Seismic analysis and design of viscously coupled walls or trusses with discrete locations for viscous dampers

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Summary

In this paper, the efficiency of using viscous dampers to connect two walls, in discrete locations along the height, is examined. The non-dimensional parameters controlling the behaviour of such structures are first identified. Those are a non-dimensional damping coefficient and the non-dimensional heights where the dampers are mounted. Then, a parametric study is conducted to gain some insight on the behaviour of the system and to attain graphs for important non-dimensional responses of interest such as displacements, inter-story drifts, absolute accelerations, wall base-shear, total base-shear and total over-turning moments. These reveal the optimal locations of the dampers and allow a simplified analysis and design.

Keywords: Earthquake engineering; seismic design; seismic retrofitting; walls; energy dissipation devices; fluid viscous dampers; passive control.

1. Introduction

It is well known that coupled shear walls present an efficient seismic resisting system, in particular for tall buildings. The coupling of the two walls using coupling beams results in a relatively stiff structure, thus, deformations are reduced. The relatively low natural period, on the other hand, attracts larger seismic loadings. Hence, the total forces in such systems are expected to be larger than those to act without the coupling beams.

An elegant alternative has been recently proposed by Rahimian [1]: using viscous dampers as the coupling elements in coupled trusses rather than beams. The advantages of using viscous dampers as the coupling elements over the use of coupling beams are related to force-based responses as well as accelerations. Tools for initial design of such systems have been supplied [2]. Those tools assume a uniform distribution of the dampers through the height. The cost of dampers and the elegance of the solution, on the other hand, depend heavily on the number of dampers.

To further make this approach more elegant, it is the aim of this paper to equip the engineer with insight and tools for the seismic design of viscously coupled walls or trusses with dampers located in discrete locations throughout the height. The controlling parameters of such systems and their effect on various responses of interest are first identified and analyzed. The results of this study are then presented in graphs that can be easily implemented in practice for the purpose of initial design. Furthermore, these results are discussed and some insight as to efficient locations for the damper is given.

2. Structural model and analysis approach

The structural model treated in this paper consists of two walls connected by a few dampers located at the same height, *h* (figure 1). A model with more than a single location for the dampers was also considered and discussed without presenting the results. The modelling assumptions made herein are similar to those made by Lavan [2]. Furthermore, an equivalent model of a cantilever beam with

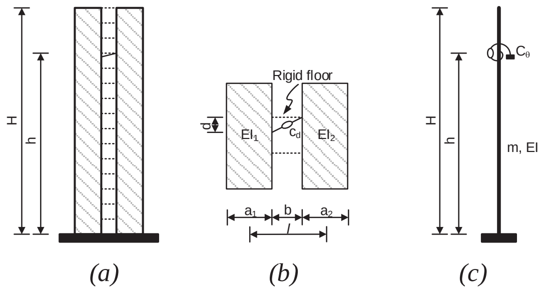

Fig. 1: Structural system considered in this study: (a) viscously coupled shear walls, (b) parameters of the viscously coupled shear walls, (c) cantilever beam with a rotational damper

a rotational damper is adopted as shown in figure 1. As a linear model is adopted and the system doesn't satisfy the Caughey criterion, the complex modal spectral analysis approach proposed by Song et al. [3] was adopted.

3. The parametric study

The number of parameters that control the behaviour of the structural model is 7. Those are: *EI* (total wall flexural stiffness), *m* (mass per unit height), *H* (total height)- parameters of the given wall structure; C_θ, *h*- parameters of the damping system (see Fig. 1); T_c (corner period), S_1 (spectral acceleration at 1.0 sec)- parameters of the response spectrum. In order to reduce the number of controlling parameters and to ensure that the results will fit a wide variety of structures, dimensional analysis is used. This reduces the number of non-dimensional parameters that control the behavior of the structure to 4. In order to further reduce the number of parameters, a normalization of all responses of interest by $S_{a,T1}$ (the 5% damping spectral acceleration corresponding to the first period of the bare structure) is made. As the system is linear the system's responses scale linearly with the acting loads thus generality is maintained. This reduces the number of controlling parameters to 3. To further reduce the number of controlling parameters, it is assumed that all relevant modes are within a single region of the response spectrum. The one is the constant acceleration region while the second is the constant velocity region. With this assumption, the actual value of T_c has no effect on the results obtained for each region of the spectrum.

4. Discussion and conclusions

In this paper, the efficiency of using viscous dampers to connect two walls, in discrete locations along the height, was examined. The non-dimensional parameters controlling the behaviour of such structures were first identified. A parametric study was then conducted to gain some insight on the behaviour of the system and to attain graphs for important non-dimensional responses of interest. These allow a simplified analysis and design.

Furthermore, the parametric study results revealed that, with reasonable damping that leads to about 60%-70% reduction in most responses of interest, a damper of a given damping coefficient is most efficient at the top. This is in contrast to what was observed in walls with outriggers. The latter have the same equations with the difference of having a rotational spring rather than a rotational damper. This finding is also in contrast to what is known when it comes to the optimal location of dampers in frame structures. It should be noted, however, that mounting the damper at the top, in addition to leading to the largest reduction in responses, also results in higher forces within the damper.

5. References

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