



Stiffness and strength degradation of steel shear walls having an arbitrarily-located opening

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ABSTRACT

Openings in steel plate shear walls (SPSWs) in buildings are provided for architectural reasons as well as for access requirements. Despite the reduction of stiffness and strength in panels with an opening being well-understood, further studies are essential in order to determine both the mechanism and the degree of this degradation, as well as its dependency on the location and the size of the opening. To accomplish this aim, a non-linear finite element analysis is used in this paper to study the behaviour of both stiffened and unstiffened SPSWs with a single rectangular opening. The size and location of the opening are varied from model to model in order to determine their influences on the stiffness and strength of the system. Based on the results obtained, the strength and stiffness degradation of unstiffened panels are affected adversely by the location of the opening. In contrast, the re-location of an opening of a specific size within the panel area in stiffened panels does not appear to influence this degradation, so that the stiffness and strength deterioration are not a function of the location of the opening. As expected, both stiffened and unstiffened panels experience a progressive reduction in their stiffness and strength with an increase of the size of the opening. It is demonstrated further that with an increase in the opening ratio (width to height), the energy absorbed by the system arising from seismic loading considerations in both stiffened and unstiffened SPSWs show a linearly decreasing trend; this trend being less stiff for stiffened panels. Unstiffened SPSWs with a central opening experience the least energy absorption. It is also shown that the absorption of energy is substantially higher in stiffened panels when compared with their otherwise identical, but unstiffened, counterparts.

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1. Introduction

Steel plate shear walls (SPSWs), as proven viable alternatives to other lateral load resisting systems, are used extensively in tall buildings and for the retrofit of existing buildings. This type of lateral force-resisting system has been the subject of intensive research and has found worldwide use over the past few decades, particularly in regions of high seismic activity. Steel buildings with SPSW panels are generally lighter in weight, and hence are subject to lower seismically-induced forces. Material compatibility with the main steel frame of the building makes the tasks of fabrication by welding and bolting and the process of erection faster and more cost-effective. Other advantages of the system are its superior strength and stiffness, its higher ductility and its exceptional capacity to absorb energy

compared with other shear wall systems. Owing to these desirable attributes, researchers, particularly in recent years, have devoted much attention to a better understanding of the behaviour of SPSWs in seismic zones.

Some of the first studies of the behaviour of SPSWs were carried out by researchers at Cardiff University in the United Kingdom [1–7]. A series of experimental tests was conducted on SPSW specimens with and without a single circular opening at the centre of the plate under cyclic quasi-static loading. In some specimens, Low Yield Steel (LYS) and aluminium were used. The results of these studies confirmed the high ductility with a stable S-shape hysteresis loop for the SPSW panels tested. It was found that the energy absorption of the system increases under loading cycles with increasing amplitudes. In addition, it was shown in these studies that the stiffness and strength of the panels decrease with an increase in the diameter of the opening.

In 2004, Vian and Bruneau [8] tested a thin-walled SPSW with 20 circular holes. A companion specimen with a quarter circle opening at one of the plate corners, using LYS, was also tested at the Structures Laboratory of the National Center for Research on Earthquake Engineering at the National University of Taiwan [8]. The test results

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