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Condition Assessment of Steel Shear Walls with Double-tapered Links under Earthquake Loading

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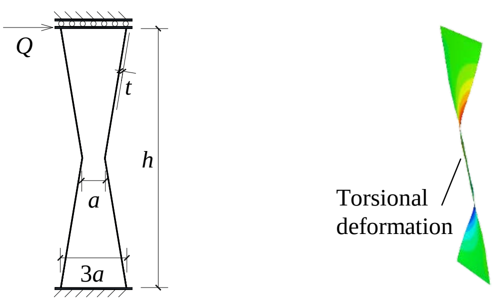
1. Introduction

The authors developed a new steel shear wall that also functions as a mean for structural condition assessment. The wall is composed of a series of double-tapered links, each of which exhibits notable torsional deformation when subjected to a predefined shear deformation. By inspecting the occurrence of notable torsional deformation with the naked eye, the maximum experienced shear deformation of the wall is easily estimated, which in return enables the condition assessment of the structure where the wall is installed. While condition assessment by using double-tapered links is feasible under the commonly adopted incremental two-cycle loading, performance of condition assessment under earthquake loading, featured by a variable amplitude history, needs further investigation.

2. Double-tapered link

A schematic of a double-tapered link under an in-plane shear force Q is illustrated in Fig. 1(a), where a, h, and t denote the mid-section width, height, and thickness of the link, respectively. When the ratio of the end-section width to the mid-section width has a value of 3, the link first yields in the quarter-height regions from its middle. At larger lateral drift, the quarter-height regions buckle out of plane and exhibit notable torsional deformation, as shown in Fig. 1(b).



(a) (b)

Fig. 1 Double-tapered link: (a) basic dimensions; (b) torsional deformation.

The initiation and growth of torsional deformation is primarily controlled by the width-to-thickness ratio ($\lambda = 2a/t$) but little affected by the aspect ratio ($\beta = h/2a$) as long as the link is neither too short nor too long (Kurata *et al.* 2014).

3. Experimental validation

3.1 Test specimens

Two identical specimens were designed as shown in Fig. 2(a). The three double-tapered links in each specimen had the same link height of 360 mm and thickness of 4.3 mm, but different mid-section widths of 30, 22 and 18 mm respectively. To make the inspection of torsional deformation in a more objective manner, two wings were added at the mid-section and reference strips were placed adjacent to the double-tapered link. The reference strip was designed narrow (20 mm wide) to remain in plane such that it provided reference to double-tapered links deformed out of plane. With the presence of wings and reference strips, notable torsional deformation was defined when the out-of-plane displacement at the wing edge was larger than one plate thickness and the corresponding rotation angle of the mid-section (R) was used for quantification.

3.2 Test results

Under an incremental two-cycle loading as shown in Fig. 2(b), torsional deformation progressed as shown in Fig. 2(c). The dashed lines indicate the rotation angles corresponding to the criterion for notable torsional deformation. Notable torsional deformation of three links occurred at drift ratios of 2.5%, 3.5% and 4.5%, respectively.

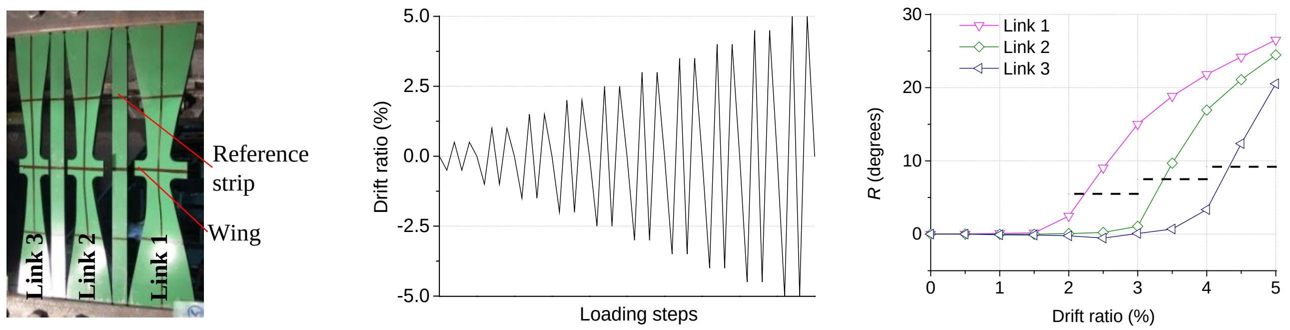
Fig. 3(a) shows a typical displacement response under a ground motion excitation, termed earthquake loading. Based on the results under the incremental two-cycle loading, the largest peak amplitude of earthquake loading was scaled to drift ratios of 2.5%, 3.5% and 4.5% respectively. Figs. 3(b)-(d) show the histories of torsional deformation under the three earthquake loadings. Notable torsional deformation occurred near the largest peak amplitude; after the largest peak amplitude, the torsional deformation remained almost constant. Based on the criterion for notable torsional deformation (dashed lines), three links showed notable torsional deformation at the largest peak amplitudes of 2.5%, 3.5% and 4.5% respectively, same as that under the incremental two-cycle loading.

4. Conclusions

The feasibility of implementing condition assessment by using double-tapered links was further confirmed under earthquake loading. Under earthquake loading, the largest peak amplitude primarily controlled the occurrence of notable torsional deformation, similarly to the cases under the incremental two-cycle loading. Thus, the incremental two-cycle loading can be adopted as the base loading protocol in the design of double-tapered links for condition assessment.

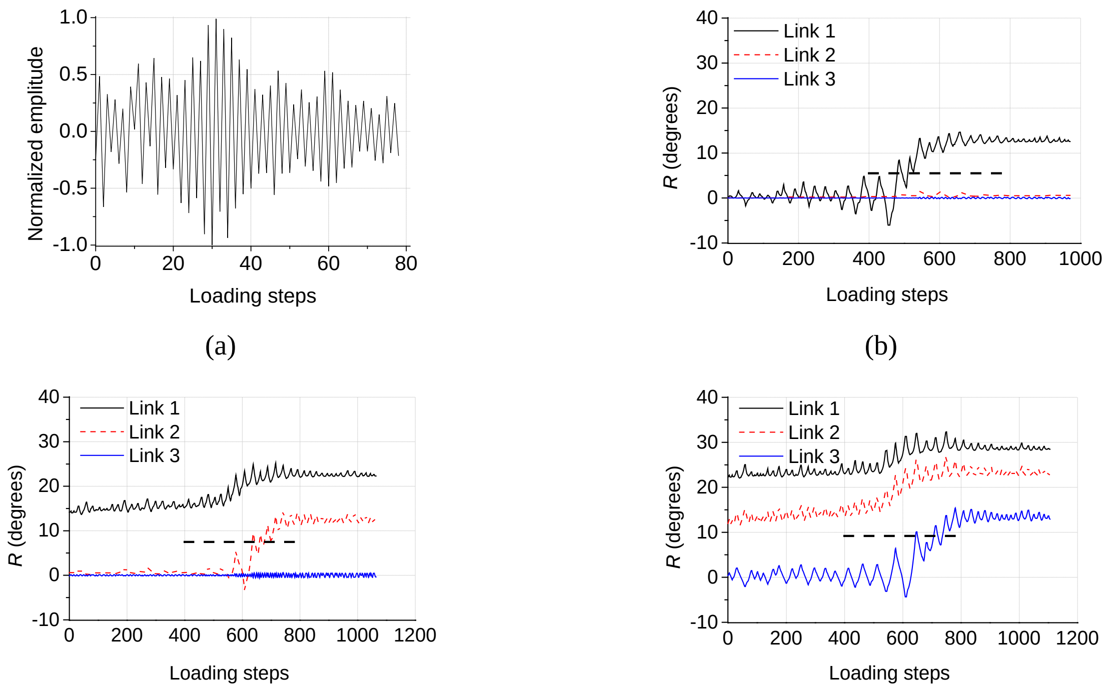
References

Kurata M., He L. and Nakashiam M. Steel slit shear walls with double-tapered links capable of condition assessment. *Earthquake Engineering & Structural Dynamics* 2014, DOI: 10.1002/eqe.2517.



(a) (b) (c)

Fig. 2 Torsional deformation under incremental two-cycle loading: (a) test specimen; (b) incremental two-cycle loading; (c) progress of torsional deformation.



(c) (d)

Fig. 3 Torsional deformation under earthquake loading: (a) earthquake loading; (b)-(d) histories of torsional deformation at the largest peak drift ratios of 2.5%, 3.5% and 4.5%, respectively.