8th International Conference on Seismology & Earthquake Engineering
11-13 Nov. 2019, Tehran, Iran

BUCKLING RESPONSE AND ELASTIC STIFFNESS OF BUTTERFLY DAMPERS

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Keywords: Buckling, Finite element model updating, Butterfly damper, yielding device

The utilization of energy dissipative devices represents a common strategy to protect structures against seismic excitations. Among the most used hysteretic damper types, butterfly dampers have been widely investigated as a profitable protection technology able to provide large energy dissipation capacity, with the possibility of easily controlling both stiffness and strength (Figure 1). The effect of altering the geometry of steel strips on the low-cycle-fatigue (LCF) resistance and ductility of yielding dampers has been a subject of interest of many researchers worldwide during the past decade (Ghabraie et al., 2010; Deng, et al., 2014, Hedayat, 2015).

Although the results suggest that it may be possible to provide more uniform plastic strain distribution along the yielding devices such as butterfly dampers by changing the edge shapes; however, removing materials from the original butterfly dampers could have significant effect on the buckling response and elastic stiffness of butterfly dampers.

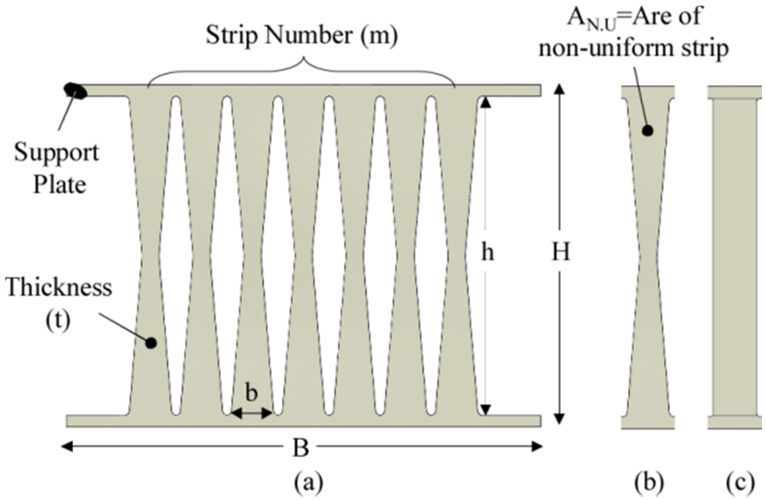
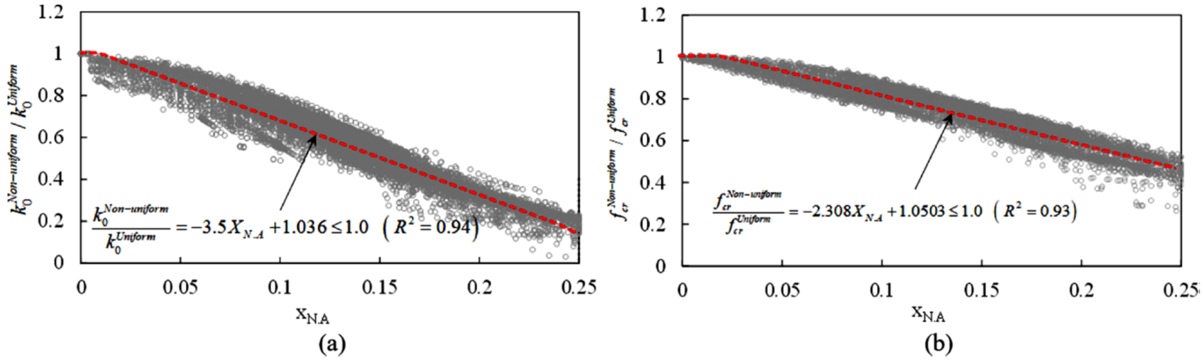


Figure 1. (a) Butterfly damper, (b) non-uniform single strip slit damper (SSSD), (c) corresponding uniform strip.

More than 200 single strip slit damper (SSSD) models with five different heights (h), six aspect ratios (h/b) and six (h/t) ratios are considered in this study. More than 10,000 non-uniform strip with random edge shape also created during the study with a MATLAB-based finite element (FE) model updating procedure that connect ABAQUS to the FE model updating algorithm. The required geometric and material nonlinear analyses during creation of random non-uniform models have been performed in a numerically validated, FE modelling protocol in ABAQUS. A set of regression analysis has been conducted in order to propose an empirical equation for reliable estimation of buckling coefficient and elastic stiffness of non-uniform, butterfly dampers.

The ratio of the elastic stiffness of SSSDs with arbitrary non-uniform shape and the elastic stiffness of corresponding SSSDs with uniform shape ($k_0^{Non-uniform} / k_0^{Uniform}$) as well as ratio of critical buckling stress for non-uniform SSSDs with arbitrary non-uniform edge shape and those of uniform SSSDs ($f_{cr}^{Non-uniform} / f_{cr}^{Uniform}$) are compared in Figure 2-a and 2-b respectively. According to the results, both buckling capacity and elastic stiffness are inversely related to ratio of removed parts to the initial area of uniform SSSD ($X_{N.A}$). The reduction in the elastic stiffness and buckling capacity of SSSD models can be expressed with linear equations as are shown in Figure 2.



(a) (b)

Figure 2.The ratio of buckling capacity and elastic stiffness of non-uniform strips to those of uniform SSSDs.

The cyclic response of SL180-2 models (h=180, b=90) with improved butterfly geometry and uniform geometry at early cycles are compared in Figure 3. As is shown, sever pinching is evident in cyclic response of butterfly model due to its significant decrease in buckling coefficient. According to the results, the cyclic response of butterfly dampers could be significantly governed the buckling in spite of corresponding uniform slit dampers.

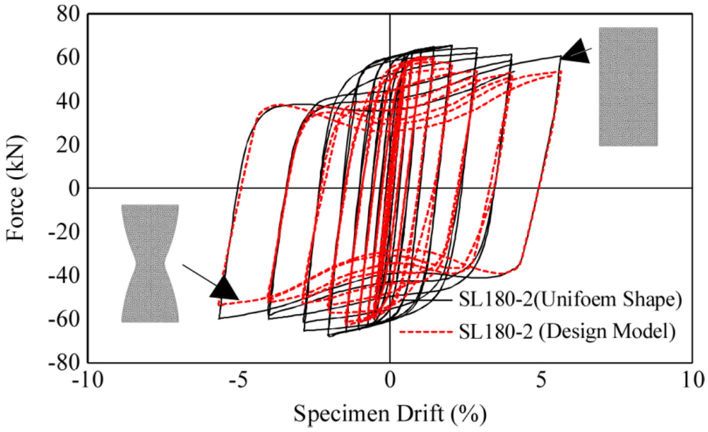


Figure 3. Cyclic response of uniform strip and corresponding butterfly strip.

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