Performance Analysis of Steel Structure Nodes

Hui Ma
School of Architecture Engineering, Binzhou University, Binzhou, 256600, China

Abstract: The main parameters of flange section shape change of beam end flange enlarged airfoil joints are selected, and a series of specimens are derived with basic specimens as prototypes. The influence of the length and width parameters of the flange plate of the enlarged beam on the bearing capacity of the joint, the development law of the plastic hinge and the location of the joint, as well as the seismic performance of the joint are studied. The basic conditions for the design of the enlarged flange joint at the end of the beam are given, which is the seismic behavior of the steel structure. The revision of design specifications can provide reference.

Keywords: Nonlinear; Expanded airfoil node; Hysteretic behavior

1. Introduction

1.1. Node parameter design

Steel structure buildings have been widely used in the world, 58% of the world's super high-rise buildings are pure steel structure, while 65% - 70% of foreign residential buildings are also steel structure. In many industrialized countries, such as the United States, Japan, Britain, Australia and so on, steel housing has become more popular. Australian steel frame housing accounts for 50% of the total number of residential buildings. American multi-storey steel structure housing technology is an integrated technology that integrates light steel structure, building energy conservation and thermal insulation, building fire prevention, building sound insulation, new building materials, design and construction. Steel structure develops rapidly under the promotion of North American Metal Structure Association, and in the United States. In the general low-rise housing, the proportion of steel structure housing has developed from 5% in the 1990s to over 25% now, and the application technology is becoming more mature and perfect. The history of steel structure building in Japan has been more than 100 years. In recent years, the steel structure building in Japan has developed rapidly. The proportion of steel structure in building construction has been increasing every year since 1965. At present, it accounts for about 50%. It is very common for low-rise buildings to adopt steel structure, such as low-rise buildings below 5 stories, which adopt steel structure. It accounts for more than 90%, with an average area of 300 square meters. Each building uses about 300 tons of steel. Compared with the traditional brick-concrete residential buildings, steel residential buildings are more in line with the characteristics of "green ecological building". It has the advantages of light weight, low cost of foundation, small occupied area, high degree of industrialization, beautiful appearance, short construction period, good seismic performance, fast investment recovery and less environmental pollution, and has better comprehensive economic benefits. The key to improve the performance of rigid joints is whether the reliability of joints can be enhanced by improving the ductility of joints. Based on the research and analysis of the traditional beam-column joints, some improved new types of joints are proposed, which can be divided into two categories: the expanded airfoil type and the weakened type. Because of the potential weld defects and stress concentration on the surface of the column, it is easy to cause premature cracks. Both methods can move the plastic hinge from the flange of the column to the beam at a certain distance from the cylinder, thus avoiding the brittle failure caused by the deterioration of the deformation capacity of the joint.

Since the 1970s, bolt-welded hybrid joints have been widely used in the United States. Before the Beiling Earthquake, some experts and scholars had doubted the seismic performance of the traditional joints based on the discrete plastic corner test data and brittle fracture of the joints in the experimental study. Professor Engelhardt of Dezhou University even proposed that the traditional joints should be paid close attention to during the large earthquake. The performance of epicenter should be improved in design method and connection structure. The basic way to solve the problem of seismic performance of steel frame connections in the United States is to shift the plastic hinges outward, which can be divided into two basic forms: weakening and strengthening. By weakening the flange or web of the beam, the weakened joint can be destroyed before the joint, so as to control the plastic hinge position of the beam. However, this weakening will reduce the bearing capacity of the beam, and increase the possibility of local buckling of the web and lateral torsional instability of the beam. Expanded airfoil joints are formed by changing the structural measures at the joints, so that the plastic hinge area on the beam yields before the joints, so as to protect the joints and increase the plastic deformation.

In view of the phenomena that Japanese steel frames exhibit different failure characteristics from American steel frames in the earthquake, Japan did not adopt the scheme of shifting plastic hinges out after the earthquake as the United States did. The research in Japan after the earthquake mainly focuses on the dynamic test, the influence of temperature on the connection performance, the material properties of steel and weld, the development of new materials and new structures. The improved form of the beam-column connection of steel frame is put forward. In the technical specifications issued after the earthquake in Japan, the setting of sector tangential angle includes open angle and open angle. There are two kinds of angle, and it is stipulated that the sectoral tangent angle can be of different shapes. The purpose is also to eliminate possible cracks and ensure the plastic properties of the structure. The failure of welded steel frame joints mainly occurs at the lower flange of the beam and is usually caused by brittle cracks at the root of the weld. There are various ways of crack propagation, from welding root to base metal or heat affected zone. Once the flange is broken, the shear connectors connected by bolts or welds are often pulled apart and extended from bottom to top along the connecting line. The most potentially dangerous is the crack that extends through the flange and web of the column at the root of the weld. A large number of invisible cracks can be found by means of ultrasonic flaw detection. From the degree of damage, visible cracks account for about 20% - 30%.

By selecting WFS-B series as the main parameters of the enlarged flange section, the development law of the bearing capacity, energy dissipation and ductility of the joints with the change of the length and width parameters of the flange plate of the enlarged beam is studied. The flange enlargement parameters of steel frame beams are shown in Fig. 1, and the parameters range of WFS-B series is shown in Table 1.

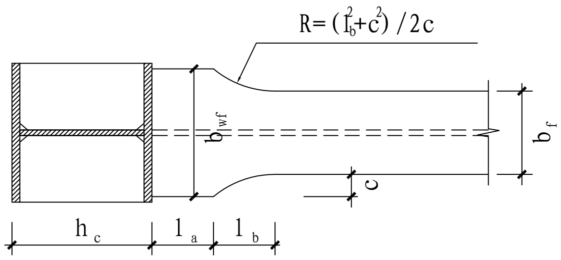

Figure 1. Girder flange enlargement parameters

Table 1. Dimension table of wing expansion parameters for WFS-B group specimens

Specimen number	la (mm)	la /bf	lb(mm)	lb /hb	c (mm)	c/bf
WFS-B1	110	0.73	110	0.36	20	0.13
WFS-B2	110	0.73	110	0.36	30	0.20
WFS-B3	110	0.73	110	0.36	40	0.27
WFS-B4	110	0.73	110	0.36	50	0.33

The section size of all specimens is HN300 x 150 x 6.5 x 9, the section size of column is HW250 x 250 x 9 x 14, the length of La segment of WFS-B group specimens is unchanged, and the flange enlargement width C takes different values.

2. Bearing Capacity

The bearing capacity of each specimen of WFS-B joint is shown in Table 2.

Table 2. The bearing capacity of each specimen of WFS-B joint is shown in table

Specimen number	WFS-B1	WFS-B2	WFS-B3	WFS-B4
C(mm)	20	30	40	50
Yield load (KN)	130.57	133.85	136.93	142.35
Ultimate load (KN)	150.08	153.94	157.57	161.13

Table 2 Finite element calculation values of bearing capacity of each specimen of WFS-B group joints

3. Ductility Coefficient

The ductility coefficients of WFS-B specimens are shown in Table 3.

Table 3. Ductility coefficients of specimens of WFS-B group nodes

Specimen number	WFS-B1	WFS-B2	WFS-B3	WFS-B4
C(mm)	20	30	40	50
U (mm)	71.65	70.09	68.47	67.48
Y (mm)	16.98	16.81	16.54	16.26
μ	4.22	4.17	4.14	4.15

Table 3 shows that the finite element analysis results of ductility coefficients of WFS-B group specimens are all above 3.0, which meets the requirements of flexural steel frame connections. It shows that the joints have good ductility performance, while improving the bearing capacity of the joints, the ductility performance is also improved. With the increase of flange width c, the ductility coefficient of WFS-B specimens ranges from 4.14 to 4.22, and the variation range is small. The influence of parameter C on the ductility of joints is not obvious.

4. Plastic and Total Turning Angles

The results of ANSYS model analysis and experimental results are shown in Table 4.

Table 4. Plastic and total rotation angles of WFS-B beams

Specimen number	WFS-B1	WFS-B2	WFS-B3	WFS-B4
C(mm)	20	30	40	50
Θp(%rad)	3.86	3.80	3.75	3.70
u(%rad)	5.17	5.13	5.11	5.09
θp/u(%)	74.67	74.00	73.33	72.67

The results show that the plastic rotation angle decreases with the increase of the flange width c, but the change is not significant. The increase of the flange width C has less influence on the seismic capacity of the joints than the increase of the flange width C.

5. Conclusions

(a)Based on the study of WFS-B series specimens, it is concluded that the bearing capacity increases with the width C of flange enlargement, but the influence of the width of column section on the bearing capacity and ductility is small, and the plastic rotation angle decreases, but the change is not significant.
(b)From the failure mode of WFS-B1, it can be seen that the plastic hinge is close to the beam-column joint, and the plastic hinge can not move out effectively, so the flange expansion width C should not be less than the flange width of double beam. Because of the limitation of the section width of column, it is suggested that the flange width of double beam should be taken as C.

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