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Finite Element Analysis of Widen Flange Section Steel Frame

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Abstract: This electronic document is a “live” template. The various components of your paper [title, text, heads, etc.] are already defined on the style sheet, as illustrated by the portions given in this document. (Abstract) Widespread and unpredicted brittle fractures have been found in weld steel beam-column connections (weld-flange-bolted-web connections) of steel frames shaken during the Northridge earthquake and the Kobe earthquake. Such fractures were most often initiated at the bottom flange weld and propagated into the column flange and the beam web. The post-earthquake studies have shown that the traditional seismic behavior of beam-column connections is not good becauseof the brittle failure prevents the welded moment connections from exhibiting the inelastic behavior expected. Extensive experimentally and numerically studies were therefore conducted to the improved beam-column connections in the worldwide.The beam-to-column connection with beam-end horizontal haunch is a kind of reinforced beam-to-column which is one of the typical forms to move plastic hinge outward from the beam and column interface connections. By widening beam flanges, the plastic hinge will form the welds that have much fracture proneness due to stress concentration and welding sensitivity, reducing the damage of brittle fracture of connections and improving the ductility of the structure.

Keywords: Widen flange section; Sductility coefficient; Plastic hinge

1. Introduction

The most common failure modes of steel structures occur in the weld zone where the flanges of beams and columns intersect, brittle fracture occurs in many joints, and even the bearing capacity is lost. Therefore, it is of great significance to study the seismic performance of joints for improving ductility of steel frame structures, preventing brittle failure of joints and improving seismic capacity of structures. The steel structure of early high-rise buildings in our country was basically designed abroad. The design and construction regulations of our country were formulated on the basis of learning the advanced technology of foreign countries. Because of the large number of high-rise steel structure buildings designed by Japan, the design, fabrication and installation personnel in China are familiar with Japan's steel structure construction methods. Most of the design regulations, especially the joint design, are formulated with due consideration of China's characteristics in accordance with Japan's regulations, and some regulations absorb the experience of the United States. At present, the traditional bolted-welded joints of beams and columns are widely used in China. There are some potential safety hazards in resisting natural disasters caused by large earthquakes. On the one hand, it is a very important and urgent strategic task to draw lessons from the existing research results and information abroad, on the other hand, to accelerate the pace of design theory and Experimental Research on new seismic joints of steel structures in China, and to improve the ability of building steel structures to withstand natural disasters caused by extraordinary earthquakes in China. Expanded airfoil joints are strengthened by structural measures, forcing plastic hinges to appear on the beam at a certain distance from the beam-column joints, so as to achieve the purpose of plastic hinges to move out to protect the joints, which is conducive to the realization of the design idea of "strong columns, weak beams and stronger joints". The expanded airfoil joints mainly include plate expanded airfoil joints, beam end flange expanded airfoil joints and side plate reinforced airfoil joints, ribbed plate expanded airfoil joints and axillary expanded airfoil joints.

Beam end flange enlarged airfoil joints can reduce the stress in the weld by increasing the flange width of the beam. Both of them can well achieve the purpose of shifting the plastic hinges out. The enlarged airfoil joints are connected with the beams through short brackets. The brackets are welded with the steel columns in the factory, and the steel beams with equal flange width are connected with the short brackets in the field. Leg bolt welding connection, so as to ensure the quality of welding seam between short bracket and column connection. Compared with the ordinary steel beam-column joints, the plastic deformation capacity of the beam end can be increased by more than one time, which greatly improves the seismic capacity of the steel frame. Width and length of enlarged wing are the main factors affecting the energy dissipation and ductility of joints in the connection of enlarged wing at beam end flange and strengthened section of side plate. The disadvantages of this connection mode are complex manufacturing process and waste of materials.

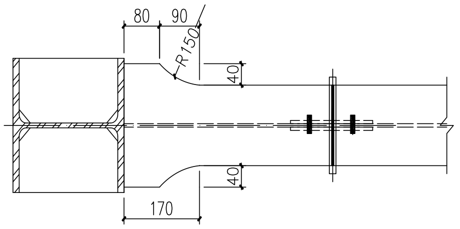
External displacement of plastic hinge is an effective way to solve the problem of seismic performance of steel frame connections, and enlarged connection of beam end flange is an effective way to realize the external displacement of plastic hinge. In this paper, based on the test of the mechanical behavior of the enlarged airfoil joints on the end flange of steel frame beams completed by Gao Peng and Wang Yan, the non-linear finite element analysis of the enlarged airfoil joints is carried out by using ANSYS software. The results of the finite element analysis are compared with the test results, and the accuracy and applicability of the finite element model established in this paper are verified. It is a future theory. The analysis and engineering application provide reference basis.

2. Finite Element and Experimental Model

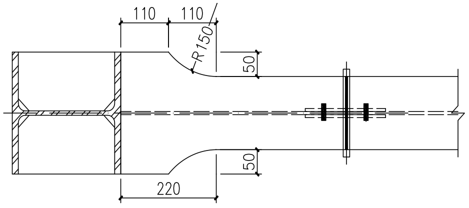
In order to verify the accuracy and applicability of the finite element model established in this paper, experiments by Gao Peng and Wang Yan were selected to verify the model. The section size and parameters of the specimens are shown in Table 1, and the schematic diagram of the joint connection is shown in Figure 1.

Table 1. Section size and wing expansion parameters of specimens

Specimen number	Beam section size	Column section size	Beam column connection type	Length of expansion wing (mm)	Widened wing width (mm)	Node type
WFS-1	HN300×150×6.5×9	HW250×250×9×14	Full welding connection	170	40	Expanded wing type
WFS-2	HN300×150×6.5×9	HW250×250×9×14	Full welding connection	220	50	Expanded wing type



(a)Expanded wing part of specimen WFS-1



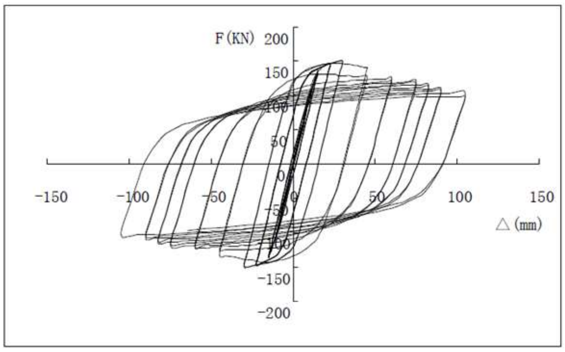
(b)Expanded wing part of specimen WFS-2

Figure 1. A schematic diagram of the node connection

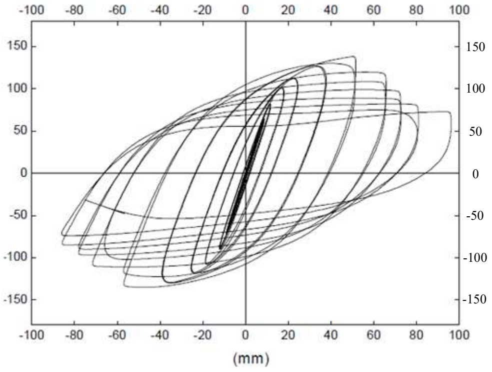
In the process of model building, SOLID92 entity element with high precision is used to divide the free mesh into three directions: X, Y and Z fixed constraints on the upper and lower ends of the specimen column, X direction constraints on the free end of the beam, Y direction displacement coupling on all nodes of the beam end section, and external force with displacement. The mode applied to the main node of the coupling surface is equivalent to the out-of-plane constraint of the beam.

3. Hysteresis Curve

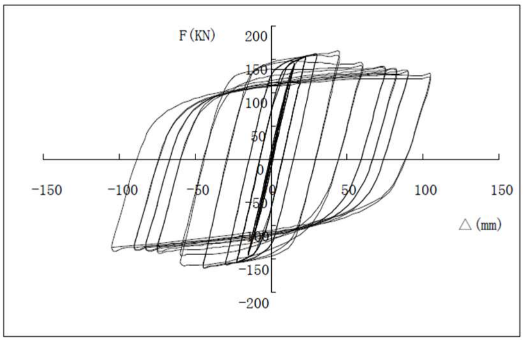
Figure 2 shows the load-displacement hysteresis curves of specimen WFS-1, WFS-2, finite element and experimental specimens.



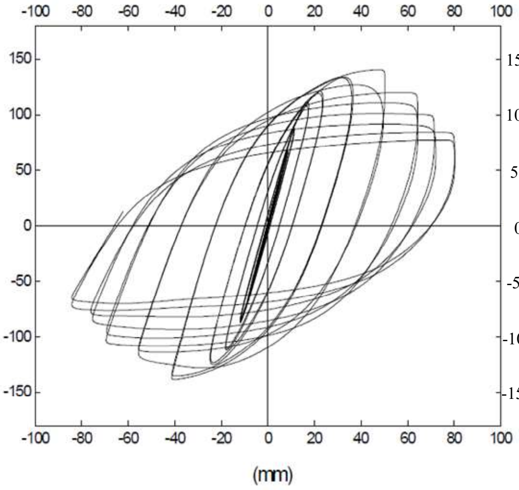
(a) Load-displacement hysteresis curve of WFS-1 beam end-finite element analysis



(a) Load-displacement hysteresis curve of WFS-1 beam end-test results



(b) Load-displacement hysteresis curve of WFS-2 beam end-finite element analysis



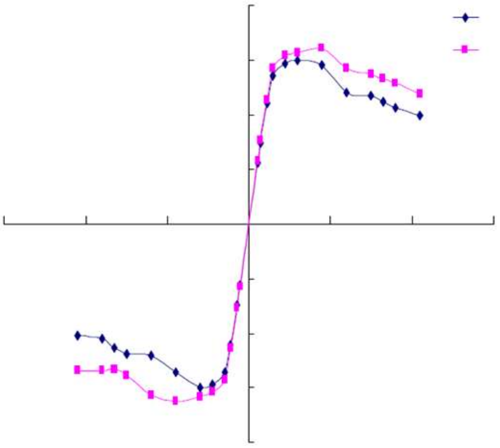
(b) Load-displacement hysteresis curve of WFS-2 beam end-test results

Figure 2. Load-displacement hysteresis curve under cyclic loading

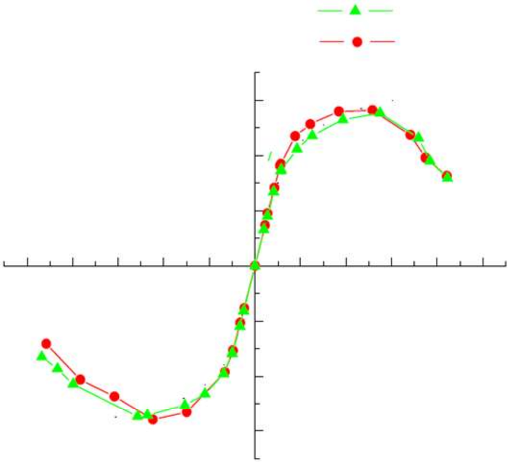
Through comparison, it can be seen that the hysteretic curves of the specimens obtained from the test are in good agreement with those obtained from the finite element simulation. The results of the two specimens'finite element simulation and the test results are very full. The hysteretic curves obtained from the two specimens show obvious phenomenon of load drop and stiffness degradation. Because of insufficient loading in the test, the drawing of hysteretic curve is imperfect, which is not full compared with the finite element simulation. The consistency between the experimental and simulated curves shows that a series of settings, such as the constitutive relationship of the material selected in finite element simulation and the element type used in simulation, are in good agreement with the reality, and the validity and success of the previous tests are also verified.

4. Skeleton Curve

The skeleton curve is the envelope of the peak point on the hysteretic curve of each cycle. It is another important basis for seismic performance. It comprehensively reflects the stress-deformation relationship of the model in the process of repeated loading as shown in Figure 3.



(a) Skeleton Curve of Connecting Joint of Expanded Airfoil——finite element analysis



(b) Skeleton Curve of Connecting Joint of Expanded Airfoil——experimental result

Figure 3. Skeleton curve under cyclic loading

By comparing the skeleton curves of the specimens obtained from the test with those obtained from the finite element analysis, the following rules can be found: (1) The skeleton curves of the enlarged beam-end joints show good plastic deformation ability, and the enlarged beam-end joints can transfer the plastic hinge from the weld at the root of the beam-column connection to the outer region.(2) There is little difference between the experimental and simulated values of the skeleton curves of the two specimens, which indicates that the simulation results of the finite element model can meet the needs of the experimental simulation very well.

5. Bearing Capacity and Ductility of Specimens

Bearing capacity and ductility coefficient are important indexes for evaluating the seismic performance of structures or components. The results of finite element analysis are compared with those of test, as shown in Table 2 and Table 3, respectively.

Table 2. Comparisons of finite element calculation and test values of bearing capacity of specimens

Specimen number	Yield load			Ultimate load		
	Finite element calculation value (kN)	Test value (kN)	Error (%)	Finite element calculation value (kN)	Test value (kN)	Result difference (%)
WFS-1	123.20	102.80	19.84	149.29	138.65	7.67
WFS-2	142.35	114.80	23.98	161.13	141.85	13.59

Table 3. Comparisons of Ductility Coefficient between Finite Element Calculated Value and Test Value

Specimen	Yield displacement δy (mm)			Limit displacement δu (mm)			Ductility coefficient μ		
	calculated value	Test value	Error %	calculated value	Test value	Error %	calculated value	Test value	Error %
WFS-1	16.62	17.10	2.81	69.51	71.10	2.23	4.18	4.17	0.20
WFS-2	16.26	16.40	0.01	67.48	67.90	0.01	4.15	4.13	0.40

By comparing the experimental and simulated values of bearing capacity and ductility coefficient, it can be found that: (1) From the comparison of Table 2 and Table 3, it can be seen that the finite element calculation values of yield load, ultimate load and ductility coefficient of the joints are close to the experimental values, so it is reliable to use ANSYS to analyze the enlarged joints at the end of the beam. (2) The yield displacement of the two specimens is larger than that of the finite element simulation. Because the skeleton curve obtained in the simulation is outside the skeleton curve obtained in the experiment, the displacement test value corresponding to the same external force is larger. (3) The ductility coefficients obtained by the test and the finite element simulation are both greater than 4.0, and the simulation values of the two specimens are greater than the test values. The reason for this result is that in the process of finite element modeling, the properties of steel materials are more ideal.

6. Acknowledgment

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