The damping effect Analysis of viscous damper in eccentric concrete frame structure

Zhou Fang1, Qiuyue Zhang1, Chongge Wang 1* and Zhichuang Liu1

1 School of Civil Engineering and Architecture, Shandong University of Science and Technology, Qingdao, Shandong 266590, China
*Corresponding author’s e-mail: chgewang@163.com

Abstract: The application of viscous dampers in structures can effectively reduce the inter-layer displacement of structures, especially they can reduce the torsional effects of structures in earthquakes. We can simplify the eccentric structure into a series rigid plate model and divide it into three types: a model of the viscous dampers are provided at position 1 of the eccentric structure, and a model of the steel supports are set at position 1 of the eccentric structure and a original structural model. Then analyzing the earthquake resistance of a 13-layer eccentric concrete structure model using SAP2000, It is concluded that the model of setting the steel supports can effectively reduce the horizontal displacement of the structure compared with the original structural model, but the effect of reducing the torsional displacement is not obvious enough; the model of setting the viscous damper can not only effectively reduce the inter-layer displacement of the structure, but also effectively reduce the torsional displacement of the structure; Setting the viscous dampers can effectively reduce the inter-layer writhing displacement of the structure than setting the steel support model on the premise of reducing the same level of horizontal inter-layer displacement.

1. The research status at home and abroad and the content of this paper

The eccentric building structures are asymmetrical building structures relative to the axial building structures. They are different from the regular building structures, and have no simple body shapes, no regular planes and three-dimensional stereoscopic, and no relatively uniform mass and stiffness distribution. However, the eccentric building structure damages are more serious in the earthquake. Studies have shown that such structures as frame structures, frame shear wall structures and so on, they are subject to severe earthquake damages, mostly due to construction quality or severe structural irregularities[1]. Therefore, reducing the damage degree of eccentric buildings as much as possible has become a key concern of experts and scholars.

In recent years, the energy dissipation and vibration reduction technology has been increasingly valued and favored by scholars and engineers at home and abroad, and promoted to a large number of practical projects[2-4]. Abdelouahab Ras, Nadir Boumecra, Luca Landi Tong Guo et al [5-7] studied the seismic design of structures with additional viscous dampers, and analyzed and calculated the BouMeldS earthquake using SAP2000 software, compared the seismic effects between linear damping, nonlinear damping and unsupported structures by showing linearity in the form of tables and graphs. And analyzed the damper support models and damper placement strategies. Jia Bin, Luo Xiaojin et al. [8-9] used a three-way seismic wave input to perform nonlinear time-history analysis on a gymnasium, and studied the mechanism and effect of viscous damper on seismic strengthening of large-span spatial structures. Tang Yuchuan, Zhang Yuliang, Guo Yuchen et al. [10-11] studied the
nonlinear dynamic analysis of the viscous damper damping structure in the high-rise building structural dynamic analysis program HBTA. Through analysis, the damping effect of the viscous damper on the structure is investigated. Based on the above literature research, we can simplify the eccentric structure into a series rigid plate model and divide it into three types: a model of the viscous dampers are provided at position 1 of the eccentric structure, and a model of the steel supports are set at position 1 of the eccentric structure and a original structural model. Through the seismic analysis of the thirteen-layer eccentric concrete structure, comparing the horizontal displacement and rotational displacement between layers between original structure with the supporting structure, and setting the horizontal displacement ,it is concluded that the provision of the viscous damper can effectively reduce the torsion of the structure. Furthermore, it provides a reference for the earthquake resistance of eccentric building structures.

2. Research method for setting viscous damper in eccentric concrete frame structure
Using the method assumed by the rigid floor, and representing each floor covered by a rigid piece. For the eccentric structure, the center of the upper and lower horizontal rigid sheets will deviate due to the existence of eccentricity, and the line formed by connecting the center of the rigid sheet must be a curve, and the formed rigid sheet system becomes a tandem rigid sheet system. The horizontal displacement and rotational displacement of the rigid piece can fully reflect the displacement generated by the eccentric structure under the action of earthquakes.

3. Seismic response analysis of an eccentric concrete frame structure

3.1. Engineering overview of eccentric structures
The model selects a 13-storey hotel with a flat structure shape of “L”. The north-south span is 48.00m and the east-west span is 36.00m. The north-south and east-west intersections have large cylinders diameter of 0.6m and small cylinders diameter of 0.4m. The column spacing is 6.00m and the building height is 3.3m. Figure 3.1 is a plan view of the building and dampers layout. Since the building is a typical type of planar irregularity, it is eccentric in both the vertical and horizontal directions, and the building will have severe torsional responses under the action of earthquakes.

3.2. Design parameters of eccentric structure
The structure is reinforced concrete structure, the concrete strength of the column and the plate is C30, the size of the side column is 800x1000mm, the size of the inner column is 1200x1200mm, the size of the corner column is 1300x1300mm, and the beam section is 450x750mm. The thickness of the curved hall is 120mm, and the thickness of the concrete slab is 100mm; the site is an 8 degree seismic zone, the site category is III, and the design earthquake group is the first group.

3.3. Arrangement of viscous dampers and steel supports in eccentric structures

3.3.1 Arrangement of viscous dampers
According to the SAP2000 operation result, the east end of the east-west span is set to the “a” end (live end), and the north end of the short span is set to the “b” end (solid end). For the eccentric structure, under the action of earthquake, the inter-layer displacement (horizontal displacement and rotational displacement) of the living end (“a”end) is larger than the displacement of the solid end (“b” end). Therefore, the steel supports and the viscous dampers should be placed at the live end of the structure. According to the analysis results of the original structure in SAP2000, the steel supports and the viscous dampers are placed at the sixth layer. The layout of the structural plane of the arrangement of the steel supports and the viscous dampers in the original structure is shown in Figure 1, and the vertical arrangement is shown in Figure 2.
3.3.2 Arrangement of steel supports in the structure

In order to compare with the case that the structure with viscous dampers, the arrangement position of the steel supports in the structure should be consistent with the arrangement position of the viscous dampers, while the other conditions remain unchanged. Steel support optional I-beam, the material is Q235 steel.

![Fig.1 The plane position of the dampers layout](image1)

![Fig.2 Schematic diagram of original structure and the layout damper structure](image2)

(a) The original structure (b) The structure of the damper

3.4. The displacement ratio comparison

The structure with only the viscous dampers and the displacement ratio of the structure with only the supports and the original structure are compared, including the horizontal displacement ratio between layers as shown in Table 1, and the structure displacement ratio is shown in Figure 3.

| Number of layers | Original structure | Add Viscous dampers structure | Add supports structure |
|------------------|--------------------|-------------------------------|-----------------------|
| 1                | 1.137              | 1.111                         | 1.077                 |
| 2                | 1.118              | 1.101                         | 1.064                 |
| 3                | 1.112              | 1.102                         | 1.059                 |
| 4                | 1.108              | 1.098                         | 1.051                 |
| 5                | 1.103              | 1.097                         | 1.046                 |
| 6                | 1.099              | 1.095                         | 1.042                 |
| 7                | 1.094              | 1.092                         | 1.038                 |
| 8                | 1.091              | 1.091                         | 1.036                 |
| 9                | 1.088              | 1.089                         | 1.033                 |
| 10               | 1.084              | 1.088                         | 1.030                 |
| 11               | 1.081              | 1.085                         | 1.027                 |
| 12               | 1.078              | 1.083                         | 1.023                 |
| 13               | 1.074              | 1.080                         | 1.020                 |
It can be seen from Table 1 that the displacement ratio of the first layer of the structure after adding the viscous damper is reduced by 2.6% compared with the original structure, and the displacement ratio of the first layer of the structure with the steel support is lower than that of the original structure. About 5.3%. It can be seen that the effect of adding steel support to reduce the displacement between layers is better than adding a viscous damper. However, the addition of the ordinary support as part of the structural member requires consideration of the support deformation to the main component in engineering practice.

As can be seen in Figure 3, the inter-layer displacement ratio of the structure is increased faster in the 1-2th layer after adding the damper, and the inter-layer displacement ratio is slowed down from the 2nd-5th layer (the floor without the damper). The 5th to 6th layers descended faster, but the displacement ratio between the layers of the 6th-10th layer (the floor without the damper) slowed down, while the effect of the 10th-13th layer was accelerated, and the overall appearance was stepped. Analysis of the above data can be obtained. In the case of adding damping or support, the inter-layer displacement ratio of the structure can be reduced, especially in the floor where the viscous damper or the support is provided, and the displacement ratio reduction effect is remarkable.

Under the action of earthquakes, the torsional effect of eccentric structures must be taken seriously. The inter-layer rotational displacement ratio is shown in Table 2. The contrast curve between the viscous damper structure, the common support structure and the original structure is shown in Figure 4.

| Number of layers | Original structure R1 | Add supports structure R1 | Add Viscous dampers structure R1 |
|------------------|-----------------------|--------------------------|----------------------------------|
| 1                | 0.00037               | 0.00014                  | 0.0006                           |
| 2                | 0.00063               | 0.00019                  | 0.0001                           |
| 3                | 0.00079               | 0.0002                   | 0.00012                          |
| 4                | 0.00087               | 0.00018                  | 0.00013                          |
| 5                | 0.0009                | 0.00014                  | 0.00013                          |
| 6                | 0.00092               | 0.00012                  | 0.00013                          |
| 7                | 0.00093               | 0.00013                  | 0.00014                          |
| 8                | 0.00094               | 0.00018                  | 0.00015                          |
| 9                | 0.00095               | 0.00025                  | 0.00017                          |
| 10               | 0.00097               | 0.00031                  | 0.00019                          |
| 11               | 0.00098               | 0.00036                  | 0.00022                          |
| 12               | 0.00098               | 0.00038                  | 0.00023                          |
| 13               | 0.00098               | 0.00039                  | 0.00024                          |
As can be seen in Table 2, the viscous damper is reduced by about 83% compared with the original structure, and the rotational displacement of the bottom layer of the structure added with the ordinary steel support is lower than that of the original structure. 62%. It can be concluded that the addition of a damper is more significant.

It can be concluded from Figure 4 that in this example, although the building structure with the viscous damper has a lower effect on the reduction of the inter-layer displacement ratio than the building structure with the common support, the viscous damping is added in the anti-torsion effect. The building structure consumes more energy than the building structure with just ordinary support. It can be concluded that under the action of earthquake, the damper has excellent energy dissipation function for the eccentric structure which may generate large inter-layer displacement, and can reduce the structural torsion effect caused by eccentricity as much as possible.

4. Conclusions and recommendations

In this paper, the original structure is analyzed by analyzing specific engineering examples, and the viscous damper and steel support are respectively arranged at position 1, and the vibration mode decomposition reaction spectrum method is used to carry out the inter-layer displacement, inter-layer displacement ratio and torsional displacement of the original structure. Compared. The following main conclusions were obtained through research:

1) By arranging the viscous damper at position 1, the viscous damper and the support can be effectively reduced when the viscous damper and the support are compared with the original structure and the inter-layer displacement of only the support structure. Inter-layer displacement. In the case of reducing the similar horizontal displacement, the viscous damper contributes more to reducing the torsional effect of the structure.

2) Using the time-history analysis method in SAP2000, the structure of the viscous damper is compared with the torsional effect of the original structure, and the viscous damper can effectively reduce the torsional displacement of the structure.

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