**Performance simulation analysis and comparison of different shearing mild steel dampers**

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**Abstract.** Mild steel dampers are widely used in the field of engineering structures energy dissipation and seismic reduction because of its advantages such as easy manufacturing, low cost and easy installation and replacement. In order to analyse and compare the performance of the different mild steel dampers, eight different shape shearing mild steel dampers are designed in this paper, and the simulation analysis is conducted using Finite Element Method (FEM) of ABAQUS/Standard. And the bearing capacity, initial stiffness and energy dissipation capacity of the different shearing mild steel dampers are compared according to the simulation results. The analysis and comparison results show that the performance of shearing mild steel damper is greatly affected by its shape. Therefore, the different shearing mild steel dampers should be selected reasonably according to the engineering requirements.

**1. Introduction**

The seismic energy is absorbed by structural plastic deformation in traditional buildings, and many main structural components are difficult to be repaired after being damaged [1]. It has become a reliable and popular seismic technology to protect the main structure from damage by setting various dampers to dissipate seismic energy and avoid the main structure to enter an obvious plastic state [2]. At the same time, the dampers have a certain degree of independence and it are an integral part of the anti-lateral fore component [3-5]. Its yield deformation and even failure will not affect the bearing capacity of the main structure. Hence, the dampers are widely used in seismic design of new buildings and seismic reinforcement of old buildings [5]. Mild steel dampers are widely used in the field of engineering structures energy dissipation and seismic reduction because of its advantages such as easy manufacturing, low cost and easy installation and replacement. Hence, many kinds of soft steel dampers have been developed in practice. In order to analyse and compare the performance of the different shearing mild steel dampers, eight different shape mild steel dampers are designed in this paper, and the simulation analysis is conducted using Finite Element Method (FEM) of ABAQUS/Standard. And the bearing capacity, initial stiffness and energy dissipation capacity of the different shearing mild dampers are compared according to the simulation results. The next few sections are a detailed description of this paper.
2. Finite element models

2.1. Model design
In this paper, eight different shape shearing mild steel dampers are designed, and the detailed dimensions of each damper are shown in figure 1, respectively. In addition, the thickness of the different shape soft steel dampers is 30mm, and the minimum width of each damper is 80mm.

![Figure 1. The detailed dimensions of each damper.](image)

2.2. Model establishment and material constitutive relation
In this paper, the finite element models are established according to the actual size using ABAQUS/Standard. And 8-node solid element C3D8R is used in the finite element models of mild steel dampers. The mild steel in the finite element models is the commonly used Q235 type with yield strength of 225MPa, modulus of elasticity of 206GPa and Poisson's ratio of 0.3. In addition, the yield stiffness is taken as 2% of the initial stiffness using a two-fold-line follow-up strengthening model in steel constitutive [6]. The stress-strain relationship the mild steel is shown in figure 2.

2.3. Loading spectrum and boundary conditions
In this simulation, displacement loading is used and the loading spectrum is shown in the figure 3. The embedded boundary conditions of upper and lower of the shearing dampers is used, and only the constraints of loading direction is released. In addition, the reference point is used to loading process, and the coupling constraint between the reference point and the loading position is adopted.
3. Results

3.1. Hysteretic curves

The hysteretic curves of each damper can be obtained by extracting the displacement and reaction force at the reference point, and the hysteretic curves of each damper is shown in figure 4, respectively.
Figure 4. The hysteretic curves of each damper.

The bearing capacity, deformation capacity, initial stiffness and energy dissipation capacity of each damper subjected to repeated loads can be reflected by hysteretic curve, and the hysteretic curve is the basis for determining the restoring force model [7]. It can be seen from the hysteretic curves of dampers that the load-displacement curve is a basically straight line without residual deformation, and the area of hysteretic loop is small, and the energy consumption is small before the damper yields. In addition, the residual deformation increases, and the hysteretic loop increases, the ring area and energy consumption increased significantly after the damper yields with the increase of displacement.

3.2. Skeleton curves
The skeleton curve can be obtained by connecting the peak load points of the first cycle under various loads in the hysteretic curve, which can clearly reflect the bearing capacity, initial stiffness and deformation capacity of the specimen [8], and the skeleton curves of each damper is shown in figure 5, respectively.
Figure 5. The hysteretic curves of each damper.

The skeleton curve is a straight line in the early stage of loading. After the damper yields, with the increase of displacement, the bearing capacity does not increase, and the degradation rate of stiffness accelerates. The bearing capacity and initial stiffness of the different shearing mild steel dampers are compared and the indexes are shown in table 1. The Park method is used to determine the yield point of the member [9].

Table 1. The index comparison table of different dampers.

| Damper  | Ultimate bearing capacity (kN) | Initial stiffness (kN/mm) | Yield bearing capacity (kN) | Yield displacement (mm) |
|---------|-------------------------------|--------------------------|----------------------------|-------------------------|
| Damper-1 | 412.9                         | 170.8                    | 412.3                      | 11.3                    |
3.3. Comparison of failure modes
The failure of mild steel damper begins with the yield position of steel. The development of the yield area of mild steel damper can be obtained from the stress nephogram, and the stress nephogram of each damper is shown in figure 6, respectively.

![Stress nephograms of each damper](image)

(a) Damper-1  (b) Damper-2  (c) Damper-3  (d) Damper-4
(e) Damper-5  (f) Damper-6  (g) Damper-7  (h) Damper-8

Figure 6. The stress nephogram of each damper.

3.4. Analysis of hysteretic energy
The energy dissipation capacity of components or structures is reflected by the size of hysteretic loop enclosure area. Normally, the larger the enclosure area of hysteretic loops; the stronger the energy dissipation capacity of components or structures [10]. The energy dissipation of each damper in the first cycle under various displacements is shown in figure 7.
Figure 7. The energy dissipation of each damper.
4. Conclusions
Mild steel dampers are widely used in the field of engineering structures energy dissipation and seismic reduction because of its advantages such as easy manufacturing, low cost and easy installation and replacement. In this paper, eight different shape shearing mild steel dampers are designed, and the simulation analysis is conducted using Finite Element Method (FEM) of ABAQUS/Standard. And the ultimate bearing capacity, initial stiffness, yield bearing capacity, yield displacement and energy dissipation capacity of the different shearing mild dampers are compared according to the simulation results. The analysis and comparison results show that the shape of shearing mild steel damper has a great influence on its performance even if the thickness and minimum width of each damper is the same. Therefore, the different shape shearing mild steel dampers should be selected reasonably according to the engineering requirements.

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