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The Effect of Structural Mass on Seismic Performance of Semi-rigid Connection Steel Frame

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Abstract: The seismic behavior of semi-rigid connection steel frame was examined by pseudo-dynamic test that mainly analyzed the influence of structural mass on the seismic performance of steel frame in strain variation, displacement response and load response. The test showed that the mass had some effect on the seismic performance of steel frames with semi-rigid connection, mainly displayed in the bearing capacity and deformation of the steel frame, and dynamic response increased more obviously with the mass of steel frames.

Keywords: Semi-rigid connection, Steel frame seismic performance, Structural mass.

1. Introduction

Steel structure had high strength, good ductility performance, and widely used in the earthquake area of building structure, especially steel frame structures. The connecting way of beam-column joints had determinal function on mechanical performance of steel frame. One of the basic assumptions of the conventional steel frame analysis was that joints were either perfectly rigid or perfectly hinged. Therefore, when a steel frame was analyzed, joints were idealized as fixed or hinged. But the connections of steel frames did not behave in either rigid or hinged but semi-rigid connection in fact. Domestic and international numerous studies had shown that semi-rigid connection steel frame had better seismic performance [1-4]. At the same time, analysis indicated that there were many factors of influencing the seismic performance of semi-rigid connection steel frame, such as semi-rigid connection stiffness, structural damping and seismic wave, etc. In this paper, the split T [5, 6] was informs used as semi-rigid connection in the two test specimen with different mass. Under the same condition but the mass, the research was focused on transforming the input mass of the steel frame to test the dynamic responses of semi-rigid connection steel frame and analyze the effect of structural mass on seismic performance of steel frame. Thus providing the basis for optimal design and application of steel frame with semi-rigid connections.

2. Pseudo-dynamic Test Principle

Pseudo dynamic test is based on the dynamic equations (Eq. 1) of structural dynamic responses for numerical calculation, using numerical integration method to solve. Through inputting the time history curve of typical earthquake acceleration and the previous moment restoring force, we solved the discreted dynamic equation by numerical integration method, then we got the displacement xi as the seismic response of the structure model. We imposed the displacement on the structure model, then we got the restoring force Pi of the structure model at the time. The loading process and applying measured displacement to the structure were carried out circularly to simulate the actual dynamic response process for the structure model under the earthquake. Eq. 1 showed that [7-9]

$$[M]\{\ddot{x}\}+[C]\{\dot{x}\}+[K]\{x\}=-[M]\{\ddot{z}\}, \quad (1)$$

where $[M]$, $[C]$, $[K]$ are the mass matrix, damping matrix and stiffness matrix of the structure respectively; $\{\ddot{x}\}$, $\{\dot{x}\}$, $\{x\}$ are the acceleration, speed, displacement of the structure; $\{\ddot{z}\}$ is the acceleration response of ground respectively.

3. Pseudo-dynamic Test General Situation

3.1. Specimens

In accordance with the specifications for design of steel structures (GB 50017-2003) [10], we took a two layers, single span and studio steel frame with semi-rigid connection by scale ratio 1:2 to conduct the pseudo-dynamic test. The height of the bottom was 2.2 m and the top was 2 m. The span and studio were 3.0 m respectively. All steel material used Q235. Beams and columns were hot-rolled H steel. The installation drawing of semi-rigid connection steel frame was shown in Fig. 1 and the T steel was shown in Fig. 2, and the specimen cross section dimension were shown in Table 1.

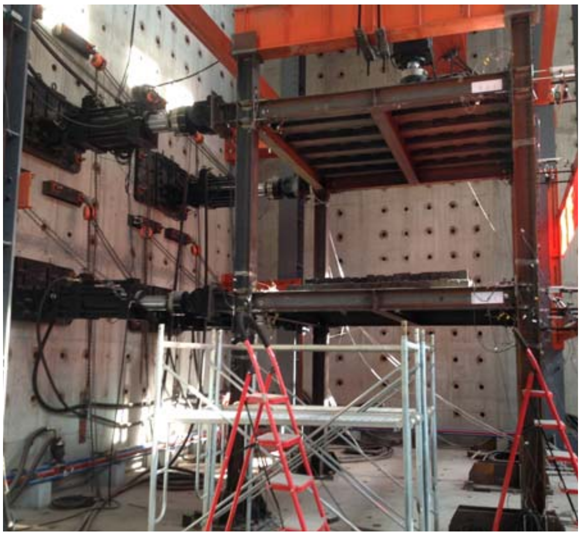


Fig. 1. Installation drawing of semi-rigid connection steel frame.

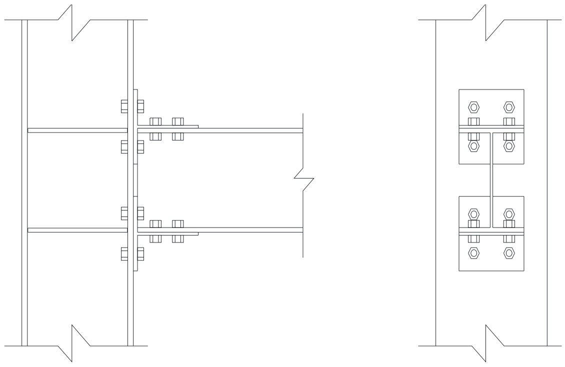


Fig. 2. T steel connection drawing.

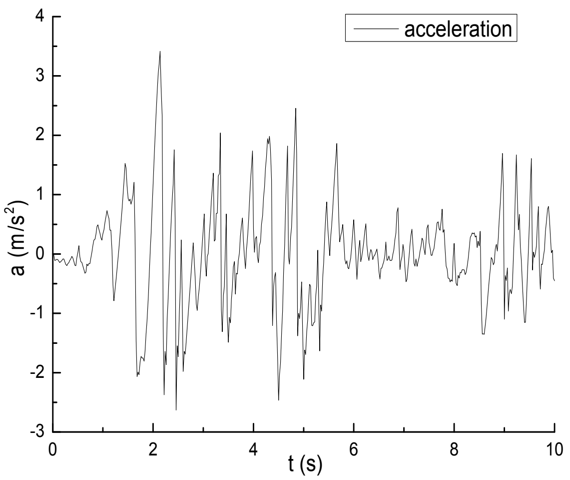
Table 1. Specimen cross section dimensions table.

Specimen	**Cross section (mm)**
Columns	HW175×175×8×11
Beams	HW194×150×6×9
T steel fittings	HW500×200×10×16
High strength bolts	M16

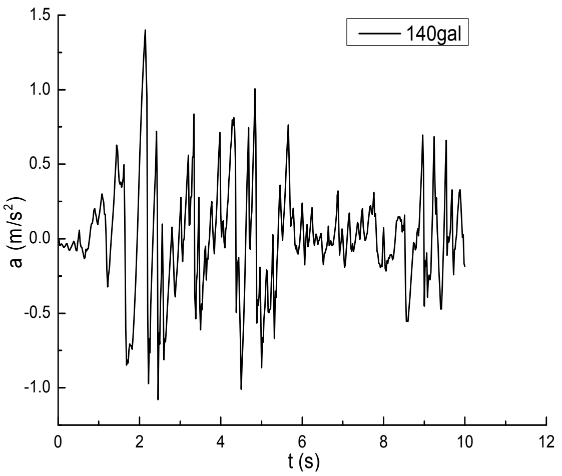
3.2. Loading Device and Steps

The test device included reaction wall, servo loading system, data acquisition system, etc. Test disposed four actuators which were horizontal that two actuators with 1000 kN were both on the top of the frame to exert horizontal dynamic response and two actuators with 500 kN were at the underlying of the frame to impose horizontal dynamic response. By built-in displacement meter and external displacement meter, we measured the displacement response of the frame and the displacement for each measuring point of the steel frame. Measuring instruments mainly included displacement meters. Through fitting one displacement meter at each layer of beam end, the changes of displacement at each layer could be measured. By the analysis of strain at the key parts with strain gages and then connected to a static signal acquisition system, strain changes were measured.

Before the pseudo dynamic test, we should measure the layers stiffness of the frame first of all, and then used the electro-hydraulic servo system to loading on the specimen. For the subsequent test, we controlled the steel frame model in the elastic stage. We used displacement control mainly in the test. We first determined the stiffness matrix, mass matrix and damping matrix of steel frame. Before the test, we preloaded the frame to test the response and the stiffness of the steel frame, then the mass of the frame were input respectively by m=5200 kg and m=10400 kg that m1 = m2=m. Then by putting the stiffness matrix [K] and mass matrix [M], we obtained the damping matrix [C]. The seismic wave for the test was according to the "regulations of buildings seismic test method" (JGJ - 96) [11] which made the select principle of seismic wave in the test, and we selected EI-centroseismic wave (as shown in Fig. 3(a)) that the peak acceleration corresponding with 140 gal (as shown in Fig. 3(b)) that was the peak value of 1.4 times. At the end of each load test, we measured the stiffness of the frame. Through inputting the seismic wave, we measured the corresponding displacement and load response and strain for measurement points.



(a)



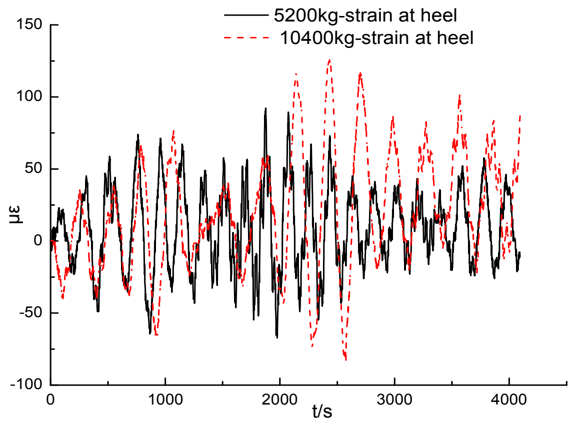
(b)

Fig. 3. EIcentro wave.

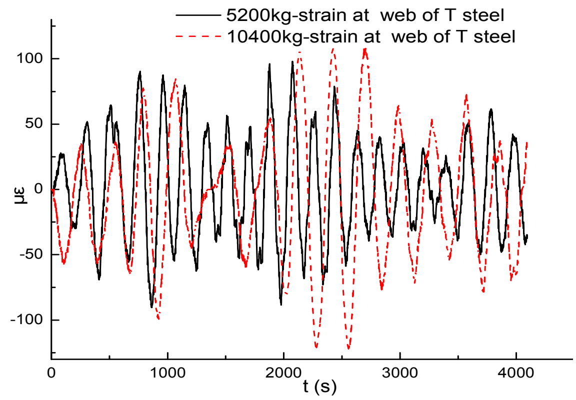
4. Results and Analysis of the Test

4.1. Strain Analysis

The time history curves of node strain were shown in Fig. 4(a), Fig. 4(b) diagrams respectively showed the strain at heel and T steel web with m=5200 kg and m=10400 kg. It got that the strain variation amplitude of m=10400 kg was slightly greater which showed that increasing the mass of steel frame could make the load capacity larger and be contributed to resistant earthquake load and increase the seismic performance of the structure.



(a)



(b)

Fig. 4. The time history curves of node strain.

4.2. Force Response

Fig. 5 showed the time history curves of force response at the bottom of frame with the layer mass of m = 5200 kg and m = 10400 kg respectively under the same earthquake.

The maximum force response at the top and bottom of the steel frame under different mass were shown in Table. 2. The peak value of the force response with different mass was almost constant. It showed that the variation of mass had little effect on the interlayer shear.

Table 2. The peak value of the force response under different mass.

Structural mass/kg	Force response at the bottom/kN	Forceresponse at the top /kN
5200	11.01	9.89
10400	10.85	9.38

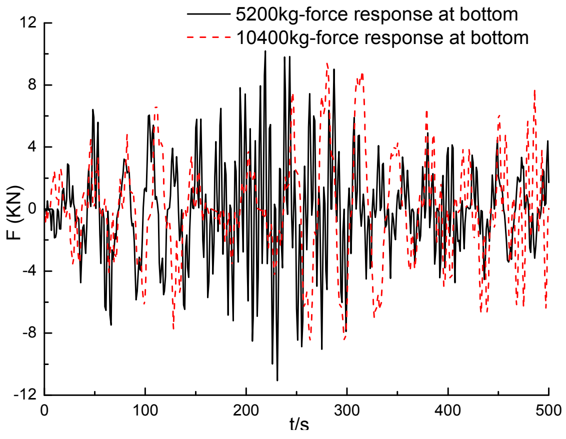


Fig. 5. Time history curves of force response.

4.3. Displacement Response

The time history curves of displacement response at the top of frame with the layer mass of m = 5200 kg and m = 10400 kg respectively under the same earthquake were shown in Fig. 5. Table 3 showed the maximum displacement response at the top and bottom of the steel frame under different mass. The peak values of the displacement response with m = 10400 kg were almost two times of m = 5200 kg. The displacement response of semi-rigid connection steel frame increased with the increasing of structural mass. In the elastic range, the deformation capacity was larger under the bigger mass to resistant the earthquake.

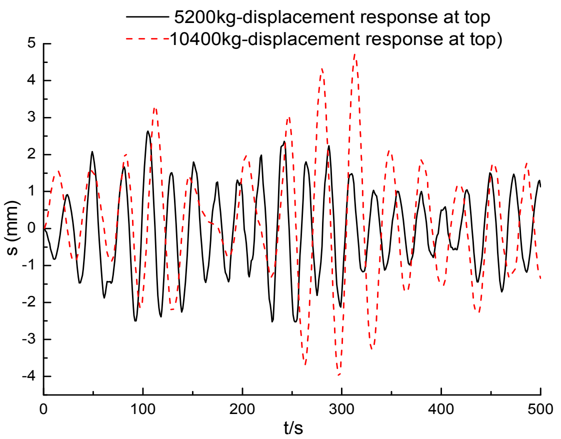


Fig. 5. Time history curves of displacement response.

Table 3. The peak value of the displacement response under different mass.

Structural mass/kg	Displacement response at the bottom/mm	Displacement response at the top /mm
5200	1.47	2.86
10400	2.80	5.03

5. Conclusions

By analyzing the test results, the conclusions were following:

1) The mass of semi-rigid connection steel frame had a certain effect on the strain variation at nodes. The strain reflected the bending bearing capacity which affected the bearing capacity of the steel frame, and the structural mass could increase the structural ability to resist seismic action;

2) The variation of structural mass had less influence on interlaminar shear of steel frame;

3) The interlayer displacement response of semi-rigid connection steel frame increased with the structural mass increasing, thus increasing the deformation ability of the structure that was advantageous to the energy consumption of seismic action and contributed to seismic performance.

All in all, increasing the mass of the steel frame can increase the bearing capacity and deformation capacity of the structure, improve the seismic performance of structures, but the rationality, applicability and economical efficiency of the steel frame should be considered in design to avoid unnecessary waste and make the mass of steel frame in a reasonable range.

Acknowledgement

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References

[1]. K. Ohi, H. Kondo, Y. Y. Chen, et al, Earthquke response tests on steel frames with semi-rigid connections, *Journal of Structural Engineering*, Vol. 39B, 1993, pp. 155-164.

[2]. N. D. Aksoylar, S. Elnashai Amr, H. Mahoud, The design and seismic performance of low-rise long-span frames with semi-rigid connections, *Journal of Constructional Steel Research*, Vol. 62, 2011, pp. 114-126.

[3]. Phu-Cuong Nguyen, Seung-Eock Kim, Nonlinear elastic dynamic analysis of space steel frames with semi-rigid connections, *Journal of Constructional Steel Research*, Vol. 84, May 2013, pp. 72–81.

[4]. L. Calado, G. De Matteis, R. Landolfo, Experimental response of top and seat angle semi-rigid steel frame connections, *Materials and Structures*, Vol. 33, Issue 8, October 2000, pp. 499-510.

[5]. Xinwu Wang, et al, Research of T steel connection for H section steel beam-column, in *Proceedings of the 2nd National Conference on Modern Structural Engineering*, 2002, pp. 20-22 (in Chinese).

[6]. James A. Swanson and Roberto T. Leon, Bolted Steel Connections: Tests on T-stub components, *Journal of Structural Engineering*, Vol. 126, Issue 1, 2000, pp. 50-56.

[7]. Yu Chen, Shimin Dong, Liping Li, The introduction for pseudo-dynamic test method in the regulation of

seismic test method, *Building Science*, 1995 (in Chinese).

[8]. Shizhu Tian, Tong Zhao, Research on seismic pseudo-dynamic test, *Earthquake Engineering*, 2001 (in Chinese).

[9]. D. Choudhury, S. Nimbalkar, Seismic passive resistance by pseudo dynamic method, *Geotechnique*, Vol. 9, 2007, pp. 699-702.

[10]. GB50017-2003, Steel Structure Design Specification, *China Building Industry Press*, Beijing, 2003 (in Chinese).

[11]. JGJ101-96, Regulations of seismic test method for buildings, *China Building Industry Press*, Beijing, 1996 (in Chinese).