Effects of Circular Opening Dimensions on the Behavior of Steel Plate Shear Walls (SPSWs)

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Abstract

In recent years there is a developing attention to steel plate shear walls (SPSWs) thanks to their proper function exposing to lateral wind and earthquake loads. Furthermore, their application in steel and concrete structures in order to strengthening them has raised a lot of focus upon. In some cases existence of opening is unavoidable due to architectural reasons or installed heating and cooling systems on the walls. That leads to a decrease in capacity and improper functioning of these systems that also results in an intense variation in in-plane stress distribution. In this paper impact of circular opening dimensions on behavior of steel plate shear walls has been closely studied. On this purpose using ABAQUS finite element method a nonlinear analysis has been conducted considering geometrical and material nonlinearity in the models. Analyzed models indicate that the reduction factor $(1\text{-}D/H)^S$ and $(1\text{-}D/H)$ respectively for resistance value and stiffness value predict lower error versus the increases in opening diameter.

Keywords: Steel plate shear wall, Opening, Nonlinear analysis, Initial Stiffness, Ultimate capacity

1. INTRODUCTION

Since early 1970‘s several types of steel plate shear walls are offered in order to use in lateral resistant system of structures. The first vast research program on steel shear panels is carried out by Takahashi and his colleagues in 1973 [1]. They have performed some tests with quasi static loading and unloading on stiffened and unstiffened steel shear panels in one or two stories. The initial method for analyzing and designing of steel shear walls is commenced with replacement of steel plate with some equivalent diagonal truss elements [2 and 3]. Now, the base of recommendations in Canadian steel structures design code about steel shear walls are comply with mentioned method. In the late 1980s, Sabouri and Roberts [4] did their theoretical and laboratory investigations related to steel shear walls which are caused a new method for analyzing and designing of the walls called Plate and Frame Interaction method (PFI). Consequently, results of 16 tests on steel shear panels are given with a low yielding stress steel plates and aluminum plate with opening. The results are redounded to offering reduction coefficient for resistance and stiffness because of openings in the walls [5 and 6]. In the year of 2005 a creditable test performed by Kharrazi [7] on one story shear panel to develop an innovated method called Modified Plate and Frame Interaction (M-PFI). In addition to shear force, overturning moment was also considered which results in attaining conservative outputs. According to improve the previously offered reduction coefficients, in this paper are suggested new reduction factors to be used in steel plate shear walls with openings at the center. It is also considered the effect of diameter increasing of openings on structural behavior of shear walls.

2. FINITE ELEMENT MODELING

All the specimens are composed of frame and infill steel shear plate which are analyzed using ABAQUS program. Prediction of models behavior is based on nonlinear quasi-static analysis including geometric and material effects. The plate and boundary elements of frame are modeled using shell element of S4R. This is a four nodes and double curvature element with 6 degrees of freedom. The material is isotropic with the same strain hardening inelastic behavior in tension and compression. The yield stress and ultimate strain are respectively assumed 250 MPa and 0.00625 for the infill plates and 350 MPa and 0.00875 for the frame elements. E=200 GPa, E_t=2 GPa and Poisson‘s ratio = 0.3 are assumed. The Von-Misses yielding criterion is adopted. All models are loaded by applying a lateral displacement control system at conjunction nodes of beams to columns.