Research on Plant Core, Patch Repair Method of Huizhou Traditional Architecture Timber

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Abstract. Huizhou traditional architecture design method of repair beams is one of the hot spots in the present study of ancient architecture. Based on the basis of a large number of data collection and on-the-spot investigation, research and combined with the national regulations of the traditional building repair method of reinforcement beams, analysis of the Huizhou traditional architecture in timber frame beams damaged reasons, summed up the ancient building timber strength, stiffness the degree of the calculation formula and the core of planting of Huizhou traditional architecture beams by the finite element method, the crack patching reinforcement method is analyzed by numerical simulation. The results show that: when the damaged section beam strength and stiffness, through strengthening after the renovation has been improved; through the core and damaged beams, crack patching reinforcement method after repair is to meet the requirements of the standard. Through theoretical calculation and numerical analysis of beams, the calculation results are consistent, repair reinforcement design verification of Huizhou traditional architecture wooden frame beams The feasibility and feasibility of this method can be used as a reference for the protection and renovation of ancient buildings in Huizhou.

1. Introduction
Huizhou ancient buildings are rich in historical significance and artistic value. Because of the long-term influence of natural environmental factors, the maintenance structure of many ancient buildings in Huizhou has gradually been destroyed, which has caused serious damage to both internal and external structures. Ancient buildings have taken certain measures to strengthen and repair, especially the safety of wooden beams plays an important role in the overall structure of ancient buildings, and its overall stability is the key to determine the safety performance of ancient buildings in Huizhou. In actual engineering, has A large number of Huizhou traditional buildings are seriously damaged, and it is necessary to study the method of strengthening and repairing Huizhou traditional buildings. At present, some experts and scholars at home and abroad have studied the wooden beams of ancient buildings. In 2005, Zhu Jinbiao et al. [1] proposed a method of simulating the damage of wooden beams, researched and analyzed the damage characteristics of damaged wooden beams reinforced with carbon fiber and how such reinforcement affects the ultimate bearing capacity, stiffness, ductility, etc. Yu Qiong and Lu Zhoudao [2] conducted in 2006 In addition to the experimental research on the bending load of wooden beams strengthened by carbon fiber, Yang Xiaojun, Wang Quanfeng and other scholars [3-5] also made related research on the reinforcement and repair of wooden beams in ancient buildings [6-7], and combined with the design principles of wooden structures [8] and national regulations [8-9] and specifications [10] to further study the wooden construction industry. However, it can be seen from the domestic and foreign research literature that the research and application of the design method for the reinforcement and repair of traditional wooden structures in Huizhou [11] rarely involve. This paper summarizes the strength and stiffness
check formulas of wooden beams of ancient buildings in Huizhou by studying the core beam and crack repair methods of traditional buildings in Huizhou. Through numerical calculation methods, the core beam and crack repair methods of wooden beams in Huizhou traditional buildings are studied by numerical calculation methods. The protection of architectural wooden beams and the inheritance of traditional buildings in Huizhou are of great significance.

2. Repair and reinforcement methods of wooden beams in traditional buildings in Huizhou

The damage of Huizhou traditional buildings is mainly due to the following three factors: first, cracking. The factors of wood cracking are mainly two points: first, the raw materials are not dry when processed, and the environmental temperature and humidity of the wooden components are changed. At the time, the degree of internal and external shrinkage of the constituent fibers is different, causing cracking; in another case, the wooden member is subjected to load for many years, the wood is aging, and the tensile and compressive and shear resistance properties are reduced, which leads to cracking. Second, deformation. When the deformation is too large after force, it will cause structural damage when it exceeds the specified value of the hazard standard. Third, the tenon is drawn. The connection between the wooden elements of traditional Huizhou architecture is called the tenon-mortar connection, if the external force is applied for a long time or the material shrinks itself too large, there will be a tenon phenomenon. For the above reasons that lead to the damage of Huizhou traditional buildings, this article summarizes and summarizes the reinforcement method of Huizhou traditional building wooden beams, that is: Huizhou traditional building core planting, crack insertion and reinforcement method.

2.1. Principles for repairing wooden beams of traditional buildings in Huizhou

Repair and reinforcement must maintain the original Huizhou architectural style, inherit the traditional building skills of Huizhou, and comply with relevant regulations and acceptance standards. The selection of repair and reinforcement materials should comply with the provisions of the "Technical Specifications for the Maintenance and Reinforcement of Ancient Wooden Structures" [12] In addition, the following requirements should be followed:

Wood. The following circumstances need to follow the content of the "Wood Structure Test Method Standard" [13] for wood physical and mechanical performance tests, and the results can only be selected for use.

1) New tree species unfamiliar with its performance;
2) Reuse the old timber that has been used for a long time as the main beam and column;
3) The color and weight of the wood used for making the wooden frame are obviously different from the wood of the same type or wood that may have deteriorated;
4) Wood with an average annual ring width of wood heartwood greater than six millimeters;
5) Wood with doubts about the performance and quality of wood.

When repairing, priority should be given to selecting the same kind of tree species as the wood used for the original component. If it is really difficult, a material with a strength level greater than the original component should be selected for replacement.

When the external factors have too much influence on the overall performance of the wooden beam structure, making the building unusable, certain reinforcement measures should be taken for the wooden beam structure, and a reliable reinforcement and repair plan should be worked out in time. The existing building body of the wooden beam was changed, and the damaged wooden beam structure was reinforced and repaired by core implantation and crack embedding to restore the wooden beam to its healthy state and ensure the safety of Huizhou traditional buildings during normal use.

2.2. Common damage of wooden beams in Huizhou traditional buildings and corresponding repair methods

The common wooden frame damage forms of Huizhou traditional buildings include the deterioration of the roots and beams of the pillars, the splitting of the column body, the breakage of the wooden
beams, the tilting of the wooden frame, the tenon pull, etc. These damages are mostly due to the humidity of the environment and the bearing. It is caused by large loads. For the wooden beams that are an important part of the wooden frame, there are mainly several types of typical damage forms, which are not only common in ancient wooden beams in the Huizhou area, but also exist in other areas.

2.2.1. Repair of cracks in wooden beams
Liang Fang has dry shrinkage cracks or split cracks. The first step is to remove the damaged wood in the cracks, carry out insect control and anticorrosion treatment, and finally deal with according to the specific size:

1. When the horizontal crack depth of the wood beam to be repaired is less than the width of the beam or a quarter of the beam diameter, embedding is used to reinforce and repair, first use wood strips and water-resistant adhesive to embed and repair the gap and embed the gap. It is strong and tight, and then tighten it with an iron hoop. The iron hoop is not less than two. When the crack is long, the spacing of the iron hoop should not exceed 500mm;

2. If the crack depth of the wooden beam is deeper than the specified limit, the bearing capacity of the wooden beam must be checked. If it can meet the requirements, it can still be repaired by 1 method; if it does not meet the structural bearing capacity requirements, it should be Replace as original.

2.2.2. Internal degradation of wooden beams
The inside of the beam is decaying but painted on the surface. In order to maximize the protection of its painting and historical information and the value of its existing cultural relics, it is appropriate to use the reinforcement method of the new core placed inside the beam. The support of the reinforced beam reduces the load. The volume of the damaged part is relatively small, the length is within a quarter of the length of the wooden beam, and the diameter does not exceed one third of the wooden beam [29]. The repair method and steps are: first punch holes on the surface of the wooden beam, one or two holes can be punched, the specific situation should be determined according to the size of the damaged part, and then the clean and decayed and damaged places are removed through the holes to be able to see the good condition. The wood shall prevail, and then remove the debris at the clean holes, and finally fill the wooden beam with epoxy resin and wood chips to reinforce. If there is decay inside the wooden beam, and the damaged volume is very large, that is, the length of the damaged part exceeds The quarter of the beam body or the diameter exceeds the third of the beam diameter, but due to the beautiful carving on the surface of the wooden beam, if the value of the cultural relics is very high, we usually choose the core planting method to strengthen and repair. Slot the back of the beam, remove the rot, remove the residue, and carry out termite control. According to the size of the space after removal and removal. Use the same tree or similar dry wood to make the shape (including the tenon) and implant it into the beam. Swing stable, center line, lay flat, after fixed with steel bolts up and down, slowly pour epoxy resin glue, after the steel bolts are reinforced, you need to close the groove with a wooden plug so that the nut is not exposed.

3. Basic formula for checking the bearing capacity of wooden beams in Huizhou traditional buildings

3.1. Check the flexural bearing capacity of the bending members of wooden beams by the following formula:

\[
\frac{M}{W_m} \leq f_m
\]  (1)
3.2. The calculation of the shear capacity of the bending members of wooden beams by the following formula:

(1) The bending member without incision is pressed

\[
\frac{VS}{lb} \leq f_v
\]

(2)

Checking:

(2) Notched bending mechanism

\[
\frac{3V'}{2bh_v} \left( \frac{h}{h_v} \right) \leq f_v
\]

(3)

Checking:

3.3. Check the deflection of the wooden beam by the following formula:

\[
\frac{l}{250}
\]

The allowable deflection is, \( \frac{5q l^4}{384EI} \), the actual deflection is

\[
\frac{5q l^4}{384EI} \leq \frac{l}{250}
\]

among them:

- \( f_m \) — Design value of flexural strength of wood (\( N/mm^2 \));
- \( M \) — Design value of bending moment of bending member (\( N \cdot mm \));
- \( W_n \) — Net section resistance moment of bending member (\( mm^3 \));
- \( f_v \) — Design value of shear strength of wood along grain (\( N/mm^2 \));
- \( V \) — Shear design value of bending member (\( N \));
- \( l \) — Moment of inertia of the full section of the member (\( mm^4 \));
- \( b \) — Cross section width (\( mm \));
- \( h \) — Height of section of member (\( mm \));
- \( q \) — Beam load on line (\( N/mm \));
- \( b_n \) — Net section height of component (\( mm \));
- \( E \) — The elastic modulus of wood transverse grain (\( Mpa \));
- \( l \) — Beam span (\( mm^3 \));
- \( S \) — Area moment of the cross-sectional area above the shear plane to the neutral axis (\( mm^3 \)).

4. Numerical analysis of wooden beams in Huizhou traditional buildings

4.1 Calculation parameters
In this paper, the wooden beam calculation model uses a rectangular cross section, and the long side of the cross section is slightly negligible. The wooden beam is 4400mm long, the cross section size is 240 × 400mm (section width × height), the iron hoop thickness is 5mm, and the width is 50mm. The actual decay situation is modeled, and the method of Ansys is used for simulation analysis before and after reinforcement.

4.2. Structural calculation conditions
1) Working condition one (internal decay): The decay of the wooden beam core is shown in Figure 1, and the decayed part is approximately a 4200 × 180 × 340mm (Long × width × High) cuboid, 30mm from the decaying part to the outer surface of the shell (see Figure 1).
2) Working condition two (partial decay of the wooden beam and beam body): the decay degree of the middle part of the wooden beam and beam body is shown in Figure 2. Rectangular (see Figure 2).

Figure 1. Cloud analysis of numerical analysis after wood beam core planting, repair and reinforcement

Figure 2. Cloud analysis and numerical analysis of local repair and reinforcement of wooden beams

4.3. Comparative analysis of numerical analysis and theoretical calculation of damaged wooden beams and reinforced wooden beams
Through the numerical analysis of the wooden beam and the theoretical calculation of the wooden beam in this paper, the data results can be obtained in Tables 1, 2, and 3 below. Three cases of partial deterioration of the beam body, and cracks across the beam body) the flexural strength, shear strength and deflection data obtained by the wooden beam using two different methods of theoretical calculation and numerical analysis.

Table 1. Working condition 1 Theoretical calculation and numerical analysis results before and after reinforcement

| Wooden beam condition | Before reinforcement | After reinforcement |
|-----------------------|----------------------|---------------------|

5
Calculation and Analysis Project

| Calculation and Analysis Project | Bending strength (N / mm$^2$) | Shear strength (N / mm$^2$) | Deflection (mm) | Bending strength (N / mm$^2$) | Shear strength (N / mm$^2$) | Deflection (mm) |
|---------------------------------|-------------------------------|------------------------------|----------------|-------------------------------|-------------------------------|----------------|
| Theoretical calculation         | 5.15                          | 10.5                         | 8.6            | 2.55                          | 0.25                          | 3.04           |
| Numerical Analysis              | 7.187                         | 6.288                        |                | 11.92                         | 2.744                         | 4.039           |

Table 2. Working condition 2 Theoretical calculation and numerical analysis results before and after reinforcement

| Wooden beam condition | Before reinforcement | After reinforcement |
|-----------------------|----------------------|---------------------|
| Calculatio and Analysis Project | Bending strength (N / mm$^2$) | Shear strength (N / mm$^2$) | Deflection (mm) | Bending strength (N / mm$^2$) | Shear strength (N / mm$^2$) | Deflection (mm) |
| Theoretical calculation | 17.6 | 0.27 | 34.76 | 2.55 | 0.25 | 3.04 |
| Numerical Analysis     | 14.77 | 1.099 | 43.98 | 3.851 | 0.116 | 3.112 |

Based on the comparative analysis and summary of the data in the above two tables, the following conclusions can be drawn:

(1) There is an error between the theoretical calculation of various working conditions and the specific values of numerical analysis, but it does not affect the judgment on whether the wooden beam before reinforcement meets the bearing capacity requirements. It can be considered that these two methods have certain reference.

(2) The shear stress of the corroded and damaged part of the wooden beam in the first working condition is large, which does not meet the requirements of the specification, and needs to be reinforced by core implantation. It can also be proved from the numerical analysis of the stress cloud.
(3) The partial deterioration of the wooden beam in the second case is due to the fact that the decayed part is located in the middle of the wooden beam, which causes the bending resistance and deflection of the wooden beam to not meet the requirements of the specifications.

(4) Although there are errors in numerical analysis and theoretical calculation in terms of specific bending, shear strength and deflection, it does not affect the judgment of whether the wooden beam meets the specifications. Greatly improved the carrying capacity of wooden beams.

(5) The theoretical calculation and numerical analysis of the wooden beams of various working conditions after being reinforced by the repair method written in this article prove that the method proposed in this article is reasonable and effective, and can be applied to engineering practice in theory.

5. Conclusion

This article has conducted in-depth research and analysis on the core beam and crack embedding methods of traditional wooden beams in Huizhou, and further demonstrated the reinforcement methods of core beam and crack embedding of traditional wooden beams in Huizhou.

(1) On the basis of field investigation and data collection, the design methods of wood beam core planting and crack embedding and reinforcement repair of Huizhou traditional buildings are summarized.

(2) Summarized the calculation formulas of bending strength, shear strength, and deflection of wooden beams in ancient buildings. According to the requirements of "Code for Design of Wooden Structures", the formulas are used to perform the calculation of bending, shear strength and deflection, so as to judge whether they meet the requirements of use.

(3) The numerical analysis of the core beam and crack patch reinforcement methods of traditional wooden beams in Huizhou, according to whether the maximum bending moment and shear force and the maximum deflection meet the requirements of the "Wood Structure Design Code", and then determine the safety of the wooden beam and this kind of Whether the wooden beam in the case of damage can meet the requirements.

(4) The comparison of the theoretical calculation and numerical analysis results of the comprehensive wooden beam, the calculation results of the two are consistent, thus proving that the theoretical calculation and numerical analysis method can be used to check the bearing capacity and deflection of the wooden structure wooden beam, and verify the Huizhou The feasibility of the method of core reinforcement and crack embedding and reinforcement of traditional wooden beams can provide a reference for the application of Huizhou traditional wooden beam reinforcement and repair methods in practical projects in the future.

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