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# Experimental study on axial compression of L-shaped profiled columns made of reconstituted bamboo and cold-formed thin-walled steel sections

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## Abstract

**Shaped column structure can connect the advantages of overall aesthetics of the building, flexibility of functional design and excellent load carrying capacity together, but the experimental research on recombinant bamboo-cold-formed thin-walled section steel combined shaped column structure at home and abroad is relatively small, and its stress performance is still to be explored. This paper describes in detail the axial compression test of recombined bamboo-cold-formed thin-walled section steel combined shaped columns, including specimen fabrication process, complete test programme, describing the test phenomena and damage morphology one by one, and analysing the test results to obtain the ultimate load carrying capacity of the specimen, the load-transverse displacement curve, and the load-strain curve, and it is concluded from the analysis that: the load carrying capacity of the L-type steel-bamboo combined shaped columns is higher than that of the L-type steel combined shaped columns and the L-type bamboo combined shaped columns. It is concluded that the load carrying capacity of L-type steel-bamboo combined shaped column is 1.21 times of the sum of L-type steel combined shaped column and L-type bamboo combined shaped column, and the load carrying capacity of L-type steel-bamboo combined shaped column is increased by 21.4%.**

## Keywords

**Restructured bamboo - cold-formed thin-walled, L-shaped, Axial compression.**

## 1. Introduction

Cold-formed thin-walled steel structure system has a lightweight and high strength, excellent mechanical properties, good seismic performance, elasticity and plasticity of the material is more convenient, relatively low price, short growth time, flexible and diverse cross-section form, easy processing, and environmental protection of building materials can be recycled, etc., has a wide range of advantages[1].

In our country to take the road of sustainable development in the context of the combination of cold-formed thin-walled steel and bamboo to change the traditional residential construction model in China, to promote the modernisation of scientific and technological housing, for the promotion of the progress of industrialised housing has an important role and significance of the steel - bamboo combination structure in the future of China's construction industry is bound to go into a completely new period of progress, the use of such a structure in the scope of use and the development of the situation is bound to be more broad[2] .

Zhang Xiuhua et al.[3] studied and analyzed the axial compression test of cold-formed thin-walled steel-recombined bamboo composite columns, three kinds of damage modes are obtained: fracture of the outer layer of bamboo boards, gluing damage of the bonding surface of steel and bamboo, and the overall destabilisation damage of the specimen. It is also analysed that the two materials, steel and bamboo, can work together to improve the ductility and ultimate bearing capacity of the specimen. Zhai Jialei[4] studied and analyzed a kind of steel-bamboo spliced beam with I-beam section, it is found that: because of the role of restructured bamboo, the overall load carrying capacity of steel-bamboo spliced beam performs well, the combined effect is obvious, and during the stress period, it shows four periods of obvious elasticity, yielding, cracking, and ultimate limit, which presents a good ductility, and in addition to having a better load carrying capacity, and the theoretical value of load carrying capacity of the spliced beam was compared with the test value, and it was found that both of them are basically the same. The theoretical values of the load carrying capacity of the spliced beams were compared with the test values, and it was found that the two were basically the same, with the error within 10%. Zhang et al.[5-6] adopted axial compression, eccentric compression test and finite element analysis on the stainless steel columns of the same category with different thicknesses and slenderness ratios of high-strength cold-formed thin-wall steel split box section. The conclusions of the test indicated that the spliced box structure columns would be damaged under the joint interference of local deformation, distortion deformation and overall deformation. On the basis of the finite element model and the test results, a lot of data were used to analyse and investigate the interference of the spliced columns. Comparison of the finite element calculations with the theoretical results of the current specification shows that the specification calculation values are conservative, and points out the design formula of the spliced section columns.

In this paper, L-type recombined bamboo combined shaped columns, cold-formed thin-walled steel combined shaped columns, recombined bamboo - cold-formed thin-walled steel combined shaped columns and designed the test programme, research and analysis of the combined beams in the loading process of the damage phenomenon, deformation and bearing capacity of the situation, and with the L-type steel combined shaped columns and L-type bamboo combined shaped columns to analyse the analysis of comparisons.

## 2. Specimen production

### 2.1. Test materials

#### 2.1.1. Reorganised bamboo panels

The recombinant bamboo panels used in this test were made of nanzhu as raw material, processed and made into the corresponding sizes by Xuancheng Hongyu Bamboo Industry Co Ltd, and the materials used were from the same production batch. The reconstituted bamboo panels are shown in Figure 1.

#### 2.1.2. Cold-formed thin-walled steel sections

The Q235 galvanised cold-formed thin-walled steel sections used in this test were produced and processed by Shanghai Bochao Industrial Co. According to the test design requirements, the use of 82mm×41mm×1200mm and 41mm×41mm×1200mm. Two types of L-type cold-formed thin-walled steel. Cold-formed thin-walled steel physical figure shown in Figure 2.

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Fig. 1 Physical drawing of reconstituted bamboo panel

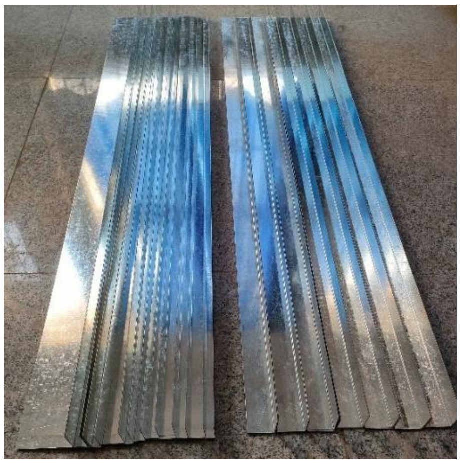

Fig. 2 Physical drawing of L-type cold-formed thin-walled steel section

## 2.2. Test piece design

The test independently designed L-type recombinant bamboo - cold-formed thin-walled steel combination of shaped column specimens, the use of epoxy resin adhesive, self-tapping screws and bolts will be recombinant bamboo and cold-formed thin-walled steel adhesive splicing. The position of self-tapping screws are designed in accordance with the requirements of the Code for Design of Cold-Formed Thin-Walled Steel Structures (GB50018-2002). The cross-section form is shown in Fig. 3, and the design parameters of this combined shaped column are shown in Table 1 below.

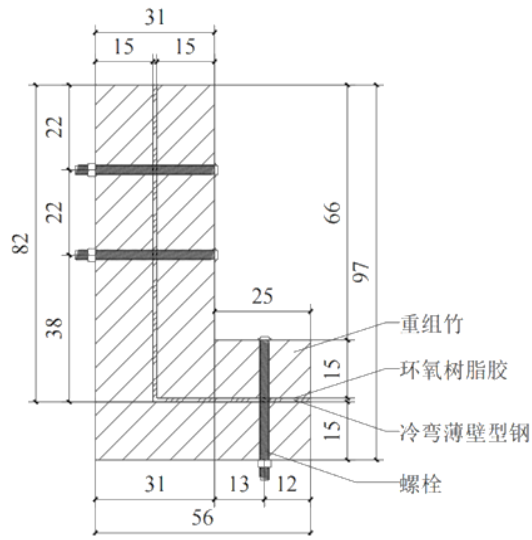


Fig. 3 Specimen cross-section dimensions

Table 1 Design parameters of combined columns

| norm | serial number | Specimen size/(mm) | Specimen height/(mm) | aspect ratio |
|---|---|---|---|---|
| L-column | L-G-Z | 82 × 41 × 1 | 1200 | 71.8 |
| | L-Z-Z | 96 × 55 × 30 × 30 | 1200 | 62.1 |
| | L-G-Z-Z | 97 × 56 × 31 × 31 | 1200 | 38.4 |

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## 3. Pilot programme

The test setup uses an electro-hydraulic servo pressure 200t testing machine from the materials laboratory of the School of Architectural Engineering, North China University of Science and Technology, for axial compression tests, equipped with a Gantner data acquisition instrument for the collection of stress and strain, and connects the 200t pressure transducer and the Gantner data acquisition instrument with a computer, which allows for real-time observation of the loading time, the size of the load, and the change of the displacement meter. The test loading device is shown in Fig. 4 and the test arrangement is shown in Fig. 5.

Fig. 4 Test loading device

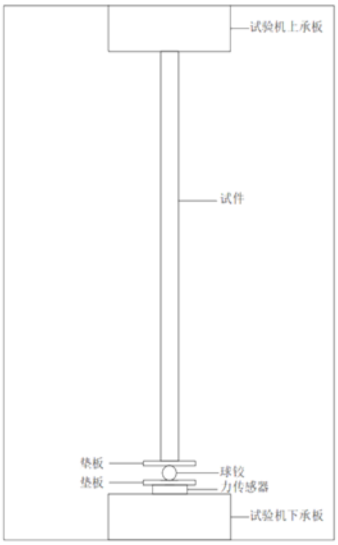

Fig. 5 Test arrangement diagram

### 3.1. Layout of measurement points

In order to better measure the stress-strain of the specimen, the strain gauges are arranged at 1/2 of the height of the column, and strain gauges are pasted on the same position of the external recombined bamboo and the internal cold-formed thin-walled steel section, with a total of 8 pieces. At the same time, the displacement gauge was arranged at the same height of the strain gauges of the external recombinant bamboo to prevent inaccurate measurement data caused by contact with the strain gauges, and the displacement gauge pointer was placed beside the strain gauges. The arrangement of the measurement points of the combined column is shown in Fig. 6.

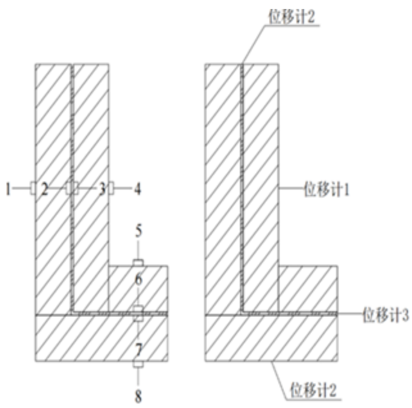

Fig. 6 L-shaped steel-bamboo combination column measurement point layout

### 3.2. Loading programme

In the preparation stage, the strain gauges and displacement gauges pasted on the specimen were connected to the collector one by one, and the strain gauges and displacement gauges were checked on the test computer to see if they were normal. In this test, the force transducer is placed at the centre of the lower base plate of the testing machine, and the homemade hinged support is placed at the centre above the force transducer, and a layer of fine sand is spread on the upper surface of the hinged support to ensure that the specimen is subjected to uniform force during the test.

In the test phase, the combined column is placed in the middle position of the hinge support, the distance between the top plate on the hydraulic press and the test piece is adjusted to about 10mm, the combined column is geometrically and physically aligned, and the top plate on the hydraulic press is adjusted to make contact with the combined column at the end of the alignment.

Set the preload to about 10% of the estimated ultimate load, check whether the displacement gauge and strain gauges are working well, and adjust the position of the combined column to ensure that the combined column is axially pressurised by observing the magnitude of the values of all the strain gauges. The test adopts displacement control, loading rate 0.005mm/s, loading to the ultimate load, in order to get the falling section of the load displacement curve, continue to load to the load falls to 50% of the ultimate load stop loading, the test ends.

## 4. Test phenomena and damage patterns

### 4.1. Test phenomenon and damage pattern of L-beam combined shaped columns

No obvious phenomenon at the beginning of loading, loading to about 2kN, the specimen began to local buckling, L-beam long side of the central flange began to expand outward, the buckling phenomenon is not obvious; continue to load, the specimen aberration buckling is gradually obvious, the long side of the flange appeared wavy buckling, the specimen end began to be deformed; loading to about 5kN, the specimen column in the position of the edge of the overall bending phenomenon; loaded to 5.6kN, the specimen When loaded to 5.6kN, the specimen issued a large sound, the specimen column flange position bending phenomenon intensified; loaded to 5.7kN, the specimen reaches the ultimate bearing capacity, the whole continues to bend, the bearing capacity began to slowly decline, and ultimately, the specimen occurred in the bending and buckling damage. After unloading, the bending degree of the specimen is basically restored, leaving the overall bending and local buckling at the 30mm flange below the centre of the column. The final damage diagram of the specimen is shown in Figure 7.

### 4.2. Experimental phenomena and damage patterns of L-shaped bamboo combination shaped columns

Begin to load the specimen without any phenomenon, continue to load the specimen is still no phenomenon; loading to 79kN or so, can be observed that the specimen began to appear bending and began to emit a small cracking sound; continue to load to 81kN, the specimen reaches the limit of the capacity, the specimen as a whole appeared to be more obvious bending; continue to load the specimen capacity began to decline, slowly down to 70kN or so, the bearing capacity of the sudden change to 50kN When the load bearing capacity of the specimen is about 70kN, the load bearing capacity suddenly changes to 50kN, the specimen makes the sound of bamboo fibre tearing, and the specimen finally undergoes bending instability. After unloading, the overall bending condition of the specimen is basically restored, and there is no damage on the outside. The damage diagram of the specimen is shown in Figure 8.

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### 4.3. Test phenomena and damage patterns of L-shaped steel-column combination shaped columns

The beginning of the loading of the specimen without any phenomenon, loaded to about 27kN, the specimen began to appear observable bending deformation; loaded to about 40kN, the specimen inside the steel section began to appear wave-like flexure, began to occasionally appear a slight glue crack sound; loaded to about 61kN, the specimen inside the steel section continues to flexure, the frequency of the glue crack sound increases, the specimen bending deformation degree increases; loaded to 105kN or so, the specimen reaches the ultimate load bearing capacity, the overall bending effect is obvious; continue to load the load bearing capacity began to decline, frequent occurrence of glue cracking phenomenon, the internal bamboo fibre began to tear gradually, and ultimately the specimen destabilisation damage. After unloading, the specimen basically recovered, the overall bending slightly, without any damage to the exterior. The damage diagram of the specimen is shown in Figure 9.

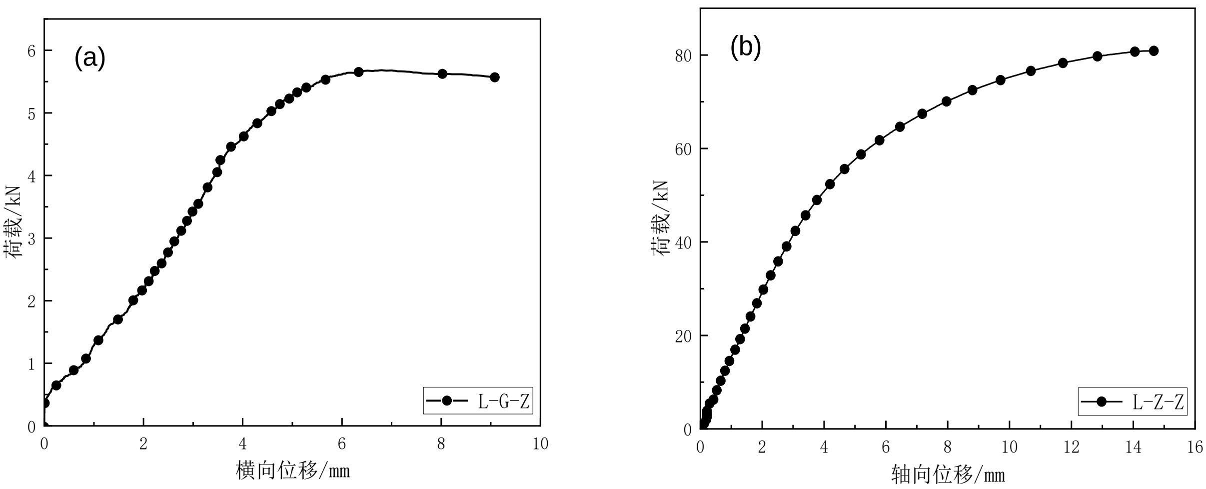

Fig. 7 Damage of L-shaped steel combination shaped column


Fig. 8 Damage of L-shaped bamboo combination shaped column

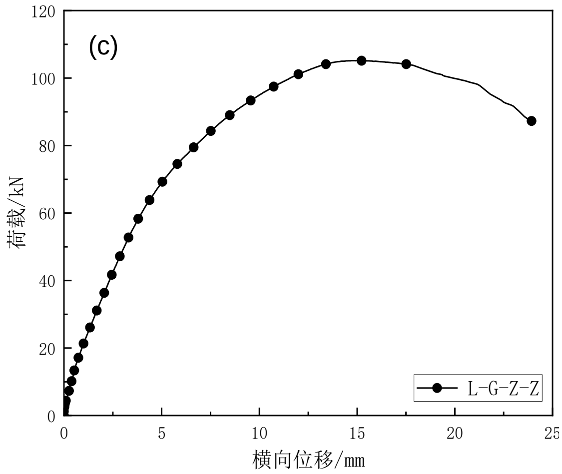

Fig. 9 Damage of L-shaped steel-bamboo combination shaped column

## 5. Analysis of test results

### 5.1. Load-Transverse Displacement Curve Analysis




(a) L-shaped steel combination shaped column (b) L-shaped bamboo combination shaped column




(c) - L-shaped steel-bamboo combination shaped column.

Fig. 10 Load-transverse displacement curve of L-type combined shaped columns

Table 2 Test results of L-type combined shaped columns

| Serial number | λ | $P_t$/kN | sabotage |
|---|---|---|---|
| L-G-Z | 71.8 | 5.68 | Partial Flexion + Bending Flexion |
| L-Z-Z | 62.1 | 80.99 | Destabilisation damage + glue damage |
| L-G-Z-Z | 38.4 | 105.18 | Destabilisation damage + glue damage + plate buckling |

The test was carried out by arranging displacement gauges at 1/2 height of the specimen, and the load-transverse displacement curves of the three L-type combined shaped column specimens under different stress stages were obtained respectively, as shown in Fig. 10, and as can be seen from Fig. 10 and Table 2:

1) L-type steel - bamboo combination of shaped column bearing capacity for L-type steel combination of shaped column bearing capacity and L-type bamboo combination of shaped column bearing capacity and the sum of 1.21 times, indicating that the L-type steel - bamboo combination of column bearing capacity increased by 21.36%, the combination of section steel and recombination of bamboo effect is good, and can improve the combination of specimen bearing capacity.

2) The lateral displacement of the specimen in the pre-test period did not change much, and the load-displacement curve was basically a linear curve, with the increase of the load to about 70% of the ultimate load, the lateral displacement increased significantly, and after the ultimate load was reached, the lateral displacement continued to increase, and the load decreased to the range of the test setting, at this time, there was a significant buckling of the L-type steel combined shaped columns, while the L-type bamboo and the L-type steel-bamboo combined shaped columns were not significantly damaged, and both specimens were destabilised. Both specimens were destabilized.

## 5.2. Load-strain curve analysis

The strain gauges of all the specimens were arranged at the middle position of the specimens, and the load-strain curves of the L-shaped combined shaped columns are analysed below, and the load-strain of the three specimens is shown in Fig. 11. The following conclusions are drawn by analysing Fig. 11:

1) From the load-strain diagram in Fig. 10(a), it can be seen that the L-beam profiled columns are in the elastic stage until they are loaded to 50% of the ultimate load, and all the strains grow

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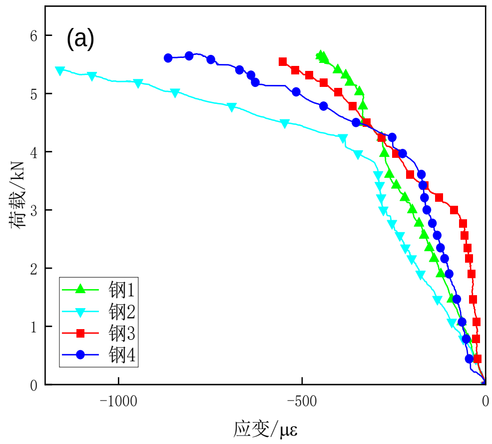
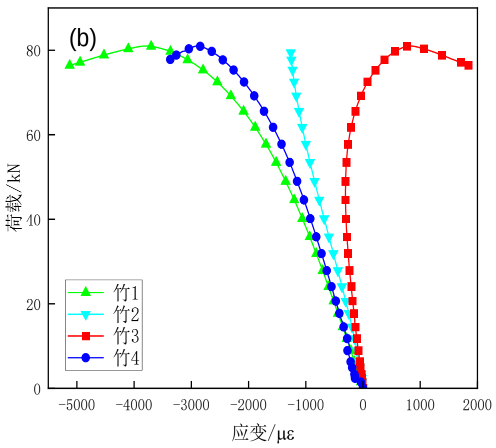
linearly. When loaded to about 4 kN, the specimen transforms into elastic-plastic stage, and the strain gauges Steel 1 and Steel 2 reach the yield load, and the strains grow rapidly compared to the previous stage, and the strain of the specimen continues to increase for a period of time after loading to the ultimate load.

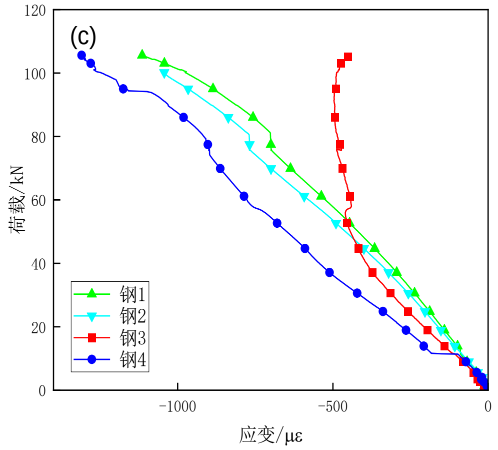
2) From the load-strain diagram in Fig. 10(b), it can be seen that the strain of the recombined bamboo is larger than that of the steel section. At the beginning of loading, the specimen is in the elastic stage, and the strain increases uniformly with the increase of load; loading to about 50% of the ultimate load, it can be seen that the strain gauges Bamboo 1 and Bamboo 2 are compressed, Bamboo 3 is basically a linear growth trend, and Bamboo 4 is tensile, and the specimen begins to be bent as a whole; continuing to load, the slope of the load-strain begins to decrease, the strain begins to increase dramatically, and the specimen undergoes an obvious overall bending deformation; the specimen When the ultimate load was reached, with the continued increase of vertical displacement, the bearing capacity of the specimen began to decrease slowly, thus indicating that the recombinant bamboo is not brittle damage, and the recombinant bamboo structure has good elastic recovery ability and toughness properties.



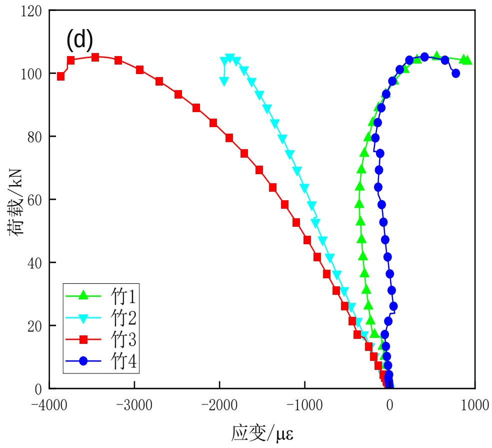
(a) L-shaped steel column load-strain curve;



(b) L-shaped bamboo column load-strain



(c) Steel load-strain curve of L-beam-bamboo shaped column



(d) Bamboo load-strain curve of L-beam-bamboo shaped column

curve;

Fig.11 Load-strain curve for L-shaped combined shaped columns

## 6. Conclusion

1) The bearing capacity of L-type steel-bamboo combined shaped column is 1.21 times of the sum of L-type steel combined shaped column and L-type bamboo combined shaped column, and the bearing capacity of L-type steel-bamboo combined column is increased by 21.4%. It

shows that the combination of section steel and reconstituted bamboo is effective and can improve the load carrying capacity of the combined specimen, which is of reference value for practical engineering applications.

2) The damage forms of steel combined shaped columns are bending and torsion damage and buckling damage, and the main damage forms of bamboo combined shaped columns and steel-bamboo combined shaped columns are destabilisation damage due to the large length and slenderness of the shaped columns. The recombined bamboo material has good elastic recovery ability and toughness performance, and the specimen basically recovers at the end of the test, and there is no obvious damage to the whole.

3) The load-transverse displacement of the axial compression specimen of the combined shaped column is analysed, and the results show that: the specimens are in the elastic stage in the early stage of the test, the axial displacement does not change much, and the load-displacement curve is basically a linear curve. With the increase of load, the specimen reaches the elastic-plastic stage, the slope of the load-displacement curve decreases gradually, and the increase of transverse displacement is obvious. After reaching the ultimate load, the transverse displacement continued to increase.

4) The load-strain analysis of the axial compression specimens of the combined shaped columns shows that the load-strain curves of all the specimens have the same trend, and the strain of the reconstituted bamboo is larger than that of the steel section under the same load. At the early stage of specimen loading, the strain curves of both steel profiles and recombined bamboo are in the linear stage, and the two materials work together; with the increase of load, the specimen enters the elastic-plastic stage. During the test loading process, the specimen as a whole is basically under pressure, and the strain values are all negative except for a few strain values.

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