Applied Mechanics and Materials
ISSN: 1662-7482, Vols. 638-640, pp 1923-1927
doi:10.4028/www.scientific.net/AMM.638-640.1923

Submitted: 2014-07-16
Accepted: 2014-07-19
Online: 2014-09-19

Experimental research on seismic behavior of new joint between concrete-filled square steel tubular column and steel beam

Nan Li[1, a] Yajun Xi[2,b]

[1]Deptment of Resources and Civil Engineering, Shandong University of Science & Technology, Taian, Shandong , China;

[2]Tai'an engineering construction standard cost office, Taian, Shandong , China;

[a]linan96@126.com , [b]junyaxi@126.com

Keywords: concrete-filled square steel tubular column; joint; hysteretic curve; seismic behavior;

Abstract: A new type of joint between Concrete-filled Square Steel Tube columns and steel beam is proposed in this paper, and the seismic behavior of this type of joint under low-reversed cyclic loading experiment is researched. Ductility behavior, dissipation of seismic energy of this joint under horizontal, repeat load are analyzed. The experimental results showed that all specimens have good ductility and energy dissipation capacity. The story angle drift ductility ratios are μ=3.23~3.63, and the equivalent viscous damping coefficients are he=0.25~0.35， which meet the needs of the code for seismic design of building.

Introduction

Concrete filled steel tubular structure has a rapid development in the field of modern structure ,because it has not only beautiful appearance and rules, but also the beam column node form is simple, short construction period, low cost. Concrete filled square steel tube with its superior mechanical properties, construction suitability and economy has been more and more widely used in our country.[1,2] The state has promulgated technical specification[3]. Researchers of concrete filled square steel tubular column and steel beam inner partition types have a lot of experimental study, while the other concrete filled steel tubular column and steel beam outer ring rib type have less researched. The purpose of this paper is to design and test a new type of joint between concrete filled square steel tubular column and H-type steel beam with exterior diaphragms and verify its good seismic performance through the calculation and analysis of the test results.

Design of the Joint Model and Experiment

Design of joint model

The main construction characteristics of this joint are as follows: T-type diaphragm is welded on the side of Concrete –filled Square Steel Tubular column, and the flange of H-type steel beam is welded with this diaphragm. The web of H-type steel beam and overhanging steel plate welded on column wall are connected by high strength bolts. Detailed dimensions of joint model are shown in Fig 1.

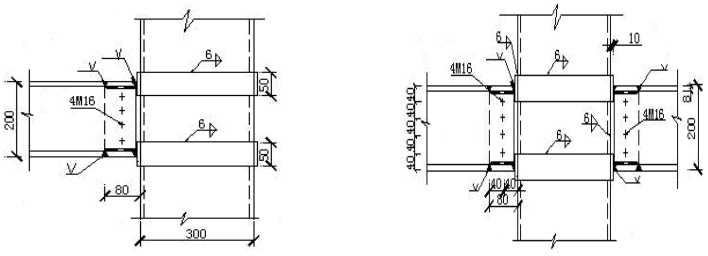


Fig.1 Detail drawing of joint

The four joint specimens in this experiment adopt Q235 steel, E43-Type hand welding electrode, and high-strength bolted friction-type of M16 . The concrete in Concrete-filled Square Steel Tubular

columns is poured and cured at processing plant. The design label of concrete is C30. Sectional dimensions of specimen are in Table 1 and the result of material test are in Table 2.

Table.1 Sectional dimension of specimen

Speciment	Sectional dimension of column（mm）	Sectional dimension of beam（mm）			
		Thickness of flange	Width of flange	Thickness of web	Depth of beam
BZ1	300*300*4	8	150	6	200
BZ2	300*300*6	8	150	6	200
ZZ1	300*300*4	8	150	6	200
ZZ2	300*300*6	8	150	6	200

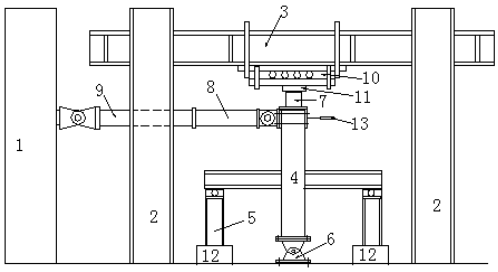
Table2. The result of material test

Material	Dimension of specime（mm）					Yield strength (N/mm^2)	Tensile strength (N/mm^2)
	t	L*b	l	l	h		
Steel	4	140*20	60	50	40	292	422
	6	190*30	90	75	50	302	438
Concrete	C30 150*150*150					Tensile strength 23.35N/mm^2	

Design of the experiment

According to the sizes and types, the four joint specimens in this research can be classified into two groups. There are four specimens in total. Two of them are joints of middle column, the others are joints of side column. The experiment adopts pseudo static test scheme in which constant axial loading is applied on the column end. We should measure hysteretic characteristics, ductility index of the beam-column nodes of median and side columns under the low-reversed cyclic loading; observe and record the failure course and characteristics; analyze the results seduced from seismic capacity experiment of two kinds of beam-column node.

This experiment adopts advanced system of electro-hydraulic servo programmable testing machine. Hydraulic loading equipment adopts hydraulic jack of 1500KN. Constant axial loading of 1300KN at the position of column top is applied by hydraulic jack, horizontal low-reversed cyclic loading at the position of column top is applied by electro-hydraulic servo actuator. Horizontal load-carrying system of this experiment is trapezoid reinforced concrete reaction wall. Test device are shown in Fig2 .



1rection wall 2rection frame 3rection beam 4 specimen 5support
6hinged bearing 7hydraulic jack 8loading transducer 9servoactuator
10rolling support 11transducer 12foundation beam 13displacement meter

Fig.2 Test device under load test

Experimental loading system

According to "Earthquake-resistant Test Method Regulation of Building", the experiment adopts pseudo static test scheme, in which the horizontal low-reversed cyclic loading is applied on top of Concrete-filled Square Steel Tubular column, at the same time vertical constant axial compression of 1300KN is applied on the top of column. This experiment adopts load-deformation double control methods. We determine the specific loading scheme of horizontal loading according to yield load and yield displacement. Before specimen yield, we adopt loading control method. According to estimated yield load P_y, we apply the loading in 3~5steps of single-cycle to P_y, namely inflection point occurred in P-Δ curve. After specimen yield, we adopt yield displacement Δy to control the loading process. We apply the loading based on such gradation loading as $1\Delta y$, $2\Delta y$, $3\Delta y$, $4\Delta y$,..., until the disruption of specimen, and there are 3 circulations in each grade.

Experimental results

Displacement-Load hysteretic curves of connection are shown in Fig.3.

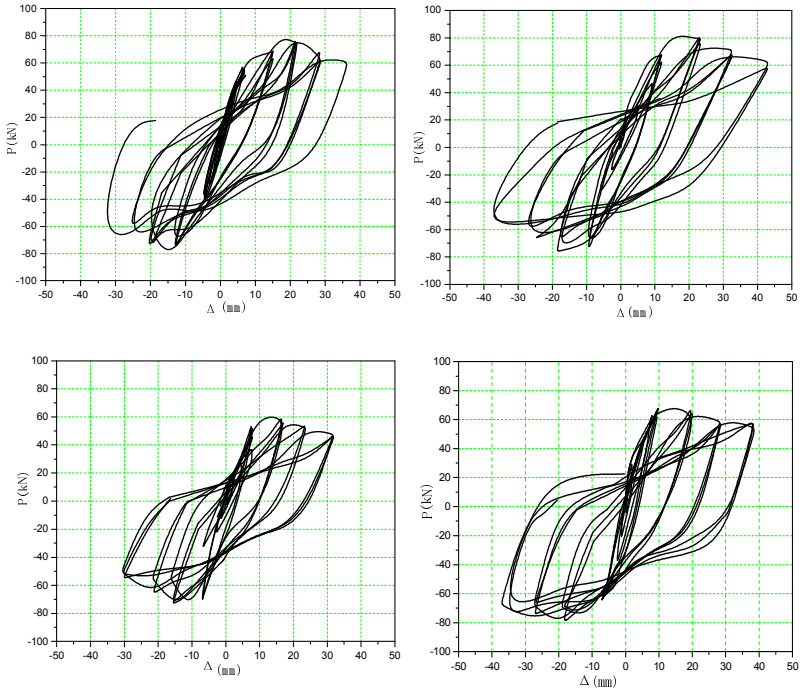
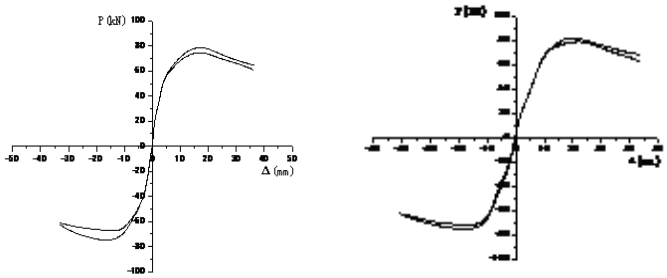


Fig.3 Displacement-Load hysteretic curves of joint

Skeleton curves of connection are shown in Fig.4.



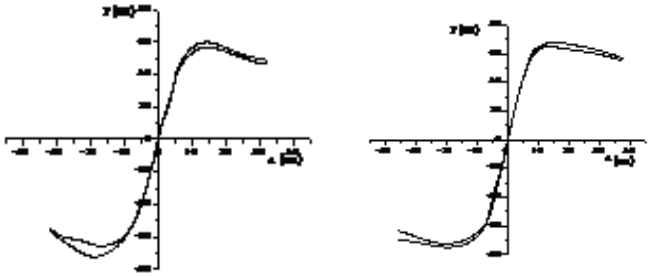


Fig.4 Skeleton curves of joint

The analysis of experimental results

Ductility and energy dissipation of the joint

Coefficients of ductility and energy dissipation of the joint specimen are shown in Table 3.

Table3.Coefficients of ductility and energy dissipation

specimen	story drift ductility parameter u	Φy	Φu	u_Φ =Φy/Φu	θu	h_e	E
ZZ1	3.42	0.0039	0.0140	3.40	0.017	0.28	1.76
ZZ2	3.63	0.0047	0.0169	3.66	0.018	0.35	2.19
BZ1	3.23	0.0040	0.0121	3.10	0.019	0.25	1.63
BZ2	3.43	0.0043	0.0149	3.46	0.016	0.30	1.88

Seen from above data, the joint's story drift ductility parameter (u) is 3.23~3.63 , its elastic limit angles of drift (Φ y) is 0.0039~0.0047 , and its elastic-plastic limit angles of drift (Φ u) is 0.0121~0.0169. Relative ultimate plastic turn angle of beam-column node (θ u) is 0.16~0.19, coefficient of equivalent viscous damping (he) is 0.25~0.35. Though the above data, we can learn that median and side column's displacement ductility and turn angle ductility meet the request of seismic design, and the energy dissipation capability of the joint is three times larger than concrete joint.

Retrogression of strength of the joint

Through the hysteretic curves of joint specimens, we can learn that the strength of specimen retrogress ceaselessly after entering the yield stage. This is because when the joint specimen is in elastic stage, the material is in the elastic stage so that its strength can not reach ultimate strength. So the member's stressed diversification can not reflect the member's strength diversification. After specimen yield, this phenomenon become more obvious because of the material's cumulative damage and adhesive failure between steel tube and concrete.

The members' retrogression of strength can be measured by depressed coefficients of bearing capacity. The degree of retrogression of carrying capacity is related to the members' load-bearing state, since when the ration of axial compression stress to strength is big enough, the members' carrying capacity usually retrogress. According to P-△ curve and measured results, the joint specimens' depressed coefficients of bearing capacity resulted from three times repeated circulation in equivalent displacement amplitude of the each stage are shown in Table 4.

Table 4.Depressed coefficients of bearing capacity of the specimen

Specimen	ZZ1	ZZ2	BZ1	BZ2
Yeild stage	0.967	0.986	0.955	0.972
Peak load stage	0.926	0.942	0.923	0.945

Conclusion

The above experimental data of middle column and side column joint test show that displacement ductility and rotation ductility of them can meet the seismic design requirements, the energy

dissipation capacity is about three times of the joint of concrete. From the P - Δ hysteretic curve and skeleton curve can be seen, yield strength degradation is appeared in each joint of the test specimens during the test process in various degree.With the displacement loop, strength decreased greatly increased. The results of this test is good for the future research and application of this kind of joint .

References

[1] Linhai Han:Modern Concrete-Filled Steel Tubular Structure Technology,edited by China architecture and building press,(2004).

[2] Linhai Han: Concrete-Filled Steel Tubular Structure,Science press,china,(2006)

[3] CECS159:2004,Technical Code on the Concrete-Filled Rectangle Steel Tubular Structures, China Planning Press, Beijing,(2004)