

Study on the Stress and Bending Performance of Wood Concrete Composite Beam Connectors

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Abstract

Shear connectors are an important component of wood concrete composite beam structures, connecting wooden beams and concrete slabs. Due to the differences in the stress performance of different connectors, selecting appropriate connectors and designing appropriate parameters are key parts of the design of composite beam structures. This article summarizes the short-term and long-term research results of wood concrete composite beam structures at home and abroad, and puts forward reasonable suggestions for the development of wood concrete composite beam structures.

Keywords

Wood Concrete Composite Beam; Shear Connectors; Creep.

1. Overview

By the end of 2023, the number of highway bridges in China has reached 1.0332 million, of which 83.7% are small and medium span bridges, with the vast majority being reinforced concrete bridges. The high emissions and pollution problems generated during the construction process are very prominent, and the concrete structure undergoes large deformation and is prone to cracking, seriously affecting the durability of bridge structures and hindering the achievement of China's goal of carbon peak and carbon neutrality. Modern wooden structure bridges have the characteristics of light weight, green and low-carbon, and good durability, which are in line with the future development trend of bridge structures in China.

The construction of bridges in our country needs to develop towards environmentally friendly structures. It is imperative to develop environmentally friendly bridge structures with lighter weight, better durability, and less construction waste. In recent years, the wood concrete field in China has shown an accelerated development trend, and modern wood deep processing technology has provided a good opportunity for the development of wood structures in China.

At present, modern wooden structures have become an indispensable part of building forms, among which the application of wood concrete composite beams is the most mature and extensive, providing new ideas and feasibility for the green development and technological innovation of small and medium span bridges in China. The wood concrete composite beam can exert the high tensile strength of wood along the grain and the high compressive strength of concrete, resulting in better bending stiffness and overall integrity. Although wood concrete composite beams have been widely used in European and American countries, they are still in their early stages in China, so there are still many research needs and development opportunities. This article summarizes the current research status of wood concrete composite beams at home and abroad, in order to provide examples and directions for the development of wood concrete composite beams.

2. Shear Connectors

Shear connectors are important components that connect wooden beams and concrete slabs. They have the function of resisting shear slip and lifting. Choosing appropriate shear connectors is the key to ensuring the coordinated work of the composite beam joint surface. Therefore, scholars at home and abroad have studied the mechanical properties of different types of shear connectors.

F é lix Su á rez Riestra et al. proposed a new type of shear joint for the study of wood concrete composite materials. The shear joint is composed of perforated steel plates glued into grooves inserted into the wood ribs, combined with reinforced corrugated steel bars glued to the top of the plate. By conducting experiments, the differences in mechanical properties of the extruded parts in three different scenarios (Figure 1) were analyzed and compared. A finite element model was established to determine an analytical expression that can predict their behavior and accurately describe their numerical analysis.

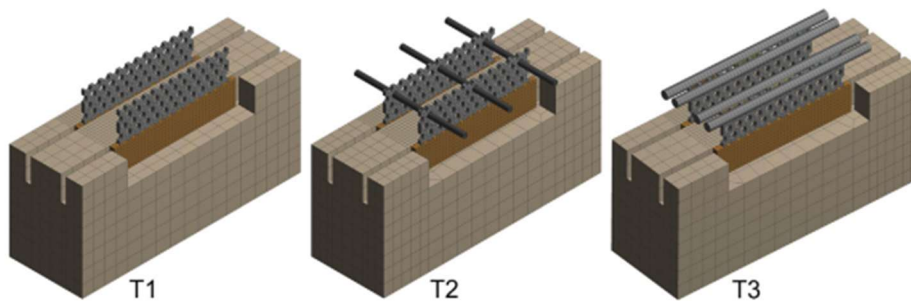


Figure 1. Schematic diagram of shear joint

T1: Metal plate

T2: Metal plate+horizontal steel reinforcement with a diameter of 8mm

T3: Metal plate+longitudinal steel reinforcement with a diameter of 12mm

Jiang Yuchen et al. conducted push out experiments on wood concrete composite beams (TCC beams) with notched connectors and evaluated the effects of concrete type, wood shear length, and notched steel reinforcement on shear performance. The results indicate that: 1. The notch joint corresponding to the partial shear fracture of the concrete or wood specimen has lower shear resistance and poorer ductility. The notch connectors that fail simultaneously at the concrete slab (through shear force) and at the reinforcement point of tension screws during bending have the highest shear resistance, followed by the notch connectors that fail due to diagonal compression of concrete. Adding screw fasteners to the gap has been proven to improve the strength, ductility, and post peak performance of the gap connection. 3. All research parameters, namely concrete type, wood shear length, and whether the gap is reinforced, have little effect on the slip modulus of the gap connection.

Hu Yafeng et al. proposed a wood lightweight concrete (TLC) composite beam connected by ductile connectors, which are made of stainless steel bolts with anchoring nuts at both ends. The experimental results show that the shear slip curve has good ductility, and its failure can be attributed to bolt buckling accompanied by cracking of lightweight concrete. The failure mode can be attributed to ductile failure. From the load slip curve (Figure 2), it can be seen that as the diameter of the anchor rod increases, the bearing capacity of the shear specimen significantly increases and the slip decreases, indicating good bonding performance between wood and concrete. The load slip response of ductile connectors exhibits good bearing capacity and ductility.

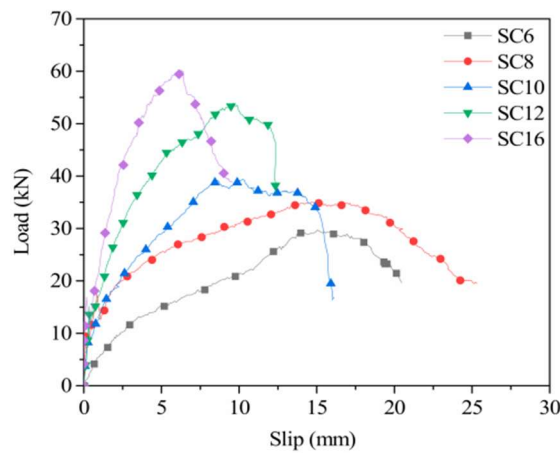


Figure 2. Load slip curve

Sheng Nanyuan et al. conducted experiments and finite element analysis to study the shear performance of diagonal screws in wood concrete composite beams with wooden partitions, and investigated the influence of factors such as screw embedding angle, wood partition thickness, concrete strength, and screw aspect ratio. The experimental results show that the failure mode of the inclined screw is tensile and shear failure under tension and shear, and the shear resistance of the inclined screw increases with the increase of concrete strength and aspect ratio. With the increase of concrete strength and screw length to diameter ratio, the improvement of shear resistance is not significant. In addition, the increase in thickness of the wooden partition reduces the shear capacity of the diagonal screws.

Shi Benkai et al. conducted push out tests on five push out specimens using tenon nail shear connectors (Figure 3) and conducted bending tests on a wood concrete composite beam using the same shear connector. The research results indicate that this type of shear connector has a relatively high initial stiffness and bearing capacity, but the test specimen undergoes brittle failure; Compared with pure wooden beams, the bending stiffness of wood concrete composite beams has increased by nearly 2 times, and the main failure mode is the bending failure of wood. Compared with traditional screw connections, the tenon nail connection method used in composite beams has a higher combination coefficient.

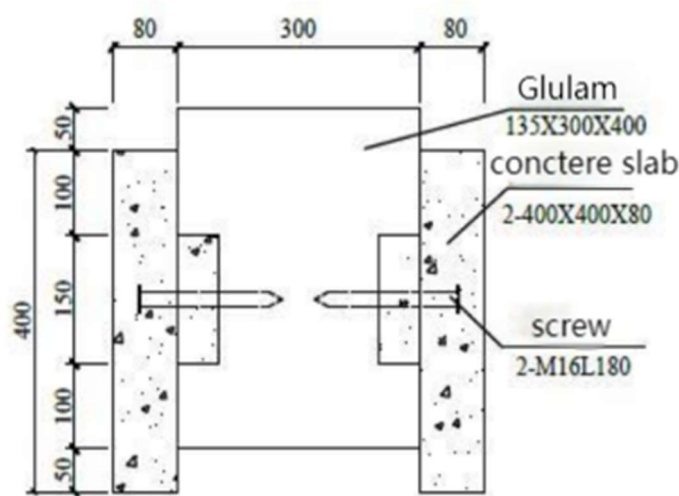


Figure 3. Schematic diagram of tenon nail shear connector

3. Long Term Performance Test Research

The time-varying effects of concrete shrinkage and creep, wood creep, etc. can cause internal force redistribution in composite beams, resulting in long-term deformation that cannot be ignored. Therefore, domestic and foreign scholars have conducted experimental research on the long-term performance of wood concrete composite beams. To measure the long-term deformation capacity of composite beams, creep coefficient is introduced and calculated according to equation (1).

$$\varphi = \frac{\varepsilon_{cr}}{\varepsilon_0} \quad (1)$$

In the formula:

φ - creep coefficient of shear connectors;

ε_{cr} - Long term slip value between concrete slab and wooden beam;

ε_0 - the slip value between the concrete slab and the wooden beam at the moment of loading.

After a long-term performance study of a wood concrete composite beam using open tenon screw connectors and steel plate screw connectors for 700 days, the results showed that using connectors with high initial stiffness and low long-term creep coefficient, such as open tenon screw connectors, can effectively delay the creep deformation of the composite beam, and setting a reasonable number and spacing of shear members can effectively control the long-term deflection of the bending member, avoiding it from exceeding the deflection limit. A long-term performance study was conducted on a wood concrete composite beam using SFS screw connectors for 4 years. The results showed that most of the deformation changes occurred during the humidity cycling process: when the wooden beam changed from a wet state to a dry state, the deformation growth of the composite beam was very rapid; When the environmental humidity rises again, the deformation of the composite beam will decrease, and in environments with significant humidity changes, the long-term deformation of the composite beam will increase rapidly. A long-term performance study was conducted on wood concrete composite beams using pin type connectors for 655 days. The creep time curve was fitted, and a creep time model was established for the connection between wood and concrete and other types of fasteners, as well as the connection between wood and wood and pin type fasteners. The final conclusion was that the creep values measured in long-term experimental tests were usually higher than those in the model shown in European Standard 5, especially for environmental conditions corresponding to Grade 2.

Through long-term experimental results, it can be found that reducing concrete shrinkage can improve the long-term performance of composite beams. Using steel fiber reinforced concrete to make components can reduce the shrinkage of concrete and reduce the long-term deformation of composite beams. A 5-year long-term experimental study was conducted on a wood concrete composite beam using 5mm screw connectors. Stress creep curves and deflection creep curves were plotted, and a deformation calculation formula for the composite beam under long-term load was proposed.

In summary, the results of long-term stress performance tests on wood concrete composite beams indicate that the long-term deformation deflection of wood concrete composite beams is large and the durability is poor. Corresponding measures need to be taken to reduce the shrinkage and creep of concrete and the time-varying effects of wood creep.

4. Conclusion

At present, there is a lack of systematic and comprehensive research on the mechanical properties of wood concrete composite beams. In order to promote the development of wood concrete composite beam structures in China, this article proposes the following suggestions:

Due to the large self weight of the wood concrete composite structure, large-sized wooden beams are required to bear the load, which reduces the economy of the wood concrete composite beam. Moreover, this composite beam is only suitable for small and medium span bridges, making it difficult to achieve the idea of lightweight and large-span. Therefore, corresponding measures should be taken in practical engineering applications to reduce the self weight of concrete and improve the stress performance of wooden beams, such as using high-strength concrete and optimizing the section design of wooden beams.

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