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Research to health diagnose model of gate and hoist machinery based on AHP

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Abstract: Safety evaluation index is a fundamental and key element in composing hydraulic metal structure healthy diagnostic model, however,the determination of weighting of Indexes is closely related to the reasonability and reliability of the whole evaluation result.Based on the safety level, importance and expertise of the main factors on hydraulic metal structure, we also combine integration of AHP method of nine marks and expert evaluation method to determine the weight coefficient of each index, the comprehensive health diagnosis of gates and hoists based on AHP method are first constructed in line with scientific and rational principles. And we use the model to achieve the specific project safety evaluation of hydraulic metal structures, also comparing it with the traditional comparative analysis, proving the comprehensive health diagnosis based on AHP model to be a more scientific, reasonable and reliable one.

Introduction

Safety evaluation index is the foundation and the key factor of building hydraulic metal structure equipment health diagnosis system, and the determination of the weight coefficient indicators, in return is directly relates to the rationality and reliability of the whole evaluation results. On the base of the author's previous research achievements [1-3], according to the safety evaluation system of hydraulic metal structure equipment , we respectively construct the gate and hoist safety evaluation index system frame structure; And according to the main factors to the influence of hydraulic metal structure safety, the importance and expert experience, we use AHP [4-10] for analysing and calculating the index weight, and nine scale method of the analytic hierarchy process (AHP), combing with expert evaluation method (expert scoring evaluation method) to determine various index weight coefficient in this paper , respectively,for the first time constructing comprehensive health diagnosis model based on AHP method of hydraulic steel gate and hoist equipment. We use the traditional evaluation method and the comprehensive health diagnosis model based on AHP for the safety assessment of practical engineering, comparing and analysing two kinds of assessment conclusion, proving integrated health diagnosis model based on the AHP method, which make the method more scientific, reasonable and reliable.

The analysis and determination of evaluation index weighing

Weight is the important information for comprehensive evaluation,and should be determined based on the relative importance of indexwhich means the contribution to comprehensive evaluation. Based on the information infrastructure, you can determine the weights by choosing the qualitative experience judges methods, precise quantitative data processing method and hybrid method. Commonly used methods to determine index weight are: statistical mean method, principal component analysis, the chain method, analytic hierarchy process and so on.

In this paper, we take AHP index to analyze and determine the weight of all levels .

To determine the construction of the matrix

Using the analytic hierarchy process to determine index weights.The specific way is that on the base of the author's previous research achievements and safety evaluation system structured for hydraulic metal structures, to construct separately safety evaluation system for gata and hoist; Tabulate to three judgment matrix by the safety ,applicability and durability, and invite senior specialist and design engineer to give a score for safety ,applicability and durabilitymark on the base of the table 1 to table 2(only for the gata), and get the value by integrated the all index.

Table 1 Steel gate safety evaluation safety index system score sheets

Evaluation index	Fine(100~90) reference standard	Good(89~75) reference standard	Medium(74~60) reference standard	Poor(<60) reference standard	score
Intensity C1	major components σ/[σ]<0.85 Overload H/H≤0.85 No ice pressure situation	major components σ/[σ]≤1.0 Overload H/H≤1.0 Ice pressure situation ≤10cm	major components σ/[σ]≤1.05 Overload H/H≤1.05 Ice pressure situation ≤30 cm	major components σ/[σ]>1.05 Overload $H_{实}/H_{设}$>1.05 Ice pressure situation >30 cm	90
Stiffness and Stability C2	Radial gate arms stable σ/[σ]<0.85 Radial gate primary beam deflection Δl/l<0.85/600～750 Flat gate primary beam deflection Δl/l<0.85/600～750	Radial gate arms stable σ/[σ]≤1.0 Radial gate primary beam deflection Δl/l<1.0/600～750 Flat gate primary beam deflection Δl/l<1.0/600～750	Radial gate arms stable σ/[σ]≤1.05 Radial gate primary beam deflection Δl/l<1.05/600～750 Flat gate primary beam deflection Δl/l<1.05/600～750	Radial gate arms stable σ/[σ]>1.05 Radial gate primary beam deflection Δl/l≥1.05/600～750 Flat gate primary beam deflection Δl/l≥1.05/600～750	80

Table 2 Steel gate safety evaluation applicability index system score sheets

Evaluation index	Fine(100~90) reference standard	Good(89~75) reference standard	Medium(74~60) reference standard	Poor(<60) reference standard	score
Vibrate C1	Open to the full process,No obvious vibration sense	Open to the full processLocally there is vibration, not strong	Open to the full process,Whole vibration,local strong	Open to the full process, strong vibration	75
Hydraulics conditions C2	Smooth flow upstream Smooth flow downstream	Fluctuation flow upstream water jump flow Downstream	A vortex flow upstream Downstream water against the gate	Upstream flow vortex, folders gas, Downstream water against the gate seriously	70
Cavitation C3	Vent size and location meet the requirements, near the gate and the gate slot no cavitation	Short vent size and bad location near the gate and the gate slot slight cavitation	short serious of vent area ,cavitation damage near the gates and gate slots	No vent, severe cavitation damage near the gate and the gate slot	70
Embedded components C4	No seepage, cavitation erosion and abrasion	Slightly seepage, cavitation erosion and abrasion	damaged	seriously damaged	65
Manufacturing and installation quality C5	fine welding quality , the material fully meet the requirements,fine manufacturing and installation rating, and all meet the design requirements	qualified weld quality , material Heavy structure meet the requirement, qualified manufacturing and installation rating Meet the main performance	General welding quality , material Having performance quite generation materials manufacturing and installation rating meet the main performance after modification basically meet the performance	unqualified weld quality,material not meet the demand, unqualified manufacturing and installation rating could not meet the performance	75
ComponentsC6	Components intact	Components Slightly damaged	Componentsserious damaged	Components missing and not intact	65

Table 3 Steel gate safety evaluation durability index system score sheets

Evaluation index	Fine(100~90) reference standard	Good(89~75) reference standard	Medium(74~60) reference standard	Poor(<60) reference standard	score
corrosion C1	Average corrosion rate≤0.03 mm/a Corrosion degrees ≤0.5mm Corrosion area≤1 m^2	Average corrosion rate≤0.05mm/a Corrosion degrees ≤2.0 mm Corrosion area≤2 m^2	Average corrosion rate ≤0.08 mm/a Corrosion degrees ≤3.0 mm Corrosion area≤3 m^2	Average corrosion rate>0.08 mm/a Corrosion degrees >3.9 mm Corrosion area>3 m^2	85
Time Limit C2	running ages: large≤5 years, Small and Medium ≤5 years	running ages: large≤15 years, Small and Medium ≤15 years	running ages: large≤30 years Small and Medium ≤20 years	running ages: large>30 years Small and Medium >20 years	65
Management C3	Complete rules and regulations, The operation comply with regulations, Regular maintenance and testing	Basically complete rules and regulations, The operation in general comply with regulations,Basic regular maintenance and testing	Regulatory failure, the operation does not operate strictly according to regulations,unscheduled maintenance and testing	Most regulations are absent , operation are at will and mistaken and can only be maintained, could not be detected	75

According to the score results of security, applicability and durability indicators, calculating indicator's difference between two points, ,we can determine the scalethrough the points difference and the relationship between scale scale value , see Table 4 to Table 6.

Table 4 Security index Saaty scale Confirming form

Score difference value scale	0-5 1	6-10 2	11-15 3	16-20 4	21-25 5	26-30 6	31-35 7	36-40 8	>40 9
Pi and Pj	Equally important		Slightly important		Quite important		Strongly important		Extremely important
C_1-C_2		10							

Table 5 Durability index Saaty scale Confirming form

Score difference value scale	0-5 1	6-10 2	11-15 3	16-20 4	21-25 5	26-30 6	31-35 7	36-40 8	>40 9
Pi and Pj	Equally important		Slightly important		Quite important		Strongly important		Extremely important
C_1-C_2				20					
C_1-C_3		10							

Table 6 Applicability index Saaty scale Confirming form

Score difference value scale	0-5 1	6-10 2	11-15 3	16-20 4	21-25 5	26-30 6	31-35 7	36-40 8	>40 9
Pi and Pj	Equally important		Slightly important		Quite important		Strongly important		Extremely important
C1-C2	5								
C1-C3	5								
C1-C4		10							
C1-C5	0								
C1-C6		10							
C2-C3	0								
C2-C4	5								
C2-C5	5								
C2-C6	5								
C3-C4	5								
C3-C5	5								
C3-C6	5								
C4-C5		10							
C4-C6	0								
C5-C6	5								

Then according to the principle of Saaty scale to assign the value of each matrix element .The judgment matrix established by weighted average are shown in Table 7 to Table 9 .

Table 7 Safety Index between two pairwise judgement matrix

B_1	C_1	C_2
C_1	1	2
C_2	1/2	1

Table 8 Durability Index between two pairwise judgement matrix

B_3	C_1	C_2	C_3
C_1	1	4	2
C_2	1/4	1	1/2
C_3	1/2	2	1

Table 9 Applicability index between two pairwise judgement matrix

B_2	C_1	C_2	C_3	C_4	C_5	C_6
C_1	1	1	1	2	1	2
C_2	1	1	1	1	1	1
C_3	1	1	1	1	1	1
C_4	1/2	1	1	1	1/2	1
C_5	1	1	1	2	1	2
C_6	1/2	1	1	1	1/2	1

To determine the Eigenvector of Matrix and validate the Consistency

To judgment the matrix from the safety index by pairwise

To analyze the safe index by pairwise from the Table 7: Eigenvector: W_{B1}=(0.67,0.33)

Because the muliple comparisons matrix is two-dimensional,CI is zero, which can satisfied meet the consistency,the whole hierarchical systems meet the consistency .

To judgment the matrix from applicability index by pairwise

To analyze the applicability index by pairwise from the Table 9:

Eigenvector: W_{B2}=(0.2063,0.1637,0.1637,0.13,0.2063,0.13);maximum eigenvalue: λ_{max}=6.1072; Consistency index:CI=0.0214; average random consistency index: RI=1.44; inconsistency ratio; CR=0.0149<0.1.So the whole hierarchical systems meet the consistency.

To judgment the matrix from durability index by pairwise

To analyze the durability index by pairwise from the Table8:

Eigenvector :W_{B3}=(0.5714,0.1428,0.2858) .

Because the muliple comparisons matrix maximum ei;genvalue λmax=3, CI=0,satisfied meet the consistency ,so the whole hierarchical systems meet the consistency .

To judgment the matrix from second-level index by pairwise

second-level indexjudgment matrix are shown in table 10.

Table 10 Safety, applicability and durability index Judgment matrix by pairwise

A	C_1	C_2	C_3
C_1	1	2	1
C_2	1/2	1	1
C_3	1	1	1

To analyze second-level indexjudgment matrix by pairwise from the table 10: Eigenvector: W_A =(0.4126,0.2599,0.3275);maximum eigenvalue: λmax=3.0536;Consistency index: CI=0.0268;average random consistency index: RI=0.58; consistency ratio: CR=0.0462<0.1, satisfied meet the consistency. So the whole hierarchical systems meet the consistency .

The third-lever index occupy the sort proportion in the general objective

Obtain the the third -lever index occupy the sort proportion in the general objective by calculation Consistency testing:consistency index:CI=0.5×0+0.25×0.0214+0.25×0=0.00535;average random consistency index:RI=1.49;consistency ratio:CR=0.00535/1.49=0.0036<0.1 meet the consistency.

Evaluation on the index weight coefficient

Using the above-mentioned analytic hierarchy process, we can for analysis and determine the weight of the per-layer index. Thus, per-layer can be obtained at all levels of evaluation index (One class index) of the corresponding weight coefficient.

To use the above -mentioned method, we can also get the corresponding per-layerindex weight coefficient from the gate and hoist .

Safety assessment model based on AHP

The overall goal of safety evaluation is the reliability of object composed by safety, serviceability and durability(First level index) and then divided into second level indexand third level indicators. According to the safety evaluation index system, list grading standards of evaluation of projects and confirm weights of three levels' indexaccording to impaction of project on metal structures. safety evaluation index system and grading standards of evaluation are can seen in Literature[1].

According to safety evaluation index system and grading standards of evaluation for hydraulic metal structure and AHP, we can confirm the weights of three levels' index .and then structure complete safety evaluation index system for hydraulic metal structure .

According to grading standards of evaluation on gate and hoist and Safety evaluation index system, Comprehensive safety evaluation model of hydraulic metal structure can be constructed.

[R] [W] [V] [K]

[R]——weights Matrix of first level indicators; [W],[V]——weights Matrix of second and third level indicators; [K]——Coefficient matrix of grading standards ABCD;

Evaluation matrix of first level indicators

Evaluation matrix of one sub-goal: $S_1=R_1$ [W] [V] [K]

Evaluation matrix of two sub-goal: $S_2=R_2$ [W] [V] [K]

……………

Evaluation matrix of m sub-goal: $S_m=R_m$ [W][V] [K]

Where R_1, R_2…R_m are weights of sub-goals; A,B,C,D are level standards of indicator. Refer to relevant literature, let A=3.7; B=3.2; C=2.7; D=2.2 for large and medium sized projects.

Evaluation matrix of overall goal

$$P=S_1+S_2+S_3+\ldots+S_m \quad (1)$$

The standards of the overall goal is referencing to relevant literature. Since the standards are provisions made to the design, its reliability will be lower than design standards after manufacturing, installation, operation, and many other aspects of working capital, even when close to the depreciation period, the index will reach the limit. Therefore, it is necessary to provide evaluation index for security identification. Index can be divided into three levels for large and medium projects:

If evaluation value $P\geq3.2$, then safe level is I (safe);

If evaluation value $2.7\leq P<3.2$, then safe level is II (Basic Sefe);

If evaluation value $P<2.7$, then safe level is III (not safe).

I grade equipment: Safe operation; II grade equipment: make strengthening, maintenance treatment for unsafety; III grade equipment: plan to do renewal and transformation for unsafety.

If $P<2.2$, demonstration should to be made for whether to be continued using. if it can reach the II level after renewal, it can be continued to use. If it is non- economy to achieve II, then updating equipment should to considered.

Case Study Evaluation

Project Overview

A reservoir is a flood control, irrigation-based, both power generation and other benefits of the integrated large (II)-type water control project. The total reservoir capacity of 416,200,000 m3 ,flood criteria: to flood once every hundred years ,design flood level is 254.6m, in every thousand for the calibration standard, check flood level is 256.4m, years for a case of dam safety checking. The reservoir project was under construction in October 1971, the main project completed in 1978, in April 1985 for final acceptance.

A total of tin spillway, orifice clear width is 14m, Set six 14m × 12.5m (width × height) exposed of radial steel gate, radial gate radius is 15.0m, gate design head is 12m, gate hoist equipment for the six 2 × 450kN fixed hoist winch . Gates and hoist installation is complete in 1979.

Safety test results and traditional evaluation

All of the reservoir spillway gate and hoist equipment safety testing and recheck computation analysis. According to the gate and hoist safety testing and recheck computation results, according to related standards, norms and experience on the gate and hoist equipment safety evaluation.

Safety testing and recheck computation analysis main achievements and safety assessment conclusion is as follows:

Gate safety testing results and evaluation

The gate is good, overall appearance form surface coating, the gate has basically aging fall off the crossbar and position of Lord below for heavier rust or serious corrosion, local some already 110pct; Weld appearance quality is poorer, the main stress weld local manufacturing defect in small amounts, but did not identify crack defects, gate manufacturing quality is poorer; In the design of water, the main beam maximum convert stress, arms (maximum axial stress and the maximum stress six small beams are already more than material allowable stress components, gate the rest the strength, stiffness and stability are meet the requirements.

Comprehensive consideration of the gate the strength of the component already cannot satisfy the security operation requirements for manufacturing quality is poorer, the gate has nearly three decades gate operation and gate member rustily and serious index factors, according to the *water resources and hydropower engineering metal structure - rejection standard (SL226-1998)*, the existing gate should be scrapped and updated.

Hoist safety testing results and evaluation

Hoist the overall appearance of good; hoist system without overload protection device, there are security risks; the surface of mechanical parts and gear reducer widespread corrosion; open gears, rolls, wire rope lubrication in poor condition; deceleration Ring gear coupling device and the aging part of the brake band has been broken; part of the hoist motor insulation resistance does not meet the requirements of safe operation; in the design level, the gate door with maximum force is less than the rated capacity of hoist ; The security review, hoist motors, brakes, gear, open gear and wire rope safety specifications are not met operational requirements.

according to the water resources and hydropower engineering metal structure - rejection standard (SL226-1998), the existing hoist should be scrapped and updated.

Safety evaluation method based on AHP

Safety Assessment of the gate

Field test results with the gate, using the established method based on AHP model for safety evaluation of hydraulic metal structures and to evaluate the safety evaluation of its matrix.

Gate safety testing according to results of evaluation of the gate level of standard safety identification. Safety assessment model re-use evaluation of the value of the overall goal to determine the rating scale, and comprehensive evaluation and analysis, the final evaluation results show:$P=2.79>2.7$.

Evaluate conclusion: gate safety rating for II class equipments. Should be based on the existing unsafe factors, do strengthening, maintenance treatment.

Hoist Safety Evaluation

Field test results with hoist, using AHP method based on safety evaluation of hydraulic metal structure model and to evaluate the safety evaluation of its matrix.

According to hoist safety testing results of hoister, safety evaluation index level standard, likewise, judging may be calculated hoist total goal evaluation value evaluation grades, and comprehensive evaluation analysis, and display the final evaluation results: $P=2.599<2.7$.

Evaluation Conclusion: hoist safety rating grade is III equipment,which should be scrapped and updated.

Comparison of two evaluation methods

By using these two kinds of evaluation methods for specific projects gates and hoists for safety evaluation, we can see that the final evaluation of the two methods was consistent. Evaluation of traditional security gate evaluation findings on the initial level of security gates are also classified as grade II equipment, mainly on account of the gate running close to three decades and severe corrosion of the gate structures and other index of factors, so the conclusions of the existing gate to scrap Update.

The traditional method of safety evaluation of hydraulic metal structure is a combination of equipment operating status of the main investigation and analysis of field. Safety testing and review the structural safety of the three main results of calculation, the comprehensive analysis of safety testing and review analysis results on the basis of calculation, according to the security gates and hoist inspection and review of the calculation results, and in accordance with relevant standards, norms and experiences On the gates and hoist safety evaluation, the final diagnosis reached conclusions safety and health equipment. More or less the final evaluation findings will be a variety of human factors.

Hydraulic steel structure because of its complexity, is a multi-level, multi-criteria evaluation. The Analytic Hierarchy Process (AHP) can be characterized by multi-objective, multi-standard, multi-factor, multi-level complex issues of qualitative and quantitative systems analysis, decision analysis, a comprehensive analysis.

Based on the AHP method of hydraulic metal structure safety evaluation in research and construction safety evaluation system of hydraulic metal structure, considering many factors, it is a kind of can satisfy multi-factor level, many standard, many factors of comprehensive evaluation method. This evaluation method is mainly investigated and analyzed the actuality with equipment operation, the site safety testing and structural safety recheck computation analysis main achievements in comprehensive analysis, the safety evaluation index, and index level standard, and on the basis of using analytic hierarchy process (AHP) fuzzy comprehensive evaluation analysis, and finally get equipment safety and health diagnostic conclusion. Based on the AHP method safety evaluation of a hydraulic metal structure can be avoided by human factors influence, make its evaluation conclusion is more close to the actual situation of equipment, the more scientific, reasonable and reliable.

Conclusions

Safety evaluation index is the foundation and the key factor of building hydraulic metal structure equipment health diagnosis system, while the determination of the index weights, will directly relate to the rationality and reliability of evaluation results. This paper fusions AHP and expert judgment method to analyze and calculate the index weight , and construct the health diagnosis mode of hydraulic metal structure which is based on AHP method .

(1) According to the main factors on the influence degree of safety, and the importance and expert experienceon of hydraulic metal structure, we take the method of nine scale ,and combine with expert evaluation method (expert scoring system) to determine the weight coefficient of each index , respectively,constructed for the first time comprehensive health diagnosis model of the gate and hoist equipment ,which is based on AHP method.

(2) Using traditional evaluation method and the comprehensive health diagnosis model based on AHP method for the safety assessment of practical engineering, we can analysis and compare the two kinds of assessment conclusion ,and verify the integrated health diagnosis model based on the AHP method more scientific, reasonable and reliable.

(3)With the accumulation of raw data, we can use the computing power,self-learning ability, self-organizing capacity, fault tolerance ,self repair ability and knowledge expression ability of neural network,and also research and development the health diagnosis system based on artificial neural network technology of hydraulic metal Structural.

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References

[1] Guangming Yang . Hydraulic metal structure safety evaluation system design and research. Nanjing: Hohai University , 2005. In Chinese.
[2] GuangmingYang ,Chongshi Gu . Water Science and Engineering,2008. 1(3).
[3] GuangmingYang . Journal of Hohai University (Nature Science Edition),2006.34(6).In Chinese.
[4] Saaty T. The Analytic Hierarchy Process. McGraw-Hill Inc, New York, 1980.
[5] Saaty T.L, Hu G. Appl. Mathe. lett. 1998, 11(4): 121-125.
[6] Fan Z, Ma J, Zhang Q. Fuzzy sets and systems, 2002, 131(1):101-106.
[7] Masood A. International Journal of Production Economics. 2001. 72(1):27-40.
[8] Forman E, Gass S. Operations Research, 2001, 49(4):469-486.
[9] Hao Wang, Da Ma.system engineering,1993,13(5):24-26. In Chinese.
[10] Dong Du. Systems Engineering and Electronics ,2000,23(5) :36-38.In Chinese.

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