Comparison of seismic reduction schemes for frame structures under frequent earthquakes

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Abstract: In recent years, viscous energy dissipation wall is widely used in China. In the case of a 5-story frame structure, the combination of viscous damping wall (VDW), buckling restrained brace (BRB) and (VDW + BRB) is used for seismic design. Under frequent earthquakes, (VDW + BRB) scheme has the best damping effect, which can effectively reduce the response of superstructure and greatly improve the seismic safety of building structures.

1. Viscous damping wall

Viscous damping wall (VDW) is a kind of energy dissipation damper used in building structure. It is mainly composed of the inner steel plate suspended on the upper floor, two outer steel plates fixed on the lower floor, and high viscosity viscous liquid between the inner and outer steel plates. During the earthquake, the relative velocity of the upper and lower floors is produced, which makes the upper inner steel plate move in the viscous liquid between the outer steel plate of the lower layer, which produces damping force, absorbs seismic energy and reduces seismic response.

The basis of structure selection: First: It is the building range that each structure type suits above all. If you build an eight-story house, you can't have a brick-concrete structure, because it only goes up to seven stories. 8 floors over limit, special treatment! Second: Choose a structural system that is both feasible and economical from an economic perspective. 3 - storey small housing, no need to use shear wall structure! Brick masonry! Third: according to the use of functions. Office need big space, had better use frame, or frame to cut structure! Fourth: there are other factors, such as duration or foundation requirements!

Damping ratio is used to express the size of structural damping, which is one of the dynamic characteristics of the structure. It is a term to describe the energy dissipation of the structure in the process of vibration. There are many factors that cause the energy dissipation of the structure (or the factors that affect the damping ratio of the structure), mainly including: (1) material damping, which is the main reason for the energy dissipation; (2) damping of the surrounding medium to the vibration; (3) damping of the surrounding medium to the vibration; (3) (4) part of the energy is lost through the support foundation. The values of so-called typical damping ratio used in general analysis are given by structure type and material classification. Considering the situation of different countries, the damping ratio of steel structure is generally between 0.01 and 0.02 (0.05 can be taken for single story steel structure workshop), and that of reinforced concrete structure is generally between 0.03 and 0.08.

2. Buckling restrained brace

Buckling restrained brace (BRB) is a kind of axially loaded member without buckling under compression. This is a kind of energy dissipation brace member which can yield under tension and
compression. It can improve the disadvantage of buckling of traditional brace in compression and improve the seismic performance of the structure. The frame system with buckling restrained brace not only has good lateral performance, but also improves the toughness and seismic performance of the structure. Buckling restrained brace (BRB) can consume a lot of energy after entering the plastic state, which can transform the vibration energy of the structure into heat energy and dissipate it, so as to reduce the dynamic response of the structure.

Because of its stable performance, clear concept and relatively low cost, viscous damping wall has been widely recognized by the engineering community that the non structural energy dissipation elements can improve the seismic performance of the structure. Among all kinds of energy dissipation devices, viscous damping wall is widely used at home and abroad because of its superior performance. Viscous damping wall with thin thickness and large output is easy to meet the requirements of architectural design on damper size.

Because of its light weight, flexible layout and convenient installation, the buckling restrained brace (BRB) and frame structure system show excellent bearing capacity and energy dissipation performance.

3. Mechanical model of shock absorber
Viscous damping wall belongs to velocity type damper, and its damping force depends on the velocity. The relationship between the damping force of viscous damper and relative deformation can be expressed as follows:

\[ F = C \times V^a \]

Where: \( F \) is the damping force; \( C \) is the damping coefficient; \( V \) is the velocity; \( a \) is the velocity index. 

Viscous damper is usually simulated by Maxwell model, which is composed of spring and damper.

For pure damper, the effect of spring can be ignored as long as \( K \) is large enough.

The buckling restrained brace belongs to displacement type damper. Its energy dissipation is realized by the plastic deformation of steel core after yielding. The restoring force is related to the post yield stiffness and maximum plastic deformation (or energy consumption). The strength performance does not appear obvious degradation due to low cycle reciprocating or displacement increase. It can be seen from the hysteresis curve that the simplified bilinear mechanical model can be used to simulate, and good simulation effect can be obtained.

4. Calculation model and damping scheme

4.1. Calculation model
Taking a 5-storey frame structure as the engineering background, the building area of the structure is: The height of the first floor is 6 m, the height of the rest is 4 m, the ratio of length to width is 2.7 and the ratio of height to width is 2.7. The seismic fortification intensity of the project area is 8? The first and second translation periods are 0.7717 s (x direction), 0.7476 s (Y direction), and the first torsion period is 0.6861 s. Because the period of translational motion of the structure is close to the period of the site, according to the functional requirements of the building, considering the seismic safety of the building, the structure adopts the seismic control technology.

In the seismic analysis, SAP2000 is used to model the whole structure. The spatial bar element is used to simulate the beam and column, the damper element is used to simulate the damping wall, and the multilinear plastic element is used to simulate the buckling restrained brace.

According to article 3.8.2 of code for seismic design of buildings (GB 50011-2010), the seismic fortification target of buildings with energy dissipation design should be higher than that of ordinary buildings. The seismic fortification goal of the building is: when the seismic structure with dampers is affected by frequent earthquakes lower than the seismic fortification intensity in this area, the main structure can continue to be used without damage or repair, and its target displacement angle limit value changes from 1 / 550 to 1 / 800.
Vdf-nl × 1700 × 80, which is commonly used in the market, is selected for this project. The viscous damper does not add structural stiffness, but only provides additional structural damping.

BRB is also commonly used in the market. The BRB is hinged double channel buckling restrained brace (jk-pdbrb).

4.2. damping scheme
According to the functional conditions of buildings, three kinds of shock absorption technical schemes are put forward as follows:

① (VDW) scheme with viscous damping walls only;
② Only Buckling Restrained Braces - (BRB) scheme;
③ At the same time, viscous damping wall and buckling restrained brace (VDW + BRB) scheme are arranged. Analysis of shock absorption effect

In the structural seismic response analysis, the story shear force, reciprocal of story displacement angle and the average of story acceleration of four kinds of structures, namely, non damping, damping (damping wall), damping (buckling restrained brace) and damping (damping wall + buckling restrained brace), are compared.

It can be seen from the above chart that the three different seismic reduction schemes can achieve different effects on the seismic reduction of the structure. Among them, the (VDW + BRB) scheme has the most obvious seismic reduction effect, and the average seismic reduction rate of each layer of shear reaches 36.9% in X direction and 32.5% in Y direction, while the average seismic reduction rate of story shear in (VDW) scheme and (BRB) scheme is 25% and 18.2% in X direction and 26.8% and 7.7% in Y direction respectively.

The ratio of story drift angle between (VDW + BRB) scheme and non seismic structure is 50.5% - 67.4% in X direction, 45% - 62.05% in Y direction, while 54.1% - 78.2% in X direction and 49.4% - 74.63% in Y direction in (VDW) scheme, and 71.8% - 87.7% in X direction and 81.7% - 89.4% in Y direction for (VDW + BRB) scheme. It can be seen that the inter story displacement angle of (VDW + BRB) scheme is smaller and meets the performance requirements of code for seismic design of buildings not greater than 1 / 550.

It can be seen from the story acceleration that the average value of floor acceleration of (VDW + BRB) scheme and (VDW) scheme is relatively close. The floor acceleration of the structure can be reduced by 21% - 25% in X and Y directions, while the floor acceleration of (BRB) scheme almost does not weaken the floor acceleration, and the floor acceleration of the first floor has a slight negative increase.

5. Conclusion
① Among the three seismic mitigation schemes, VDW + BRB is the best, followed by (VDW + BRB), and (BRB) is relatively poor.
② All the three schemes can reduce the seismic response of the structure to a certain extent, but the (BRB) scheme does not achieve the effect of reducing the structural floor acceleration, while the viscous damping wall can achieve good seismic reduction effect in three aspects of story shear, story drift angle and floor acceleration.

Generally speaking, the viscous damping wall is an ideal damping device for this frame structure under frequent earthquakes, and the combination of viscous damping wall and buckling restrained brace can achieve better damping effect.

Reference:
[1] Zhou Fulin. Seismic control of engineering structures [M]. Beijing: Earthquake Press, 1997
[2] OuJin. Theoretical analysis and experimental study on vibration reduction of viscous damping wall structures [D]. Nanjing: Southeast University, 2006
[3] Wang Dayang, Zhou Yun, Wang Yihua, et al. Progress in research and application of viscous damping structures [J]. Engineering seismic and reinforcement, 2006, 28 (4)
[4] Yan Feng, LV Xilin. Comparative shaking table test of RC frames with and without viscous damping walls [J]. Acta architectural structures, 2005, 26 (5)
[5] Tan Zaishu, Qian Jiaru. Study on seismic response of viscous damping walls for reinforced concrete frames [J]. Acta architectural structures, 1998, 19 (2)
[6] Luo Kaihai. Design method of buckling restrained brace system [J]. Building structure, 2011, 41 (11)
[7] Lin Xin, Xia xubiao, sun Feifei. Study on hybrid arrangement of buckling restrained brace and ordinary brace [J]. Building steel structure, 2010, 12 (2)