The Function and Economic Effective of Fluid Viscous Dampers to Reduce Seismic and Wind Vibrations in High-rise Buildings

Yongqi Chen[1], Cheng Peng[1], Hengli Xue[1], Liangzhe Ma[1]
(1.Beijing Qitai Shock Control and Scientific Development Co. Ltd., Beijing 100037, China)

Abstract: Fluid Viscous Damper (FVD)-as the best high-rise structural protection system play the important role in the rapid expansion of High-Rise building in the world. Seven buildings with FVD include the Silvertie Center and Pangu Plaza, the two buildings in Beijing are reviewed and compared in the aspects of installation, the damper's function and the economic for the reducing of vibration subjected to seismic or wind load. There also include Wuhan Poly Plaza, of which the dampers have a good effect to the reaction of structure torsion, and Tianjin International Trade Center, which is the first building in China to adopt the toggle-brace-damper. The evaluation for these topics are put forward would like discuss with readers.
Keywords: Fluid Viscous Damper; Mega brace; Toggle

1 Introduction

Fluid Viscous Damper (FVD) has developing fast in structural engineering during the past twenty years. It is widely recognized that the structural protection system is significant in the structure, especially in the tall and super high-rise buildings. June 2008, an American article, in journal *STRUCTURE*, was entitled as "A new era of viscous dampers is arrived". Actually, we can obviously realize the era has arrived by the application of dampers in engineering, especially in building structure all over the world.

1） The successful case

In structural engineering, there is already a good example – Mexico Torre Mayor building.

Fig.1 Mexico Torre Mayor building

In 1985, an 8.1 earthquake in Mexico had totally destroyed the Mexico City. In 1999, a 57-story, 225-meter-high building – Torre Mayor (Fig.1) was start to build, which would cost 250 million. Jan 21st 2003, coastland of the state of Colima, Mexico, suffered from a 7.6 earthquake. This great earthquake brought a huge damage again to the Mexico City where located in fault zone. Over 13,000 residential buildings and 600 commercial buildings were broken. Among them, over 2700 buildings were totally destroyed. But the miracle was, during the 30 seconds of the strong tremor, the seismesthesia of the Torre Mayor building, which had just open 31 floors, was much lower than other buildings nearby. As an important protection, the FVDs operated successfully, and had kept the structure response in elastic range. Therefore, the Torre Mayor building has become a symbol of using dampers for seismic resistance in whole Latin America and even all over the world.

2） Development of damper fabrication technique

We have realized by the united pre-detection of ASCE that, the high-quality damper can be trust for operating safely several decades, and is reliable to suffer its designed damping force.

The fabrication technique of damper develops as years go on. Frictionless metal-hermetic damper [1], the high power damper which can work continuously, has developed and applied, and has done a good job in TMD system and wind resistance.

Seismic dampers should be applied in the case of wind load, small displacement and low velocity, that is, the dampers should work during micro-vibration. The application of displacement amplifier like *toggle* and *scissor jack* also made the fabrication and safety technique developed.

3） Development status

The high-rise building has epochal developed in our country. We have also step in this new era of viscous dampers with the international trend. In our country, there are 4 buildings: Beijing Silvertie, Pangu, Wuhan Poly and Tianjin international trade center have done the damper analysis and installation. Further more, there nearly 10 buildings that will use dampers are under analyzing, designing or under construction, such as Tianjin FULI building (400m).

What the change is, the design company and the owner both have approved the effect in seism or wind resistance as well as the economic effect of the damper. And several buildings which may have saved the cost by using damper are doing seismic and economic analysis.

2 Cases study

There are dozens of projects which have installed FVD to reduce vibration induced by seismic and wind load in the world. In China, the Silvertie Center, Pangu Plaza in Beijing and Poly Plaza which is under construction in Wuhan provide us with abundant

experience and cognition. The famous Torre Mayor Building in Mexico which proposed some issues on conceptual application of the dampers, have proposed a lot of subjects that are worth further investigating.

For several typical high-rise buildings installed with viscous dampers, the following issues on the damper application will be discussed：

- The concept of design and calculation for the high-rise building with dampers;
- Configuration of the damper Installation;
- The function of the dampers;
- The economical efficiency of the dampers;
- The comparison of different dampers;

The following comparison with seven high-rise buildings installed with FVD on design concept, actual results and economical efficiency could be referred to by designers and researchers.

1） Mexico Torre Mayor Building

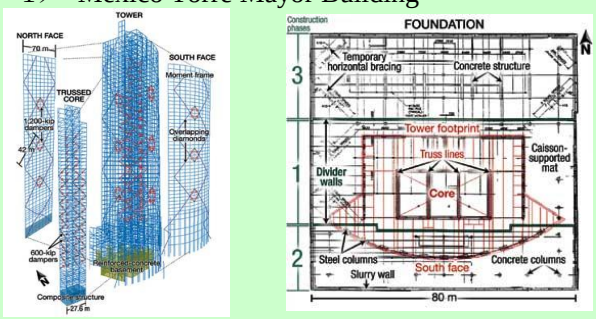


Fig.2 Mexico Torre Mayor Building

The 55-story, 225m Torre Mayor is one of the first high-rise buildings installed with viscous dampers for reducing vibration that result of seismic load. Its upper parts is steel structure and the columns were encased by reinforced concrete below the 30~35-story.The design included a total system of 98 dampers which increase the critical damping ratio up to 12% in east-west direction and 8.5% in south-north direction, which make a good effects on reducing vibration of the earthquake. When a magnitude 7.6 earthquake rocked the city in 2003, the structure had just been occupied but survived without a scratch.

2） 111 Huntington building in BOSTON,MA[2]

This steel structure which has 38 stories with 60 dampers for wind-resistant whose maximum force is 1300kN. Half of the dampers are installed in diagonal configuration, others in toggle-brace configuration. They have done great job in wind-resistant and have improved seismic performance of the building. Similar design and application could be found in other buildings in Boston, such as the Millennium tower.

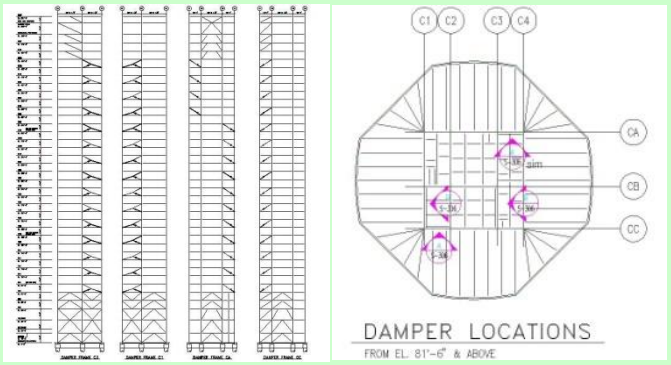


Fig.3 Boston 111 Huntington Tower and Damper Layout

3） Silvertie Center[3]

The 63-story, 265m steel structure located in Changan Street in Beijing includes a total of 73 dampers which ensure that the pulsating wind vibration of the structure to meet the requirement of the specification for comfort level under a centennial wind. The application of dampers has improved the performance of the structure which locates in Beijing where the seismic fortification intensity level is 8 and subjects to maximum considered earthquake.

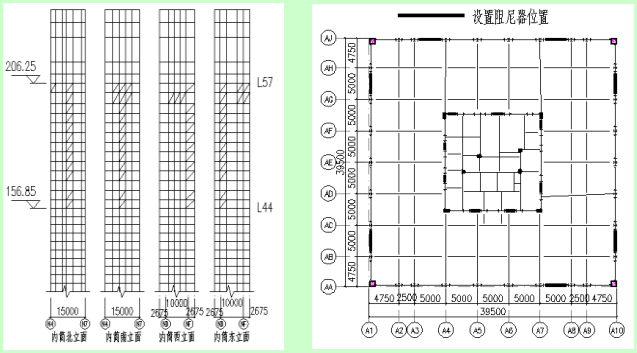
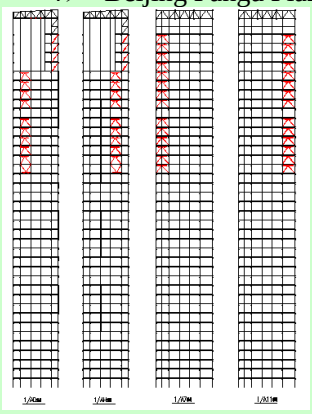
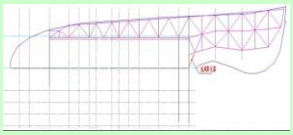


Fig.4 Beijing Silvertie Center and Damper Layout

4） Beijing Pangu Plaza[4]





Dampers for wind-resistant in the roof truss

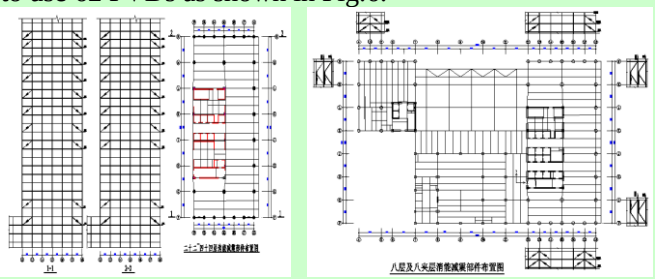
Fig.5 Beijing Pangu Plaza and Damper Layout

This 45-story, 191m super high-rise steel building has installed 100 FVDs and 8 fluid viscoelastic dampers based on the analysis and optimization results for earthquake and wind load performed by the writer in

association with John Martin, Inc. registered in the USA. The damping system substantially moderated the effect of earthquake and wind load on the structure and achieved good economic benefits.

5） Wuhan Poly Plaza

The building of Wuhan Poly Plaza, which located in the downtown of Wuhan, is a 44-story, 210m comprehensive office building. The layout of building is L-shape and there is a connective corridor between the main building and vice building. After analysis, decided to use 62 FVDs as shown in Fig.6.



(a) 22nd~44th floor (b) 8th floor and its interlayer

Fig.6 Wuhan Poly building Damper Layout

The analysis and study on this high structure shows that, the FVDs played an effective role in the aspects of reducing displacement and stress of structural elements, improving torsion resistance property of the building and reducing earthquake response of non-structural element in the case of frequent earthquake and rare earthquake. The damping effect of the FVDs is comprehensive.

6） Tianjin International Trade Center[5][6]

Tianjin International Trade Center is a 250m steel structure tower. It had been half-finished building for 10 years, which had already built to 25th floor. Now during redevelopment, according to the need, use FVDs to reduce the wind-induced acceleration. After repeated optimization, 12 FVDs in toggle-brace configuration were installed at the 3 refuge floors respectively.

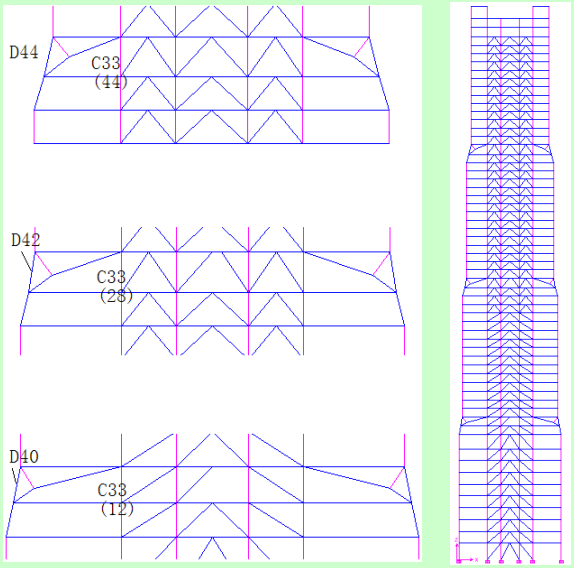


Fig.7 Tianjin International Trade Center Damper Layout

After installing the FVDs, the wind-induced story acceleration of Tianjin International Trade Center has effectively reduced, so that has met the requirement of Chinese code *JGJ 99-98*. In the case of earthquake, the FVDs also improved the ability of energy dissipation for the building.

7） Tianjin FULI building[7]

Tianjin FULI building, which located in block A09 of Tianjin, is a 94-story, 403m frame-corewall structure. The story 17, 29, 40, 51-55, 70 and 81 is the 6 refuge floors of the building, and its seismic fortification intensity level is 7. The dead load of the structure is relatively small, which result in the acceleration of the building in fluctuating wind increased.

Fig.10 Architectural rendering & structure model

After numerous plan comparison, we have found the most effective and economical plan of energy dissipation that, to install toggle-brace-dampers in the refuge floors of the building. It has raised an important reference for the method of new damper layout plan to replace traditional plan that place dampers every or every other story of the building.

8） Artux BURAQ building in Xinjiang

The Artux BURAQ building is a 26-story frame-shear wall structure which up to 78m. The idea for structure design is that, to design the main structure with the design intensity, 8, which is half a degree lower than the local design intensity, 8.5, and then meet requirement of local design intensity by means of energy dissipation design with the help of FVDs.

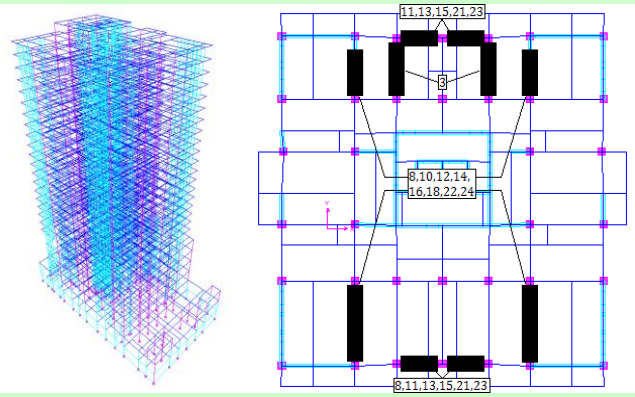


Fig.10 Structure model

After using 56 toggle-braced-dampers, the story drift and base sheer of the structure are dramatically decreased so that has met the requirement of code. So we can find that, dampers can effectively reduce the seismic response of the structure and without changing the stiffness of the structure itself. That will be an ideal alternative of energy dissipation design.

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Chen Yongqi *（1944～）male, doctor, senior engineer, earthquake engineering.*

Peng Cheng *（1987～）male, bachelor, research area: structural seismic resistance.*

Xue Hengli *（1988～）female, bachelor, research area: structural seismic resistance.*

Ma Liangzhe *（1973～）male, master, research area: passive control of structure.*

Linkman: Chen Yongqi

Beijing Qitai Shock Control and Scientific Development Co.,Ltd

Room201, Unit1, Building2, Zengguang Garden, No.27 Zengguang Road, Haidian District, Beijing 100037

Yqchen@bluelakeint.com 010-68713707，139109611