:

$$d_k = \left\| R^k - R^* \right\| \tag{13}$$

The consistency degree between the individual judgement matrix R^k and the comprehensive judgement matrix R^* is the distance $d = (R^k, R^*)$ between the two matrix. Then the compatible importance vector of the expert groups was obtained:

$$w_i = (w_1, w_2, \cdots, w_n) = (\sum_{k=1}^{n} d_k - d_k) \Big/ \sum_{k=1}^{n} d_k \tag{14}$$

By normalizing the importance vector of the expert groups, the posterior importance value of each expert was:

$$w_i^2 = w_i \Big/ \sum_{i=1}^{n} w_i \tag{15}$$

The Objective Expert Importance

Since the prior expert importance and the posterior expert importance have equally influence on the objective expert importance, the arithmetic mean method was adopted to obtain the objective expert importance:

$$w_i^o = (w_i^1 + w_i^2)/2 \tag{16}$$

where w_i^o is the objective expert importance, w_i^1 is the prior expert importance, w_i^2 is the posterior expert importance.

THE INTERACTIVE OBJECTIVITY AND SUBJECTIVITY EXPERT IMPORTANCE ANALYSIS

Based on the subjective expert importance analysis and the objective expert importance analysis, the interactive objective and subjective expert importance analysis was performed.

Suppose n experts were invited to evaluate the diagnosis set $U = \{u_1, u_2, \cdots, u_m\}$ which consists of m diagnosis indexes, the subjective importance vector which the i th expert evaluates on the diagnosis indexes was:

$$w_i^s = (w_{i1}^s, w_{i2}^s, \cdots, w_{im}^s) \tag{17}$$

Then the subjective expert importance matrix which n experts evaluate on the m diagnosis indexes was:

$$W^s = \begin{bmatrix} w_{11}^s & w_{12}^s & \cdots & w_{1m}^s \\ w_{21}^s & w_{22}^s & \cdots & w_{2m}^s \\ \vdots & \vdots & \vdots & \vdots \\ w_{n1}^s & w_{n2}^s & \cdots & w_{nm}^s \end{bmatrix} \tag{18}$$

The objective importance vector of n experts was $(w_1^o, w_2^o, \cdots, w_n^o)$.

Then the subjective expert importance was modified through the objective expert importance to obtain the interactive expert importance:

$$W = [W_1, W_2, \cdots, W_m] = [w_1^o, w_2^o, \cdots, w_n^o] \cdot \begin{bmatrix} w_{11}^s & w_{12}^s & \cdots & w_{1m}^s \\ w_{21}^s & w_{22}^s & \cdots & w_{2m}^s \\ \vdots & \vdots & \vdots & \vdots \\ w_{n1}^s & w_{n2}^s & \cdots & w_{nm}^s \end{bmatrix} \tag{19}$$

CASE STUDY

Mianhuatan concrete dam was taken to have health diagnosis, and four levels of diagnosis indexes system was built up as shown in Fig.2. The subsystem of monitoring behavior was evaluated by four experts, and the subjective expert importance analysis was used to determine the importance of the diagnosis indexes as follows:

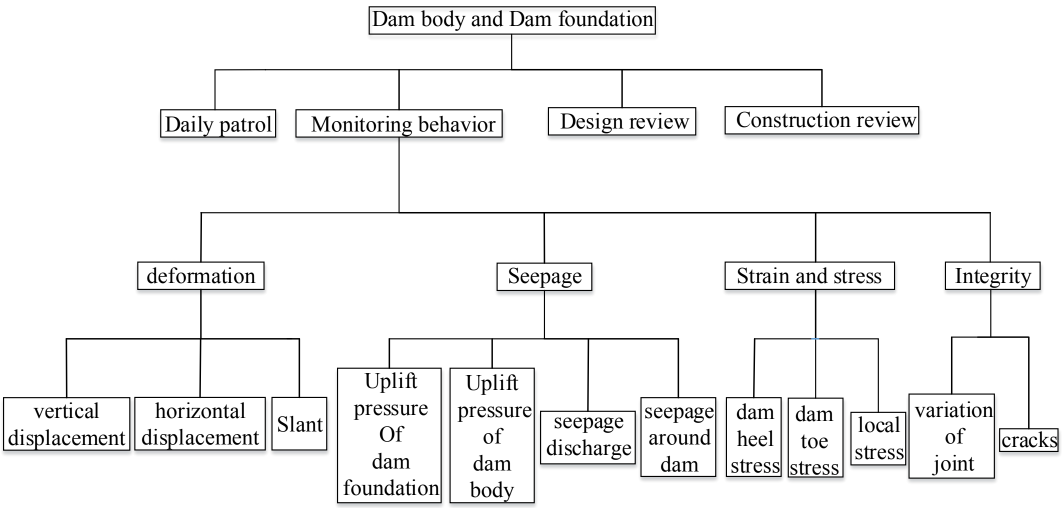

Figure 2 the four levels of diagnosis indexes system of Mianhuatan concrete dam

$$A=\begin{bmatrix}0.5 & 0.5 & 0.7 & 0.6\\ 0.5 & 0.5 & 0.8 & 0.7\\ 0.3 & 0.2 & 0.5 & 0.4\\ 0.4 & 0.3 & 0.6 & 0.5\end{bmatrix}, B=\begin{bmatrix}0.5 & 0.4 & 0.7 & 0.6\\ 0.6 & 0.5 & 0.7 & 0.7\\ 0.3 & 0.3 & 0.5 & 0.4\\ 0.4 & 0.3 & 0.6 & 0.5\end{bmatrix}$$

$$C=\begin{bmatrix}0.5 & 0.4 & 0.6 & 0.6\\ 0.6 & 0.5 & 0.7 & 0.7\\ 0.4 & 0.3 & 0.5 & 0.5\\ 0.4 & 0.3 & 0.5 & 0.5\end{bmatrix}, D=\begin{bmatrix}0.5 & 0.6 & 0.7 & 0.6\\ 0.4 & 0.5 & 0.6 & 0.5\\ 0.3 & 0.4 & 0.5 & 0.4\\ 0.4 & 0.5 & 0.6 & 0.5\end{bmatrix}$$

where A, B, C, D mean the Expert A, B, C, D, respectively.

The fuzzy consistent judgement matrixes were obtained by adjusting the judgement matrixes according to equation (3) as follows:

$$A'=\begin{bmatrix}0.500 & 0.467 & 0.650 & 0.583\\ 0.533 & 0.500 & 0.683 & 0.617\\ 0.350 & 0.317 & 0.500 & 0.433\\ 0.4174 & 0.333 & 0.567 & 0.500\end{bmatrix}, B'=\begin{bmatrix}0.500 & 0.450 & 0.617 & 0.567\\ 0.550 & 0.500 & 0.667 & 0.617\\ 0.383 & 0.333 & 0.500 & 0.450\\ 0.433 & 0.383 & 0.550 & 0.500\end{bmatrix}$$

$$C'=\begin{bmatrix}0.500 & 0.43 & 0.567 & 0.567\\ 0.567 & 0.500 & 0.633 & 0.633\\ 0.433 & 0.367 & 0.500 & 0.500\\ 0.433 & 0.367 & 0.500 & 0.500\end{bmatrix}, D'=\begin{bmatrix}0.500 & 0.567 & 0.633 & 0.567\\ 0.433 & 0.500 & 0.567 & 0.500\\ 0.367 & 0.433 & 0.500 & 0.433\\ 0.433 & 0.500 & 0.567 & 0.500\end{bmatrix}$$

The parameter α was set as $2(m\text{-}1)$ to decrease the influence of the selection of parameters on the judgement matrix, and the importance value w was calculated as follows:

$$w_i=\frac{1}{m}-\frac{1}{2(m-1)}+\frac{1}{\mathrm{m}(m-1)}\sum_{j=1}^{m}r_{ij} \tag{20}$$

The subjective expert importance of diagnosis indexes are calculated as follows:

Table 7 the subjective importance of diagnosis indexes for the four experts

Subjective importance	Deformation	Seepage	Strains and stress	Integrity
A	0.275	0.292	0.200	0.233
B	0.267	0.295	0.208	0.233
C	0.258	0.292	0.225	0.225
D	0.283	0.250	0.217	0.250

Then we calculate the objective expert importance. Based on the dominance least included angles method, the reliability of expert evaluation was judged with the scores listed in Table.8.

Table 8 the subjective importance of diagnosis indexes for the five experts

Scores	Position	Education background	Job titles	Done programs	Prizes	Academic conferences
Expert A	20	20	35	20	10	10
Expert B	35	50	20	35	35	35
Expert C	10	35	50	35	20	20
Expert D	10	35	35	20	20	20

Scores	Knowledge structure	Practical experience	Familiarity degree of the subject	published papers	numbers of citations	criterion of citations
Expert A	10	20	35	30	25	40
Expert B	50	35	50	30	35	40
Expert C	20	10	35	45	40	45
Expert D	10	35	35	35	30	35

After the transition based on the equations (9) and (10), the dominance matrix was obtained as shown in Table.9.

Table 9 the dominance matrix of the experts' evaluation values

A	0.163	0.080	0.245	0.163	0.041	0.041	0.020	0.163	0.245	0.222	0.195	0.395
B	0.500	0.500	0.080	0.500	0.500	0.500	0.500	0.500	0.500	0.222	0.383	0.395
C	0.041	0.245	0.500	0.500	0.163	0.163	0.080	0.041	0.245	0.500	0.500	0.500
D	0.041	0.245	0.245	0.163	0.163	0.163	0.020	0.500	0.245	0.302	0.281	0.302

Then the prior importance values of the four experts were calculated as follows:

$$W^1 = (w_1^1 , w_2^1 , w_3^1 , w_4^1) = (0.150 , 0.385 , 0 \tag{21}$$

For the posterior importance of the experts, we should judge the logical judgement ability of the experts. After transforming the judgement matrix which the four experts evaluate on the four diagnosis indexes based on equation (3), the four experts were considered to have relatively strong logical judgement ability and the same importance of the experts, which have the equally influence on the posterior importance. Then the group compatibility should be emphasized. Based on the prior importance values, the comprehensive fuzzy judgement matrix was obtained:

$$R^* = \begin{bmatrix} 0.500 & 0.472 & 0.612 & 0.569 \\ 0.528 & 0.500 & 0.640 & 0.598 \\ 0.388 & 0.360 & 0.500 & 0.457 \\ 0.431 & 0.402 & 0.543 & 0.500 \end{bmatrix} \tag{22}$$

The posterior importance of the four experts was as follows:

$$W^2 = (w_1^2 , w_2^2 , w_3^2 , w_4^2) = (0.272 , 0.311 , 0 \tag{23}$$

The prior importance and posterior importance were considered to have equally influence on the objective importance, therefore the objective importance of the experts was obtained:

$$(w_1^o, w_2^o, w_3^o, w_4^o) = (W^1 + W^2)/2 = (0.211, 0.348, 0.258, 0.183) \tag{24}$$

Based on equation (19), the interactive expert importance was calculated as follows:

$$\begin{aligned} W &= \left[W_1, W_2, W_3, W_4\right] = \left[w_1^o, w_2^o, w_3^o, w_4^o\right] \cdot \begin{bmatrix} w_{11}^s & w_{12}^s & w_{13}^s & w_{1m}^s \\ w_{21}^s & w_{22}^s & w_{23}^s & w_{24}^s \\ w_{31}^s & w_{32}^s & w_{33}^s & w_{34}^s \\ w_{41}^s & w_{42}^s & w_{43}^s & w_{44}^s \end{bmatrix} \\ &= \left[0.211, 0.348, 0.258, 0.183\right] \cdot \begin{bmatrix} 0.275 & 0.292 & 0.200 & 0.233 \\ 0.267 & 0.295 & 0.208 & 0.233 \\ 0.258 & 0.292 & 0.225 & 0.225 \\ 0.283 & 0.250 & 0.217 & 0.250 \end{bmatrix} \\ &= \left[0.269, 0.285, 0.212, 0.234\right] \end{aligned} \tag{25}$$

For Mianhuatan concrete dam, the time-effect displacements are almost steady and the change rules of both horizontal displacement and vertical displacement are normal. Since the deformation monitoring is the most intuitive and effective reflection of the monitoring behavior of the dam, the analysis of the deformation monitoring data is adequate for a long time and the monitoring accuracy is relatively high. Therefore the deformation monitoring has relatively larger importance in the whole diagnosis indexes.

The seepage monitoring has the characteristic of intuition and could reflect the operation status of the dam under the effect of various loads. Moreover, the seepage state plays more important role in reflecting the safety status of the dam foundation. In fact, the foundation of Mianhuatan concrete dam is rather complex and the effect of the curtain grouting is not good. The uplift pressure in some places of the foundation is abnormal and the underground water has the erosion effect on the concrete. These factors make the situation that the seepage is more important than other monitoring programs.

The stress and strain monitoring belongs to the introspection, which provide reference for the designs and construction. However, the monitoring accuracy of stress and strain is not good. Hence, the importance degree of stress and strain is lower than seepage monitoring and deformation monitoring.

The integrity is an important aspect which reflects the operation status of the dam. The monitoring of joints and cracks could immediately reflect the safety status of the dam. However, the monitoring of joints and cracks are not systematically, the development trend of the cracks is difficult to make judgement, the mechanical analysis method could provide help. Hence, the importance degree of integrity of dam is lower than deformation monitoring and seepage monitoring, and it is slightly more important than stress and strain monitoring.

Based on the practical analysis of the Mianhuatan concrete dam, the research methods are verified, which could provide reference for the overall evaluation of the concrete dam based on the expert diagnosis.

CONCLUSIONS

The safety evaluation of concrete dam based on the expert diagnosis indexes was studied in this paper. Based on the characteristic of fuzziness and uncertainty on the safety evaluation of concrete dam and the characteristic of experts' diagnosis, subjective expert importance analyses, the objective importance analysis and the interactive objectivity and subjectivity expert importance analysis were studied. Through the practical analysis of Mianhuatan concrete dam, the proposed methods were verified to provide reference for the overall evaluation of concrete dam based on the expert diagnosis.

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