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Experimental study of steel truss girder with Z-shaped clips

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***Abstract*—This paper describes the mechanical properties of truss girders with Z-shaped clips through experiment. The result shows that the failure mode of truss girder is categorized as lateral buckling-induced destabilization. By comparing the mechanical performance and the economy indices between truss girder with butterfly-shaped clips and truss girder with Z-shaped clips, the feasibility of truss girder with Z-shaped clips is demonstrated.**

***Keywords:* Z-shaped clips, steel truss girder, experimental study, mechanical performance**

I. Introduction

Cold-formed steel residential system has been studied by many researchers all over the world [1-3]. Nested light-weight steel joist system can effectively avoid the waste of materials, and it is used to design butterfly-shaped clips different from Canadian web steel system [4]. Light gauge steel (LGS) truss girders or C-shaped joists were widely used in floor system, and some experimental researches showed that the failure mode of C-shaped joists is distortional buckling [5-7], then, together with Oriental Strand Board (OSB), Cold-formed steel were applied as composite floor. And the mechanical property of the floor was investigated by researchers [8-11]. However few laboratory studies were carried out concerning (LGS) truss girders, and the composite floor supported by LGS truss girders [12,13]. Thus, In this paper, Further investigation of LGS truss girders was conducted.

In the application of nested light-weight steel joist system, it is found that for joists with butterfly-shaped joists, the mechanical performance of lower and upper chord members is limited to a certain extent; there is large bending moment at connection of butterfly-shaped clips and upper & lower chord members, which is the weak point in truss girder and causes much deflection of construction member. On the contrary, Z-shaped clips not only cause less wastage and loss during the stamping process, but also reduce the bending moment at the connecting joists. As a result, the deflection of truss girder is decreased, which helps to maximize the mechanical performance of construction member. This paper preliminarily analyzed the mechanical features, failure mode and load carrying capacity of truss girders with Z-shaped clips through experiment. And the test data can provide basis for the finite element model and analyzing the mechanical properties of the truss girder with Z-shaped clips. By comparing the mechanical performance and their economy indices between two truss girders, we also can demonstrate the feasibility of truss girder with Z-shaped clips.

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II. Experimental Program

A. *Material Properties*

Tests of material properties were completed in Key Laboratory of New Technology for Construction of Cities in Mountain Area. Table I lists the measured average yield strength, tensile strength and modulus of elasticity.

TABLE I. MATERIAL PROPERTIES OF STEEL IN THE TESTS [N/mm^2]

Member	Yield strength	Ultimate strength	Modulus of elasticity
Rectangular pipe	426	472.5	199000
Clip(connection)	390.5	478.2	196200

a. *Test Specimen*

In this experiment, four truss girders (L1, L2, L3, ZL1) were tested, L1-L3 have butterfly-shaped clips, and ZL1 has Z-shaped clips, as shown in Figure.1. □, □ and □ respectively denote the relative position of clips and tubes: double-sided, outer-sided and inner-sided. The truss girder with Z-shaped clips was a full scale specimen with a 260mm cross section height, and the span of the girder is 4.73m. The upper chord of truss girder was a 40mm×60mm rectangle tube, and the lower chord, a 40mm×40mm rectangle tube; both of them had a thickness of 0.8mm. The thickness of Z-shaped clip was 1.5mm. All of them were made of S350 galvanized steel.

The rectangular tubes and clips were fastened together by self-tapping screws, the diameter of self-tapping screws head was 4.8mm, and the screw length was 16mm. Before doing the experiment, two truss girders were connected in parallel in order to maintain the out-plane stability of a truss girder. Two truss girders net space was 320mm, the upper chords were connected firmly with rectangular tubes at a certain distance, as did the lower chords. The ends of the upper chords were put on the 50mm×70mm rectangle tubes, connected together by L-shaped connections.

B. *Experimental Scheme*

One support of the truss girder was steel triangle support, and the other was the roller support, both were placed at the top of the concrete piers. Equidistant 6 points load was employed to simulate uniformly distributed load in the Z-shaped truss girder test. Owing to the low rigidity of weighted platform, the loading force can move along with loading points, and the loading can be exerted on truss girders uniformly. Loading mode and experimental facility of truss girder with Z-shaped clips are showed in Figure. 2.

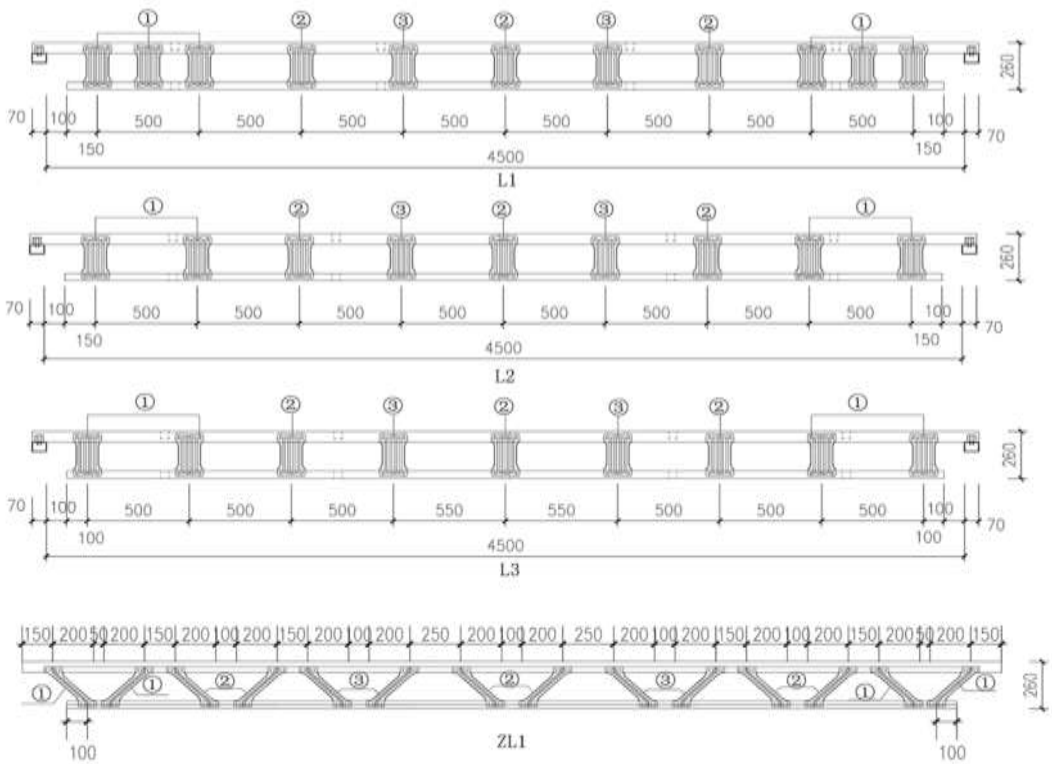
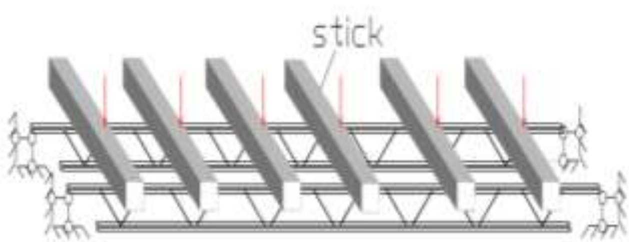


Figure 1. Layout of specimens



(a) Loading mode

(b) Experimental layout

Figure 2. Loading mode and experimental layout of the truss girders

The reaction frame for loading was longitudinally arranged along the girder. Two load distribution beams were employed, and the load was applied by lifting jack. One end of the jack was fixed to a steel beam. Then, a 5t statical strain indicator was placed between the other end of jack and another steel beam above the jack. The load on the truss girder was collected by static digital strain indicators. Vertical displacements of mid-span under various loads were measured by dial indicators, the strain of the key parts of chord members and the middle part of Z-shaped clips were collected by DH3816 strain acquisition box.

III. Results and discussion

A. *Comparison of Mechanical Performance*

Since the load was exerted on the specimen through equidistant 6 points load, the ultimate load values of the specimens under uniform load should be converted according to the principle that the bending moment at mid-span of specimens in two load schemes are equal [14]. And the ultimate loads and failure information for test specimens with butterfly-shaped clips and Z-shaped clips are shown in Table 2. The failure phenomena of the specimens are shown in Figure.3.

As we can know from Table II, the first clip on L1 and L2 was distant from the ends, thus the bending failure occurred at the ends; For L3, the distance between the first clip and the end of the girder was smaller, and the lateral buckling occurred at the mid-span, which was similar to the failure mode of ZL1. The ultimate bearing capacities of four girders were comparable. was smaller than that of truss girder with butterfly-shaped clips. The reason was that the internal force was transmitted via bending moment at the joints of butterfly-shaped clips and upper or lower chord members

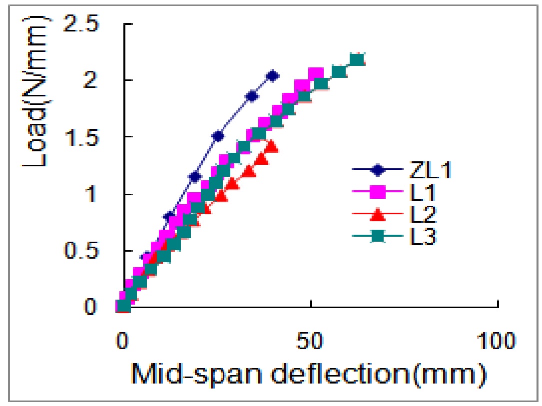
TABLE II. TESTS RESULTS OF FOUR TRUSS GIRDERS [N/mm]

Tests	Ultimate Load	Failure Location	Failure Mode
L1	2.11	Left side of the joint at the upper chord end	Bending failure
L2	2.12	Left side of the joint at the upper chord end	Bending failure
L3	2.19	Joint in the mid-span of the upper chord	Buckling failure
ZL1	2.14	Joint in the mid-span of the upper chord	Buckling failure

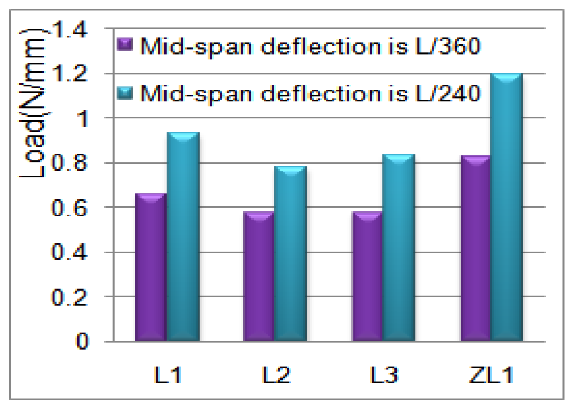
(a) L1 (b) L2

(c) L3 (d) ZL2

Figure 3. Failure phenomenon of truss girders



(a) Load-deflection curve



(b) Load comparison

Figure 4. Load-deflection relationship for each truss girder

In normal service conditions, according to Technical Specification for Web Steel Building System (DBJ/CT045-2008) [15], the deflection of floor girder should not exceed L/360 and that of roof truss should not exceed L/240. Experimentally established load-deflection relationship for every truss girder and the corresponding loads are shown in Figure.4.

In Figure.4, It is showed that under equal load, the mid-span deflection of truss girder with Z-shaped clips (ZL1)

As the load increasing, the joints will move and the bending moment at upper chord member will increase, thus lead to the increase of the deflection of entire truss girders. While for truss girder with Z-shaped clips, the internal force was transmitted via the shaft force of Z-shaped clips between lower and upper chord members. Although the shaft force on Z-shaped clips increased with the increase of load, the bending moment of upper chord members at joists was smaller than that of joists with butterfly-shaped clips, resulting in a smaller deformation and a smaller mid-span deflection.

The load bearing capacity of truss girder with Z-shaped clips at allowable deflection was enhanced by 20%-50%. Thus, it

can be concluded that the truss girder with Z-shaped clips have better mechanical performance than the truss girder with butterfly-shaped clips.

Table III. STEEL CONSUMPTION OF EVERY GIRDER

Specimens	L1	L2	L3	ZL1
Number of connections	17	13	13	18
Total weight of girder (kg)	16.3	14.8	14.8	14.5
Weight per unit length（kg/m）	3.5	3.2	3.2	3.0

B. *Comparison of Steel Consumption*

Table III shows the steel consumption of every girder. The total steel consumption of truss girder with Z-shaped clips is less than that of truss girder with butterfly-shaped clips.

Although the number of joists of truss girders with Z-shaped clips is slightly more than that of truss girders with butterfly-shaped clips, the weight per unit length is reduced, and the mechanical performance is also enhanced.

IV. Conclusion

Based on the experiment of truss girders with Z-shaped clips and butterfly-shaped clips, the mechanical performances of the two types of truss girders were obtained respectively, and economy indices of the two types of truss girders were compared, and related conclusions are showed as following:

(1) The failure position of truss girder with Z-shaped clips occurred at the joists near the mid-span; the failure mode was categorized as lateral buckling-induced destabilization.

(2) Truss girder with Z-shaped clips and truss girders with butterfly-shaped clips had comparable limits of load carrying capacity, but the rigidity of truss girder with Z-shaped clips at allowable deflection was 20%-50% higher than that of truss girders with butterfly-shaped clips, which demonstrates that truss girder with Z-shaped clips had better mechanical performance than truss girder with butterfly-shaped clips.

(3) Truss girder with Z-shaped clips is more economical than truss girder with butterfly-shaped clips.

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