A numerical simulation on multi-functional mild steel damper

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1. Introduction

Multi-functional Mild Steel Damper (MMSD) can be applied in various positions of structures and can resist compression, tension and bending. MMSD dissipates seismic energy through plastic deformation of steel sheets hence prevents seismic damage of main structures. In this study, ANSYS and COMSOL are used to conduct numerical simulation on the mechanic response of MMSD under different loads. Optimization process, which includes the improvements of shape of steel sheet and adjunction of rubber, is taken in order to improve MMSD's mechanical property. Simulation results prove that a mechanically appropriate shape of steel sheets play an important role in improving initial stiffness and hysteretic loop of MMSD. Besides, it is proved that rubber can enhance MMSD's energetic dissipation capacity under load of small deformation.

2. Design Motivation and Idea

In the field of structural engineering, improving ductility of beam-column joints and increasing damping coefficient are effective ways to enhance structure's resistance against seismic loads. Thus, MMSD is aimed to optimize structures' resistance in preventing seismic damage by increasing ductility and damping coefficient of important parts of structures, such as joints connections, etc.,

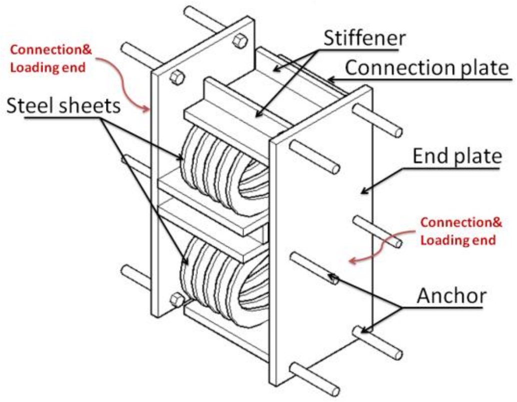

Fig. 1 Design of MMSD

The design idea is to make MMSD resistant to compression, tension and bending so that it could be applied in beam-column joints, braces, shear wall etc., which is the reason that MMSD is named multi-functional. In general, a traditional steel damper bears shear force and has limited applications. While in order to produce a more applicable damper, MMSD is designed (Fig. 1). As shown in Fig. 1, MMSD can be placed in site by connecting the end plates with structure through the anchors (or bolts or welding). Three typical applications of MMSD are shown in Fig. 3, Fig. 4 and Fig. 5. In these applications, steel plates are considered to be core members in MMSD, since they are expected to dissipate energy and fail first.

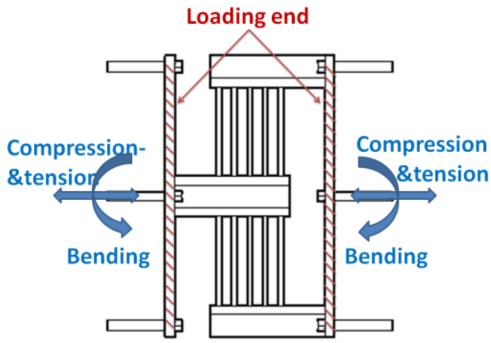

Fig. 2 Loading system

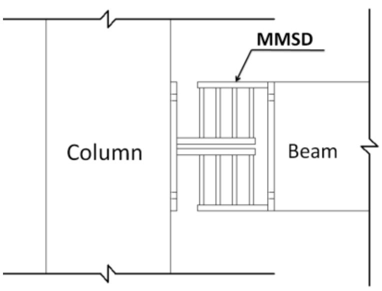

Fig. 3 MMSD applied in bracing system

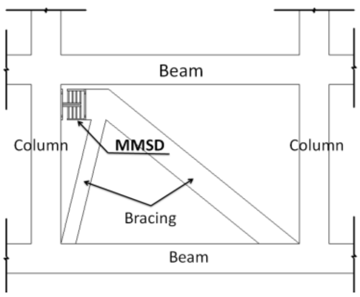

Fig. 4 MMSD applied in beam-column joint

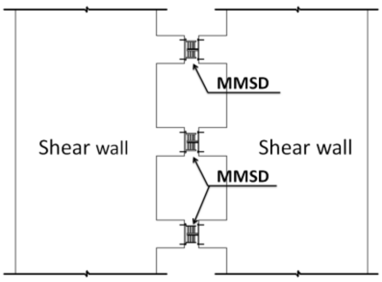

Fig. 5 MMSD applied in shear wall system

3. Numerical Simulation

In the numerical simulations, compression-tension hysteretic load and bending hysteretic load are exerted on MMSD respectively. According to the research done, initial stiffness and area of hysteresis loop are most influential factors on the effects of the damper. Since steel sheets are core members, the strain of steel sheets under specific load is given (Fig. 6), which shows the strain of the steel sheets (Area 1, Area 2 and Area 3) is largest of MMSD under the load. Therefore, in practice, steel sheets fail first if applied load is exceedingly large, as proposed by design.

Compression-tension hysteretic load and bending hysteretic load exert on the end plates of MMSD. Hysteretic results are shown in Fig. 6 and Fig. 7 respectively. The hysteresis loops in both figures are acceptable so that MMSD has enough energy dissipation capacity under these loads. Moreover, if needed, the maximum response force or moment could be further enhanced by adding more steel sheets while in this analysis, 10 sheets are used. Besides, changing other variables also works, like the thickness of a steel sheet, the dimension of MMSD or the yielding stress of steel materials. However, more parametric studies need to be conducted.

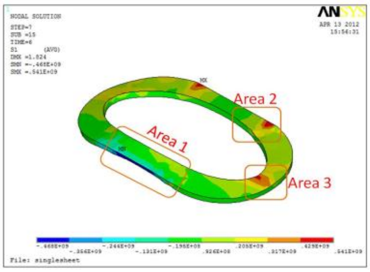

Fig. 6 Strain of steel plate

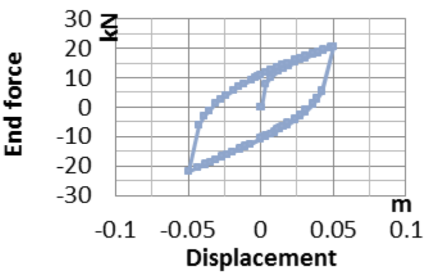

Fig. 7 Hysteresis loop under compression-tension load

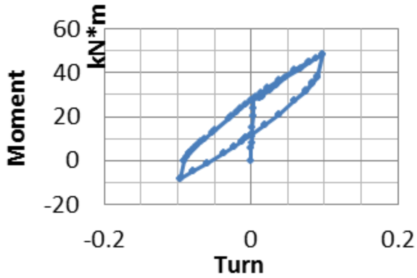

Fig. 8 Hysteresis loop under bending load

In addition, rubber is used in order to increase the damping coefficient of MMSD. According to composite material theory, if a material with high stiffness and small damping coefficient (steel) combines with a material with low stiffness and large damping coefficient (rubber), the composite material has high stiffness and large damping coefficient. Thus, MMSD with the composite material is tested and compared with the initial design (steel material only). As shown in Fig. 9 and Fig. 10, larger energy dissipation is expected for the composite damper under small displacement (when steel is elastic).

4. Conclusions

It is found that the MMSD has good resistance against compression, tension and bending force and dissipates hysteretic energy by developing plastic deformation. The shape of steel sheets plays a significant role in MMSD's mechanical behavior. Besides, rubber increases MMSD's visco-plastic property under small deformation (when steel is elastic) and thus improves energy dissipation capability. However, the hysteresis behavior has small difference between MMSDs with and without rubber.

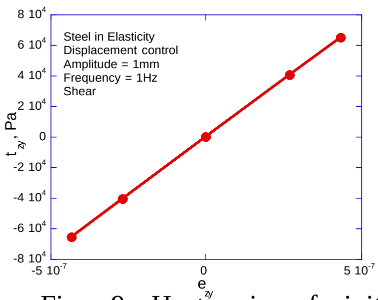

Fig. 9 Hysteresis of initial design under small deformation

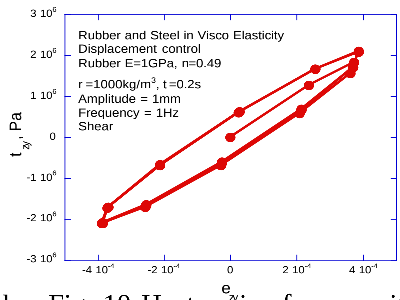

Fig. 10 Hysteresis of composite design under small deformation

Furthermore, since this study is a feasibility study of MMSD, more elaborate analyses and experiments are needed to determine the optimized variables so that MMSD can be designed and produced according to the needs of construction projects.