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Evaluating Response Modification Factors of Steel Plate Shear Wall Buildings

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Abstract

Steel plate shear walls (SPSW) consist of thin web steel plates that infill frames of steel beams and columns, denoted as horizontal and vertical boundary elements, respectively. The unstiffened thin web plates have a tendency to buckle at small lateral loads and the so-called tension field develops, providing ductility and energy dissipation through tension yielding of web plate. In this paper, the over-strength, ductility, and response modification factors of code-based designed SPSWs is assessed by performing static pushover analysis, nonlinear incremental dynamic analysis as well as the linear dynamic analysis of model structures with various stories. According to the analysis results, the response modification factors derived from nonlinear incremental dynamic analysis match well with values given in design codes. It was also found that the number of stories of buildings has great effect on response modification factors, especially those obtained from static pushover analysis.

Keywords: Steel plate shear walls, Ductility, Response modification factor, Incremental dynamic analysis, Static pushover analysis.

1. INTRODUCTION

Recently, steel plate shear walls (SPSW) have been used as a primary lateral load resisting systems in buildings in region of high seismicity. This system consists of thin web steel plates that infill frames of steel beams and columns, denoted as horizontal and vertical boundary elements (HBE and VBE), respectively. The unstiffened thin web plates have a tendency to buckle at small lateral loads and the so-called tension field develops, providing ductility and energy dissipation through yielding of web.

In 2005, the American Institute of Steel Construction's Seismic Provisions for Structural Steel Buildings added criteria for designing SPSW for the first time, which utilized capacity based design approach. The design philosophy required that horizontal boundary elements should have adequate strength to resist induced forces from tension field yielding of web plates. Also, the vertical boundary elements must be designed against tension field yielding of web plates and formed plastic hinges in HBEs. So, the main objective of the provisions in AISC is to provide boundary elements with sufficient strength and stiffness for web plates in order to ensure full development of the web's plate tension yield [1].

Till now, efficiency of SPSW has been confirmed in many studies worldwide. Utilization of the post-buckling strength of thin web steel plates in SPSW under lateral load was investigated through a series of analytical and experimental studies at the University of Alberta in the early 1980's. Thorburn et al. developed a simple analytical model to study the shear behavior of thin unstiffened steel plate shear walls [2]. The model was based on the pure diagonal tension field. In order to evaluate the so-called strip model proposed by Thorburn et al., Timler and Kulak conducted a test on single-storey large scale SPSW specimen under cyclic load. They modified the inclination angle of the tension field that proposed by Thorburn et al. and found reasonable agreement between the predicted angles of inclination with the measured angles during the test [3]. Roberts and Sabouri-Ghomi investigated unstiffened steel plate shear wall panels with centrally placed circular opening under quasi-Static cyclic load. Their results showed adequate ductility and stable S-shaped hysteresis loops. In addition, strength and stiffness of the panels decreased approximately linearly with increasing size of openings [4]. In another experimental study, Driver et al. assessed seismic performance of a half-scale four-storey unstiffened steel plate shear wall. Their results showed that specimen was initially stiff, very ductile, and with significant energy absorption. Also, a large deformation capacity existed after yield point and moment resisting boundary frame prevented the severe pinching of the hysteresis