Design And Analysis of Energy Dissipation and Vibration Reduction of Reinforced Concrete Frame Structure

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Abstract. Accompanying earthquake, some buildings that do not meet the seismic design requirements may tilt or even collapse. Many existing reinforced concrete frame structure buildings in China cannot meet the seismic requirements, these buildings need timely reinforcement. Energy dissipation technology helps the structure to consume seismic energy by adding dampers, which provides a new way for structural seismic reinforcement. In this paper, the friction damper is designed and applied to the reinforced concrete frame structure to achieve the effect of seismic reinforcement. The main work is as follows: a natural ground motion Chi-Chi wave from Taiwan is selected to carry out the time history analysis of the uncontrolled reinforced concrete frame structure and the structure with friction damper, and the interlayer displacement angle obtained by the analysis before and after the structure reinforcement is compared and analyzed. The analysis shows that the interlayer displacement angle is significantly smaller after the friction damper is added, which can effectively reduce the seismic response of the structure.

Keywords: Friction damper, energy dissipation, finite element, time-history analysis.

1. Introduction

Earthquake is one of the most serious natural disasters. It has strong energy, sudden strong, destructive and cannot be accurately predicted, which poses a great threat to the safety of people ' s lives and property. To minimize the damage caused by earthquakes is an important issue that human beings must solve. The seismic performance of reinforced concrete frame structure is weak. Many contents and requirements have been revised in the Chinese Code for Seismic Design of Buildings GB50011-2010'(2016 edition) [1]. For example, the basic seismic acceleration of design in 7 intensity areas is increased from 0.1 g to 0.15 g, and the basic seismic acceleration of design in 8 intensity areas is increased from 0.2 g to 0.3 g. Therefore, many existing reinforced concrete frame structure buildings in China cannot meet the seismic requirements, and these buildings need to be reinforced in time. The traditional reinforcement, in the form of “hard resistance,” continuously increases the cross-section and increases the reinforcement [2]. On the contrary, it increases the self-weight of the structure and leads to the increase of seismic action. At the same time, the cost is huge, and the seismic reinforcement efficiency is unsatisfactory [3]. With the progress of society and the development of science and technology, energy dissipation technology has entered people ' s attention. It absorbs and dissipates seismic energy by adding energy dissipation devices in the structure to form a whole with the original structure, and effectively reduces the seismic action [4]. Compared with the traditional seismic, it is not only economical and effective, but also has better seismic effect in the reinforcement of high-rise and large-span buildings [5].

2. Engineering overview

This project is a reinforced concrete frame structure with seismic fortification intensity of 8 degrees. The peak value of the design basic seismic acceleration is 0.3 g. The design earthquake is divided into the second group, the II type site, and the site characteristic period is 0.40 s. In the form of concrete frame structure, the number of floors is 4, the height of the building structure is 16.10 m, the area is 2579.78 m2, the seismic grade of the frame is one level, and the structural period reduction coefficient is 0.85. Belongs to the key fortification class, class B building. The three-dimensional model of reinforced concrete structure is established by using the finite element software SAP2000, and the model diagram is shown in Figure 2-1.

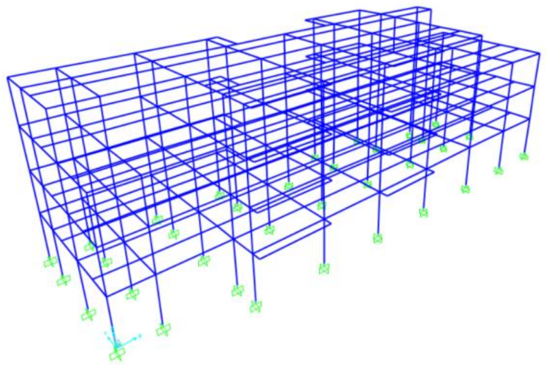


Figure.2-1 SAP2000 Original Structure Model Diagram

3. Seismic response analysis of original structure

In the finite element analysis software SAP2000, the seismic response analysis of the structure with 8 degrees of 0.2 g is carried out by using the mode decomposition response spectrum method, and then the seismic response analysis with 8 degrees of 0.3 g is carried out. The data of the two analyses are integrated and compared to obtain the inter-story displacement angle comparison, as shown in Figure. 3-1.

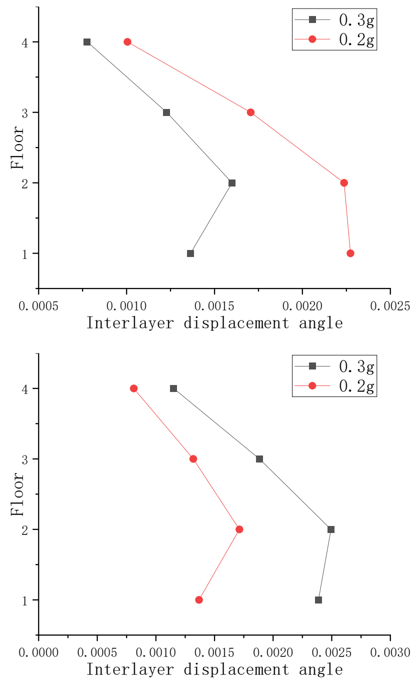


Figure 3-1 Interstory displacement angle of uncontrolled structure under frequent earthquakes

Before the revision of the code, the limit value of the story drift angle of the existing building structure under the seismic fortification intensity of 8-degree 0.2 g is 1/550. It can be seen from the above chart that the maximum story drift angle of this structure is 1/584, 1/625,1/731, which is less than the limit value and meets the requirements. However, after the revision of the code, the seismic fortification intensity is adjusted to 8-degree 0.3 g, and the maximum displacement angle of the structure is 1/401, 1/419, 1/440, which exceeds the limit value of 1/550 in the code and does not meet the requirements.

4. Seismic Response Analysis of Damping Structures

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

4.1. Friction damper reinforcement design

The energy dissipation device is divided into displacement damper and velocity damper. The velocity damper is represented by viscous damper and viscoelastic damper. The displacement damper mainly includes metal damper and friction damper. The damper used in this paper is friction damper. Within the range of building partition wall, its main advantages are:(1) The hysteresis curve of friction damper is close to the ideal rectangle, and the energy dissipation capacity is good. (2) Good stability and durability (3) General maintenance free, easy replacement after earthquake. One to three layers of friction dampers are arranged in the same position. Taking one layer as an example, the detailed layout plan is shown in Figure. 4-1.

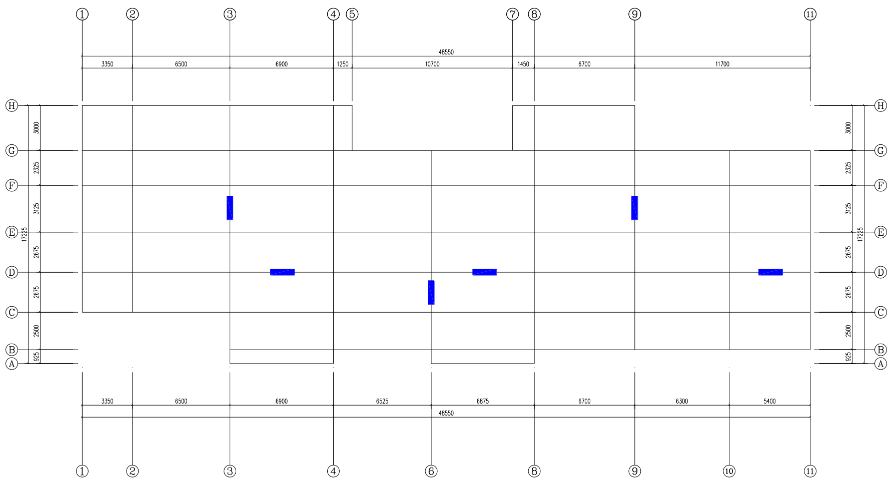
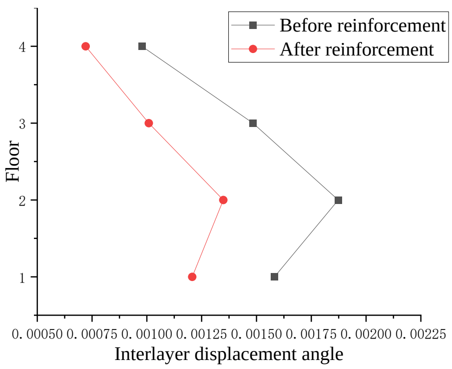


Figure.4-1 Plane layout of friction damper

4.2. Time History Analysis

The natural waves of the same site type were selected for the time history analysis of this project (ChiChi-Taiwan-NO0505-0.005-0.4). The energy dissipation of the friction damper is considered in the damping model [6]. The maximum acceleration of ground motion taken in the elastic analysis is 110 cm/s2, which is analyzed by nonlinear FNA method. That is, only the nonlinearity of the damper is considered, and the other parts of the structure remain elastic. The frequent earthquake time history analysis of the structure before and after reinforcement is carried out, and the inter-story displacement angle is compared, such as Figure 4-2 and Table 4-1.



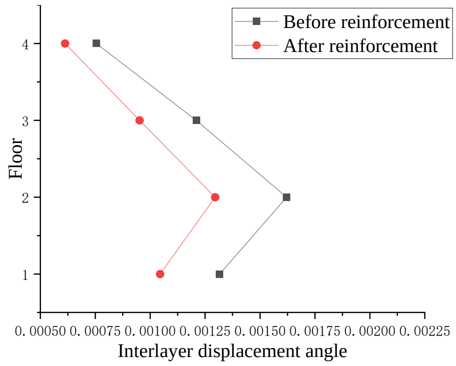


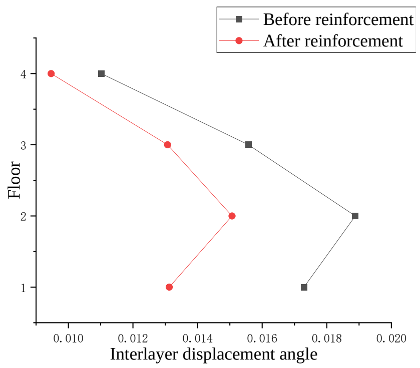
Figure 4-2 Interlayer displacement angle in direction X and Y under Taiwan wave

Tab 4-1. Calculation results of bending toughness

Floor	X-Direction			Y-Direction		
	Before reinforcement	After reinforcement	Damping rate	Before reinforcement	After reinforcement	Damping rate
1	1/632	1/829	23.7%	1/760	1/957	20.6%
2	1/534	1/742	28.0%	1/617	1/772	20.1%
3	1/674	1/991	32.0%	1/827	1/1051	21.3%
4	1/1024	1/1388	26.3%	1/1325	1/1632	18.8%

From the above chart analysis, it can be concluded that under frequent earthquakes, the displacement angle of each layer of the structure with friction damper decreases. The maximum displacement angle of the lower layer under Taiwan wave action is from 1/534 to 1/742 in X direction and from 1/617 to 1/772 in Y direction. The maximum damping rate is 32.0% and the minimum damping rate is 18.8%.

The maximum acceleration of ground motion taken by elastic-plastic analysis is 510 cm/s2, that is, under the action of rare earthquake, the change of interlayer dis-placement angle before and after structural reinforcement is analyzed, as shown in Figure 4-3 and Table 4-2.



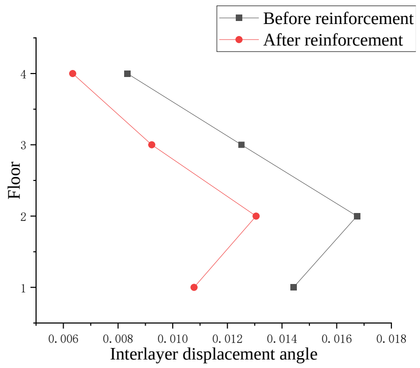


Figure 4-3 Comparison of inter-story displacement angles before and after rein-forcement under rare seismic waves

Table 4-2 Comparison of inter story displacement angle and damping ratio before and after structural reinforcement under rare earthquake

Floor	X-Direction			Y-Direction		
	Before reinforcement	After reinforcement	Damping rate	Before reinforcement	After reinforcement	Damping rate
1	1/58	1/76	24.1%	1/69	1/93	22.0%
2	1/53	1/66	20.2%	1/60	1/77	25.2%
3	1/64	1/77	16.1%	1/108	1/108	23.9%
4	1/91	1/106	14.1%	1/158	1/158	24.0%

From the above chart analysis, under the action of rare earthquakes, the structure with friction damper is added. The analysis of the inter-story drift angle of each lay-er is as follows: the maximum inter-story drift angle of the structure in X direction changes from 1/53 to 1/66, and the maximum inter-story drift angle in Y direction changes from 1/60 to 1/77, with the maximum damping rate of 25.2% and the mini-mum damping rate of 14.1%. After reinforcement, the inter-story drift angle of the structure decreased significantly, and the maximum value of each inter-story drift angle after reinforcement met the requirements of the specification limit of 1/50, which could protect the main body of the structure.

5. Conclusions

The project is a high-rise reinforced concrete frame structure located in the high-intensity area. Due to the partial revision of the seismic code for buildings in China, before its revision, the building structure meets the parameters requirements of 0.2 g of 8 intensity, which is mainly reflected in the interlayer displacement angle limit. However, under the condition of 0.3 g of 8 intensity required by the latest code, the parameters of the structure are increased, and the maximum interlayer displace-ment angle is 1/401, which exceeds the specification limit of 1/550. Therefore, to strengthen it, this paper adopts the energy dissipation technology. The time-history response analysis of reinforced concrete frame structure with or without friction damper under frequent and rare earthquakes is carried out. The maximum inter-story displacement angle of the reinforced structure is 1/742, which meets the specifica-tion limit of 1/550, and meets the limit under rare earthquakes. It shows that the set-ting of damper can prevent the expansion of structural displacement, which proves that the damper has good energy dissipation capacity and remarkable reinforcement effect.

Data Availability

The data used to support the findings of this study are available from the corre-sponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] China Academy of Architecture. Code for seismic design of buildings (GB50011-2010) [S]. Beijing: China Construction Industry Press, 2010: 6.

[2] Yichu Zhang. Energy dissipation and seismic reduction analysis and design of a teaching building in Jinnan Campus of Nankai University [J]. Building structure, 2021, 51 (S1): 831–836.

[3] Tao Zhang, Yaoming Geng, Qingyu Kong. Analysis and Design of Energy Dissipation and Seismic Reduction of Teaching Building in Beijing School Middle School [J]. Building Struc-ture, 2020,50 (13): 95-100.

[4] Wei Yu. Seismic reinforcement design of an existing frame structure [J]. Sichuan architecture, 2021,41 (05): 25-28

[5] Qiufang Liu. Application and Analysis of Energy Dissipation and Damping Reinforcement Technology in Class C Frame Teaching Building [J]. Fujian Construction Science and Tech-nology, 2021 (01): 26-28+62.

[6] Junchang Bai, Jinping Jin. Discussion on seismic wave selection for time history analysis [J]. Shanxi Building, 2007 (03): 62-63