Effect of Openings in Stiffened Steel Plate Shear Walls using Ansys

Isha Verma, S. Setia

***Abstract:** In Recent Years Researchers Have Shown High Interest In Application Of Steel Plate Shear Walls For Construction Of Commercial And Residential Buildings Due To Its Better Seismic Behavioral Properties. Due To Certain Architectural Requirements It Becomes Imperative To Induce Openings Which Compromise With The Load Resisting Behavior Of Building Structures. This Research Investigates The Effect Of Opening On Spsw Using Techniques Of Fea (Finite Element Analysis). The Opening Types Used In Analysis Are Circular And Rectangular Shape. The Cad Model Is Developed In Design Modeler And Analysis Is Conducted In Static Structural Platform Of Ansys Workbench. The Stresses, Deformation And Buckling Loads Are Determined From Simulation.*

***Keywords:** SPSW, Openings, FEA, ANSYS*

I. INTRODUCTION

From last three decades there has been limited use of steel plate shear walls (SPSW) as primary load resisting system. Various research programs were conducted in last three decades to study seismic behavior of SPSW at United States, Canada and Japan. Various building all over world represent good example to use SPSW as primary lateral force resisting system for example: United States Federal Courthouse situated at Seattle, WA has 23-story building (350') utilizing SPSW , Sylmar Hospital, Los Angeles, CA has six-story building using SPSW, Canam-Manac Headquarters Expansion, St. George, Quebec— six-story building etc.

Figure 1: Planar SPSW

The application of SPSW has been tested in Kobe office building and Sylmar hospitals which were exposed to fairly significant earthquakes in 1994 without causing much structural damage [1] which was tested since 1970s and recognized in the National Building Code of Canada (NBCC) since 1994.

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After that it is included in the American Institute of Steel Construction (AISC) Seismic Provisions in 2005. The research on SPSW begun from early 70's. Un-stiffened SPSW and thin SPSW system [1] are commonly used and applied in North America. Widespread use of SPSW system initially started in Japan.

A. Advantages of SPSW

Wall Thickness: As compared to thickness of concrete shear walls, SPSW need less structural wall thickness. From the study conducted on Century project, the findings have shown that average wall thickness required is 18" as compared to concrete wall thickness of 28". Cost savings amounted to 2% per square feet.

Building Weight: SPSW structures are lighter in weight as compared to buildings that use concrete shear walls. Results by Century project shows that total weight reduction of 18% is obtained from building made from SPSW system also results in reduction of foundation loads due to gravity and overall building seismic loads.

Fast Construction: Considerable reduction of construction time is achieved using SPSW system. Also easy to erect and no curing period required. A Century project study indicated a one-month reduction in construction time. The findings from federal courthouse have also indicated easy erection of SPSW as compared to concentrically braced frames.

Ductility: Post buckling capacity of thin steel plate is excellent. The tests have shown that SPSW systems can bear 4% drift without experiencing much damage and damages were noticed on outside of steel plate panel. It is observed that due to bending, some pinching and tearing close to the corners of the panel occurred. However, Plate capacity and stiffness does not reduce due to tearing[1].

B. Disadvantages of SPSW

Stiffness: The SPSW systems exhibits higher flexural flexibility in comparison to concrete shear walls. Therefore, when using SPSW in tall buildings, the engineer must provide additional flexural stiffness.

Construction sequence: Excessive initial compressive force in the steel plate panel may delay the development of the tension-field action. The sequence of construction should be such that excessive compression of panel is avoided.

II. LITERATURE REVIEW

Memarzadeh et al. [2] conducted a study on dynamic explicit analysis of a steel plate shear wall subjected to ElCentro earthquake. Hong-Gun Park et al. [3] reviewed the cyclic nonlinear analysis of thin infill plate. Infill steel plates were idealized with inclined tension strips. Abhishek Verma et al. [4] carried out a study on push over analysis of unstiffened steel plate shear wall. Steel plate shear wall with relatively larger aspect ratio exhibits the greater loadcarrying capacity and deformation capacity than the one with smaller aspect ratio. The ultimate load carrying capacity increases linearly with increasing the thickness of steel plate. Valizadeh et al. [5] conducted experimental investigation on cyclic behaviour of perforated steel plate shear walls. The creation of openings decreases the initial stiffness and strength of the system. Existence of an opening at the center of the panel causes a noticeable decrease in energy absorption of the system. ErfanAlavi et al. [6] conducted experimental study on diagonally stiffened steel plate shear walls with perforation. A circular opening with the dimension of diameter adopted was ⅓ depth of the panel at the wall center. Jian Guo Nie et al. [7] conducted experiments on lateral resistance capacity of stiffened steel plate shear walls. Various test results proved showed that stiffeners used as reinforce the openings which enhance the stiffness and stability of steel plate shear walls.

III. OBJECTIVE

The current research is intended to study the behavior of steel plate shear walls subjected to different types of opening i.e. rectangular shape, circular shape. The analysis type includes structural and eigen value buckling type and analysis platform is ANSYS workbench.

IV. METHODOLOGY

To carry out the analysis FEA (Finite Element Analysis) method is used which is based on discretization of volume. The analysis is conducted in three stages which involves preprocessing, solution and post processing of results. The details are described below.

A. Preprocessing Stage

The CAD model of SPSW is developed at this stage followed by meshing and applying loads and boundary conditions. The CAD model of SPSW as per specified dimensions is developed in ANSYS design modeler as shown below.

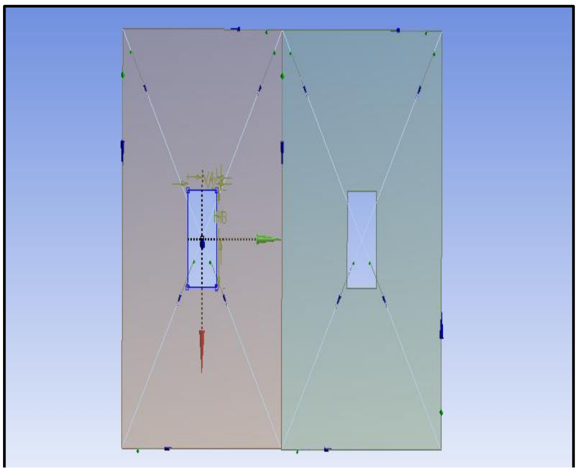

Figure 2: CAD model of SPSW using ANSYS design modeler

The CAD model developed is imported in ANSYS mesher where it is meshed using hexahedral elements. The meshing involves discretization of continuous body into elements and nodes as shown below. Total number of elements formed is 9472 and total number of nodes generated is 10190.

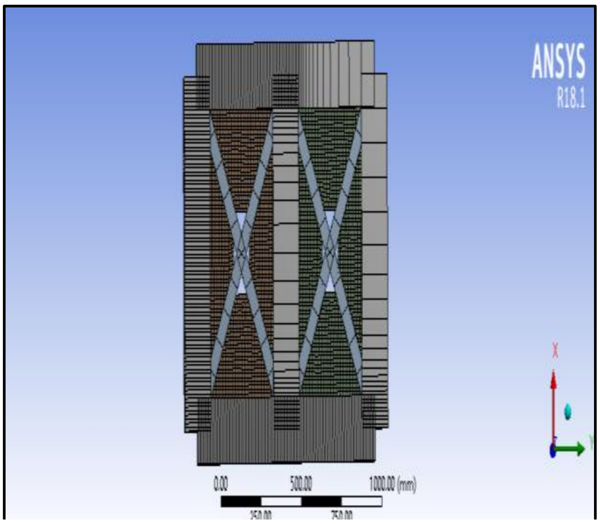

Figure 3: Meshed model of SPSW

The loads and boundary conditions are assigned after meshing stage. The bottom face is applied with fixed support and top face is applied with static load of 900000N as shown in figure 4 below.

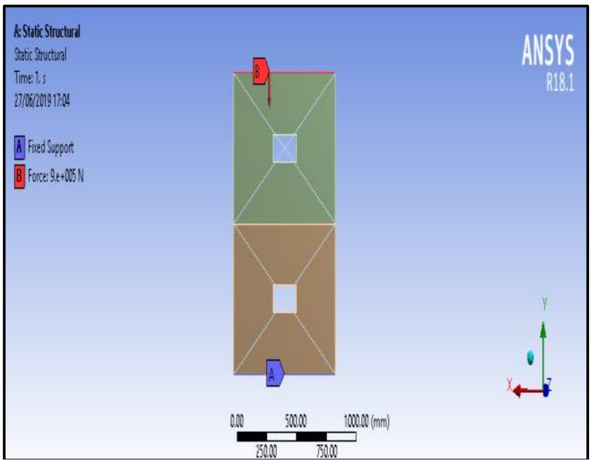

Figure 4: Loads and Boundary Conditions

C. Solution Stage

In solution stage software carries formulations of element stiffness matrix, assemblage of global stiffness matrix along with inversions and multiplications. The results are calculated at nodes and interpolated for entire element edge length. The solution time depends on meshing i.e. high computational time for fine meshing and low computational time for coarse meshing.

D. Post Processing Stage

In post processing stage the results of stresses deformation and buckling are viewed and changes for material or designs are suggested.

V. RESULTS AND DISCUSSION

From the analysis is conducted on first design i.e. rectangular shape the buckling load and stresses are determined along with deformation. The deformation plot is shown below.

CASE 1: Rectangular Hole

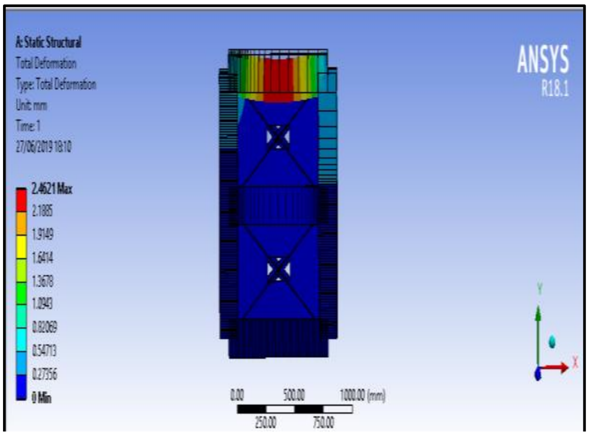

Figure 5: Deformation using rectangular opening

The deformation plot using rectangular hole is shown in figure 5 above shows maximum deformation value of 2.46mm on top mid portion of SPSW while other portion has lower deformation as shown by light blue contour and dark blue contours.

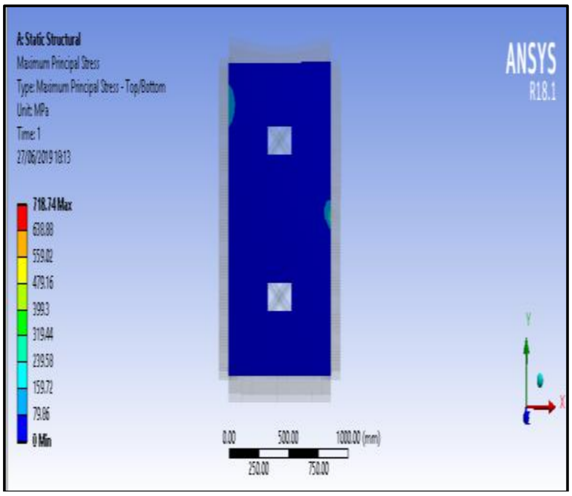

Figure 6: Maximum principal stress

The maximum principal stress value is obtained on right most portion of first floor with magnitude of 718.74 MPa and on left most portion of 2nd floor. The remaining portion of SPSW has lower maximum principal stress values.

After conducting buckling analysis, the buckling load using eigen value method is found out using following formula:

Buckling load = load multiplier * applied load

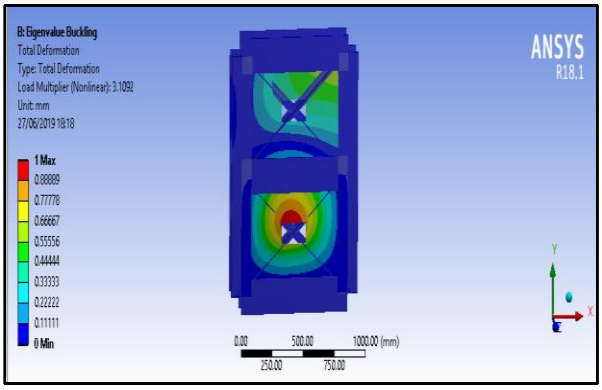

Figure 7: Load multiplier for buckling analysis with rectangular hole

The load multiplier from buckling analysis is found to be 3.1092 which has to be multiplied to applied load to determine buckling load which gives 2798280 N as magnitude.

CASE 2: Circular Opening

The results of FEA analysis using circular opening is described below.

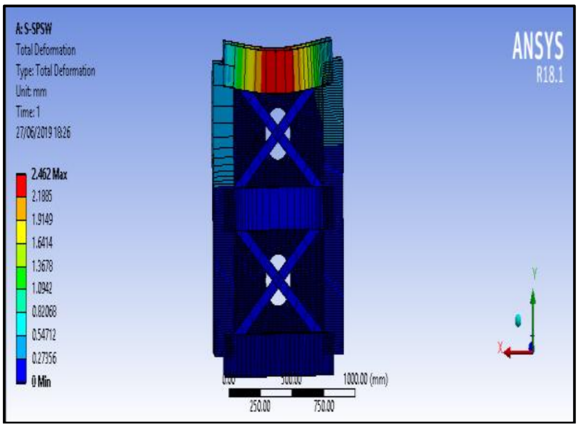

Figure 8: Deformation using circular hole

The deformation plot using circular hole is shown in figure 8 above shows maximum deformation value of 2.46mm on top mid portion of SPSW while other portion has lower deformation as shown by light blue contour and dark blue contours. The principal stress plot is shown in figure 9 below. The plot shows maximum magnitude of principal stress of 705.82 MPa. The two portions have higher magnitude of stresses which are on top right portion of lower segment and top left portion of upper segment.

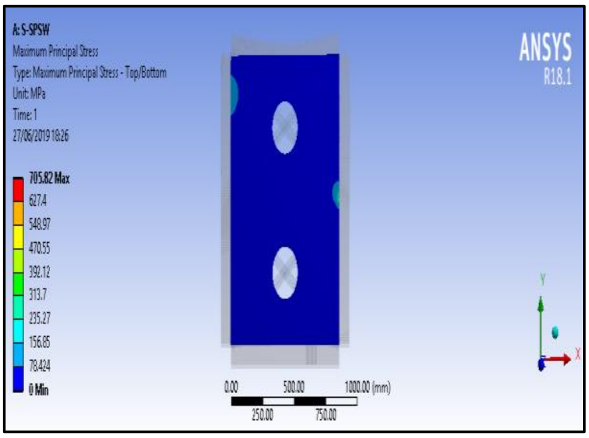

Figure 9: Maximum principal stress using circular hole

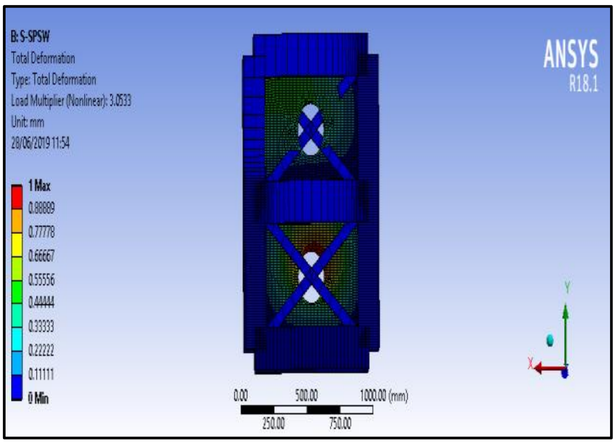

Figure 10: Load multiplier for buckling analysis with circular hole

The load multiplier value obtained from analysis is shown in figure 10 above which shows maximum magnitude of 3.0533. On multiplying this load multiplier to applied load we get the value of 2747970N.This calculated value is buckling of SPSW.

Table 1: Result comparison between two designs

Design Type	Principal Stress (MPa)	Buckling Load (N)
Rectangular Opening	718.74	2798280
Circular Opening	705.82	2747970

As its evident from figure 11 below, the maximum principal stress generated under given loading conditions is observed using rectangular opening in SPSW which is of magnitude 718.74 MPa and circular opening shows lower principal stress which if of magnitude 705.82 MPa.

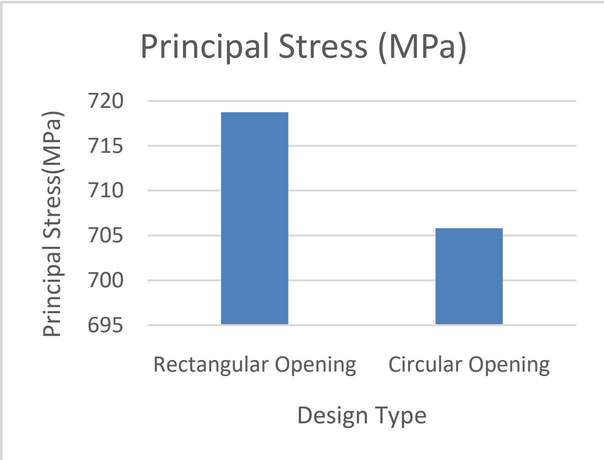

Figure 11: Principal stress comparison using different types of openings

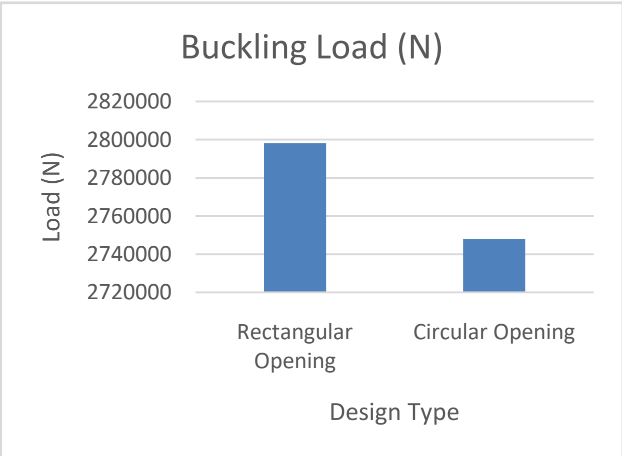

Figure 12: Buckling load comparison using different types of openings

From buckling load comparison as shown in figure 12 above, it shows that SPSW design with rectangular opening has higher buckling load in magnitude of 718.74 MPa and circular opening has lower buckling load in magnitude of 705.82MPa.

VI. CONCLUSION

In this study the behavior of Steel plate Shear Walls with two different types of wall openings are analyzed using ANSYS software. The wall openings used for analysis of SPSW are rectangular type and circular type. Under the given conditions of applied load, the findings have shown that SPSW with rectangular opening has higher magnitude of principal stresses as compared to SPSW with circular opening. The critical buckling load calculated from FEA analysis shows that load required to buckle SPSW with rectangular opening is higher as compared to circular opening type. The buckling load difference is 50310N which is 1.79% higher for SPSW with rectangular opening type.

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