The application of viscous dampers in frame shear structure

Shuang Huang [a], Peng You [b], Xinming Chen [c]

School of Civil engineering and Architecture, Southwest Petroleum University, Chengdu 610500, China

[a]hs3221901@163.com,[b]525719823@qq.com,[c]529710915@qq.com

Abstract

The earthquake is a sudden, devastating natural disaster, it constitutes a serious threat to human society. Since the earthquake caused the collapse of a large number of buildings, and thus caused heavy casualties, in order to reduce earthquake damage to buildings, study on the seismic performance of buildings is extremely urgent by buildings set viscous dampers can play to the function of good shock absorption, so as to avoid causing significant economic property and casualty, energy dissipation and damping system can better control the structural lateral displacement, in the rare case earthquake, the viscous damper start energy, can meet the requirements of the strong earthquake without collapse.

Keywords

Earthquake; Damping principle; Story drift ratio; Viscous damper

1. Introduction

China is an earthquake prone country. The feature of China earthquake is widely distributed and scattered, frequent and strong [1]. Such as the Xingtai earthquake (1966), Yangjiang earthquake (1969), Liyang earthquake (1974), Haicheng earthquake (1975), Tangshan (1976), the May 12, 2008 Wenchuan earthquake occurred a huge earthquake of magnitude 8, April 14, 2010 Qinghai Yushu 7.1 earthquake occurred, in November 8, 2011, a magnitude 7.2 earthquake on April 20, 2013, the East China Sea, a 7 earthquake occurred in Sichuan, Mount Lu in July 22, 2013, a magnitude 6.6 earthquake on February 12, 2014, Lu Dingxi, a magnitude 7.3 earthquake on August 3, 2014, Xinjiang Yutian, Yunnan 6.5 earthquake occurred in Ludian, housing construction in the earthquake destruction and collapse is the main reason causing casualties. World 130 times huge casualties in the earthquake, of which more than 95% of the casualties is due to the lack of seismic capacity of buildings caused by the collapse of. Therefore, to improve the seismic capacity of buildings is to reduce the earthquake disaster are the most effective measures. A sudden earthquake instant can make a beautiful and bustling city or region become a piece of ruins, claiming the lives of tens of thousands of people, a large number of buildings were destroyed or even collapse, transportation, telecommunications, water supply and other urban lifeline engineering was interrupted and is likely to further cause floods, fires, disease and other serious secondary disasters, causing great damage to human life and property.

It can be seen that most of the earthquake caused by the loss caused by the collapse of the house. However, with the progress of society, the progress of urbanization, urban population density is very increased, the earthquake caused by the harm will be more and more serious. In order to mitigate the damage caused by earthquake, the seismic capacity of the structure should be improved. The traditional method of seismic design is through the control of the building stiffness and enhance the structure's seismic performance (such as increasing the section size, improve the level of strength of the material), to resist earthquake action, can make the structural component in inelastic stage has better ductility, mitigate the impact of the earthquake on the structure, in order to meet the requirements of seismic fortification. Although the traditional anti-seismic design method through practice proved to have certain effect, but with a large earthquake, you need to increase the section size of components and improve the material strength to strengthen its structure strength and stiffness, this is not good to solve the safety of the structure, and will improve the structure of cost and the aseismic measures is passive.

2. Research Status and Application

Viscous fluid dampers are widely used in the field of military, aerospace and mechanical vibration control. With the end of the cold war, this technology has been gradually applied in the vibration control of buildings and bridges. The United States and Japan in this area of research started early, the most advanced technology. Constantinou [2] et al. (1992) the shaking table test was carried out on one layer and three layer structure model with viscous fluid dampers. The results show that the damper can effectively reduce the seismic response of the structure. Domestic research in this area started late, Professor Ou Jinping [3] of Harbin University of architecture in 1999 on the cylinder gap damper for theoretical and experimental research. Wu Bo, Li Hui [4][5], (2000) with the design method of the structure of viscous dampers were studied proposed between layers of the structure under rare earthquake action of elastoplastic deformation simplified method and seismic design procedure. Fan Feng, Shen Shizhao [6] (2000) will be used in the shell structure of the viscous damper, the results show that the damping effect of the shell structure with viscous dampers is very obvious, the seismic performance has been greatly improved. With the further research on the performance of viscous fluid damper, some buildings have been successfully used in this kind of high efficient damper. In 1994, the new SanBernardino medical center in the United States installed more than and 200 viscous dampers [7]. There is a Italy bridge 1000 meters long, weighs more than 25 thousand tons, each abutment is installed under a viscous fluid damper. Each damper weighs 2 tons, 2 meters long, the stroke of the piston rod up to 500 mm, can provide 500 tons of force, the energy dissipation of 2 million tons of coke [7]. The control tower of the Pearson airport in Toronto, Canada, is ready to install a viscous damper in 2003 to reduce the wind induced vibration of the structure [7]. The Boise airport, built in 2002, also uses a viscous damper to enhance the structure's ability to withstand earthquakes. A Japanese building named Jimb small Cho 23 storey building in the installation of 241 such dampers[6]. The first application of this area is the Chinese Academy of construction, the use of foreign production of the damper on the strengthening of the Beijing Hotel. Southeast University is currently in this area of research, and has developed two types of fluid dampers.

3. The damping principle of viscous dampers[8]

Initially, the viscous damper is a damping device for mechanical engineering, and it is widely used in small and high efficiency characteristics. Constantinou, such as the development of the viscous damper used in civil engineering as speed dependent energy dissipation device, can be used to describe the mechanical behavior of the first order Maxwell model:

$$F_d + \lambda \dot{F}_d = C_o \dot{u} \tag{1}$$

Notes: F_d is the damping force; λ is the relaxation time coefficient; C_o is the zero frequency damping coefficient; $\dot{u}$ is the damper at both ends of the relative speed. The theoretical value obtained from the Maxwell model is found $\lambda \dot{F}_d$ to be negligible when the frequency is less than 4Hz, that is, the damping effect is shown as a pure viscosity independent of frequency. The vibration of most engineering structures is less than 4Hz, and the type (1) can be simplified as the wind or earthquake:

$$F_d = C_o \dot{u} \tag{2}$$

The mechanical model of the viscous damper is expressed as the Taylor company in the United states:

$$F_d = c\,\mathrm{sgn}\left(\dot{u}\right)\left|\dot{u}\right|^{\alpha} \tag{3}$$

Notes: c is damping coefficient; sgn is function symbols; α is velocity index; when $\alpha = 1$, (2) and (3) the same, said linear viscous damping; nonlinear viscous damping; when $\alpha < 1$ damping force velocity is small to rise very quickly, with the speed of increasing damping force slowing growth; when $\alpha > 1$, said to lock the damping, opposite with nonlinear viscous damping, the damping force velocity was bigger, the rapid growth.

In the design life of the engineering structure, the maximum of the earthquake probability is encountered, so the damper should have good energy dissipation effect under the small earthquake. Considering the strength and bearing capacity of structural members, the maximum output of the damper should be limited under rare earthquake, so the $\alpha \le 1$ dampers used in the seismic design of building structures are considered.

The dynamic equilibrium equation of the structure is not provided with viscous dampers:

$$[M]\{\ddot{X}\} + [C]\{\dot{X}\} + [K]\{X\} = -[M]\{\ddot{I}\}\ddot{X}_{g(t)} \tag{4}$$

Notes: [M] is Structure mass matrix; structural damping matrix; [C] is structural stiffness matrix; [K] is earthquake action position vector; $\ddot{I}$ is nodal acceleration velocity displacement vector; $\{\ddot{x}\}$, $\{\dot{x}\}$, $\{x\}$ is nodal acceleration velocity displacement vector; $\ddot{X}_{g(t)}$ is ground motion acceleration. Due to the small dead weight of the damper unit, the effect of the damper on the mass matrix is neglected:

$$[M]\{\ddot{X}\} + ([C] + [C_d])\{\dot{X}\} + [K]\{X\} = -[M]\{\ddot{I}\}\ddot{X}_{g(t)} \tag{5}$$

Notes: $[C_d]$ is an additional damping matrix of the damper, which is obtained by the integration of the element damping matrix.

4. Research Contents and Results

4.1 Project Overview

15 story frame shear wall structure is adopted in the model. The height of the first floor is 4.2m, the height of the standard layer is 3.3m, the beam column concrete is C40, the plate and the wall adopt C30 concrete. The building area seismic fortification intensity for 8 degrees, soil as class II, soil basic characteristic period for 0.4 s, basic seismic acceleration is 0.2g, pure frame shear structure in the upper layer deformation is large, concentrated in the structure arranged on the upper part of the damper.

Table. 1 Component information table

Bottom column	0.8m*0.8mRectangular column	The thickness of the wall	200mm
Other column	0.6m*0.6mRectangular column	Plate thickness	120mm
Beam	0.3m*0.6mRectangular section beam		

This paper analyzes the use of ANSYS finite element software. The model is reinforced concrete frame shear structure (Fig. 1). Beams and columns are use finite strain beam element BEAM188.The support use three dimensional bar element LINK180. The floor is made of elastic shell element SHELL181, and the viscous damper is made of COMBIN14, and the solid element is made of SOLIDE65 reinforced concrete element. Boundary conditions: at the bottom of the column and shear wall are considered and fixed, the model structure can be equivalent to a block forever connected on the basis of the cantilever beam, subjected to horizontal seismic load.

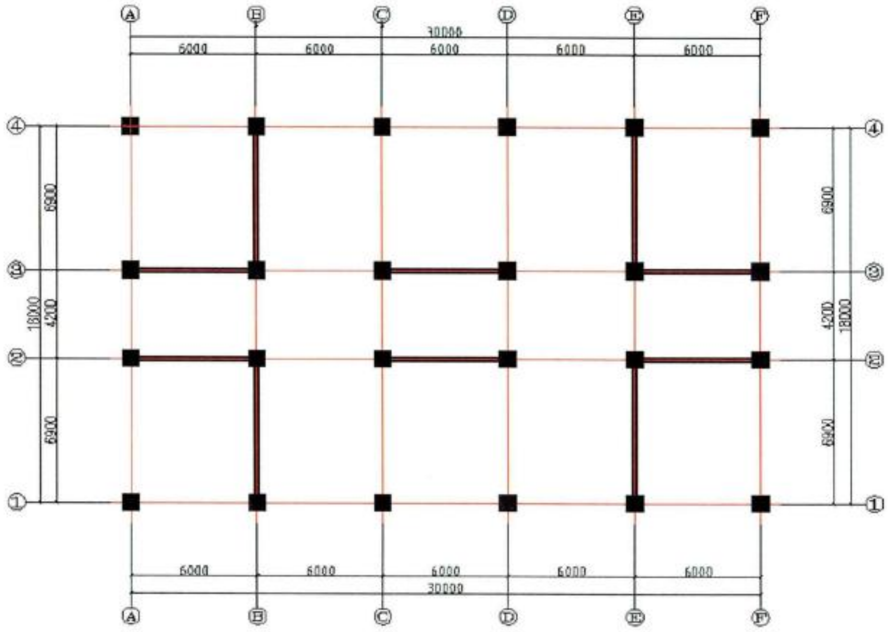

Fig. 1 Schematic diagram of structure plane

The damper is arranged as follows: the damper is arranged evenly along the floor, and six dampers are symmetrically arranged on each floor(Fig. 2).

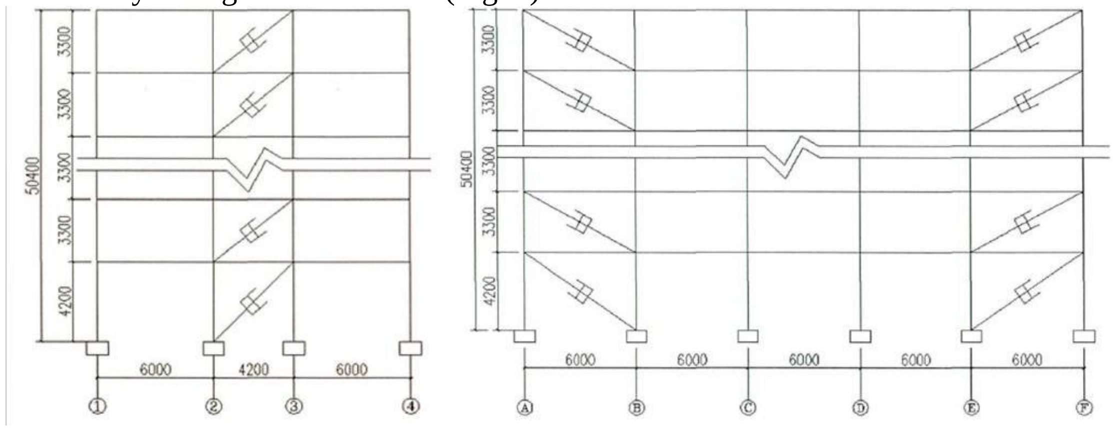

Fig. 2 Viscous damper arrangement scheme

For the choice of seismic wave, it is preferable to give priority to the actual strong earthquake occurred on the site which is similar to the site of the building, and its excellent period should be close to the site of the building. According to the condition of the seismic wave selection, this paper chooses 1 groups of natural seismic waves which are suitable for the II type site: EL-Centro seismic wave. The basic parameters and acceleration time history curves of seismic waves are shown in Fig. 3.

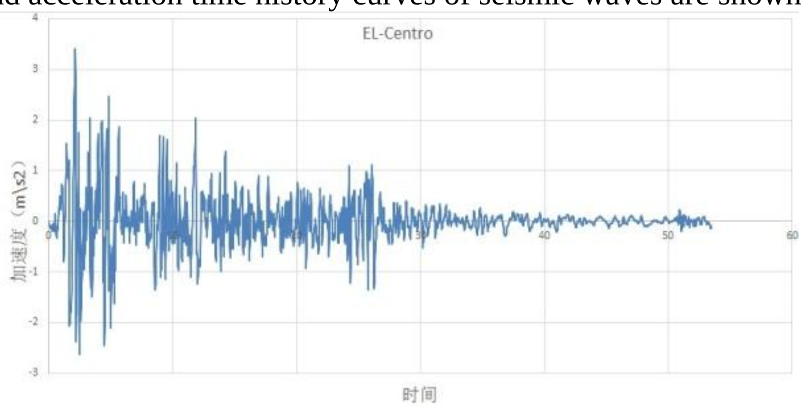

Fig. 3 EL-Centro seismic wave (wave length is 0.02s, and the duration is 54s)

4.2 Project Results

(1)Results of elastic-plastic dynamic time history analysis of viscous dampers are not provided:

Table. 2 Results of elastic-plastic dynamic time history analysis

Floor number	EL CENTRO		
	Layer displacement	Story drift	Story drift ratio
1	5.08E-03	5.08E-03	1/826
2	1.35E-02	8.43E-03	1/391
3	2.50E-02	1.15E-02	1/288
4	3.91E-02	1.41E-02	1/234
5	5.54E-02	1.63E-02	1/202
6	7.36E-02	1.81E-02	1/182
7	9.30E-02	1.95E-02	1/169
8	0.11352	2.05E-02	1/161
9	0.13461	2.11E-02	1/156
10	0.15594	2.13E-02	1/155
11	0.17717	2.12E-02	1/155
12	0.19804	2.09E-02	1/158
13	0.21834	2.03E-02	1/163
14	0.23794	1.96E-02	1/168
15	0.25575	1.78E-02	1/185

(2) The analysis of the Story drift ratio of initial scheme and scheme of the viscous dampers has been set up:

Table. 3 Results of story drift ratio

Floor number	EL CENTRO		
	Initial scheme	Set damper scheme	Reduced amplitude
1	1/826	1/1165	29.10%
2	1/391	1/553	29.29%
3	1/288	1/404	28.71%
4	1/234	1/335	30.15%
5	1/202	1/296	31.76%
6	1/182	1/273	33.33%
7	1/169	1/259	34.75%

8	1/161	1/251	35.86%
9	1/156	1/248	37.10%
10	1/155	1/248	37.50%
11	1/155	1/251	38.25%
12	1/158	1/256	38.28%
13	1/163	1/262	37.79%
14	1/168	1/270	37.78%
15	1/185	1/278	33.45%

Data in the table shows: initial scheme of weak layer in the upper layer, in El seismic waves under 1-4 layer displacement angle is smaller, 5-15 interlayer displacement angle larger, wherein the interlayer maximum angular displacement value appeared in the 9, 10 layer, interlayer displacement angle for 1/155. This change in response to a high degree of change is mainly due to the stiffness of the reinforced concrete frame shear wall structure. The inter layer displacement angle is an important factor that affects the relative stiffness ratio of the structure, and determines how the internal force of the structure is in the elastic and plastic stage, which influences the distribution of the seismic force. Under the action of EL seismic wave, the maximum story drift angle of the proposed scheme is 38.25% less than that of the initial solution. Under rare earthquake, by setting the damper, reinforced concrete frame - shear wall structure displacement layer, interlayer displacement, angular displacement, velocity and acceleration were decreased, plays a role in energy dissipation.

5. Conclusion

(1) the layout scheme of viscous damper, damping effect are different under the different seismic waves, of viscous dampers in the structure layout scheme, the damping effect is different, so it should be the arrangement structure try to optimize the design.

(2) the new type of damping support has been applied in practical engineering, but there is no detailed introduction about the effect of this kind of unconventional support on energy dissipation.

(3) the design should consider the effect of viscous dampers inside and outside environment and the material itself, the actual use of the process of viscous dampers of these factors may determine the service life of the damper, deal with damper and structure of applicability and durability to do further research.

(4) the effect of various seismic waves on the structure should be selected, and the damping effect of the viscous dampers is observed.

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