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The Effect of Connection Conditions on the Cyclic Behavior of U-shaped Metallic-Yielding Dampers

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ABSTRACT: The metallic dampers are one of the most widely used energy dissipation devices that can be used in building and non-building structures such as bridges. U-shaped metallic strips are among these tools. The effects of some parameters such as the number and arrangement of connection bolts on the cyclic behavior and energy dissipation capability during earthquake events will be evaluated in this study using nonlinear finite element method. According to the numerical results, simulation of the bolts, and their number and arrangements have significant effects in the resultant behavior in the transverse cyclic loading.

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1- Introduction

The idea of using metallic devices in structures to dissipate seismic energy began with the conceptual and experimental work by Kelly et al. in 1972 [1] and Skinner et al. in 1974 [2]. They introduced and tested several simple metallic devices as energy dissipation tools. U-shaped metallic strips were among them. The experimental tests showed that U-shaped metallic strips could sustain large displacements in the inelastic range and dissipate energy through the plastic deformation of the steel.

The energy dissipating properties of U-shaped steel strips were also confirmed by Aguirre and Sanchez [3]. Complementary studies in order to make it applicable were done by Dolce et al. [4]. They tested experimentally and simulated numerically circular arrangement of U-shaped plates as an elasto-plastic biaxial device for the passive control of structures. Moreover, recently a crawler steel damper consists of two U-shaped steel energy dissipation plates, which can be used in the isolation system of bridges, has been developed and tested by Deng et al. [5].

The simulation of connection bolts has been neglected in all above mentioned numerical studies. In this paper, a three-dimensional finite element model is established to investigate the effects of number and arrangement of connection bolts on the cyclic behavior of U-shaped dampers.

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2- Finite Element Modeling and Verification

Figure 1 shows the typical U-shaped damper parallel to the loading direction. At first, for the purpose of verification, three specimens of the experimental work by Deng et al. [5] were simulated using the general purpose FEM software ABAQUS. The thickness and height of the U-shaped plates are different in these specimens. The FEM model is shown in Figure 2. Non-linear material, geometrical and contact analyses were carried out to predict the load–displacement curves of the dampers under cyclic loads.

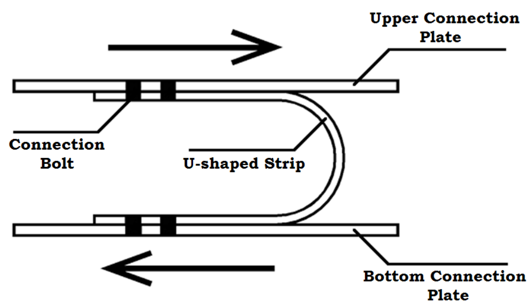

Figure 1: Typical U-shaped damper

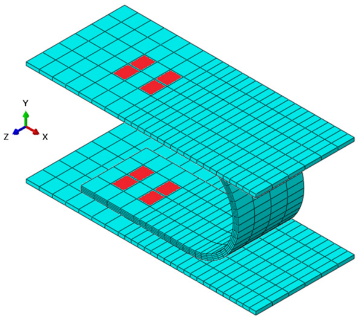

Figure 2: Finite element model

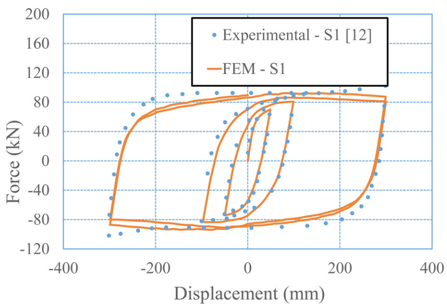

Figure 3: Comparison between simulated and experimental hysteresis loops

The hysteresis curve obtained from the numerical simulation is compared with that of the experimental data in Figure 3 for the standard specimen. It can be observed that the FEM analysis results agree very well with those obtained from the tests.

3- Results and Conclusions

Detailed simulation of the bolted connections was added to the previous FEM model and the numerical analyses were carried out under two loading directions: parallel to the longitudinal axis of the plate, and normal to the longitudinal axis. The obtained results are shown in Figures 4 and 5, respectively. Also, in these figures the results are compared with those of models without simulation of connection bolts. Figures 4 and 5 show that the elimination of the bolts in the FEM modeling has not significant effects for the longitudinal cyclic loading, but causes incorrect results for the transverse cyclic loading. Also, in the latter case, contrary to the former one, the number of connecting bolts is a significant parameter affecting the cyclic behavior of the damper.

To further investigate the effects of number and arrangement of connection bolts on the cyclic behavior of U-shaped dampers loaded in the transverse direction, four arrangements according to Figure 6 were simulated. The numerical results are compared together in Figure 7. It is observed that increase of the number of bolts can increase the stiffness and strength of the U-shaped damper.

A biaxial device can be realized by simply combining U-plates in a circular pattern, as shown in Figure 8. Each element in this arrangement can deform along any horizontal direction. The numerical results show that the hysteresis loop for this case can be achieved by combining the results of previous simple models, if the connecting bolts are simulated exactly.

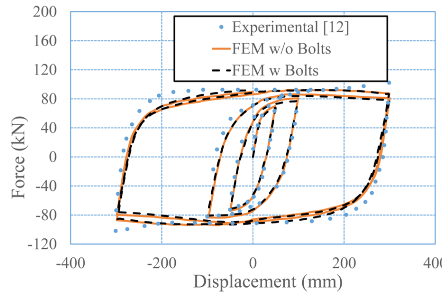

Figure 4: Hysteresis loops with and without simulation of connecting bolts under longitudinal cyclic loading

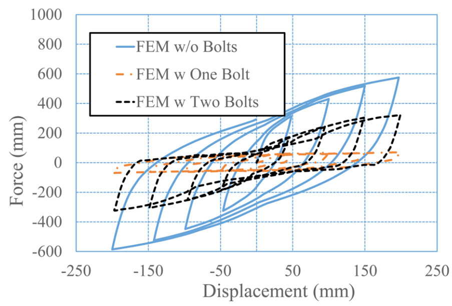

Figure 5: Hysteresis loops with and without simulation of connecting bolts under transverse cyclic loading

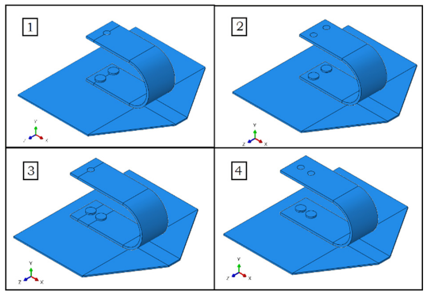

Figure 6: Four arrangements of connecting bolts

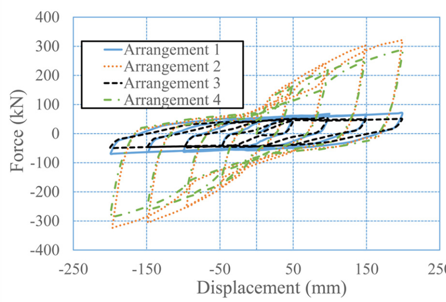

Figure 7: Hysteresis loops for different arrangements of connecting bolts under transverse cyclic loading

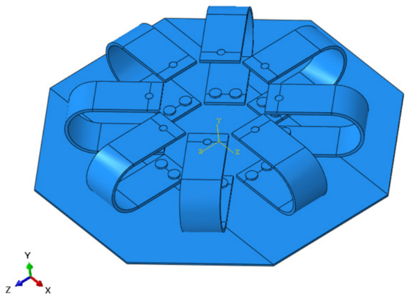

Figure 8: Circular arrangement of U-plates

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