



## Research paper

## Research on the full life cycle safety of levee based on BIM+mechanism algorithm

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**Abstract:** Levee is the oldest and most widely used water conservancy project in human society, and its safety is directly related to the safety of people's lives and property. According to current regulations, calculations about seepage stability and sliding stability are required during the design and operation management of levees, which including section modeling, soil index organization and boundary condition setting. Due to the characteristic of long distance and multiple sections, these calculations are time-consuming, labor-intensive, and prone to manual errors. This article proposes an innovative research method for the full life cycle safety of levees based on BIM+Mechanism algorithm. Take West danger Levee project for example, firstly study the three-dimensional geological modeling of levees based on databases, providing the physical and mechanical properties data of geological strata for subsequent calculations; then improve the efficiency of structural modeling and modification by BIM parametric design; finally, construct BIM+GIS data base to integrate the structural and geological information. Then, this article develops finite element seepage calculation program and limit equilibrium method calculation program, further more providing data and functional interfaces to support online calling of external programs. The above research is used for levee design, extracting calculation models from design sections and calling calculation modules for batch solving, hereby improving the situation where levee design and calculations are separated from each other and enhancing design optimization efficiency. On the other hand, applied to digital twin, the safety data base and Mechanism Algorithms of levee are used for safety evaluation after construction.

**Keywords:** levee project, BIM, mechanism algorithm, full life cycle, engineering safety

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## 1. Introduction

Levee is the oldest and most widely used water conservancy object in human society, and its safety is a major issue related to national economy and people's livelihood. Therefore, the research on safety evaluation of Levee project has important theoretical significance and practical value [1]. On July 2024, a pipe surge occurred in the first line levee (stake 19+800) of the Dongting Lake in Tuanzhou, Hunan Province, which quickly became the focus of national attention. After 44 hours of emergency rescue, 5445 people were safely evacuated, and the 226 meter wide levee burst was finally blocked [2].

Levee project has the characteristics of long routes, large changes in variable geological and river conditions along the way, According to the different internal mechanisms and causes of levee failure, the failure modes of levees can be summarized as damage caused by seepage (such as piping and soil flow) and instability (such as landslides and bank collapses). Safety analysis is required in the new construction, renovation design, and post construction safety evaluation of levees. The Code for design of levee project (GB5028-2013) stipulates that "the design calculation of levees includes seepage and seepage stability calculation, sliding stability calculation, and settlement calculation, etc"; The safety evaluation of levees should include current situation investigation and analysis, on-site inspection, and recheck calculation. The recheck calculation includes "recheck the height of the levee top, the sliding stability of the levee slope, the permeability stability of the levee body and foundation, the stability of the levee, and the safety of crossing buildings". It can be seen that seepage stability and sliding stability are the main calculation contents of Levee project, and recheck analysis is required in the design, construction, and operation of levees.

Due to the complex and variable characteristics of the levee foundation and other natural conditions along the axis line, the design of the levee body is usually carried out in sections. Based on experience, several standard sections are first formulated for mechanical and permeability stability calculations, and then the design section is determined after economic comparison. This process involves the interaction of section design, safety analysis, and economic comparison. Due to the long axis line of levee project, the workload of section design is relatively large.

Due to the fact that the foundation of levees is mostly natural, it is difficult for the levee body to conduct standardized design and construction like earth dams. The distribution of soil layers and the variability of geotechnical parameters result in that levee safety evaluation is a difficult problem [3]. Compared with the safety evaluation of dam, China has not yet formed a unified evaluation method and standard for the safety evaluation of levee project. Zhou Xiaowen [4] believed that it is difficult to accurately calculate the dynamic seepage of levees and various complex situations of slopes by deterministic method. They established a seepage safety evaluation and landslide prediction model based on monitoring data, and developed a DSEWS levee safety monitoring and early warning system. Based on monitoring data, conducting safety assessment and prediction of levees is a logically simple and effective back analysis method. However, this method relies on hardware foundation and has high requirements for the quantity, quality, and survival rate of monitoring instruments arranged on the levee. Otherwise, it cannot achieve the goal of real-time monitoring. The automation of levee monitoring is an inevitable requirement and trend [5]. Install corresponding automated monitoring instruments

in important parts of the levee to regularly monitor the operational status of the levee [6], to timely detection and handling of dangerous and hidden dangers in levees is expected to gradually be achieved with the promotion of digital twin technology in water conservancy.

On the other hand, based on the current situation of Levee project in China, there are many studies on establishing a reasonable safety evaluation model to evaluate and predict the safety status of levees. Cai Xin [7] et al. introduced grey theory and constructed a risk assessment index system and mathematical model for levee safety based on the geological conditions of levee foundation engineering, river stability, permeability stability, sliding stability, levee integrity, and engineering management as the basic elements; Wang Xiujie [8] et al. proposed a comprehensive evaluation model for levee safety based on the combination of mutation theory and BP neural network; Lanbo [9] et al. used an improved fuzzy analytic hierarchy process (FAHP) and entropy weight fusion to determine the weights of various evaluation indicators; Gu Chongshi [10] et al. proposed a comprehensive weighting model for Levee project safety assessment experts, which integrates subjective and objective weights of experts, using fuzzy mathematics, pattern recognition theory, and dynamic clustering methods. Zhao Xin [11] et al. established a safety evaluation model for Levee project based on the core idea of Analytic Hierarchy Process (AHP) and safety index. Shi Jiafeng [12] et al. used the G1 method and CRITIC method optimized based on the C-OWA operator to subjectively and objectively weight the indicators, and constructed a safety evaluation model for Levee project using a grey fixed weight clustering method with a mixed center point triangle whitening weight function. The above research establishes a set of levee safety evaluation index system, determines the index values through automatic collection, data investigation, and expert scoring, and introduces multiple mathematical methods for comprehensive analysis of the indicators to obtain conclusions on the safety status of the levee. These studies provide new theories and methods for the daily safety evaluation of Levee project. However, during flood season, the sharp rise in water level leads to extremely harsh working conditions for levee inspection, making it difficult to obtain numerous indicators and timely analysis and calculation. Usually, the danger can only be discovered when it reaches the surface of the levee.

## 2. Technical principle

In recent years, with the development of computational mechanics, new possibilities have been provided for real-time safety assessment of levees. This article innovatively proposes a real-time positive analysis method for levee safety based on physical mechanisms. The logic of this method is shown in Fig. 1, and the BIM+Mechanism Algorithm method is applied to the full life cycle safety assessment of levees in West danger Levee standard reinforcement project. In the engineering design phase, construct geological modeling after geological survey data treatment, and then parametrically design to quickly formulate the levee structure. The BIM model can be used to automatically cut the section and extract the levee body and geological parameter information, which is automatically converted into a calculation model file. The finite element seepage algorithm and limit equilibrium anti-skid stability algorithm are deployed on the server side to perform batch calculations on multiple calculation model files,

improving the efficiency of design calculations. During the construction and operation phase, the calculation model files will be integrated into the data base of the levee safety, Integrate real-time and forecast water level, to further play the role of safety assessment, achieve the forward movement of safety risk analysis, better support the flood control command department to deploy manpower, materials, equipment and other flood control measures in advance.

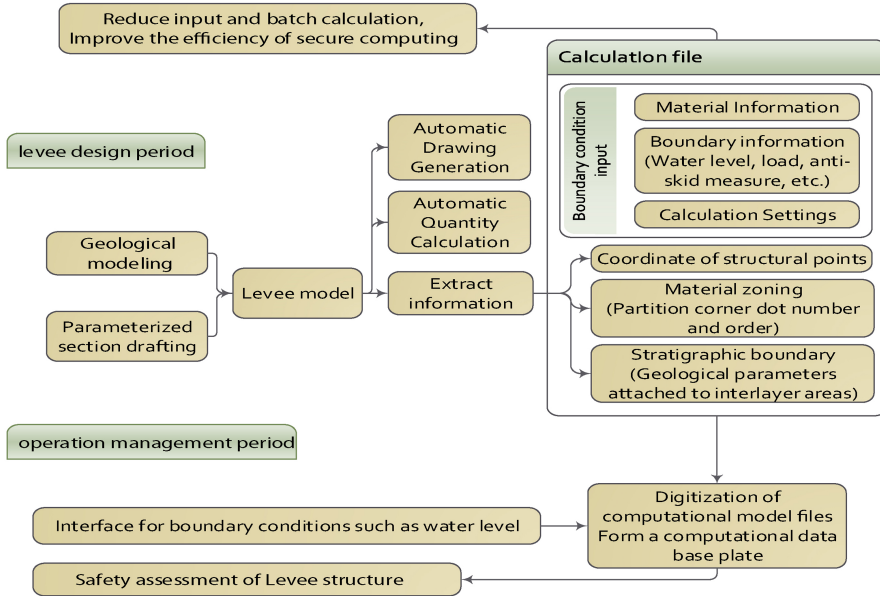


Fig. 1. Logic diagram of levee safety assessment using BIM+Mechanism algorithm

### 3. Project overview

West danger Levee is located on the right bank of Dongtiaoxi River in the Tiaoxi River Basin (one of the eight major water systems in Zhejiang Province), and is an important flood control barrier for Hangzhou City and the Hangzhou Jiaxing Huzhou Plain. The West danger Levee was first built in the Eastern Han Dynasty. After generations of construction, the rolling flood in the Dongtiaoxi River basin was stopped outside the levee, and led into the Tai Lake. With the passage of time, the West danger Levee has been aged and urgently needs to be reinforced to meet the standards.

The West danger Levee standard reinforcement project is a key project for the “Thousand Trillion” water network safety improvement in Zhejiang Province, and a major construction project for people’s livelihood by the Zhejiang Provincial Government in 2023. This project is a Class I project with a flood control standard of once every 200 years and a levee level of Grade 1 building. After reaching the standard for reinforcement, the West danger Levee and the large and medium-sized flood control reservoirs, detention areas, and diversion gates in the basin will jointly dispatch and work together to improve the water safety guarantee capability.

Taking into account factors such as anti-seepage, sliding stability, construction conditions, and surrounding conditions, the reinforcement of West danger Levee meets strict standards. Engineering measures such as dense pile arrangement at the foot of the levee, anti-seepage walls at the body of the levee, raising and widening of the top of the levee, and repair of flood control roads are adopted. At the same time, ecological, landscape, and cultural factors are organically integrated. Different cross-sectional forms are proposed and selected according to the needs of each levee section. West danger Levee will be constructed as a “safe levee, smart levee, and ecological levee”. The West danger Levee standard reinforcement project aims to create a model of digital twin levee projects within the province and even nationwide. It requires the establishment of a digital “intelligent” governance system with functions of forecasting, early warning, rehearsal, and contingency planning (“four pre”), empowering business application scenarios such as engineering safety, automatically simulating and analyzing engineering safety issues, providing comprehensive analysis, supervision, and management methods for engineering safety, and ensuring the reliable operation of the project.

## **4. Creation of levee safety data base**

### **4.1. Geological modeling of levees based on databases**

The structural safety of levees is closely related to the geological conditions of the levee foundation. In traditional geotechnical engineering surveys, when using two-dimensional graphics, documents, and other professional methods to provide information, there is a lot of geological information but a lack of integrity and continuity, making it difficult to visually and scientifically display the actual geological environmental conditions [13].

In the geological survey of embankment foundation, various geophysical methods including high-density electrical method and micro motion are introduced to obtain the apparent resistivity and transverse wave velocity profiles of underground media through inversion. At the same time, a small amount of drilling is used to verify and infer the distribution and trend of various rock soil interfaces, creating a three-dimensional geological model of the embankment project as a carrier of the obtained physical and mechanical parameters, and conducting a basic database for the verification of embankment permeability and deformation stability. 3D Geological models can make full use of terrain and geological data, intuitively display the composition, spatial morphology, distribution of strata, facilitate cutting analysis, structural design, and so on.

As a mathematical model, the modeling of three-dimensional geological models is a process of mathematical simulation through interpolation and fitting [14]. Due to the anisotropy and complexity of geological environments, three-dimensional modeling of geological bodies poses significant challenges [15]. In practical work, due to the influence of engineering cost, the number of engineering geological boreholes is generally rare and unevenly distributed, and there is no actual connection between each borehole. The range of rock strata relationships exposed by each borehole is limited. This means that relying solely on drilling data to establish accurate and complete 3D geological models is far from enough, needing conjecture based on work experience, on-site environment, and other survey information. Develop a professional program based on Civil 3D, and the program logic is shown in Fig. 2.

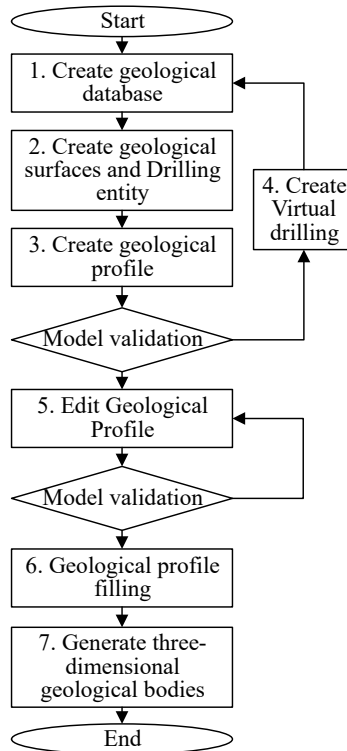


Fig. 2. Geological 3D modeling process

1. Create a geological database. Including geological and drilling information, such as geological feature description and physical and mechanical parameter indicators; Drilling number, location, and stratigraphic segmentation, etc.
2. Create geological surfaces and drilling solids. Automatically generate geological surface and drilling solid models based on information from geological databases.
3. Create a geological profile. Convert the levee axis into a cutting line and automatically cut out the geological profile.
4. Create a virtual borehole. Based on the speculation of the extinction point, add virtual boreholes and use them to modify the 3D geological model.
5. Edit geological profiles. Adjust the stratigraphic line on the profile diagram and synchronize it to the stratigraphic surface. By indirectly modifying the geological profile, the geological surface can be modified, which conforms to the speculation habit.
6. Conduct geological model inspection by combining two and three dimensions. After the inspection is completed, fill the special layer areas between the stratigraphic lines.
7. Create interlayer entities to form a complete 3D geological model

Firstly, the geological database is sorted out, and the formation surface is automatically created using drilling data. The accuracy of the surface is improved by using the elevation points on the survey map for the current terrain at the top layer. The surface is created along the

axis, and the formation surface is indirectly modified by modifying the geological profile. Then, based on the geological layer model, geological entities are created between adjacent geological layers, and finally integrated into a complete 3D geological model, as shown in Fig. 3.

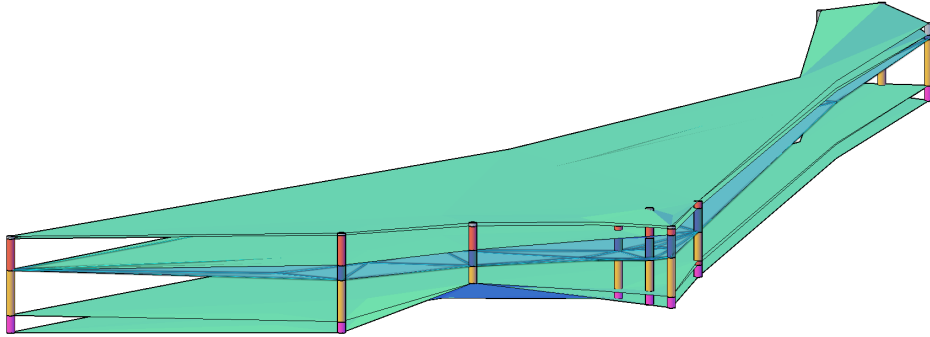


Fig. 3. Three dimensional model of levee geology

According to the “Recommended Values Table for Physical and Mechanical Indicators of Soil Layers” in the design report, the physical and mechanical indicators of each soil layer are attached to the corresponding soil layer entities for easy calculation of the cross-section and extraction of geological information from the soil layer entities.

## 4.2. BIM parametric design of levee structures

The design of the West danger Levee section comprehensively considers factors such as levee seepage prevention, sliding stability, construction conditions, and surrounding conditions, while organically integrating ecological, landscape, cultural, and other factors. Different section forms are proposed separately, and each levee section is selected according to the needs. Fig. 4 shows the structure at pile number k26+414.

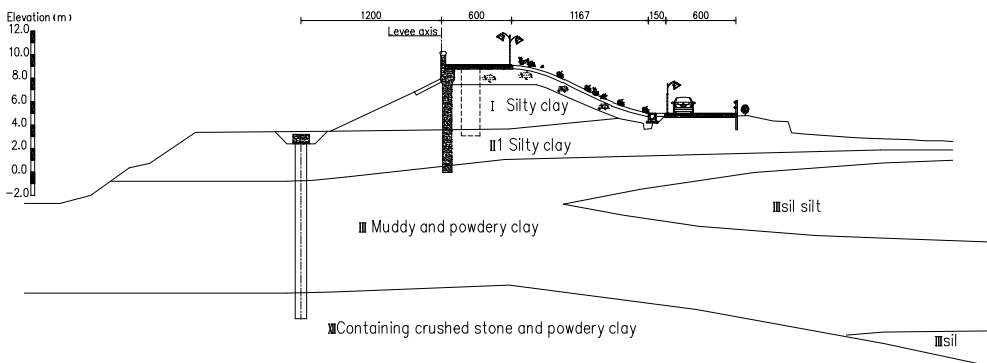


Fig. 4. Typical cross-section of the third section of West Danger Levee

The structural design of levees involves a repeated process of section drafting, structural calculation, and section adjustment. Due to the long route and numerous sections, the workload of the above process is enormous. Adopting the BIM parametric design method shown in Fig. 5, efficiency can be improved in section drafting, calculation interaction, and optimization adjustment.

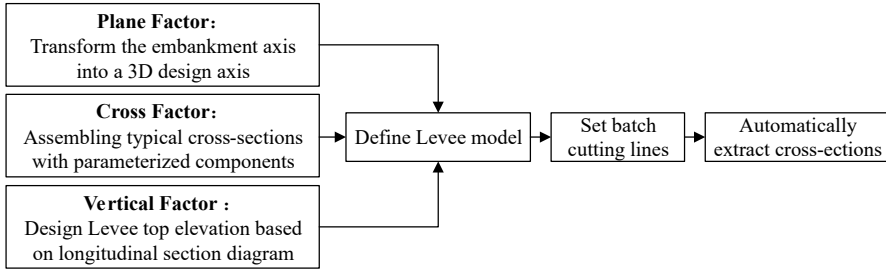


Fig. 5. BIM parametric design process diagram for West Danger Levee

Adopt the design concept of “achieving standardization through discretization”, common components such as wave walls (as shown in Fig. 6), road surfaces, slope protection types, drainage ditches, and levee bodies are extracted from common levee section types and designed into standardized forms according to their characteristics. In the design of levee sections, they can be assembled into sections as needed, which is not only efficient but also easy to design and manage.

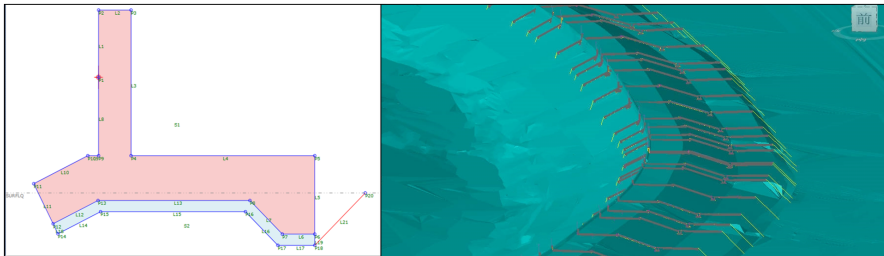


Fig. 6. Parameterized components and BIM model of West Danger Levee

### 4.3. BIM+GIS integration

BIM is a technology for dynamically managing information throughout the entire lifecycle of a building; GIS is a technology for processing spatial information and conducting relevant spatial geographic analysis [16]. BIM+GIS can integrate micro level building model information with macro level site environment information, forming a fully integrated digital twin of indoor and outdoor, above ground and underground elements.

This project survey adopts the CGCS2000 national geodetic coordinate system, selecting the geographic coordinate system EPSG: 4490 and the projection coordinate system EPSG: 4549 (3-degree Gauss Kruger CM 120E) for coordinate conversion and model registration between the plane and sphere. Afterwards, conducting model lightweighting, edge fusion, and rendering release, the West danger Levee BIM+GIS data base was formed as shown in Fig. 7.



Fig. 7. BIM+GIS data base of West Danger Levee

#### 4.4. Extracting calculation model

Use BIM models as the carrier of information integration [17], firstly, geological drawings, structural drawings, reports and other engineering basic data are linked to the corresponding leveeing structural and soil objects. Select calculation sections on the BIM model and automatically extract calculation information including structural zoning, geological stratification, and soil physical and mechanical indicators; On this basis, supplement the analysis and calculation conditions, such as boundary conditions for seepage calculation, search range for stable calculation, etc., to form a complete calculation model. The calculation file supports exporting as a text file, making it easy to modify and reuse in the future. Therefore, the cross-section in Fig. 4 can be saved according to the information listed in Table 1, and its corresponding calculation model is shown in Fig. 8.

Table 1. Necessary information included in the calculation profile

Information classification	Main information
Structural partitioning	Corner points and coordinates of each partition, partition material numbers, etc
Material information	Material parameters, including bulk density, permeability coefficient, strength index, etc
Grid information	The size or composition information of the grid
Seepage analysis	Location of seepage boundary (including fixed head boundary, outflow boundary, flow boundary, etc.)
Stable calculation	Search range for stable calculation, selection of seepage field, distribution of seismic acceleration, etc



Fig. 8. Seepage and stability calculation model of K26+414 section

## 5. Mechanism algorithm research and development

### 5.1. Algorithm principle

According to current regulations, seepage analysis requires obtaining results such as the infiltration line, infiltration amount, and elevation of the escape point, and determining whether the escape gradient behind the levee is greater than the allowable gradient of the soil to value the possibility of seepage failure. Sliding stability analysis mainly obtains the sliding stability safety factor and the most dangerous sliding arc to determine whether the stability meets the regulatory requirements and the areas where sliding may occur.

Levee seepage is a saturated unsaturated, unstable-stable development process, and the development of seepage algorithms needs to consider the existence of varying degrees of heterogeneity, anisotropic geometric shapes, and complex boundary conditions in the seepage field. Taking stable seepage as an example, a non-homogeneous anisotropic two-dimensional seepage field that conforms to Darcy's law is obtained, and the head potential function satisfies the differential equation

$$(5.1) \quad \frac{\partial}{\partial x} \left( k_x \frac{\partial \phi}{\partial x} \right) + \frac{\partial}{\partial y} \left( k_y \frac{\partial \phi}{\partial y} \right) + Q = 0$$

In the formula  $\phi = \phi(x, y)$  is the potential function of the water head to be solved, and  $x, y$  are the plane coordinates;  $K_x, K_y$  are the permeability coefficients in two directions.

The boundary conditions for seepage analysis in Levee project usually include the following:

1. The water head is known at the upstream boundary

$$(5.2) \quad \phi = \Phi_n$$

2. When the water head at the escape boundary is equal to the position elevation

$$(5.3) \quad \phi = y$$

3. At a certain boundary, the seepage amount  $q$  is known

$$(5.4) \quad k_x \frac{\partial \phi}{\partial x} l_x + k_y \frac{\partial \phi}{\partial y} l_y = -q$$

where  $l_x, l_y$  are the cosine of the outward normal of the boundary surface in the  $x, y$  directions.

Solve the seepage field analysis by finite element method (FEM). Discretize the calculation area using finite element method, as shown in Fig. 9. Assuming that the head function potential of the seepage field within the unit is a polynomial variation, the variational form of the problem can be determined by the differential equation and boundary conditions, leading to a system of linear equations:

$$(5.5) \quad [H]\{\Phi\} = \{F\}$$

In the formula,  $[H]$  is the permeability matrix;  $\{\Phi\}$  For the seepage field head;  $\{F\}$  Provide node seepage flow.

By solving a system of linear equations, the node head is obtained, and physical quantities such as hydraulic slope and flow velocity are obtained from it to complete the analysis of the seepage field.

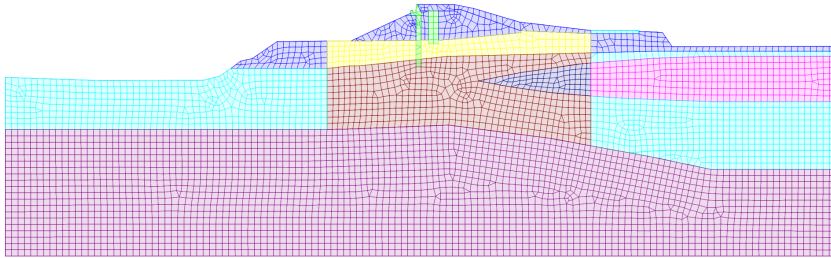


Fig. 9. Finite element mesh for seepage calculation of K26+414 section

According to the requirements of current regulations, the sliding stability of levees mainly adopts the rigid limit equilibrium method. The more common methods are the Swedish method and the simplified Bishop's method. The calculation formula for the latter is as follows:

$$(5.6) \quad K = \frac{\sum \{[(W \pm V) \sec \alpha - ub \sec \alpha] \tan \phi' + c' b \sec \alpha\} / (1 + \tan \alpha \tan \phi' / K)}{\sum [(W \pm V) \sin \alpha + M_C / R]}$$

In the formula:

- $W$  the weight of the soil strip (kN);
- $K$  the safety factor of Bishop's method;
- $V$  the vertical seismic inertial force (kN);
- $u$  the pore pressure acting on the bottom surface of the soil strip (kN/m<sup>2</sup>);
- $\alpha$  the angle (°) between the gravity line of the block and the radius passing through the center of the block's ground;
- $b$  the width of the soil strip;
- $c', \phi'$  The effective cohesion (kN/m<sup>2</sup>) and effective internal friction angle (°) of the bottom surface of the soil strip;
- $M_C$  The moment of horizontal seismic inertia force on the center of the circle (kN·m);
- $R$  arc radius (m).

According to different considerations of additional pore pressure, stability calculation is divided into total stress method and effective stress method. The total stress method does not consider pore water pressure and uses the total stress intensity index (fast shear index); The effective stress method takes into account the additional pore water pressure and uses the effective stress intensity index. The effective stress method is a universal calculation method that is applicable to various working conditions. The stable seepage period considers that the additional pore water pressure has dissipated and is not considered. The construction period and water level drop period should be included in the additional pore water pressure for cohesive soil.

## 5.2. Algorithmic programming

Develop calculation programs that comply with design specifications and industry practices, and after stability and reliability verification, put them into engineering applications. Using object-oriented technology to program the above calculations into corresponding functional calculation classes, accompanied by necessary functional and parameter interfaces, as shown in Table 2.

Table 2. Algorithm programming functions and parameter interfaces

Command	Function	Parameter
*bc_seep_h	Seepage fixed water level	side hw name istep. Among them, side is left/right. Hw is the water level. Name is the water level name [can be omitted]. ISTEP is the working condition number [can be omitted]
*bc_seep_mh	Fixed water level under multiple operating conditions	side name1 hw1 name2 hw2...
*bc_seep_ht	Boundary of seepage water level change	side, t0, hw0, t1 hw1...
*bc_seep_p0	Boundary conditions for seepage and escape	side,istep. Among them, istep is the working condition number [can be omitted]
*mesh	Grid division	maxH tri tol. Among them, maxH is the grid size, which can be omitted. Tri specifies the unit type, =1 is a triangular unit Tol is the repair tolerance
*solv_seep_steady	Solving for stable seepage flow	sp0 sp1 sp2... Specify the name of the infiltration line for each seepage condition. The number of names shall not be less than the actual number of stable seepage conditions
*solv_seep_unsteady	Solving Transient seepage Flow	nstep endtime sp0 sp1. Nstep is the number of steps for solving How many hours does NSTEP take to solve. Sp0, sp1 are the names of the infiltration line before and after the descent

By calling the member functions of the above classes in the CAD environment, the solution for seepage and stability analysis can be performed. With the help of CAD secondary development technology, read the cross-sectional position information, and the solution results such as infiltration line and sliding arc line are drawn to achieve automatic return of calculation results, combining the originally fragmented design and calculation process and improving the efficiency of design optimization. According to the design requirements for calculation, the calculation results are shown in Table 3.

Table 3. Main calculation results

Calculation type	Main Result
Seepage analysis	Single width permeability of the profile, elevation of the escape point, representative value of hydraulic slope, and location of the infiltration line (graphical results)
Stability analysis	Anti slip stability safety factor; The most dangerous sliding arc (graphical result)

In addition, deploy the computing program on the server and call it through the command line to achieve the transformation from offline to online facilitates the unified management and maintenance of algorithm programs, while laying the foundation for the integration of algorithms into the information platform.

## 6. Application benefit

### 6.1. Design and calculation integration

According to the method in Section 2.2, the parameterized typical section is initially proposed, and the algorithm is called for batch calculation in the design environment. Calculate in the order of seepage first and then sliding stability, and use the simplified Bishop method for sliding stability calculation. Calculate optimize recalculate until the structure is determined.

The water level combination for seepage calculation is as follows:

Stable seepage condition: The upstream side is at the design flood level ( $P = 0.5\%$ ), and the downstream side is at the corresponding low water level.

Transient seepage condition: The design flood level on the upstream side drops sharply to the normal water level (falling time of 250 hours), and the downstream side is at the corresponding water level.

The seepage stability of the levee body and foundation must meet  $J \leq [J]$ , and the settlement results are shown in Table 4.

Table 4. Calculation results of seepage at K26+414 section

Pile Number	Stable seepage condition		Transient seepage condition	
	Maximum seepage ratio drop	Allow seepage ratio to decrease	Maximum seepage ratio drop	Allow seepage ratio to decrease
K26+414	0.01	0.32	0.23	0.32

The stability calculation of levees is divided into normal and abnormal conditions, including four working conditions. The simplified Bishop method is used, and the calculation results are summarized in Table 5, all of which meet the requirements of the specifications. The most dangerous sliding arc during normal operation is shown in Fig. 10.

Condition 1: Stability calculation of the backwater side levee slope during stable or transient seepage periods at the design flood level;

Condition 2: The design flood level on the water side drops sharply to the normal water level (with a drop time of 250 hours), and the stability of the levee slope on the water side is calculated.

Condition 3: Constant water level on the water facing side, groundwater level on the water facing side (1.0 m below ground level), and stability calculation of levee slopes on the water facing and water facing sides.

Condition 4: When encountering an earthquake at the average water level for many years, the stability calculation of the levee slope on the water side.

Table 5. Calculation results of sliding stability of K26+414 section

Pile Number	Anti slip stability calculation			
	Working condition		Anti-skid coefficient	
			Calculation Value [K]	Allow Value [K]
K26+414	Normal operating conditions	Stable seepage period (downstream slope)	1.696	1.50
		Water level sudden drop period (upstream slope)	1.513	
	Abnormal operating Conditions I	Construction period (upstream slope)	1.323	1.30
		Construction period (downstream slope)	1.352	
	Abnormal operating ConditionsII	Seismic conditions (upstream slope)	1.467	1.20

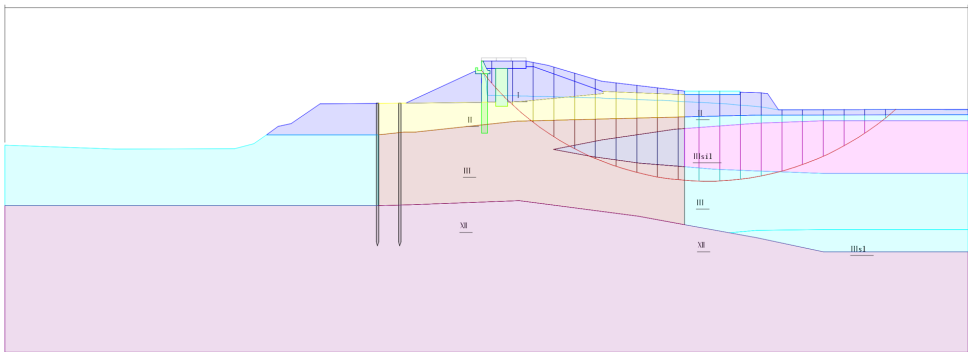


Fig. 10. Calculation results of anti-skid stability of K26+414 section

## 6.2. Security assessment of digital twin engineering

The safety evaluation of Levee project is not a static event, but a continuous dynamic process. At present, research on the formation mechanism and prediction technology of levee hazards is basically at the stage of observing phenomena and organizing and analyzing monitoring data. With the help of the Mechanism Algorithm in this article, the traditional mesh inspection and management mode of Levee project can be improved, enabling early assessment of levee safety risks, transforming passive risk investigation into active safety assessment, and achieving predictive engineering management.

The main factors affecting the safety of levees include geological parameters of soil layers and calculated water levels. The former can be updated through geological exploration and geotechnical testing, while the latter is transmitted in parameter form through the levee's online monitoring data interface, such as docking with a flood forecasting system, matching with mileage and latitude and longitude to extract corresponding predicted water levels for real-time calculation and evaluation.

## 7. Conclusion and prospect

This article focuses on the safety assessment of the entire life cycle of levees, and conducts research on 3D geological modeling, BIM parametric design, and Mechanism Algorithm development. It provides innovative technical solutions for Levee project design calculation, operation period safety evaluation, and forecasting. The main conclusions are as follows.

1. The essence of BIM is a database constructed according to the intuitive physical form of buildings, containing various geometric and non geometric data information. The essence of BIM application lies in integrating this information throughout the entire lifecycle of the project. This article is based on BIM transmitting parameters such as levee structure and geology during the design and operation management stages, which is a practical implementation of BIM throughout the entire lifecycle and has practical reference significance.
2. The safety assessment of Levee project is a complex system engineering. This article believes that research based on the underlying mechanisms and structural characteristics can accurately, comprehensively, and long-term reflect and predict the objective characteristics of things. The cloud based application of Mechanism Algorithms is a process of combining professional knowledge with information technology, which is of great significance.
3. The original intention of digital twin is to build a digital, high fidelity tested system in a virtual space. Based on this system, structural damage and other situations that physical engineering cannot withstand can be simulated and rehearsed at low cost. The research content of this article belongs to the key technologies of digital twin and intelligent simulation in Levee project, which has reference value for similar tools.

Due to the fact that levee projects are mostly products of different historical periods, there are significant differences in the natural geographical conditions, socio-economic conditions, and other factors of the regions where they are located, resulting in a wide variety of

hazards and complex disaster mechanisms. The underlying mechanical analysis method of the Mechanism Algorithm in this article contains many assumptions, and a reasonable levee safety evaluation model needs to be continuously verified and modified through mechanism calculation, detection and monitoring results. Therefore, the next step will focus on studying the mechanism mathematical coupling safety algorithm.

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