Risk Assessment Technology and Strength Reliability Analysis of Old Building Reconstruction

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Abstract. As a product of the infrastructure era, old buildings have impeded urban renewal. The uneven level of construction technology in the past has led to the unpredictability of whether various old buildings can continue to be used and accept the reinforcement treatment. In order to solve these problems, the main components of the old building are sampled and tested by testing methods, including foundation bearing capacity, structural strength, crack development, structural size, etc. Then, according to the statistical principle, the reliability of each component is analyzed to obtain the 95% probability guarantee rate limit requirement under the normal function distribution law, which is regarded as the bearing capacity of the structure. Finally, the calculated bearing capacity limit is compared with the minimum bearing capacity required by the reinforced component specification. If it is met, the component meets the normal use standard; if not, the reinforcement is carried out. The research shows that the method can be used to analyze the monitoring results of the bearing capacity of each component quickly and effectively, and the bearing capacity assessment and reinforcement method can effectively help obtain the information of the components required for the reconstruction of the old building. The method is feasible and can bring great economic effects to the reconstruction of old buildings.

Keywords: Renovation of old buildings; Risk assessment; Strength; reliability

1 Introduction

At present, many cities in China are faced with many problems such as insufficient funds, and it is necessary to rationally optimize the use of funds, and at the same time, in order to reduce the adverse impact of existing old buildings on the environment, the old building reconstruction and expansion technology has gained much attention.

The technology of renovation and expansion of old buildings requires first to investigate the situation of old buildings [1-3], and to conduct safety appraisal of the old building according to the inspection results [4], then it requires to carry out reinforcement and protection measures, and finally to take targeted measures to carry out

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reconstruction and expansion construction. A large number of scholars at home and abroad are engaged in this research. For example, Martina omodíková et al. [5] who had been studying old bridges around the world, carried out bearing capacity analysis and research according to the age and degree of degradation, and estimated the detailed reliability and life of the later bearing capacity reduction trend, and put forward reinforcement needs. Chen Zhang[6] analyzed and researched the application of chemical reinforcement technology in seismic reinforcement construction, concrete wet spray method to brick wall reinforcement construction technology, and concrete column component sticky steel reinforcement technology in this project. Wei Huan [7] considered the time-varying nature of load and resistance and the randomness of basic variables, and established the load effect model and resistance effect model for structural reliability analysis, including considering the evaluation base period and the live load effect correction coefficient so as to establish the vehicle load effect model. Yao Rui [8] proposed reinforcement and protection measures for the inaccurate exploration of existing houses, insufficient estimation of foundation bearing capacity and structural component design, poor quality during construction, excessive use of groundwater, natural disasters, etc., resulting in overall settlement or uneven settlement of buildings or doing damage to structural components [9-10].

2 Project overview

As for the reconstruction and expansion of the old hospital building in a southern city, the main building of the house is three-storey and the annex building is a two-story brick-concrete structure with a height of 10.6 m and a total construction area of 2359.4 m^2. It was built in the 1980s and no design drawings were left.

The top of the old building is a prefabricated panel roof. There are no circle beams and structural columns. However, there are ground beams and a sheet stone strip foundation. The site diagram is shown in Figure 1.

Fig. 1. Current situation of old buildings

The reconstruction and expansion of the old building refers to the reinforcement on the basis of the existing building and the renovation and expansion around the original building. The expansion process will destroy the original structure. Therefore, the existing building needs to be strengthened, and the strength of the existing building needs to be tested before reinforcement.

The strength testing of existing buildings mainly includes the foundation, the bearing capacity testing, the identification and inspection of structural members, the lateral displacement (verticality) measurement of the structure apex and the bearing capacity checking calculation of the main structure.

3 Existing building strength testing

3.1 Foundation inspection and bearing capacity inspection

The detection of foundation mainly focuses on ground cracking, tilt and deformation, and analyzes the bearing capacity of its components according to the detection data.

The “light cone dynamic penetration method” is often adopted to detect the bearing capacity of the foundation at the bottom surface elevation. The light cone dynamic penetration is a method in which a certain hammering energy (hammer weight 10 kg) is used to drive a certain specification of cone probe into the soil and the bearing capacity of the foundation soil will be inferred according to the number of penetration hammers. For the detection of the bearing capacity of the staircase, the project tested 3 places of foundation excavation. The foundation is mainly a sheet stone foundation, and the buried depth is 900 mm. The detectable foundation part was mainly excavated. The excavation status is shown in Figure 2.

3.2 The defect detection of crack and quality of structures and components

The quality inspection of structural components is mainly aimed at the quality defect of masonry structures and concrete components. The test needs to be focused on the structural form of the staircase, the appearance of the floor, slab, wall and other structures, and the overall condition of the staircase based on the deformation of the appearance.

According to the on-site inspection and overall inspection, it can be seen that the cracking between the prefabricated panels of each layer is relatively common, and there is a certain overall risk. But when the masonry structure of the house was inspected, no obvious cracking and deformation phenomenon in the wall was found. It is generally known that there is a certain deformation displacement between the structures, but its deformation is controllable, and there is no irreparable and reinforced deformation accident.

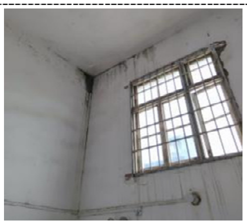

Fig. 2. Status diagram of stair cracks

3.3 Structural component identification and testing

The structural components are mainly masonry mortar, sintered brick, concrete and their component sections. Different detection methods are adopted for different components, as follows:

1) Masonry mortar compressive strength test

Masonry mortar testing adopted the "penetration method" to test the compressive strength of the masonry mortar of the project, extracted 6 components, and tested the strength of masonry mortar according to the relevant provisions of the Technical Regulations for Detecting the Compressive Strength of Masonry Mortar by Penetration Method (JGJ/T 136-2017).

2) Concrete compressive strength test

The compressive strength test of concrete was tested by the "springback method", and 5 components were extracted and mixed back compressive strength according to the Technical Regulations for Detecting the Compressive Strength of Concrete by the Rebound Method (JGJ/T 23-2011).

3) Inspection of reinforcement of concrete structural components

The reinforcement detection of concrete structural components was carried out by using an integrated rebar scanner, and five members of the beam components in the inspectable area of the project were randomly selected to detect the number of main stressed steel bars and stirrup spacing.

3.4 Lateral displacement (perpendicularity) detection of vertices of the structure

The verticality detection uses a theodolite combined with a steel tape to measure the lateral displacement (verticality deviation) in 6 directions of the 3 large angles that can be measured in the project. The measured height of the main building is 10.2 m, and the measured deviation value is 14 mm, 18 mm, 22 mm, 16 mm, 12 mm, 16 mm.

4 Detection intensity and reliability analysis

4.1 Structural reliability design and evaluation method

The bearing capacity of each component can generally be expressed as

$$R_k = \frac{\mu_R}{\chi_R} \tag{1}$$

The structural mean coefficient x_R in the formula is determined according to the safety factor of each component, but at this time, the component coefficient μ_R of the bearing capacity coefficient should be determined according to the mean coefficient of the component, and the bearing capacity of the component R_k is determined according to the standard values η_{Rk}, f_{ik}, and a_{ik} of the calculation mode indefinite coefficient η_R, material strength f_i, and geometric parameters a_i, as shown in Equation 2.

$$R_k = \eta_{Rk}\left(f_{1k}, a_{1k}, f_{2k}, a_{2k}, \ldots\right) \tag{2}$$

In the formula, the specific parameters are detailed in Equations 4-5:

$$\eta_{RK} = \frac{\mu_{\eta R}}{\chi_{\eta R}} \tag{3}$$

$$f_{ik} = \frac{u_{fi}}{\chi_{fi}} (i = 1,2,\ldots) \tag{4}$$

$$aik = \frac{\mu_{a_i}}{\chi_{a_i}} \tag{5}$$

The value of χ is shown in Equation 6-8:

$$\chi_{\eta_R} = 1 \tag{6}$$

$$\chi_{a_i} = 1 \tag{7}$$

$$\chi_{f_i} = \frac{1}{1 - 1.645\,\delta_{f_i}} \tag{8}$$

That is, the standard value of bearing capacity is determined by a guarantee rate of 95%, specifically shown in Equation 9:

$$\chi_R = \frac{\mu_R}{\mu_\eta R\left(\frac{\mu_{f_1}}{\chi_{f_1}}, \mu_{a_1}, \frac{\mu_{f_2}}{\chi_{f_2}}, \mu_{a_2}, \ldots\right)} \tag{9}$$

4.2 Safety structure identification standards and handling requirements

Structural identification of structural member safety can be divided into single member, sub-unit and unit identification. A unit is composed of subunits, and subunits are composed of components. When the component meets the overall structural bearing capacity, the safety level is a, which is the best state, as shown in Table 1.

Table 1. Safety appraisal grading standards and processing requirements

grade	Grading criteria	Processing Requirements
a_u	The safety meets the requirements of this standard for AU level and has sufficient bearing capacity.	It is not necessary to take action.
b_u	The safety is slightly lower than the requirements of this standard for the AU level, and it does not significantly affect the bearing capacity.	No action may be taken.

c_u	The safety does not meet the requirements of this standard for the AU level, which significantly affects the bearing capacity.	Measures should be taken.
d_u	The safety is extremely inconsistent with the requirements of this standard for AU level, which has seriously affected the bearing capacity.	Measures must be taken promptly or immediately.

Table 2. Safety appraisal grading standards and processing requirements of identification units

grade	Grading criteria	Processing Requirements
A_u	The safety meets the requirements of this standard for A_{su} level and does not affect the overall bearing.	There may be a very small number of general components that should be acted upon.
B_u	The safety is slightly lower than the requirements of this standard for A_{su} level, and it has not significantly affected the overall bearing.	There may be very few components that should be acted upon
C_u	The safety does not meet the requirements of this standard for A_{su} level, which significantly affects the overall bearing.	Action should be taken, and there may be a few components that must be acted upon immediately.
D_u	The safety is extremely inconsistent with the requirements of this standard for A_{su} level, which seriously affects the overall loading.	Immediate action must be taken.

4.3 Safety testing and evaluation of each component

The component test results are selected from multiple samples, and the mean and variance calculations are carried out based on the bearing capacity value obtained by multiple samples. The critical value of bearing capacity can be defined as the bearing capacity standard value under the event of a probability of 95% according to the distribution of normal functions. And compared with the permanent value of the load required for the strength of reconstruction and expansion, the safety level is high when it is greater than the permanent value, and low when it is less than it, as shown in Table 3.

Table 3. The standard value of bearing capacity of each component is guaranteed at 95%.

serial number	place	Type of carrying capacity	Number of samples	average value	Standard value (at 95%)	Security rating	Actions
1	Foundation 1	Measured hammer number (hit/30cm) presumed basic bearing capacity (kPa)	18	99	78	b_u(Slightly below the standard 80KPa)	No action may be taken.
2	Foundation2		20	115	97		
3	Foundation3		18	99	75		
4	East floor wallQ～S×10	Mortar compressive strength conversion	10	0.8	0.6	d_u(Less than 90% of the	It should be reinforced with a reinforced mesh
5	East two-story		10	3.1	2.6		

	wallQ～S×17	value $f_{c2,j}$(MPa)				standard value)	mortar surface (concrete surface).
6	East three-story wallQ～S×17		10	0.8	0.6		
7	West floor wallQ～S×10	Measuring area compres-sive strength value f_{1i} (MPa)	10	11.8	9.7	b_u(Slightly lower than the standard 9.2MPa)	No action may be taken.
8	West two-story wallQ～S×17		10	10.8	8.7		
9	West three-story wallQ～S×17		10	8.4	7.9		
10	Roof beamsT×7	Conversion value of concrete compressive strength(MPa)	15	24.0	22.7	d_u(Slightly lower than the standard 23.5MPa)	Ribbed rein-forcement should be anchored to. concrete with adhesives
11	Three-layer beamS～T×9		15	24.6	23.0		
12	Two-story beamS～T×10		15	25.1	23.9		

The results of Table 3 show that the safety identification of different parts is different, as follows:

Foundation safety appraisal rating: The on-site inspection did not find that the house had cracking and deformation caused by uneven settlement of the foundation, and the house did not tilt. Referring to the relevant provisions of the foundation safety appraisal rating in Table 1, the foundation safety appraisal rating of the house is b_u.

2) Safety appraisal rating of upper load-bearing structure: According to the existing appearance quality of the structure, the main structure of the house has no obvious deformation and tilt, but the ratio of masonry resistance to load effect in many parts of the house is less than 0.90. In Table 2, the safety appraisal of the superstructure of the building is rated as d_u.

3) Safety appraisal rating of identification unit: Based on the on-site test results and referring to the relevant provisions of Table 3 on the safety appraisal rating of the appraisal unit, the building safety level is rated as D_u.

5 Reinforcement method

The inspection of existing buildings is mainly for testing the bearing capacity strength and reliability of each component of the building. The main body of the structure is designed according to the monitoring results of each component. The test results determine the construction method and corresponding measures are taken to strengthen the existing components.

5.1 Reinforcement engineering

Planting is a process that the ribbed steel bars or fully threaded screws are anchored into the base concrete with a special structural adhesive. Holes of a certain diameter and depth are drilled in the concrete, and adhesives are used to firmly bond the new steel bars or screws which can conform to the expected performance of the design to the concrete. The tensile force acting on the reinforcement is transmitted to the concrete by the adhesive. The planting process is simple, and the anchoring is fast, safe and reliable, so it is widely used in structural reinforcement, reinforcement, new and old structural connection, buried steel bars, and buried steel components.

5.2 Rebar mesh mortar surface (concrete surface layer) reinforcement wall works

1) Grassroots treatment

Ensure that the reinforcement layer is reliably bonded with the original wall, and the parts of the original wall that are damaged or have more serious alkali should be partially dismantled and repaired first. The original stucco layer with low strength and weak bonding of the wall, smooth face brick or stone finish layer, etc. must be removed, and cleaned with a wire brush and pressure water. The well-bonded original cement mortar stucco layer without empty expansion can not be removed but should be chiseled, and the surface oil stain should be brushed clean with high-pressure water. This ensures reliable bonding between the surface layer and the base layer.

2) Reinforcement mesh laying

When laying the rebar mesh, the vertical rebar should be close to the original wall. The gap between the rebar mesh and the wall is not less than 5 mm, and the short steel bar or concrete pad is used to erect the rebar mesh to ensure the distance. The connection between the rebar mesh and the surrounding component walls, such as the welding of short rebar, expansion bolt and rebar mesh, should be checked and verified. When reinforcing the steel mesh and wall on both sides, the S-shaped 6 steel bar is used to drill through the wall. The spacing is 900 mm in a plum blossom-like arrangement. The single-sided reinforcement adopts L-shaped 6 steel bar. The steel bar is anchored and a hole is excavated to be filled with M10 cement mortar. the hole size is 60 mm* 60 mm and the depth is 150mm. The spacing between each hole is 600mm, arranged in a plum blossom pattern.

3) Cement mortar surface layer

The cement mortar strength grade of M10 is used for plastering. The wall will first be watered and then plastered when the wall is slightly dry. Cement mortar must be plastered layer by layer and the thickness of each layer should be consistent with the design one. The mortar surface layer is divided into three layers and plastered one by one. The first layer requires the gap between the steel mesh and the masonry to be solid; the second layer is plastered after the first one sets and the mortar is required to cover the steel mesh completely; the thickness of the third layer is required to conform to the design one.

6 Conclusion

Before the reconstruction and expansion of old buildings, it is necessary to test the bearing capacity strength of them. However, due to the randomness of the sample point, the strength test result cannot be directly applied. Therefore, there is a need to carry out the normal function distribution of the sample point through random probability to obtain the available 95% probability standard value and select reinforcement methods based on the evaluated structural safety level. The contents are as follows:

1) The bearing capacity strength of the foundation is slightly lower than the standard 80KPa, and the safety level is $b_{u;}$ The strength of the eastern wall of the old building is less than 90% of the standard value, and the safety level is d_u; The strength of the western wall of the old building is slightly lower than the standard 9.2 MPa, and the safety level is b_u; the strength of the beam is slightly lower than the standard 23.5 MPa, and the safety level is b_u.

2) According to the safety rating results of the old building, the eastern wall of the old building was supplemented and reinforced with steel reinforcement, and the beam structure was reinforced with reinforcement, which met the bearing capacity requirements of the reconstruction and expansion project.

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