Research on bolt connection of steel-wood structure based on numerical simulation test

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Abstract. Compared with other connection methods, bolt connection has the advantages of simple structure, diverse types, reliable connection, convenient assembly and disassembly, and low cost. The test design scheme adopted in this paper is as follows: the index parameters to clearly measure the safety of steel-wood structure are bolted connection and wood type, and the load-displacement curve, stress analysis and bearing capacity under these two factors are explored.

1. Introduction
Steel-wood structure is a new type of building material, which retains the firmness and durability of steel structure, as well as aesthetics. Chen Qiang, Lang Jianke, etc. [1] established a bamboo-wood composite beam test model and carried out a three-point load-bending comparison test to analyze the failure mode, ultimate bearing capacity, bending stiffness and strain change laws of the two structural beams.

Xue Jingcheng, Chen Zhiqi, etc. [2] have carried out low-cycle repeated load tests on a glulam pure frame structure and a glulam frame-CLT shear wall structure. The planting bar and the angle steel are mixed connection. The failure modes and failure mechanisms of the two structures are deeply discussed, and the test phenomena, ultimate bearing capacity, lateral stiffness and energy dissipation capacity are comprehensively analyzed.

Wang Jiejun and Qu Bo [3] conducted a static model test and finite element numerical analysis of a larch glulam pedestrian arch bridge. The tensile and compression tests along the grain and the tests on the flexural modulus of elasticity and Poisson's ratio were carried out. Considering the structural counterweight, crowd load and the most unfavorable force on the arch rib control section, the load is divided into 9 working conditions to test the strain and displacement of the arch rib. The finite element software is used to establish a finite element model for numerical analysis of the wooden arch bridge model.

2. Model parameters

2.1. material
The steel structure parameters used in this test are the moment of inertia of 34286.4cm⁴, the bending modulus of 941.2cm³, the radius of gyration is 23.4cm, and the aspect ratio is 16.6. The wood chooses ordinary plywood and mahogany. Use 8.8 high-strength bolts to connect, and apply a large pre-tension to the tightening nut to produce a pressing force between the contact surfaces, so there is a large
friction perpendicular to the screw direction, and rely on this friction to transmit Connect shear force. Wood characteristic parameters are shown below:

Table 1. Wood characteristics.

| Numble       | El (Mpa) | Er (Mpa) | Et (Mpa) | μRT | μRT | GRT (Mpa) | GRT (Mpa) | GRT (Mpa) |
|--------------|----------|----------|----------|-----|-----|-----------|-----------|-----------|
| Korean pine  | 144530   | 450      | 450      | 0.45| 0.45| 0.54      | 986       | 766       | 986       |
| Glued wood   | 15000    | 500      | 500      | 0.53| 0.53| 0.39      | 675       | 675       | 653       |

2.2. Specimen parameters

Number the test pieces respectively, from M1-M6. The first three sets of test pieces are mahogany with different bolt spacing, and the last three sets are ordinary plywood with different bolt spacing.

Table 2. Formatting sections, subsections and subsubsections.

| Specimen name | Aspect ratio | Wood properties (Mpa) | Bolt margin (mm) | Bolt diameter (mm) |
|---------------|--------------|-----------------------|------------------|--------------------|
| M1            | 16.6         | mahogany              | 30               | 24                 |
| M2            | 16.6         | mahogany              | 50               | 24                 |
| M3            | 16.6         | mahogany              | 70               | 24                 |
| M4            | 16.6         | ordinary plywood      | 30               | 24                 |
| M5            | 16.6         | ordinary plywood      | 50               | 24                 |
| M6            | 16.6         | ordinary plywood      | 70               | 24                 |

2.3. Model

In this paper, the model is axisymmetric. Its structure adopts solid186, and the calculation is simplified by symmetry analysis. Only 1/4 of the model is used. The three-dimensional direction of the model takes the vertical upward as the y-axis, and the force direction is shown in the figure.

Figure 1. Model.
3. Calculation results

3.1. Load-displacement curve
It shows a smooth curve. The load-displacement curve obtained from the test is a smooth curve that grows with time, which grows slowly at the initial stage, and the ultimate load value is 1000kn. The test shows that as the load increases, the deformation of the steel-wood structure is also increasing, and reaches the limit value when the load stops.

3.2. Stress cloud
Under the action of various parts of the wood against external load, the stress value is unevenly distributed and the upper bearing capacity is insufficient. Under the unbalanced force, the bolts of the steel-wood structure show a tendency that the lower stress becomes larger and the upper stress becomes smaller.

3.3. Carrying capacity analysis
The content explored in this paper still has limitations. Only when the load is not more than 1000kn and the deformation value is less than 5mm, the test simulation value is compared and analyzed with the specification.

| Specimen Name | Yield Strength (KN) | Tensile Strength (KN) | Initial Stiffness (KN/mm) |
|---------------|---------------------|-----------------------|--------------------------|
| M1            | 973.27              | 1000                  | 556.43                   |
| M2            | 731.88              | 1000                  | 427.11                   |
| M3            | 754.23              | 1000                  | 403.82                   |
| M4            | 864.63              | 1000                  | 375.89                   |
| M5            | 744.13              | 1000                  | 491.44                   |
| M6            | 723.14              | 1000                  | 432.19                   |

4. Data comparative analysis

4.1. Comparison of theoretical and simulated values
According to the wood structure design specification, the tensile strength and yield strength of steel for load-bearing wood structures must meet the requirements, and the diameter of the H-shaped steel must also be tested to ensure.

| Specimen Name | 5% Yield load (KN) | Tensile Strength (KN) | Design specification (KN/mm) |
|---------------|--------------------|-----------------------|-----------------------------|
| L1            | 973.27             | 1000                  | 747.22                      |
| L2            | 751.48             | 1000                  | 782.31                      |
| L3            | 794.03             | 1000                  | 756.40                      |
| L4            | 854.63             | 1000                  | 546.87                      |
| L5            | 724.44             | 1000                  | 578.03                      |
| L6            | 793.01             | 1000                  | 583.44                      |
5. Conclusion

The test design scheme adopted in this paper is as follows: the index parameters to clearly measure the safety of steel-wood structure are bolted connection and wood type, and the load-displacement curve, stress analysis and bearing capacity under these two factors are explored. Concluded as follow:

- As the load increases, the displacement of the steel-wood structure also increases, reaching the tensile strength when the load stops, and the structure is damaged.
- Due to the anisotropy of the wood, the stress at the upper part of the bolt becomes smaller and the lower part becomes larger, making the structure stable.
- The larger the bolt spacing, the smaller the yield strength and tensile strength, and the mahogany structure has greater tensile strength than the plywood, which means that the plywood is the first to fail when the loading force reaches the limit. When the bolt spacing reaches 50 and 70mm, the yield strength and tensile strength have little effect on the bolt spacing.
- The larger the bolt spacing, the smaller the initial stiffness, and the mahogany structure has a greater initial stiffness than plywood, indicating that mahogany structure is more stable than plywood. When the bolt spacing reaches 50 and 70mm, the initial stiffness has little effect on the bolt spacing.

References

[1] Chen Qiang, Lang Jianke, etc. Experiment and numerical simulation of flexural bearing capacity of bamboo-log composite beam [J] Journal of Central South University of Forestry & Technology. 2020.40(4): 120-125.
[2] Xue Jingcheng, Chen Zhiqi, etc. Glued wood frame-CLT shear wall structure seismic performance test[J] Journal of Civil Engineering and Management. 2019.36(5): 150-155.
[3] Wang Jiejun and Qu Bo. Full bridge model test and numerical value of static performance of glulam arch bridge Analysis [J] Journal of Central South University of Forestry & Technology. 2018. 38(8): 110-113.