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Experiment on Bending Performance of Truss Beams

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Abstract

With the continuous advancement of the development of green buildings in China, cold-formed thin-walled steel has begun to show its prominence. As a new building material, cold-formed thin-walled steel still has a large room for development in light steel buildings, so the research on the force performance analysis of cold-formed thin-walled steel has great engineering value. Through the experiments on the bearing capacity and deformation of the cold-formed thin-walled C-type composite truss beam under hierarchical loading, the finite element model was established by ABAQUS, and the influence of factors such as whether there is a batten plate and self-tapping screws on the bearing capacity of the combined truss beam is studied. The test shows that the bare skeleton beam is destroyed due to the shearing of the self-tapping screw, and the ultimate bearing capacity depends on the shear resistance of the screw; the reinforcement of the batten plate has a significant effect on improving the bearing capacity of the beam.

Keywords

Cold-bent Thin-walled Steel; Combination Truss Beams; Load Carrying Capacity; Batten Plate; Self-tapping Screws.

1. Introduction

Cold-formed thin-walled steel structure system is composed of load-bearing members, sub-bearing members and retaining members [1] There are many studies on cold-bent thin-wall steel in China.Chen,J.[2] uses the method of finite element simulation,created a flat shell unit with 4 nodes and 20 degrees of freedom,lipped channel is studied under pure bending load. In the study of the steel structure roof frame, Zhou,X. [3] proposed that the calculated length coefficient of the compression chord of the cold bending member is 1.0, the calculated length coefficient of end inclined rod and end vertical rod is 1.0, the calculated length values of other web member are recommended to use at 0.9L(L is the geometric length of the component). The connection form of the self-tapping screw is taken as the variable, used the method of shear resistance test ,Guan, Y.[4] studied on the screw connection between the C-shaped cover beam and the U-shaped edge beam and the pressed steel plate, the results show that:The shear bearing capacity of self-tapping screw between floor beams is increased. In the study of high strength cold bent thin-walled steel shaft pressure short column, Zhou,L.[5] came to the conclusion; When the width-to-thickness ratio b/t of section element of the specimen is larger,the local flexion effective section of high strength steel is the main factor affecting the component bearing capacity. Study on type steel beam and steel plate. Bu, L.[6] used the method of pasting steel plates in my research on the reinforcement of type steel beams,effectively avoid the use of open fire in the traditional welding methods,more secure and convenient. The following conclusions can be obtained from its study: The yield strength and ultimate bearing capacity after the pasted steel plate are significantly improved, increase the thickness of steel plate, the bearing capacity of the beams also increases;type steel beam in the case of sticking the steel plate, the form of destruction is bending destruction,and meets the flat-section assumption. In the study of steel structure gate frame in industrial plant,Xie, Y.[7] found the problems in the use process of the steel structure plant that increase of roof or floor load and aging of structural components, the existence of these problems made the structure have hidden safety risks, so that the structural components can not meet the specification requirements. Therefore, a reinforcement measure was taken to attach the lower chord rod to the section steel beam, change it into BSS, and change the force mode of the beam, and through the method of supporting reinforcement to reduce the span of the beam,enhance the carrying capacity of the beam.In the study of the bending resistance of the secondary stressed steel beam with pasted steel plate, Liu, H.[8] came to the following conclusion:when the thickness of the pasted steel plate increases, the bearing capacity of the beam increases accordingly, but when the thickness of the steel plate reaches a certain value, the bearing capacity of the beam is no longer significantly increased.

2. Experimental Analysis

2.1. Sample Design

The test is based on the engineering practice, with the combined truss beam as the research object. The parameter is the number of batten plate of the truss beam, explore the carrying capacity and deformation, in order to find a safer and more durable combination way, to provide reference for engineering construction.

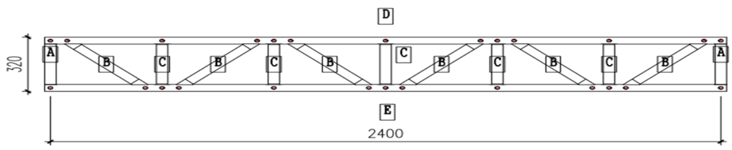

Figure 1. Design schematic diagram of truss beam (unit: mm)

Table 1. Part Dimensions

Each component number	Designation	Quantity (root)	Length (mm)
A	End of the web member	2	316
B	Inclined web member	6	433
C	Vertical web member	5	316
D	Up chord member	1	2440
E	Down chord member	1	2440

According to specification[9] and actual engineering situation,Test choose S550-AZ150 cold bent thin wall C-type steel with a yield strength of 550 MPa and 1.5 mm surface galvanizing layer,the galvanizing coating has a certain resistance to the environmental corrosion. The design length of the beam is 2400 mm and the beam height is 320 mm. In order to prevent the end of web member is force-deformed to contact with the upper and lower chord member, cause damage to chord member, vertical web member take the sample at 316 mm and inclined web member take the sample at 433 mm. The schematic design diagram of the truss beam is

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shown in Figure 1. Among them, the dimensions of the components of each part of the truss beam are shown in Table 1.

2.2. Load Scheme

The loading method in the trial was performed by grading loading. We implement a preloading scheme for the tested truss beams before the official loading of the load. The pre-load shall not exceed 30% of the bearing capacity. The preload shall be carried out in three levels to test the normal operation of each test instrument. In the formal loading session, a single load of 1 kN was stationary for two minutes after each loading to obtain stable test results, while test phenomena were observed and recorded.

2.3. Material Mechanical Properties Test

The section size of S550-AZ150 cold bent thin wall C-type steel is 89×41×2 mm and the thickness is 0.8 mm. The test specimen are taken from the steel strip produced in the same batch as C-type steel. We determine the test piece size and test method according to the Room Temperature Test Method (GB / T228- -2010)[10]. The tensile test is done by WDW-100 kN micro-control electronic universal test machine. The cut specimen is shown in Figure 2, the three specimens were numbered 0.8-1, 0.8-2 and 0.8-3. Tie the steel sheet with a clamp and start the loading procedure. The destruction of the specimen after stretching is shown in Figure 3.

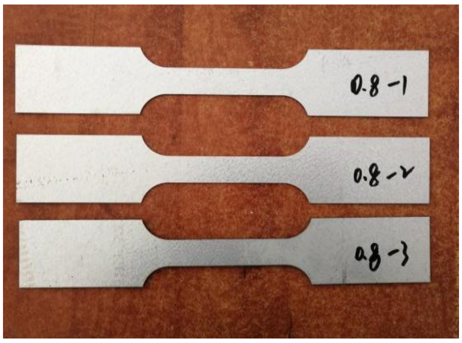
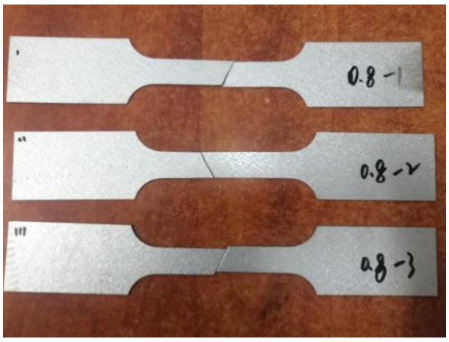

Figure 2. Test piece before stretching **Figure 3.** Test after stretching

Table 2 shows the ultimate tensile strength, yield strength and elastic modulus and the respective average values measured in the tensile test of the three specimens. Data for the shear test of self-tapping screws are shown in Table 3.

Table 2. Strength and elastic modulus of materials

Test specimen identifier	Ultimate tensile strength/MPa	Yield strength /MPa	Modulus of elasticity /N·mm2
1	606.1	569.7	188.6
2	606.4	568.5	187.1
3	610.7	570.3	192.7
average value	607.7	569.5	189.5

Table 3. Force properties of the screws

Test specimen identifier	Measured value / kN	Average value/ kN	Destructional forms
1	4.3	4.1	Deformation of hole wall; Slant pull damage
2	3.9		
3	4.1		

3. Force Performance Test of Combined Truss Beam

3.1. Loading Scheme and Device

The jack with a range of 5 t is used, the truss beam net span is 2400 mm, the distribution beam is 800 mm, the jack is placed on the I-shaped assign beam and the lower part of the assign beam is welded with two semi-annular grooves, the grooves spacing is 0.8 m, a cylindrical roller is placed under the groove, pressed on the gasket at the loading point of the beam. The force sensor is connected to the data collector, and the loading rate and load size are controlled by the reading. The deflection was measured using the LVDT displacement sensor and test data were collected by the strain book system computer. Figure 4 shows the combined truss beam loading device of the unattached plate. Figure 5 shows the layout diagram of the measuring point.

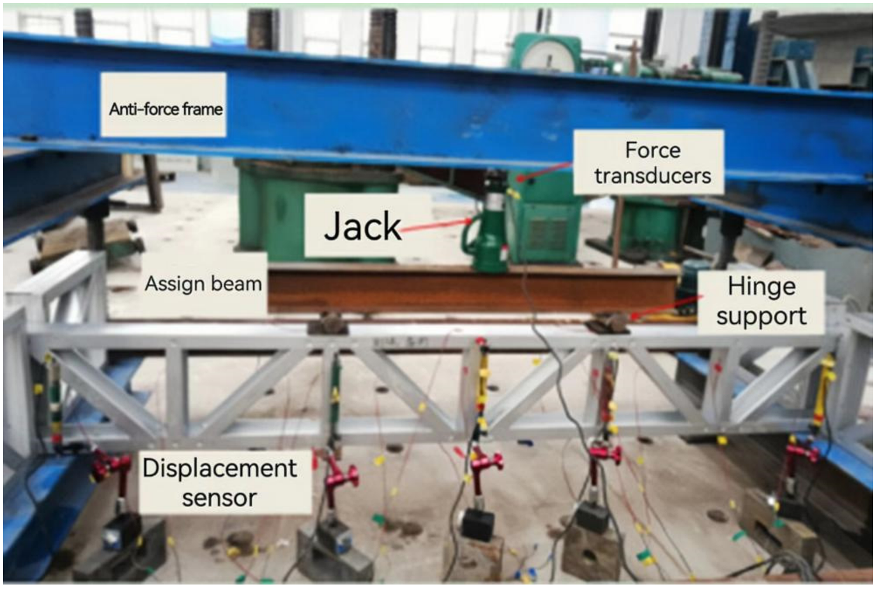

Figure 4. Test the loading device

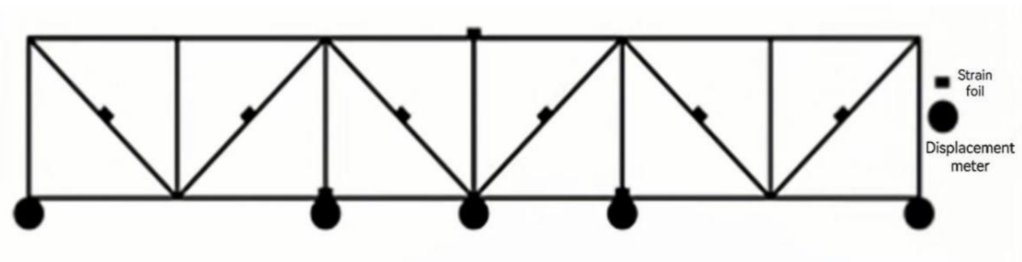

Figure 5. Survey point layout

3.2. Experimental Phenomena and Forms of Destruction

The three cold-formed thin-walled steel composite beams are: L1 is a truss beam without batten plate, L2 is a one-sided batten plate, and L3 is a truss beam with batten plate on both sides.

When the combined truss beam L1 is loaded to 5.94 kN, the diagonally pulled screw is cut and the loading stops, figure 6 shows the failure characteristic diagram of L1; The load of the combined truss beam L2 of the single-side batten plate is 10.6 kN, batten plate of up chord member in the gasket position is bent, the bearing capacity is reduced, and the component is destroyed,figure 7 shows the local characteristics at destruction of L2; Combination truss beams with two-side batten plates L3 is loaded to 22.8 kN, local buckling occurs on the additional batten plate, figure 8 shows the local characteristics at destruction of L3.

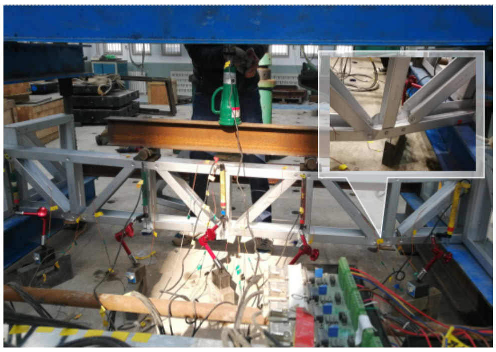

Figure 6. Schematic diagram of the destructive characteristics of L1

Figure 7. Schematic diagram of the destructive characteristics of L2

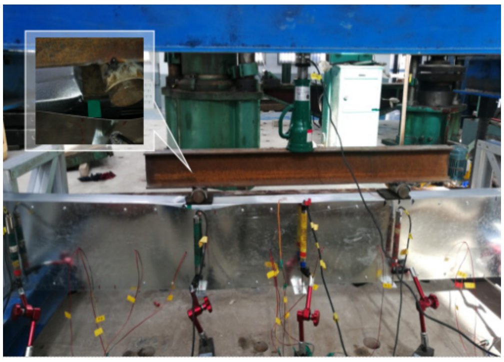

Figure 8. Schematic diagram of the destructive characteristics of L3

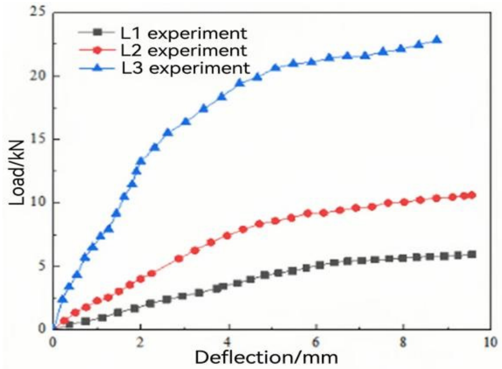

Figure 9. Load deflection curve of the beam

The ultimate bearing capacity of each test piece is shown in Table 4. The test shows that the reinforcement effect of the test beam L3 is better. Under the same case,the bearing capacity of beam with a single-sided batten plate is 78.45% higher than that of beam without batten plate, and the ultimate bearing capacity of beam with two-side batten plate can be increased by 115.09% compared with the reinforcement truss beam of single-side batten plate. The load deflection curve of the three beams is shown in Figure 9.

Table 4. The ultimate bearing capacity of the beam

The numbering of the beam	Ultimate load carrying capacity (kN)	Ratio to the theoretical value of L1 (%)
L1 theoretical value Pu	5.21	--
L1	5.94	14.10
L2	10.60	103.45
L3	22.80	337.60

4. Numerical Analysis of Cold-Bent Thin-Wall C-Type Steel Composite Beam

Due to the repetitiveness of the truss beam components and the complexity of the connection of the components, the analog was modeled in SAP2000 software, and then the model was imported into ABAQUS software for finite element analysis. In the modeling, the self-attack screw connection mode can not be really simulated, so the coupling constraint method (welding) is adopted in the analog. The steel model selected in the numerical simulation test is the same as the actual test, that is, the cold-bent thin-wall type steel of S550 model is used. According to the results obtained by the material property test, it can be seen that the elastic modulus of the material is E=189.5×10^3MPa, Poisson's ratio μ is taken to 0.3, yield stress σ =569.5 MPa, both the type of elasticity and the hardening of plastic are isotropic. The mass density is 7850 kg/m^3. Edit cross-section type is shell / homogeneity, shell thickness is 0.8 mm.

Figures 10, 11 and 12 are the force deformation cloud diagrams of truss beam L1, L2 and L3. Figure 13 shows the midspan deflection curve of the numerical analysis of three beams.

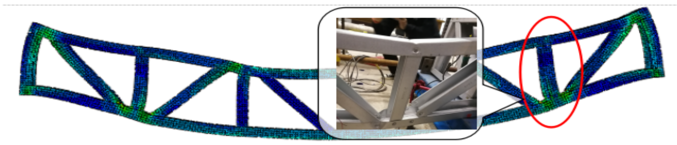

Figure 10. Force deformation cloud diagram of truss beam L1

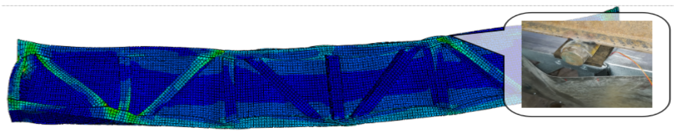

Figure 11. Force deformation cloud diagram of truss beam L2

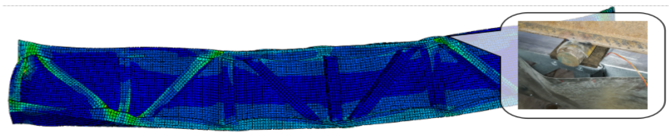

Figure 12. Force deformation cloud diagram of truss beam L3

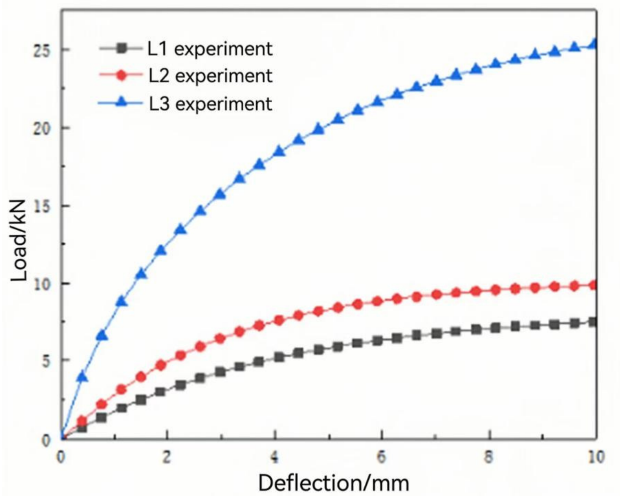

Figure 13. Midspan deflection curve of the numerical analysis of beam

5. Conclusion

Through the mechanical properties test and structural bending test and numerical analysis of three different combinations of cold-formed thin-walled C-type steel composite beams, The conclusions are as follows:

ISSN: 2688-8653

The ultimate bearing capacity of the single-sided board beam is increased by 60.8% compared with that of the bare skeleton beam, and the ultimate bearing capacity of the truss beam reinforced by the double-sided patch panels is increased by 138%, and appropriate reinforcement measures can be taken according to the actual force characteristics in the project;

The force-destroyed process of the combined truss beam is divided into three stages:The first stage is the elastic phase, the load-displacement curve is approximately an oblique line; The second stage is elastoplastic stage, the linear relationship between stress and strain is disrupted and the strain increases significantly; The third stage is the destruction stage, and the curve shows a downward trend. The self-tapping screw shear damage occurs on the bare skeleton beam, and the cold-bent thin-walled C-type steel composite beam with the attached patch plate is damaged by the local buckling of the batten plate;

It can be seen from the load-strain relationship curve of the test that with the increase of the number of additional plates, the bearing capacity of the beam increases significantly and the stiffness increases.

References

[1] Wang, H. Create a new situation in the scientific development of the steel structure industry - the development and characteristics of domestic steel structure in the past two decades[J].Housing facilities in China,2007(09):31-33.

[2] Chan,J.; Gu,Q.,; Chan, S. Flexion analysis of thin-walled lipped channel beam plates and the effective flakiness ratio of the compression flange(I) [J].Journal of Xi'an University of Architecture and Technology (Natural Science Edition), 1996 , 28(1):14-18.

[3] Shi,Y.; Zhou, X.; Guan,Y.; Yao,X. Study on the force performance of cold-formed thin-walled steel roof trusses and the calculated length of members[J]. Journal of Building Structures, 2019,40 (11): 81-89.

[4] Guan,Y.; Zhou,X.; Yao,X.; Shi,Y. Experimental study on shear resistance of cold-formed thin-walled steel composite roof and self-tapping screw connection[J]. Chinese Journal of Civil Engineering, 2018, 51(10):27-36+67.

[5] Zhou, L. High strength cold-formed thin-walled steel axial pressure short column test and theoretical research[D].Chang'an University,2007.

[6] Bu,L.; Liu,H. Bonded steel plate reinforced steel beam bending test study[J]. Highway Engineering, 2020, 45(03):38-43.

[7] Xie,Y.; Dai, Y.; Wang; Y. Application of new reinforcement technology for portal rigid frame steel structure workshop[J]. Jiangsu Architecture, 2019(04):57-60.

[8] Liu, H. Subject to bending test studies of reinforced steel beams with steel plates pasted[D]. Hunan University, 2019.

[9] Technical specifications for cold-formed thin-walled steel structures:GB 50018--2002[S]. Beijing: China Standards Press, 2003.

[10] Tensile testing of metal materials Part 1 Room temperature test methods GB/T 228.1-2010, [S].