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Research on Seismic Behavior of honeycomb composite beam-column joints

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ABSTRACT

In order to study the seismic performance of cellular beam- column joints. Based on the existing test of honeycomb composite beam-column joints, taking the research method of combining theoretical analysis and numerical simulation, the seismic performance of beam-column joints of the cellular beam steel frame with the floor is analyzed , the cellular beam is a regular hexagon, Opening rate is 65%.A finite element model of the honeycomb cellular beam column joints is established, and compared with the experimental results, the rationality of parameters setting in the model is verified, it laid a foundation for the analysis of seismic performance of cellular beam column joints . Set up five honeycomb composite beam-column joints with different thickness of the floor .A study on the low cycle reciprocating load of the cellular beam- column joints, then we analyzed the hysteretic behavior of these joints . The result of the study shows :the composite beam-column joints with 90mm thickness of slab and 65%porosity can externally move the plastic hinge to honeycomb holes. The increase of thickness of slab can promote the stiffness and bearing capacity of the slab is not obvious. The degradation of every test specimen is very close and it is more obvious after the test specimen go into yielding situation.

Keyword: cellular composite beam-column joints, quasi static test, The thickness of the floor ,seismic performance

1. INTRODUCTION

Steel frame beam- column joints may produce brittle crack and cause the phenomenon of structural damage in earthquake , a lot of scholars both at home and abroad put forward many design methods to improve the seismic performance, theoretical analysis and experimental study on the beam-column joints[1-5].One of the local weaken the beam end near the node is one of main methods to improve the seismic performance of beam-column joints, Honeycomb beam due to the existence of holes make the orifice place easy to give in first[6], to reduce the possibility of brittle fracture of honeycomb joist steel frame node welds, And improve the ability of rotation, thus increase the ductility of the structure, improve the seismic behavior of the beam-column joints[7-8]. Compared with the honeycomb beam section, combination section greatly improves the original beam section bearing capacity and stiffness , At the same time increase the shear capability of orifice area, For better realize earthquake on off shoring plastic hinge to the cellular structure in the process of hole of ductility design, this paper studies the floor thickness of honeycomb composite beam-column joints, vibration resistance for honeycomb provides the theory basis for design of beam-column joints.

2. EXPERIMENTAL STUDY HONEYCOMB COMPOSITE BEAM-COLUMN JOINTS

2.1 Specimen design

Beams and columns Use Q345B steel, Sectional dimension are H450×300×12×16 and H400×200×8×12, beam length is 2400mm, opening ratio is 65%. Concrete grade is C30, plate thickness is 90mm, width is 850mm. Concrete and steel mechanical properties obtained from the test are shown in Table 1 and Table 2, the main dimensions of the specimen shown in Figure 1.

Table.1 Mechanical properties of concrete materials

strength grade of concrete	Ec/MPa	fcu,k/MPa
C30	3.1×104	31.5

Table.2 Mechanical properties of steel materials

steel	Size /mm	Es/ MPa	fy/MPa	fu/MPa
steel plate	8	2.0×105	367	521
	12	2.0×105	357	501
	16	2.0×105	352	496
rebar	Φ8	2.0×105	411	579
	Φ10	2.0×105	402	562

2.2 Loading method

Axial compression ratio is 0.25. Displacement control loading system is 1Δ、1.5Δ、2Δ、2.5Δ、3Δ……, Δ is the yield displacement. Loading device is shown in figure 2.

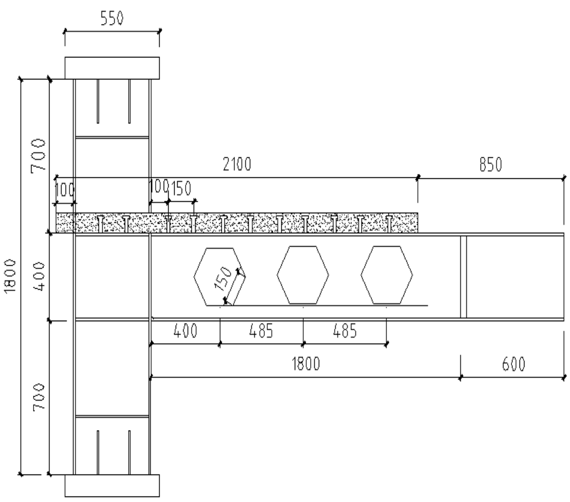


Fig.1 Dimension of specimen

Fig.2 Loading device figure

2.3 Test phenomenon

Test through the observation of the strain gauge data and finite element simulation of the numerical control experiment. At the start of the test, specimens were at the elastic stage, the deformation is small, the honeycomb hole edge is smooth, only transverse cracks of concrete surface appear small, with the increase of load and cycle times, increase the crack expanding. Steel beam without any obvious change phenomenon. Specimen with two directions of the yield displacement are almost 16 mm, controlled by the yield displacement of multiple load at this time. When the displacement control, touch the edge of the concrete slab and column to form cracks and expand, when the displacement into 2 times the yield displacement, honeycomb beam Angle of the first hole to hole the first split, with the increase of number of cycles to make it bigger and bigger, and downward flange extends continuously, the concrete floor in the increase in the number of the crack on the top of the second honeycomb holes, plate column fracture at the edge of the form on the edge of plate. When the displacement increase to 2.5 times the yield displacement, the second cellular distributed Angle are torn, but smaller than the first cellular distributed Angle, reach the specimen the limit load of 215.3 kN. When the cycle to the third week, along the honeycomb beam flange on the surface of concrete under a main longitudinal cracks, concrete began to fall off. When the displacement increase to three times the yield displacement, the third Angle of honeycomb distributed and cracking, and growing. When the cycle to the third week, the border between concrete crushed, and the upper and lower flange yield phenomenon is obvious, the load has fallen below 85% of the ultimate load, the end of the test.

3.HONEYCOMB COMPOSITE JOINT HYSTERETIC PERFORMANCE OF FINITE ELEMENT ANALYSIS

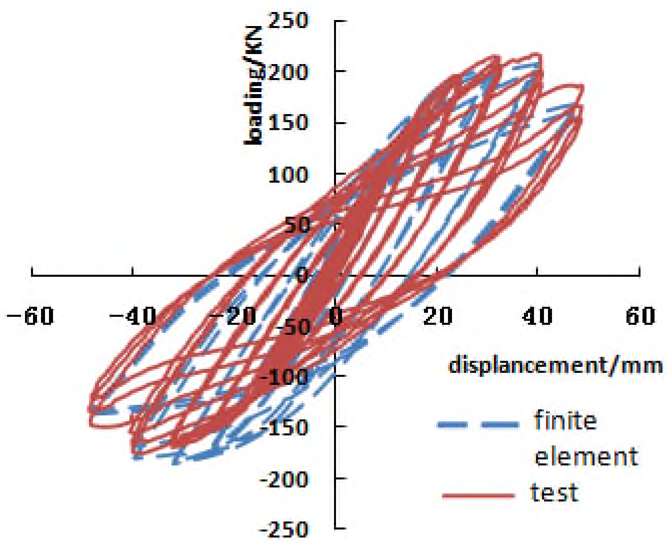
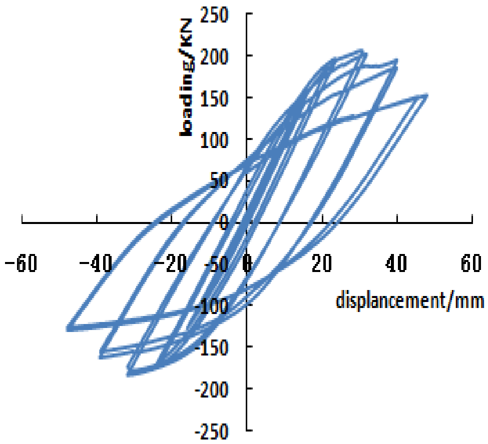
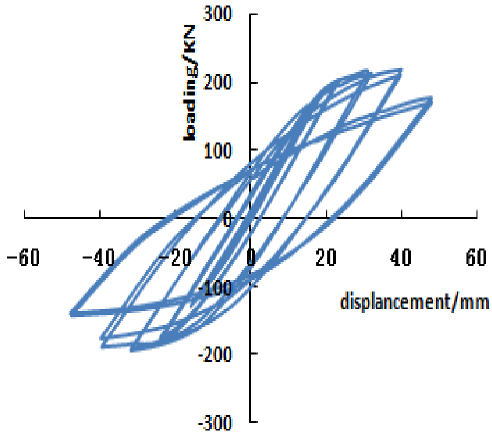


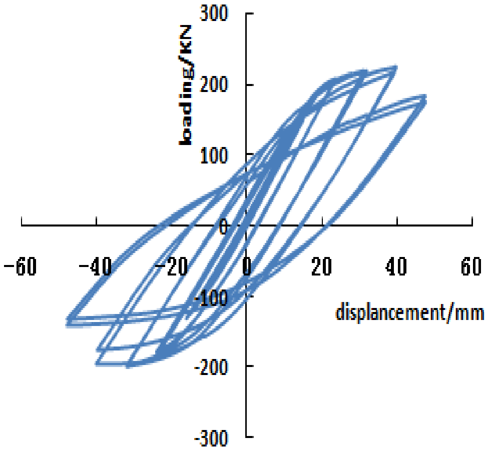
Fig.4 Comparison between experimental and finite element hysteretic curves



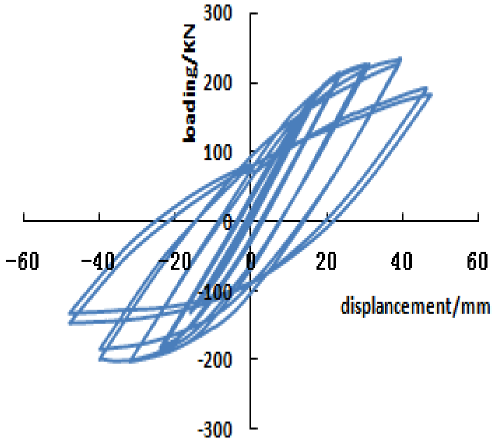
(a) FZL-1



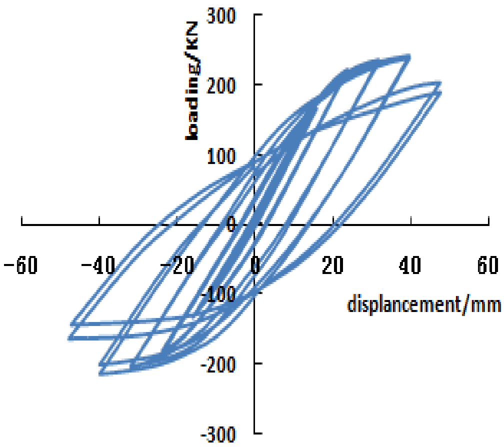
(b) FZL-2



(c) FZL-3



(d) FZL-4



(e) FZL-5

Fig.5 Hysteresis curve contrast figure

By figure 4 hysteresis curve contrast can be seen that the hysteresis curve shape of finite element simulation and experimental comparison, from the aspects of bearing capacity, the finite element simulation values and experimental values were similar, error control within the scope of the permit, the effective, an analog simulation can be used for further analysis.

4.SEISMIC BEHAIOR OF HONEYCOMB COMPOSITE BEAM-COLUMN JOINTS

Using the finite element software to establish the thickness of the floor is 80 mm, 90 mm, 100 mm, 110 mm, 120 mm ,5 honeycomb composite beam-column node model, Respectively named FZL-1、FZL-2、FZL-3、FZL-4、FZL-5.

4.1 hysteresis curve

The hysteresis curve of the specimens is shown in figure 5. Through the comparison, found that there was no evident difference five h curve of the specimens, were pinched condensation phenomenon, and not enough plump, its reason lies in the web hole is very big, cross section weaken severely, the structure of the energy absorption capacity decreased. With the increase of the thickness of the floor slab, the full hysteretic curve, concrete compression side area is more than concrete tensile area surrounded by the delay back curve shows that composite beams of concrete in compression performance is better than that of concrete tensile performance, the concrete compressive strength is not consistent hysteresis .

4.2 The skeleton curve

From figure 6, all specimens of skeleton curve development trend, the increase of the floor slab thickness, improve the honeycomb composite stiffness and ultimate bearing capacity of beam-column joints, but the floor thickness increased to 90 mm later on the influence of the cellular beam-column node rigidity and bearing capacity of composite decreases. In composite beams, the bearing capacity is mainly controlled by the steel beam to the specimens. With the increase of the thickness of the floor, when the stress of reinforced concrete plate and the plate to assume the role of the bending moment and shear force is larger, so the ultimate bearing capacity of the honeycomb composite beam-column joints with the increase of the thickness of the floor. Formed in the honeycomb beam plastic hinge, floor retired from work, the combination of bearing capacity drops rapidly, the smaller the thickness of the floor, the downward trend, the greater the show floor thickness of honeycomb beam ultimate bearing capacity cannot be ignored.

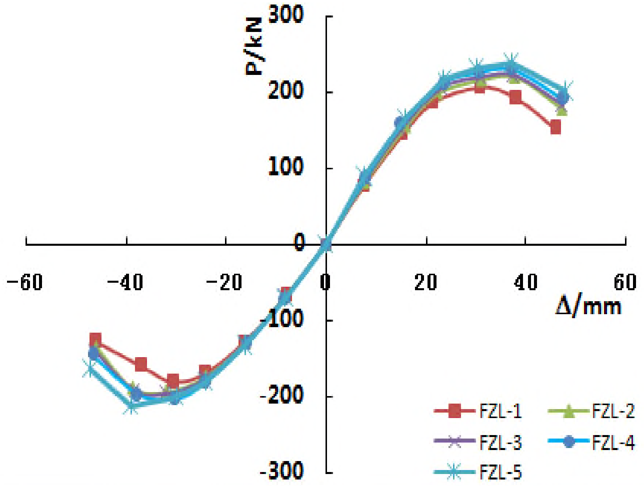


Fig.6 Skeleton curves of each test part

4.3The ductility and energy dissipation performance analysis

Table3 The ductility coefficient of specimen

number	yield displacement /mm	limiting displacement /mm	ductility factor
FZL-1	14.9	42.76	2.87
FZL-2	15.4	45.12	2.93
FZL-3	15.7	47.26	3.01
FZL-4	16.1	49.11	3.05
FZL-5	16.3	50.04	3.07

Table.4 The peak load energy dissipation coefficient of specimens

serial number	equivelant viscous damping coefficient	energy dissipation factor
FDL-1	0.267	1.68
FDL-2	0.278	1.75
FDL-3	0.288	1.81
FDL-4	0.296	1.86
FLD-5	0.302	1.90

The ductility coefficient of each specimen are shown in table 3, with the increase of the thickness of the floor, all specimens of the yield displacement and ultimate displacement has increased ductility performance is good, the main reason is due to the increase in the thickness of the floor slab, the composite of the neutral axis location of the cross section, the lower steel bearing size increases, the deformation of the flange, to become a plastic hinge formation of the
sensitive area, and the thickness of the floor, the shear effect, the better, concrete slabs flange constraint is relatively good.

(2) performance analysis of energy consumption

Comparison in table 4 equivalent damping coefficient and energy dissipation coefficient values found that the increase of the floor slab thickness, improve the ability of node energy, mainly because of increased the thickness of the floor, make the stress of the honeycomb composite beams section, improve the bearing capacity of the section, the increased stiffness of the node, to exert the same specimen displacement, the greater the counterforce of the specimens, so as to improve the energy dissipation capacity of nodes.

4.4Stiffness degradation

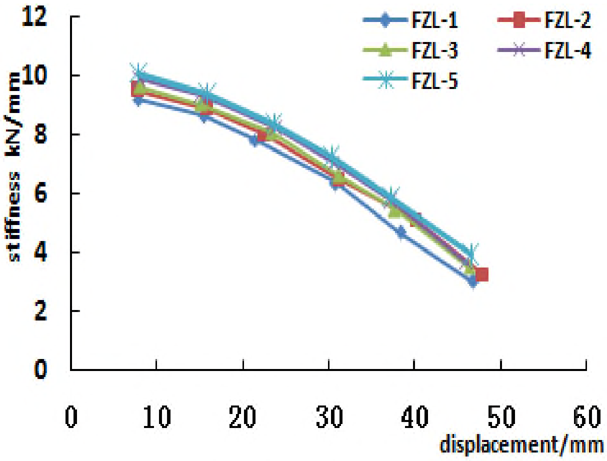


Fig.7 Schematic of Stiffness degradation of specimens

According to the figure 7 each curve of stiffness degradation of the specimens can conclude that the thickness of the floor stiffness degradation trend roughly the same under different conditions. All specimen stage stiffness degradation situation is not as obvious stage, specimen in the early stage of the stiffness degradation is relatively slow, mainly due to the gradual damage of concrete, with the increase of displacement, load increasing, when specimens into the yield and the yield stress increases quickly and the orifice flange and stiffness degradation curve down significantly. Weaken the reflected on honeycomb hole section and the hole Angle of stress concentration to the detriment of the honeycomb beam stress influence.

5. CONCLUSIONS

(1)Through the experimental study shows opening rate is 65%, the opening form for hexagonal honeycomb composite beam-column node force is reasonable, can achieve the purpose of offshoring plastic hinge, reduced the possible structure of brittle failure, can maximum limit to reduce the hazards.

(2)Comparing the hysteresis curves and energy dissipation of the specimens, the increase of the thickness of the slab split hole rate is 65%, the opening form for hexagonal honeycomb composite is good seismic performance of beam-column joints, the thickness of the floor, the greater the hysteretic curve is full, the stronger the energy dissipation capacity.

(3)The floor thickness increases, honeycomb composite beam-column joints bearing capacity and stiffness are improved, but after floor thickness of 90 mm, along with the change of the thickness of the slab bearing capacity and stiffness are not obvious.

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