Fuzzy intelligent system of safety assessment for river-way levee

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ABSTRACT: The safety of river-way levee relate with a lot of factor such as flood water level, rainfall, material property, river-way levee section and river-way shape, etc. The seepage and slop failure of river-way levee often results from the combined disadvantage factors. Safety assessment of river-way levee is difficult due to fuzzy and uncertainty of river-way levee safety factor. In this paper, based on the quantitative and qualitative analysis of river-way levee safety factors, the system frame of analytic hierarchy process (AHP) combined Artificial Neural Network (ANN) for river-way levee safety is presented. The valuation aggregation of river-way levee safety including external and internal factor was discussed. Water level, rainfall, flood, river scouring and engineering grade are the external factors. Internal factor means the character and parameter of river-way levee body and foundation such as clay content, dry density, size-grade distribution of river-way levee material, percent saturation, river-way levee level and percolation gradient, etc. Besides internal and external factors mentioned above, river-way levee defect and its remedy measure also are important for evaluating the river-way levee safety. Topping, outburst, avulsion and their compounding are the failure pattern of river-way levee and dependent on the effect factors of river-way levee safety. Whereafter, the effect of all factors on river-way levee safety and the possible failure was discussed, the static weight model of extension AHP, expert interval marking method and ANN are used to the safety assessment of the river-way levee engineering. In the end, the representative section of Yellow river river-way levee was taken as an example and a computer system for safety synthesis assessment of river-way levee was developed by using fuzzy comprehensive appraisal method to syncretize the effect of all factors of river-way levee safety.

1 GENERAL INSTRUCTIONS

The safety of river-way levee relate with the national economy and the people's livelihood. Safety assessment of river-way levee is difficult due to fuzzy and uncertainty of river-way levee safety factor. In this paper, based on the quantitative and qualitative analysis of river-way levee safety factors, the system frame of analytic hierarchy process (AHP) combined Artificial Neural Network (ANN) for river-way levee safety is presented.

2 FACTORS INFLUENCING THE SAFETY OF RIVER-WAY LEVEE PROJECT

River-way levee failure can be classified into burst, crevasse of rushing and overtopping according to the manifestation forms(Hagerty D J. Spoor M F . Uilrich C R .1981). Most breaching happens because of the interior incipient fault of creeping, piping and leak resulting from the long-term action of high water level at strong leaking foundations. When the corresponding measures to strengthen river-way levee can't be done in time, it then grows into crevasse. Most crevasse of rushing happens because of the change of riverbed, which leads to the river mainstream rush the river-way levee body or erosion on river-way levee slope by wind wave. And the river-way levee material usually is arenaceous soil and it is lack of effective protection measures, so the river-way levee becomes crevasse when these problems can't be solved properly. The crevasse of overtopping happens when the river-way levee height doesn't reach the standard or the extreme flood goes above the standard. The definition of the engineering order of the river-way levee, the design water frequency, specified superelevation and the calculation of design flood water level are considered in the safety assessment of river-way levee. River-way levee failure, according to the inner mechanism and the cause of formation, are generalized into the failure caused by the action of seepage (such as piping, running soil) and the failure caused by instability (such as slide, sloughing).

2.1 *Seepage failure*

Seepage failure is very common in river-way levee project, which has a relation to most of the crevasse

in history. Almost all the dangerous condition of crevasse is caused by seepage failure except overtopping. Under the action of high water level in flood season, seepage occurs at both the foundation and the river-way levee, which are the main external factor for seepage deformation. As to the interior factors, it is mainly related to the seepage coefficient and the porosity. The coefficient is the property of materials at the foundation and materials that fills up the river-way levee. These factors directly determine the seepage velocity and seepage gradient, the larger the seepage coefficient is, the easier the seepage deformation according to Darcy's law. So river-way levee filled by materials with larger coefficient such as sand clay or sandy loam soil is easier to generate deformation than by materials of clay or loam soil, so does the strong leaking foundation than less leaking ones. Besides, the type of river-way levee cross-section, the structure and properties of soil layer, the river-way levee crack, artificial and biologic cavern, multifarious incipient fault at river-way levee foundation and body. The strong scouring to the river-way levee front by wave and sand-carried turbulence are also important factors for seepage failure.

2.2 *the stability of bank slope*

The stability of bank slopecan be divided into four classes(Abam TKS. 1993): the natural factors of geology, river and hydrodynamics, hydrometeorology and factors of anthropokinetics. Of all the factors, the geological factor is the intrinsic cause which constitutes the foundation of bank slope and plays a decisive importance in stabilized state; factors of river hydrodynamics and hydrology contain part of intrinsic cause deciding the stabilized state and also part of external cause influencing its change; factors of meteorology and anthropokinetics are external cause having great influence on the stability of bank slope, too.

By comprehensive analysis, the main intrinsic cause influencing the stability of bank slope lies in the condition of river-way levee bank, which is the constitution, physical and mechanical properties of soil body; the characteristics of seepage, etc; the action of high level water and the influence of rainfall are the main external factors of bank slope's stability. High water level and rainfall can both help raise the groundwater level, as a result of being soaked in ground water for a long time, the material of river-way levee will be saturated, in a state of weak-plasticity and shear strength will be decreased, which often cause the failure of bank destabilization. Besides, incipient such as the layout of river-way levee axis, the type of river-way levee cross-section, the crack existed in river-way levee, biologic and artificial cavern also have important effect on the stability of bank slope of the river-way levee.

From the two points above-analyzed, material properties, type of cross-section, river-way levee crack and creature cavern are the interior and the main influencing factors of the river-way levee failure. In whatever way it fails, water level and river flow erode is the most basic and most important external factor to the safety of foundation and river-way levee. Meanwhile, the soil body of the river-way levee will be softened after being soaked in flood for a long time, which will influence the stability of the river-way levee project.

Meanwhile, after experiencing times of dangerous condition, river-way levee project will be reinforced to different extent. Therefore, the capacity of river-way levee resisting failure will be strengthened correspondingly.

From above we can see that factors influencing the safety of river-way levee are very complex. While making assessment on the safety condition of the river-way levee, attentions should be paid to the influence of multi aspects with the standing out of emphasis as well as the main factors. So after the initial classification, a factor set of safety assessment is established from the aspect of load condition, river-way levee condition, daily management, historical dangerous record, eliminating danger and enforcement measure. The safety of river-way levee engineering can be assessed by use of AHP and ANN models of the synthesis assessment based on the factor set.

3 STRUCTURE OF SYNTHESIS ASSESSMENT FOR THE SAFETY OF RIVER-WAY LEVEE PROJECT

The main reason for breaching of river-way levee project lies in the interior incipient fault or creeping, piping and leak, etc. If saving measures are not done properly, it will result in breaching. So the network structure of index system of safety assessment factor should be considered in the following aspects:

(1) the influence of load factors such as water pressure and rainfall. Water pressure factor include riverward and un-riverward water level, the process and duration of water-level change, etc. The influence of rainfall includes rainfall intensity, elapsed time and process of rainfall, etc.

(2) the condition of river-way levee itself is the intrinsic factors causing river-way levee burst. It can be separated into two parts: the river-way levee body and the foundation. The river-way levee body condition include the cross-section condition, soil zoning, initial water ratio, etc. The detail condition of cross-section include river-way levee height, the top width, the front and back gradient And river-way levee's seepage characteristics (represented by seepage coefficient), which are synthetically reflected by filling zoning condition, filling porosity, filling ma-

terial property, etc. The foundation of river-way levee is embodied by the maintenance condition, structure of stratum and the seepage characteristics (represented by seepage coefficient). Therein maintenance condition include grouting and cutoff wall; then the structure of stratum are synthetically imaged by the factors whether it is monolayer, double-layer, multi-layer or crevasse-place, etc. Then seepage characteristics are synthetically analyzed by the stratum layer zoning, porosity ratio and the constitution of soil body (such as the content of clay soil, dry density, etc) and so on. Apart from the load factors and the characteristics of river-way levee itself above-mentioned, river-way levee defect detecting, the data of daily inspection and maintenance, historical risk circs, the eliminating risk and river-way levee strengthen circs are also important factors synthetically reflecting whether the river-way levee project will breach. River-way levee defect detective includes the orientation, kinds (such as cavern, crack, layer of loose earth and crevasse-place, etc); historical risk circs mainly refers to dangerous condition ever happened including creep, piping, leak, sloughing and crevasse, etc. Elimination risk and river-way levee strengthen circs mainly refers to the river-way levee strengthen condition after the occurrence of danger including side widening, cutoff wall, grouting, relief well and revetment etc. From above analysis, the network structure of analytic hierarchy process (AHP)(Satty TL. 1980) for index of safety assessment of dike breaching can be gained.

4 SAFETY SYNTHESIS ASSESSMENT FACTOR’S EVALUATION AND WEIGHING

There are many factors that affect river-way levee project’s safety. Each factors play different part in river-way levee safety assessment. If we simply plus the value of safety assessment factors to represent the whole river-way levee’s safety condition, the result may have a distortion of truth safety of river-way levee. So we should synthetically evaluate and weigh the relative importance of each effect factors for river-way levee safety. There are many methods for weight analysis(Rocha, M. etal. 1958& Silveria, A. F. Pedro. Jose. 1964). They can be generally divided into two categories: objective evaluating weight and subjective evaluating weight. The former is decided according to the information that is provided by determining matrix. The latter is a method evaluates according to the subjective emphatic degree of each index such as analytic hierarchy process. The weight deviation among factor indexes is decided based on the objective importance of effect factor for river-way levee safety synthesis assessment. The factor weigh of analytic hierarchy process is calculated by multiplication scale method. When comparing each index’s importance by twos, it sets up only two but not excessive comparing grade, and multiplication scale analysis is processed step-up. After certain data are accumulated, we can use artificial nerve network analysis to calculate weight .The qualitative index has characteristic such as fuzzy and un-quantitative. So it is hard to be indicated with exact numerical value. We can only do quantitative treat to the fuzzy information by fuzzy mathematics method. Here we use extremum linearity quantitative method and export marking method to determine the qualitative index, the worst one is 1, and the best one is 0.

5 SYNTHETIC ASSESSMENT SYSTEM

With extension AHP method and Artificial Neural Net (ANN) method(Hecht-Nielsen R. 1989), a safety assessment system of river-way levee on the basis of the principle above-mentioned was developed to assess in time the safety of river-way levee and provide data support for river-way levee strengthening. The specific function of the system includes some branches such as effect factor Set management system, weight analysis system, data management system and on line help. The system main menu and flowchart was showed as following fig 1.

5.1 *initial data input and management*

The system provides a well database connection to achieve the efficient management of data .We can not only fetch data from database conveniently, but also increase data to the database by handiwork or file input means. Considering the actual situation will change at any time, the system provides customers with the function of increasing and deleting river-way levee safety assessment factors. It can adjust the effect of each factor according to exports suggestion or the river-way levee’s actual running condition

5.2 *Safety assessment factor weight analysis*

The system provides two weight analysis methods :administrative level analysis and nerve network .It can adjust the deviation coefficient of the two weight analysis results , compose weight for fuzzy synthesis assessment .

5.3 *Fuzzy synthesis assessment of river-way levee safety .*

After the safety assessment factor and its weight are decided, the system provides customers with fuzzy synthesis assessment model of river-way levee safety .It can assess each river-way levee section’s safety condition at any time , and then provide data

support for river-way levee's avoiding danger and reinforcing .

5.4 *Friendly on line help.*

There are quite detailed systems operating help files for customers to use conveniently. Customers can operate the system easily according to help files .They can also understand the function and operational process by reading help files.

Note: (1)Database Connectivity, (2)Data Input, (3)Weight Analysis , (4) Fuzzy Synthesis Assessment, (5)Effect Factor Set Management, (6) System Management, (7)Online Help (8)EXIT

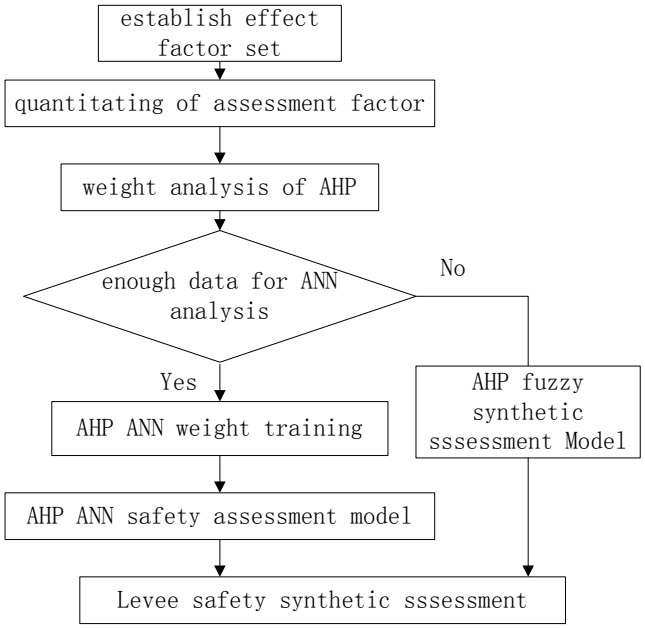

Fig.1 The main menu and flowchart of river-way levee safety Synthetic assessment system

5.5 *System management*

The system provides customer management. Different limits of the authority are defined according are defined according to different customers. It also provides customers with back-up function .customers can save all sorts of data which are needed at any time.

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