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Application of a new environmental protection building material in Steel Structural system

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Abstract. The cavity wall material is a kind of new saving energy and environmental protection building material having good physical and mechanic performance including lightweight, high strength, heat insulation and thermal insulation. Making full use of good physical and mechanic performance, as the infilling wall of steel frame structure, a new cavity composite masonry wall material is put forward, which can bear lateral load with steel frame together. Based on test of two specimens, the failure process and pattern is analyzed in detail in this paper, and the hysteretic behavior, energy dissipation and stiffness degeneration under the seismic force. Comparing with the steel frame, the cavity composite masonry infilling wall steel frame structure has higher strength, light weigh, higher stiffness, good anti-seismic behavior and ductility. The conclusion is reference for the seismic design of the infilling wall steel structure.

Introduction

Recently, as the state banned the use of solid clay brick and restricted the use of hollow clay brick, because of their advantages of self weight, easy to install, short construction period, seismic performance, the benefits of rapid ROI and little environmental pollution, structural steel residential building in the country by the system of universal concern. Meanwhile, in order to speed up the industrialization of residential building, the state promulgated a series of policies to encourage the construction industry actively promote the width application of steel structure. In the steel structure, the selection of building envelope is key technology to promote the use of its. In Chinese, it isn’t considered that the contribution to the anti-lateral frame with all types of masonry infill walls[1]. But in practice, as the coupling that connects the masonry infill wall with the beams-column there are large differences between the infill wall frame structure and pure frame in mechanic behavior. A lot of damage investigation, theoretical analysis and model tests show that the seismic performance of masonry infill wall in reinforced concrete frame structure is better than in the pure frame structure[2]. But there isn’t the steel structural engineering example that considers the anti-lateral action of the masonry infill wall on the steel structural frame in Chinese, and reported rarely regarding on the research results in the word. In this paper, a new anti-lateral steel frame system is put forward, based on achievement on the reinforced concrete frame with the masonry infill wall, namely the steel frame anti-lateral system with the cavity masonry infill wall.

1 Summary

1.1 Test specimens design

The Cavity material is a kind of new energy conservation and environmental protection construction materials with patented technology, light weight, high-strength, seismic performance, insulation, thermal insulation and other advantages[3]. The cavity wall material mainly includes two series:

board material and block material. In order to take full advantage of good mechanical properties and physical properties of the cavity material, the new compound wall is put forward. The cavity masonry is sandwiched as the core wall in composite sandwich shear wall between two sides of 30mm-thick fine aggregate concrete with ф4@50 wire-meshes (Fig.1).

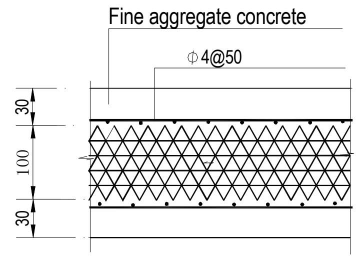
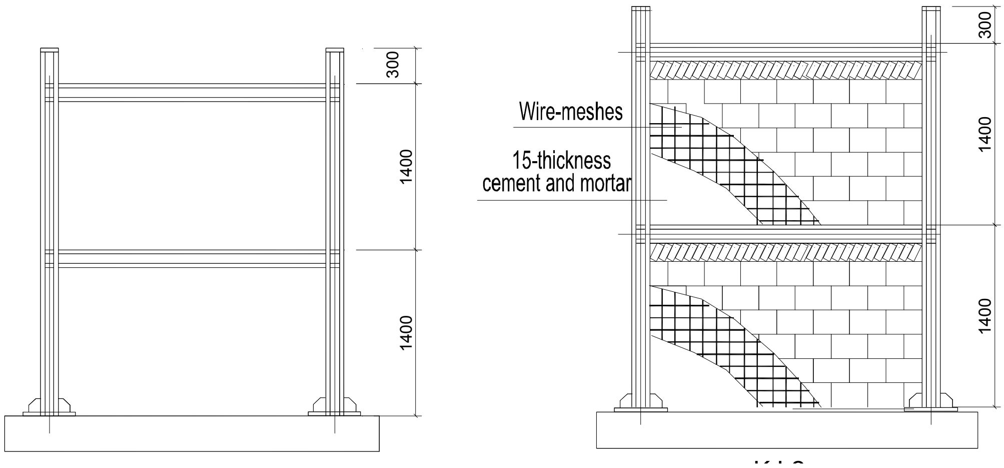


Fig. 1 The cavity composite masonry wall



(a) KJ-1 **(b) KJ-2**

Fig. 2 The detail of test specimen (unite: mm)

In the course of the force, between the substrate surface and through close bond to work together and form a whole, this can delay the walls cracking and improve the shear strength. Two 1:2 scale of steel frame specimens (Fig.2) are tested under the reciprocating load. The specific details are shown in Table 1. Cement mortar of M7.5 is used in bonding mortar, and C15 small stone concrete is used in the surface of infill wall use. Q235 steel material is used in the steel frame, and hot-rolled H-Shape Steel produced by Shandong Laiwu steel company are used in the beam, column and braced of the frame. All bolts used 10.9 grade friction-high-strength bolts, and weld used E4311 electrode welding electrode. The steel frame is connected with precast concrete foot-beam using the bolts to guarantee that the connecting is rigid.

1.2 Loading and test loading method

The specimens have been tested under the cyclic loading in the laboratory of Wuhan University of Science and Technology. The test equipment is shown in Fig.3.

80 kN vertical load exerted on the top of steel frame by two hydraulic jacks all at once, and the top of the column can produce free level displacement that remains unchanged during loading process. The method of controlling force is adopted before cracking, when the wall crack the method of controlling displacement is adopted until specimen damage. The loading system is shown in Table 2.

1.3 The partial results

KJ-1 doesn't incur brittle failure, which shows that dog bone joint changed and weaken stress distribution of beam end and prevented brittle failure.

At the end of test, the crack distribution of the infill wall of KJ-2 is even with 1mm-width, and there isn't obvious the oblique angle cracks. The integrity of the infill wall is still better. The infill wall crack is shown in Fig.4. Because of smaller whole lateral displacement, there isn't plastic hinge in steel frame, but only partial yield in the foot of column and beam end.

Table 1 The geometric characteristics of test frame

No.	Span /mm	Story height /mm	Beam' material	Column' material
KJ-1	2400	1400	H200×100×6×8	H150×150×7×10
KJ-2	2400	1400	H200×100×6×8	H150×150×7×10

Table 2 The loading system

No.	Before yield /kN						Yield		
KJ-1R	20	40	60	70	80	…	$1\Delta_y$	$2\Delta_y$	…
KJ-2R	50	70	90	110	130	…	$1\Delta_c$	$2\Delta_c$	…

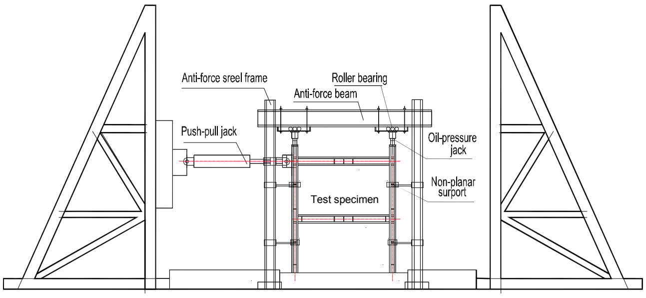


Fig.3 The loading device and test loading

Fig. 4 The crack distribution of infill wall of KJ-2

By KJ-1 and KJ-2 Comparative analysis tells us that the integrity of the steel frame with cavity masonry infill wall is better than the pure steel frame, and greater capacity bearing with about 68 percent increase. The Partial results of specimen test are shown in Table 3.

Table 3 Summary of the partial test results

	KJ-1		KJ-2	
	Push	Pull	Push	Pull
Yield load / kN	80	80	90	90
Yield displacement / mm	22	22	2.77	2.77
Limit load / kN	150	132	245	240
Limit displacement / mm	95	95	28	28
Ductility coefficient	4.75	4.75	10.12	8.56
Initial stiffness / kN/mm	5.44	5.44	27.4	27.4

2 Seismic Performance Analyses

2.1 Hysteresis behavior

Hysteretic curve is the comprehensive seismic performance of the structure. The load-displacement hysteresis curve of specimen KJ-1 and KJ-2 are shown in Fig.5. This shows that:

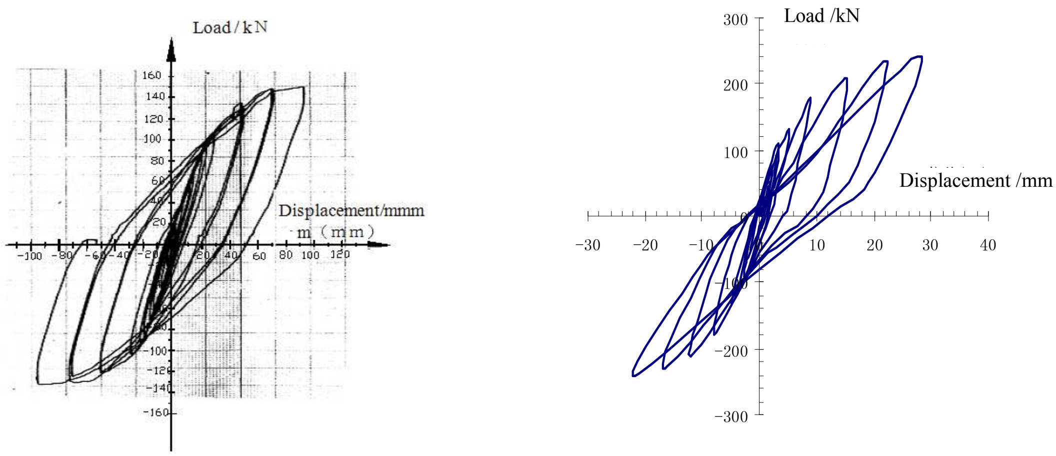
(1) The hystersis loops of two steel frame specimens is nearly same, full spindle and no reduction in pinch, this show that the two frame specimens have good energy-consuming behavior and ductility.

(2) The load-displacement hysteresis curve of steel frame with cavity masonry infill wall is S-type, this show that this structure can absorb more energy, and is conducive to the seismic and ductility.

2.2 Skeleton curve

Skeleton curve is of hysteresis the outsourcing Continuum (Fig.6).

The specimens have experienced the flexibility, yield and limit three-stage. Comparing with pure steel frame, the capacity bearing of the steel frame with cavity masonry infill wall increase largely, but the ultimate deformation obviously reduces.



（a） KJ-1 （b） KJ-2

Fig.5 The load-displacement hysteresis curve of specimen

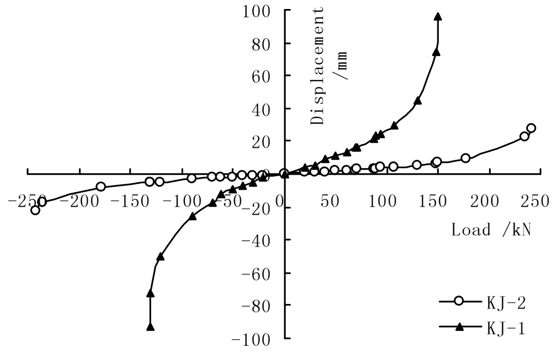


Fig.6 Skeleton curve of frame

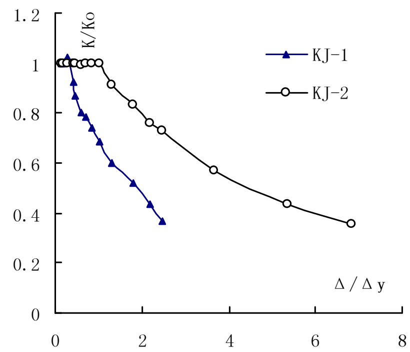


Fig. 7 The curve of stiffness degradation for frame

2.3 Stiffness degradation

From Table 2 we can see that the initial stiffness of the steel frame with infill wall is five times of the pure steel frame. This shows that the cavity masonry composite infill wall largely contribute to stiffness of steel frame in flexibility stage. Even in limit stage, the value of the stiffness with 10kN/mm is still far higher than the initial stiffness of pure frame. This shows that the cavity masonry composite infill wall play an important role in improving stiffness very clear.

From Fig.7 we can see that the stiffness of the steel frame with the cavity masonry composite infill wall almost don’t occur the phenomenon of stiffness degradation before crack of the wall. The speed of stiffness degradation of the steel frame with infill wall is far slower than pure steel frame after crack.

Clearly, the cavity masonry composite infill wall can significantly improve the anti-lateral stiffness of steel frame, improve their deformation performance, and then effectively improve the anti-lateral performance of the steel frame.

2.4 Ductility coefficient

The ductility coefficient μ of the steel frame is listed in the Table 2. From the Table 2 we can see that:

(1) The ductility of both two frames meets the demand of code;

(2) The ductility coefficient of KJ-1 is 4.75, the ductility coefficient of KJ-2 of the ductility coefficient is from 8.56 to 10.12, and both showed a better ductility;

(3) The ductility coefficient of the steel frame with the cavity masonry composite infill wall is more than the pure steel frame, which show that the steel frame wit infill wall has good ductility. The cavity masonry composite infill wall improves ductility of the steel frame, and improves seismic behavior of the steel frame.

2.5 Energy dissipation capacity

The energy dissipation coefficient E is adopted to illustrate energy dissipation capacity [4]. The relationship between E and Δ is shown in Fig.8. With the displacement increasing, the energy dissipation capacity of KJ-1 specimen increases, its E is more than 1.13. With the displacement increasing, the energy dissipation capacity of KJ-1 specimen reduces, and its E is more than 0.8. This shows that the cavity masonry composite can absorb a part of the earthquake energy.

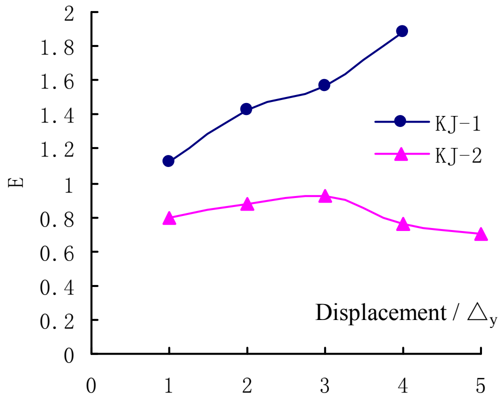


Fig.8 The energy dissipation

3 Conclusions

(1) The cavity masonry composite infill wall can improve the anti-seismic performance and ductility of the steel frame;
(2) The cavity masonry composite infill wall can improve the ultimate bearing capacity of steel frame;
(3) The cavity masonry composite infill wall can improve integrity of steel frame.
(4) The cavity masonry composite material is environment-friendly building materials with light weight, high-strength, seismic performance, insulation, thermal insulation.

Acknowledgements

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