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Research Article

The Effect of Damping on Seismic Performance of Food Factory Steel Frame

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Abstract: To study the effect of damping on seismic performance of food factory steel frame, using the pseudo dynamic test by inputting damping and no damping to analyze the seismic performance of semi-rigid food factory steel frame. Analysis was focused on the effect of damping on the panel zone strain, story drift and interlayer force. The conclusion was that under the more severe earthquake, the structural damping had effects on the seismic performance of semi-rigid food factory steel frame.

Keywords: Damping, food factory steel frame, seismic performance

INTRODUCTION

Damping was a kind of features during free vibration which was due to external influence or structural effect that decreased amplitude of structure and was one of the important characteristics that formed the seismic performance of structure (Yu *et al*., 1995). In the process of the amplitude decreasing, vibration system dissipated energy through different mechanisms of action. When researchers analyzed the seismic performance of food factory steel frame, they often idealized the damping through setting linear viscous dampers or shock absorber in the food factory steel frame that could't reflect the real implication of the damping to the structure. Calculating the damping coefficient of the semi-rigid food factory steel frame and inputting damping value and undamped in the pseudo dynamic test, the variations about displacements, strains and loads for the semi-rigid food factory steel frame were analyzed. It was concluded that under the more severe earthquake, the structural damping had effects on the seismic performance of food factory steel frame with semi-rigid connection.

THE CALCULATION FORMULAS OF STRUCTURAL DAMPING COEFFICIENT

In structural dynamic analysis, through the reasonable selection of damping coefficient, the energy that the mechanism of action dissipated and the energy dissipation by vibration were equal. Before the calculation of damping coefficient, it was necessary to determine the damping ratio that was the ratio of damping coefficient and critical damping coefficient. Viscous damping model was adopted in the practical engineering and the damping ratio was defined as a constant. The paper employed 0.02 as the damping ratio of food factory steel frame. The Rayleigh damping coefficient method was used to calculate the damping coefficient.
Damping matrix was calculated according to Eq. (1):

$$[C] = \tau_M[M]+\tau_K[K]. \quad (1)$$

$$\tau_M = 2(\lambda_i\omega_j-\lambda_j\omega_i)\omega_i\omega_j/(\omega_j-\omega_i)(\omega_j+\omega_i). \quad (2)$$

$$\tau K = 2(\lambda i\omega j-\lambda j\omega i)/(\omega j-\omega i)(\omega j+\omega i). \quad (3)$$

In which [C], [M], [K] were mass matrix, damping matrix, stiffness matrix of the structure respectively; ω_i, ω_j were the circular frequency of vibration mode i, j respectively; λ_i, λ_j were damping ratio of modal i,j respectively, $\lambda_i = \lambda_j = 0.02$.

Circular frequency were solved according to the structural dynamic Eq. (4):

$$[M]\{\ddot{u}\}+[C]\ \{\dot{u}\}+[K]\ \{u\} = [M]\ \{\ddot{u}g\} \quad (4)$$

$$\text{Assuming } u_1 = \varphi_1\sin(\omega t+\theta);\ u_2=\varphi_2\sin(\omega t+\theta) \quad (5)$$

Inputting Eq. (5) into homogeneous equation, then got Eq. (6) and (7):

$$-m_1\omega^2\varphi_1+(k_1+k_2)\ \varphi_1-k_2\varphi_2 = 0 \quad (6)$$

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$$-m_2\omega^2\varphi_2-k_2\varphi_1+k_2\varphi_2 = 0 \quad (7)$$

ω_i, ω_j were solved.

Substituting circular frequency ω_i, ω_j and 0.02 damping ratio Eq. (2) and (3), τ_M and τ_N were solved. Then put them in Eq. (1).

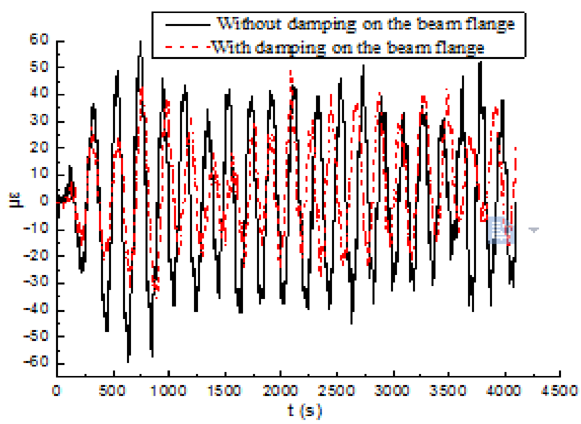
MATERIALS AND METHODS

Pseudo-dynamic test:

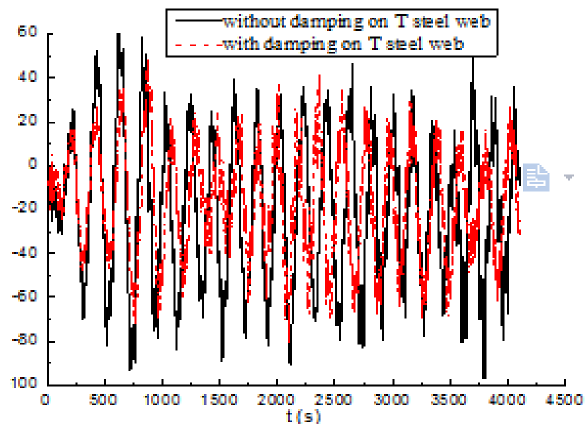
Experiment: The pseudo dynamic test of semi-rigid food factory steel frame, which had a scale ratio of 1:2 with two layers, single span and studio was carried out. The food factory steel frame was designed according to the specifications for design of steel structures (GB 50017-2003) (Shizhu and Tong, 2001). The underlying height was 2.2 m, the top height was 2.0 m, span and studio were both 3.0 m. The steel used were Q235 steel and beams, columns and subdivision T steel were hot-rolled H steel. Fitting M16 and 10.9 high strength bolts to connect beams, columns and T steel. The cross section sizes of specimen were followed:

Column: HW175 mm×175 mm×8 mm×11mm;
Beam: HW194 mm×150 mm×6 mm×9 mm.
T steel: HW500 mm×200 mm×10 mm×16 mm.

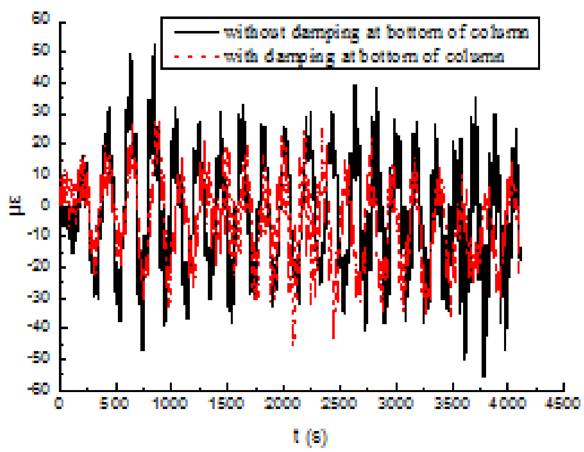
Test procedure: Literature (Gao, 2003) introduced the principle of pseudo-dynamic test. Test equipment included reaction wall, stents, the electro-hydraulic servo loading system and data acquisition system (DH-3816N static signal acquisition instrument). Test loading device equiped four horizontal actuators that two 100t horizontal actuators were at the top story and the underlying frame decorated two 50t horizontal actuators. The seismic wave of test was EIcentro wave selected according to the "regulations of buildings seismic test method" (JGJ-96) and adopted 70 gal seismic acceleration peak value. Test used mixed load displacement control and firstly to determine the stiffness matrix, mass matrix and damping matrix of food factory steel frame, m^1 = m^2 = 5200 kg. Putting the stiffness matrix [K] and mass matrix [M] into the Eq. (1), got the damping matrix [C]. Then the specimen was loaded by inputting the damping coefficient and



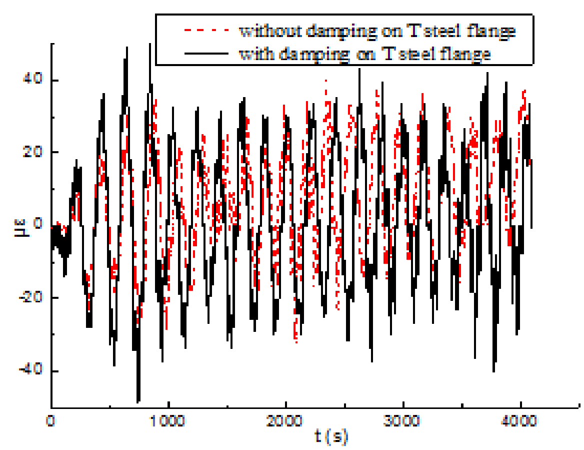
(a) Strain on the beam flange



(b) Strain on T steel web



(c) Strain at the bottom of column



(d) Strain on T steel flange

Fig. 1: Panel zone strain with and without damping

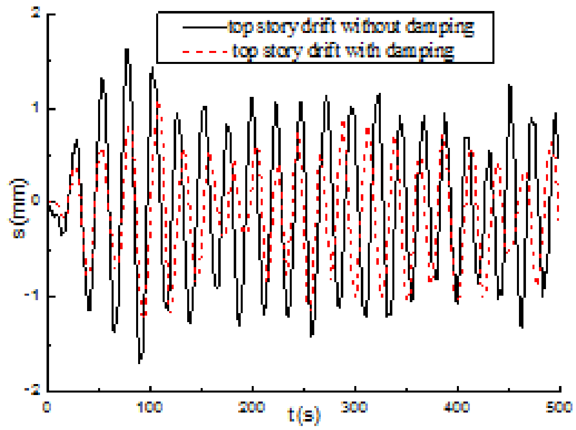


Fig. 2: Story drift

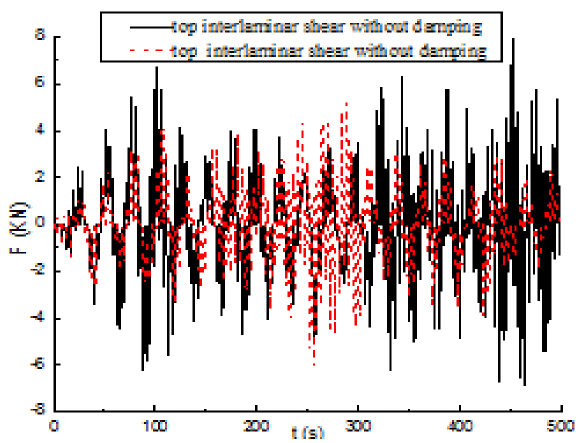


Fig. 3: Interlaminar shear

without damping. Using static signal acquisition instrument and displacement meters to measure the panel zone strain and the node displacement and using force sensors and displacement sensors to get load feedback and displacement feedback of food factory steel frame (Fawei *et al*., 2000).

RESULTS AND DISCUSSION

The analysis of test results:

Panel zone strain: The time history curve of panel zone strain was shown in Fig. 1a to d diagrams respectively showed the strain at beam end flange, T steel web, the bottom of the column and T steel flange in the undamped and damped. It got that the undamped strain variation amplitude was slightly greater than the damped strain amplitude, but the difference was minor that the damping had little effect on the strain.

Story drift: Time history curve of displacement was shown in Fig. 2. It showed that the peak value of story drift undamped was greater than that with damping and food factory steel frame without damping had larger sidesway and the response amplitude was bigger.

Interlaminar shear: The time history curve of interlayer shear was shown in Fig. 3 that the load feedback peak of frame with damping was less than undamped frame which showed the maximum of interlayer shear decreased under the influence of damping.

CONCLUSION

Through analyzing the test results, it concluded that:

- The structural damping had little effects on the strain, but it had impact on the story drift and interlaminar shear which was in keeping with literature (Peng, 2011).
- It also showed that the displacement of food factory steel frame under dynamic loading not necessarily decreased as the stiffness of nodes increasing and the factors included damping.
- Under the effect of damping, the story drift and interlaminar shear peak of the semi-rigid connection food factory steel frame decreased which was contributed to the structural seismic.

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