Research on crack principle and reinforcement method of wood structure

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Abstract: wood structure material is an ancient building material, which has played an important role in the development history of human architectural culture and showed its unique charm. Wood structure building materials still occupy an important position in modern architecture because of their light weight and high activity. At the same time, with the development of modern green architecture, wood structure building materials will re emit light. For wood structural materials, because of its high activity, it will expand and shrink with the change of environment. At the same time, its internal fiber structure will also change with the change of time, so cracks will occur. Cracks have a serious impact on the service life of wood structure buildings. Targeted reinforcement measures should be taken according to the types of components, causes of cracks, crack width, crack depth, crack hazards and other factors. This paper analyzes the causes and classification of wood structure cracks, and discusses the reinforcement methods of wood structure cracks, hoping to provide some effective ideas for the research and practice of wood structure reinforcement.

Key words: wood structure; Causes of cracks; Crack classification; Reinforcement method

In the process of wood processing, production and use, the change of external temperature and humidity will cause different moisture content or drying degree of each part of the wood, resulting in inconsistent internal and external shrinkage of the wood fiber. The wood fibers are separated from each other along the longitudinal direction to produce longitudinal shrinkage cracks. With the passage of time, the original shrinkage cracks of the stressed components of the wood structure continue to deepen and widen under the external force, The bearing capacity is greatly reduced. There are a large number of wood structure buildings in ancient Chinese architecture. There are many cracks in the wood structure. The causes and development laws of cracks are complex, which easily lead to the brittle fracture of wood structure components, and then affect the health of buildings.

1. Advantages and disadvantages of wood structure

In the early stage of human society, the level of productivity was low, and building materials were mostly from nature, mainly wood and stone. At that time, people's reprocessing ability for materials was relatively low, and the secondary processing of wood and stone was relatively simple. Wood played a more important role in the architecture of early society because it was easier to process and transport, and its regeneration was strong. In the long-term development of architecture, people have a unique emotion for wood, and a unique architectural aesthetics has been formed in this kind of material with a breath of life. Unique wooden buildings have been developed not only in China, but also in Canada, Japan, Finland, Sweden and other countries with national characteristics. The wooden residential buildings in these countries have their own characteristics, showing a variety of wood structure architecture culture.

In modern society, with the increasing pursuit of green life and green building, wood structural building materials have re presented their unique charm. The action plan for promoting the production and application of green building materials issued in 2017 clearly points out that yo ah promotes the production and application of green building materials, among which wood structure building materials is a typical green building material, and the development of wood structure buildings will show a new prosperity.

Compared with reinforced concrete building, wood structure building has light weight and small rigidity, which makes it play a significant role in resisting natural disasters such as earthquakes. Nowadays, people still regard wood structural materials as important shock absorption materials, and wood structural materials play an important role in the research of shock absorption buildings. Because the wood structure material is taken from nature and the secondary forging is relatively simple, it shows high activity. During the use of wood structure buildings, buildings show certain periodic changes in moisture content, temperature, microbial proportion, etc. with the change of seasons, and the fiber composition inside the wood structure material will also change, As a result, wood structural materials reflect "vitality". With the seasonal changes, the periodic changes of temperature, humidity, microbial content and other active factors make the wood structure materials shrink and expand, and then produce the problem of cracking. The cracking problem of wood structure building materials is one of the important factors affecting the service life of buildings, and it is also one of the important problems to be solved in the development of wood structure buildings.

2. Cracking causes and classification of wood components

The wet expansion and dry shrinkage of wooden building materials occur in the whole life cycle. Therefore, cracks are inevitable. The cracking problems of wood structural materials can be divided into several categories: dry shrinkage and wet expansion, stress cracks. The tangential drying shrinkage and radial drying shrinkage are caused by the change of wood structure caused by the reduction of water content in the wood, resulting in cracks. The cracks formed by cell wall division caused by wet expansion and dry shrinkage are longitudinal dry shrinkage cracks, which are the most common type of cracks in wood components. There are many influencing factors of wet tension and dry shrinkage, such as the influence of early and late wood, the inhibition of radial wood rays, the difference of lignin content between the

radial wall and the tangential wall of cells, and the number of pits, which will affect the wood structure and may lead to cracks. The cracks caused by structural stress are called stress cracks. The reason for this kind of cracks is that the stress of wood exceeds the limit value it can bear, which leads to the separation of cell wall of wood structure or the fracture of internal fibers. The cracks caused by comprehensive factors are also common. Firstly, the wood structure members produce dry shrinkage cracks due to the change of dry and wet, resulting in the weakening of the bearing capacity, and then the stress cracks are caused by the stress effect, which is also a common cause of cracks in the wood structure members.

In the treatment of wood component cracks, different reinforcement methods should be adopted according to the causes of cracks and the influence of crack cracking degree on the structural bearing capacity.

2.1 Longitudinal cracks in members subjected to tension and compression

The members mainly stressed by tension and compression include timber structural columns, lower chords of timber roof truss, web members and other components. The most common cracks in such construction are dry shrinkage cracks. The axial tensile and compressive strength formula is:

$$\frac{N}{A_n} \leq f$$

Where: f is the design value of the tensile (compressive) strength along the grain of the component material; N is the load design value of axial tension (compression) member; A_n Is the net sectional area of the component. When the safety of axially tensioned and compressed members is not controlled by stability, even if two separate bodies are formed under the development of longitudinal cracks, the size of the net section of the member is almost not affected, so the safety of the member is basically not affected. It can also be said that the longitudinal cracks of axially tensioned and compressed members are less harmful to the whole member. According to the formula, theoretically, this kind of crack has little effect on the bearing capacity of wood structure, but for the consideration of durability and visual sense, it can not make this kind of crack grow larger and larger, so it should be weakened.

The longitudinal crack may also be caused by stress, because the longitudinal split crack caused by the concentrated force of the connecting nodes in the node area will cause the stress to change, so it is necessary to carry out safety check calculation to determine its harmfulness, and then take targeted reinforcement measures according to the actual situation.

2.2 Transverse cracks in members subjected to tension and compression

The transverse crack of the axially loaded member will inevitably reduce the net cross-sectional area of the member, which will reduce the safety factor of the wood structure. This kind of crack is mainly the stress crack, so the safety checking calculation of the stress structure must be carried out and the treatment must be strengthened.

2.3 Longitudinal crack of member mainly subjected to bending

Beams, hangars and wooden watchboards are all bending members, and longitudinal cracks are common in bending members.

$$\frac{M}{W_n} \leq f_m$$

Where: f_m Is the design value of material bending strength of member material; M is the design value of bending moment of bending member; W_n Is the net section resistance moment of the flexural member. According to the theory of material mechanics, for the vertical crack in the longitudinal crack, even if the two ends of the crack are connected, so that the structure is divided into two parts with independent force, it can also meet the W_{n1}=It is necessary to $W_{n2}+W_{n3}$That is to say, the flexural capacity of the member after cracking does not change; For the horizontal crack in the longitudinal crack, when the crack develops to a certain extent, the A-B section can no longer bear the internal shear force generated by the bending moment, and finally lead to W_{n1}>It is necessary to $W_{n4}+W_{n5}$.

2.4 Transverse crack of member mainly subjected to bending

The transverse crack of the main member under bending will inevitably lead to the reduction of the flexural modulus of the net section of the member, and then reduce the safety factor of the member. This kind of crack is mainly caused by stress factors, so it is necessary to carry out structural stress analysis and strengthen treatment.

2.5 Oblique crack of component

Oblique cracks are generally mechanical cracks. Such cracks often appear in the weight bar, beam and other components. These components are subjected to the action of torque to produce fiber fracture, and at the same time produce transverse cracks and longitudinal cracks, which develop from the joint action of transverse and longitudinal cracks to oblique cracks. Most of the cracks can be judged according to the direction of the cracks and the type of components, but some of the structures with complex stress need to be modeled and analyzed to determine whether they are stress cracks.

3. Reinforcement method

3.1 Embedded reinforcement method

The embedded reinforcement method is mainly used for dry shrinkage cracks with little damage. The basic method is to firmly bond the cracks with water-resistant glue and wood strips, and then tighten them with iron hoops. When only the surface layer of wood components is corroded, the surface layer can also be removed first, and then the embedded reinforcement method can be used. Foreign scholars have found that using epoxy resin as adhesive and wood chips and glass fibers as fillers to fill and repair wood decay, cracks and other damage can avoid material loss caused by repair and embedding. But the actual effect still needs to be tested by practice. According to the design standard for

timber structures, for dry shrinkage cracks with a depth not exceeding 1/3 of the column diameter or the section size in this direction, the method of patching can be used alone for reinforcement; For cracks with width less than or equal to 3 mm, putty can be used to coat the gap tightly; For cracks with a width of 3 mm □ 30 mm, wood strips and iron blocks can be used to patch them and stick them firmly; For cracks with a width greater than 30 mm, 2-3 iron hoops shall be added at the repair site.

3.2 Iron reinforcement method

Iron reinforcement method is a traditional reinforcement method, which can effectively enhance the bearing capacity of wood structural members. This reinforcement method mainly includes iron hoop reinforcement, iron sheet reinforcement, iron hook reinforcement and iron nail reinforcement. The biggest disadvantage of iron reinforcement is that it is often irreversible, which destroys the original state of the wood structure and seriously affects the beauty of the building. The reinforcement method of wood structure of rural residential buildings in China often adopts the principle of "adjusting measures to local conditions, using local materials, economical and practical", and uses rivets, wood strips, steel plates and other components as reinforcement materials.

3.3 Carbon fiber reinforcement

With the further development of chemical research, the application of FRP reinforcement method is more and more widely, which is an effective supplement to the current inlay reinforcement process and iron bone reinforcement process. The experimental results show that the FRP reinforcement method can transfer the stress of the broken fiber of the wood structure, effectively repair the fiber fracture and stress damage of the wood, and the bearing capacity of the repaired beam can be increased by more than 60%. The application of FRP reinforcement method to strengthen the beam of wood structure can effectively enhance the bending capacity of the beam of wood structure, improve the compressive capacity of the building, and improve the ductility of the building.

3.4 FRP reinforcement method

Because people's awareness of protecting traditional monographs has been increasing in recent years, new wood structure reinforcement methods have been emerging. Under the FRP reinforcement method, CFRP (carbon fiber cloth), GFRP (glass fiber cloth), BFRP (basalt fiber cloth), AFRP (aramid fiber cloth) and other branches have been developed. Compared with the traditional reinforcement method, FRP reinforcement method has more advantages in aesthetics. At the same time, because FRP has the advantages of light weight, high strength, acid resistance, easy operation and corrosion resistance, it can improve the bearing capacity, stiffness and ductility of wood members. With the continuous development of wood structure reinforcement technology, FRP reinforcement method will also continue to innovate and develop in an increasingly effective direction. FRP reinforcement method has the least intervention on building materials and can give full play to the performance of wood materials to the greatest extent. In the future research and application of FRP reinforcement method, how to improve the durability and optimize the long-term performance of FRP is the research focus.

3.5 Professional screw reinforcement

Self tapping screws also have outstanding effect in the reinforcement of longitudinal cracks and transverse cracks. A good repair rate can be achieved by penetrating the cracks with self tapping screws. Compared with the ordinary beam, the ultimate bearing capacity of the new self tapping screw strengthened beam has been greatly improved, and the maximum bearing capacity can be increased by 70%; In terms of stiffness, the performance of the beam strengthened with self tapping screws is also better, and its bending deflection change is less than that of the ordinary beam under the same load.

Epilogue

With the deepening of the research on wood structure reinforcement, the reinforcement method has been developed from the traditional way of inlay and iron hoop to chemical FRP reinforcement, which has significantly improved the performance repair degree and aesthetics. In recent years, the self tapping screw reinforcement method is also developing. Engineers can select the reinforcement method according to the actual situation of wood structure cracks.

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