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Research Article

Seismic Performance of Semi-rigid Connection Food Warehouses Steel Frame

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

Keywords: Food warehouses steel frame, seismic performance, semi-rigid connection

INTRODUCTION

Food warehouses steel structure had high strength, good ductility performance and widely used in the earthquake area of building structure, especially food warehouses steel frame structures. The connecting way of beam-column joints had deteminal function on mechanical performance of food warehouses steel frame. One of the basic assumptions of the conventional food warehouses steel frame analysis was that joints were either perfectly rigid or perfectly hinged. Therefore, when a food warehouses steel frame was analyzed, joints were idealized as fixed or hinged. But the connections of food warehouses 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 food warehouses steel frame had better seismic performance (Ohi *et al*., 1993; Aksoylar *et al*., 2011). At the same time, analysis indicated that there were many factors of influencing the seismic performance of semi-rigid connection food warehouses steel frame, such as semi-rigid connection stiffness, structural damping and seismic wave, etc. In this study, the split T was informs used as semi-rigid connection in the two test specimen with different mass (Xinwu *et al*., 2002). Under the same condition but the mass, the research was focused on transforming the input mass of the food warehouses steel frame to test the dynamic responses of semi-rigid connection food warehouses steel frame and analyze the effect of structural mass on seismic performance of food warehouses steel frame. Thus providing the basis for optimal design and application of food warehouses steel frame with semi-rigid connections.

All in all, increasing the mass of the food warehouses 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 food warehouses steel frame should be considered in design to avoid unnecessary waste and make the mass of food warehouses steel frame in a reasonable range.

MATERIALS AND METHODS

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 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.Equ.1 showed that (Yu *et al*., 1995):

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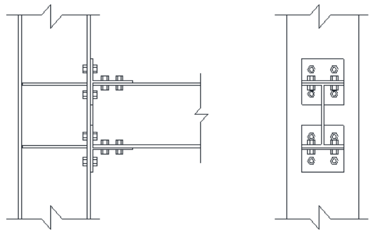


Fig. 1: T food warehouses steel connection drawing

Table 1: Specimen cross section dimensions table

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

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

In which,

$[M], [C], [K]$ = Mass matrix, damping matrix and stiffness matrix of the structure respectively

$\{\ddot{x}\}, \{\dot{x}\}, \{x\}$ = Acceleration, speed, displacement of the structure

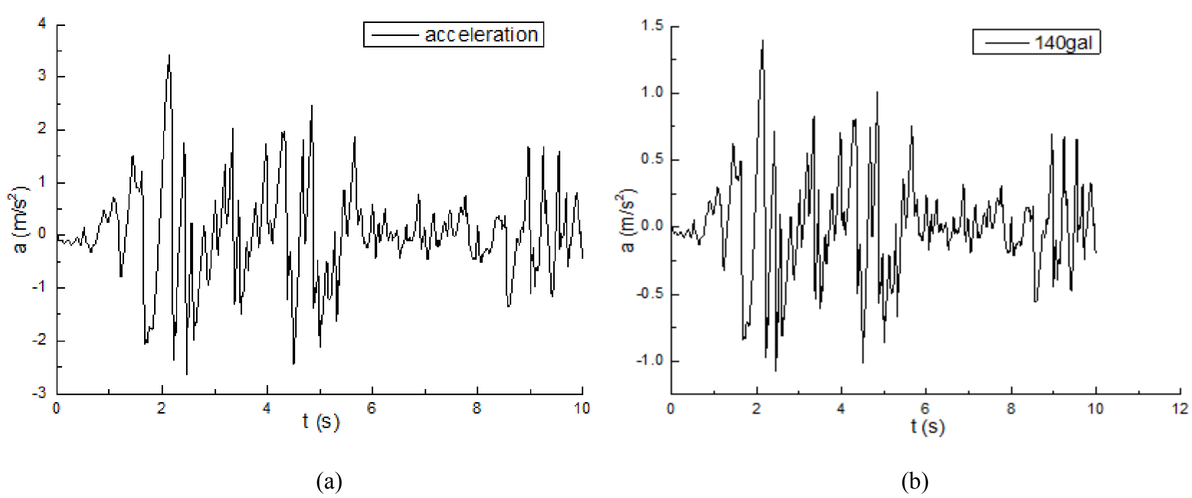
$\{\ddot{Z}\}$ = The acceleration response of ground respectively

Pseudo-dynamic test general situation:

Specimens: In accordance with the specifications for design of food warehouses steel structures (GB50017-2003, 2003), we took a two layers, single span and studio food warehouses 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 food warehouses steel material used Q235. Beams and columns were hot-rolled H food warehouses steel. The T food warehouses steel was shown in Fig. 1 and the specimen cross section dimension were shown in Table 1.

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 food warehouses 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 food warehouses 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 food warehouses steel frame. Before the test, we preloaded the frame to test the response and the stiffness of the food warehouses steel frame, then the mass of the frame were input respectively by m = 5200 kg and m = 10400 kg that m1 = m^2 = 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" (JGJ101-96, 1996) which made the select principle of seismic wave in the test and we selected EI-centroseismic wave (Fig. 2a) that the peak acceleration corresponding with 140 gal (Fig. 2b) that was the peak value of 1.4 times.



(a) (b)

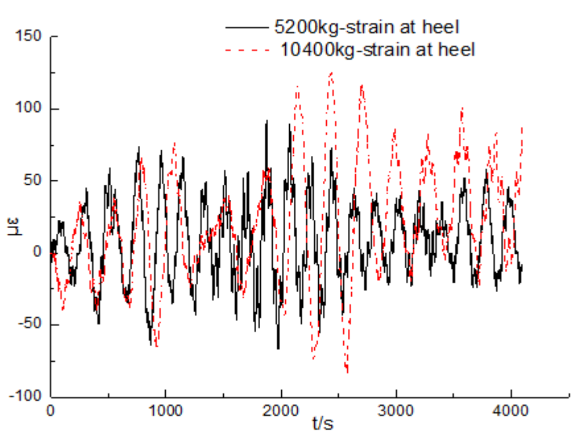
Fig. 2: EIcentro wave

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.

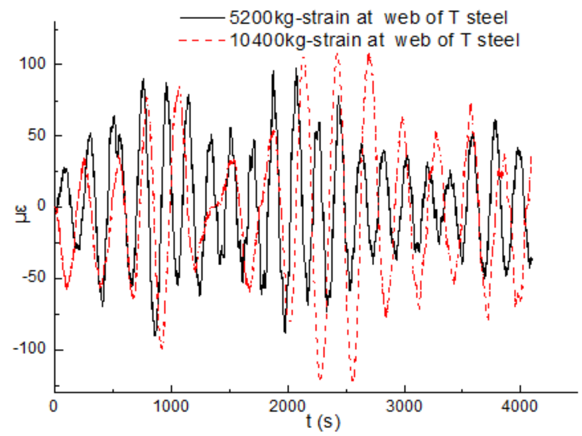
RESULTS AND DISCUSSION

Strain analysis: The time history curves of node strain were shown in Fig. 3a and b diagrams respectively showed the strain at heel and T food warehouses 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 food warehouses steel frame could make the load capacity larger and be contributed to resistant earthquake load and increase the seismic performance of the structure.

Force response: The maximum force response at the top and bottom of the food warehouses steel frame under different mass were shown in Table 2. The peak value of the foce response with different mass were a mostly constant. It showed that the variation of mass had little effect on the interlayer shear.



(a)



(b)

Fig. 3: The time history curves of node strain

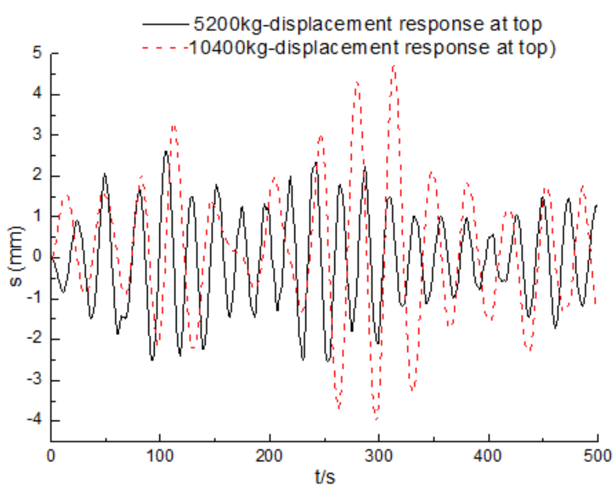


Fig. 4: Time history curves of displacement response

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

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

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

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. 4. Table 3 showed the maximum displacement response at the top and bottom of the food warehouses steel frame under different mass. The peak values of the displacement response with m = 10400 kg were a mostly two times of m = 5200 kg. The displacement response of semi-rigid connection food warehouses 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.

CONCLUSION

By analyzing the test results, the conclusions were following:

- The mass of semi-rigid connection food warehouses 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 food warehouses steel frame and the structural mass could increase the structural ability to resist seismic action.
- The variation of structural mass had less influence on interlaminar shear of food warehouses steel frame.
- The interlayer displacement response of semi-rigid connection food warehouses 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 ferformence.

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