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Cyclic Response of Steel Plate Shear Wall with Corrugation and Perforations

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Abstract

Steel plate shear walls are widely used nowadays because of the attracting resistance to cyclic loading. In this paper a new technology is applied by providing corrugations and perforations of different shapes such as circular, square, triangle and diamond shapes. Corrugated steel late shear walls construction is an innovative and efficient lateral force resisting construction. This study is an investigation on the cyclic response of the steel plate shear wall (SPSW) with corrugation and geometric perforations. The corrugated steel plate shear wall was modeled and analyzed in ANSYS 16.2 workbench and the result shows that the CSPSW can withstand under cyclic loading. Introducing corrugation and different perforations shapes in the steel plate shear wall act as a passive energy dissipator and also result in reduction of the total weight of the structure and also wastage of materials can be reduced.

Keywords: *corrugated steel plate shear wall, perforations, cyclic loading, energy absorption, hysteresis curve.*

1. Introduction

Steel plate shear walls with corrugation are an attractive, innovative and efficient option for earthquake engineering design. Number of experimental and computational programs have been conducted on CSPSW and have been implemented in buildings located in Canada, Japan and elsewhere. Corrugated steel plate shear wall(CSPSW)construction have been widely used has an effective lateral load resisting construction due to the reason including significant strength, ductility, reduced cost, high initial stiffness, lighter weight, less invasive construction; faster erection and increased speed of construction are the primary motivation of these type constructions. Compared with SPSWs, the out of plane stiffness of the infill panels is increased significantly due to corrugation. The main function of corrugated steel plate shear wall is to mitigate the early buckling behavior of CSPSW and to resist the horizontal story shear and overturning moment due to the lateral loads. The investigation of corrugated steel plate shear wall with perforations is limited.

The inclusion of the perforation on the CSPSW reduces the wastage of materials, act as energy dissipator and also reduces the total weight of the structure. Therefore, in this paper, the cyclic responses exhibited by CSPSW with different geometric perforations are investigated and compare the energy absorption.3D non-linear finite element analyses software, ANSYS 16.2 has been chosen to conduct the investigation.

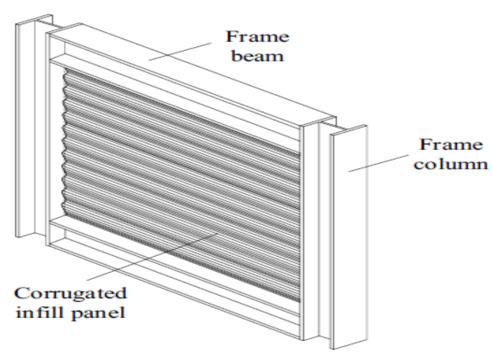

Fig.1. Corrugated steel plate shear wall

2. Objectives

This study will mainly be focused towards the energy absorption and stiffness. The Main objectives of the study are;

1) To study the variation of cyclic response of SPSW with various geometric perforations and Corrugations based on the cyclic loading.

2) To compare and discuss the stiffness and energy absorption behavior of CSPSW based on the analyzed perforations using parametric study

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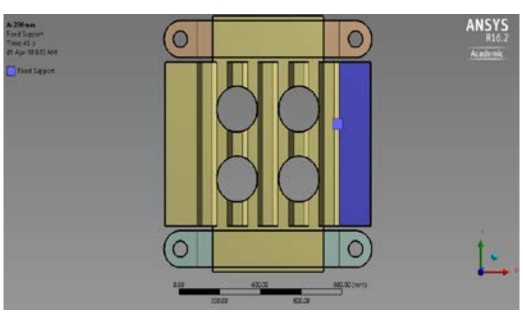
3. Structural Model and Material Property

Corrugated Steel Plate Shear walls with perforations of different shapes such as circular, diamond and square shapes were modeled. Trapezoidally corrugated steel plate shear walls with perforations are studied and analyzed with the finite element package ANSYS 16.2. The models were meshed and then fixed support condition was given at the right end (see Fig. 2) and then the cyclic load was applied for the analysis. Boundary conditions are provided according to the experimental setup. The supporting members are modeled to create fixed end condition at the right side and free end at the left side are displaced up and down. The material properties are illustrated in table.1

Table.1 Material properties

Properties	Values
Plate thickness (mm)	13
Modulus of elasticity (Pa)	2.1e+11
Yield strength (Pa)	3.1e+08
Ultimate strength (Pa)	4e+08
Poisson's Ratio	0.3
Density (kg/m^3)	7850
Young's modulus (Pa)	2e+11
Bulk modulus (Pa)	1.6667e+11
Shear modulus (Pa)	7.6923e+10
Tangent modulus (Pa)	6e+08



. Fig 2 Fixed Supports

3.2 Loading program

Two types of loading programs were employed to investigate the behavior of steel plate shear wall and to simulate earthquake load, quasi static cyclic loading and monotonic loading. Quasi static cyclic loading were performed under displacement controlled loading. The loading is started from 0sec and is continued upto 43sec. Quasi static cyclic displacement controlled loading graph is illustrated in Fig.3.

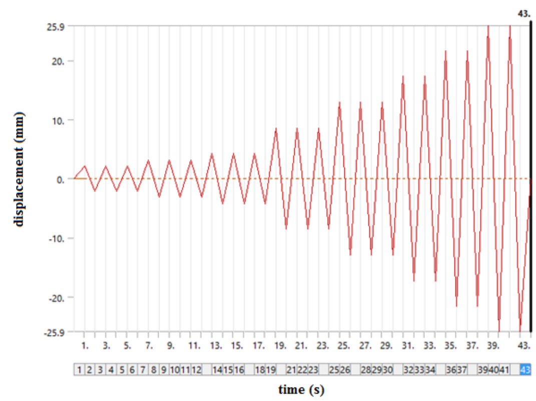


Fig .3 Quasi static cyclic displacements controlled loading graph

The CSPSW was loaded according to ATC 24 loading protocol. The ATC-24 loading protocol was adopted assuming a shear distortion angle at yield, δy/a= 0.5%, to allow a consistent loading protocol for all specimens where, a, is the horizontal distance between pins, a= 864 mm, displacement protocol are illustrated in table.2. The same loading pattern is applied to all the CSPSW inorder to study the effect in difference in the shape of perforations in the steel plate.

Table.2 Displacement Protocol

shear displacement δ	shear displacement, δ (mm)	Shear distortion angle, δ/a, %	Number of cycles
0.5 δy	2.2	0.25	3
0.75 δy	3.2	0.37	3
1.0 δy	4.3	0.5	3
2δy	8.6	1	3
3δy	13	1.5	3
4δy	17.3	2	2
5δy	21.6	2.5	2
6δy	25.9	3	2

3.3 Modelling

Corrugated steel plate shear wall with openings are considered for the investigation of steel plate shear wall under lateral loading. All the geometrically different steel plate shear walls have the same material properties and boundary conditions. Trapezoidally corrugated steel plate shear walls with 50mm corrugation depth were considered for the study. Geometry of trapezoidally CSPSW and Different numerical models used for the study are illustrated in Fig.4 –10

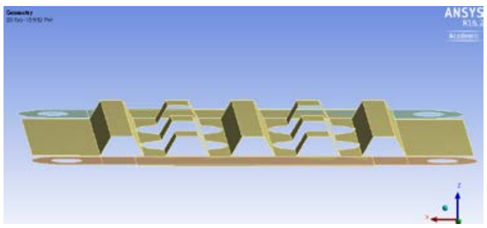


Fig.4 Geometry of trapezoidally CSPSW

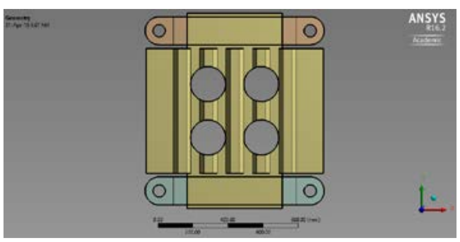


Fig.5 Corrugated steel plate shear wall with 200mm diameter opening

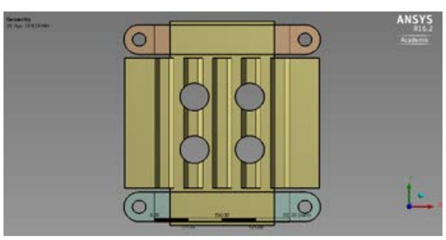


Fig.6 Corrugated steel plate shear wall with 150mm diameter opening

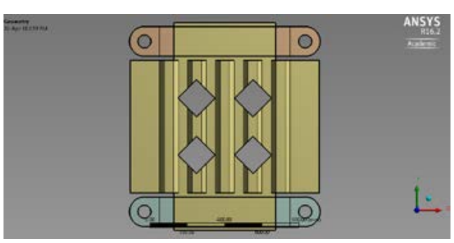


Fig 7 Corrugated steel plate shear wall with diamond shape inscribed in 200mm diameter opening

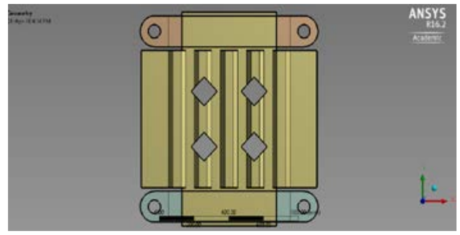


Fig 8 Corrugated steel plate shear wall with diamond shape inscribed in 150mm diameter opening

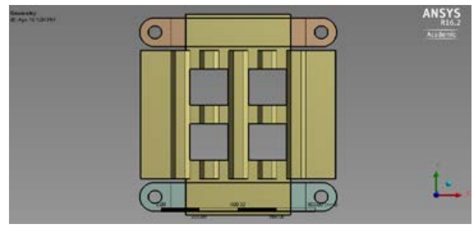


Fig.9 Corrugated steel plate shear wall with square shape inscribed in 200mm diameter opening

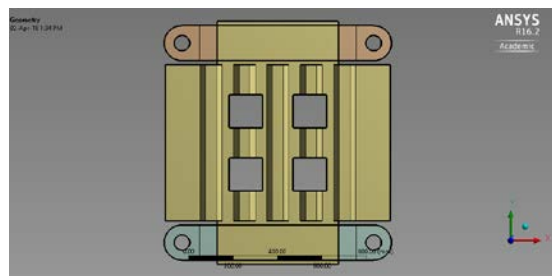


Fig. 10 Corrugated steel plate shear wall with square shape inscribed in 150mm diameter opening

3.4 Meshing

It is the most important part of an analysis and is done to discrete the structure. Mesh convergence is used to fix the size of the element. Here a mesh size of 15mm is provided for all the models. Fig 11 shows the meshing.

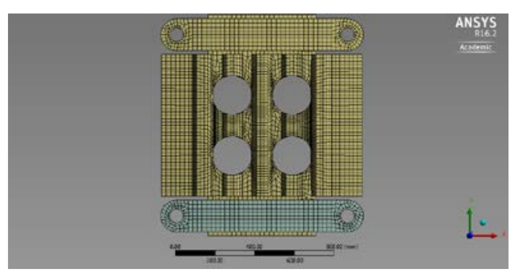


Fig. 11 Meshed View

The displacement load and direction of displacement load applied is shown in the Fig 12 and Fig 13

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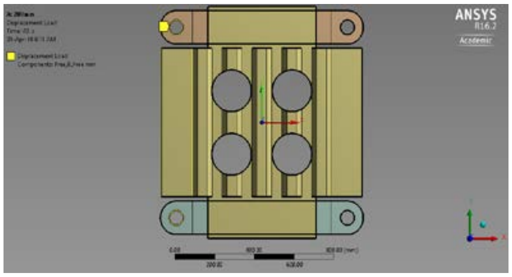

Fig.12 Displacement load

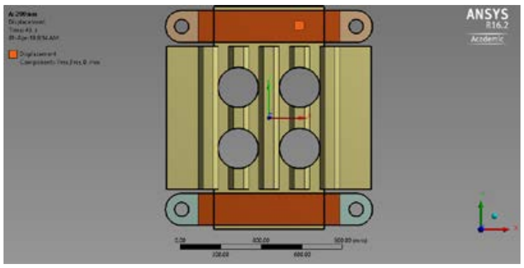

Fig. 13 Direction of Displacement Load

4. Results and Discussions

During a severe earthquake the structure is likely to undergo inelastic deformations and has to rely on its hysteretic energy absorption capacity and ductility to avoid collapse. The results of non linear static analysis of corrugated steel plate shear walls under cyclic loading condition are presented here

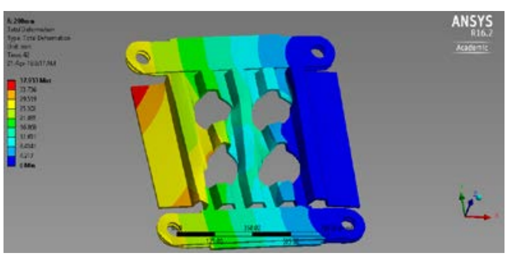

Fig 14 Total Deformation of CSPSW with 200mm diameter circular opening

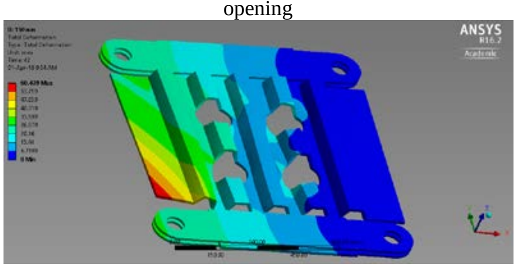

Fig 15 Total Deformation of CSPSW with 150mm diameter circular opening

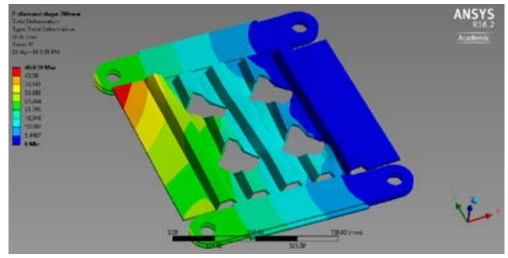

Fig 16 Total Deformation of CSPSW with diamond shape inscribed in 200mm diameter opening

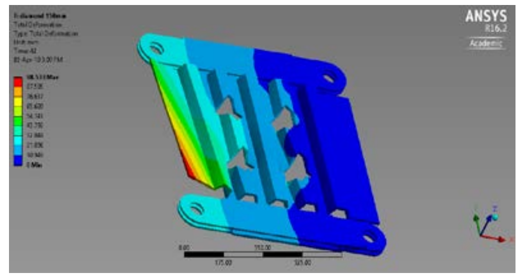

Fig 17 Total Deformation of CSPSW with diamond shape inscribed in 150mm diameter opening

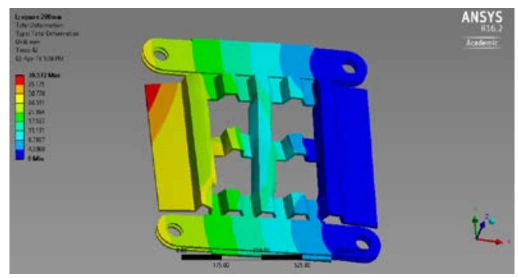

Fig 18 Total Deformation of CSPSW with square shape inscribed in 200mm diameter opening

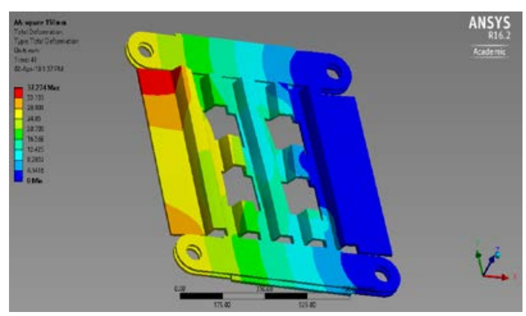

Fig 19 Total Deformation of CSPSW with square shape inscribed in 150mm diameter opening

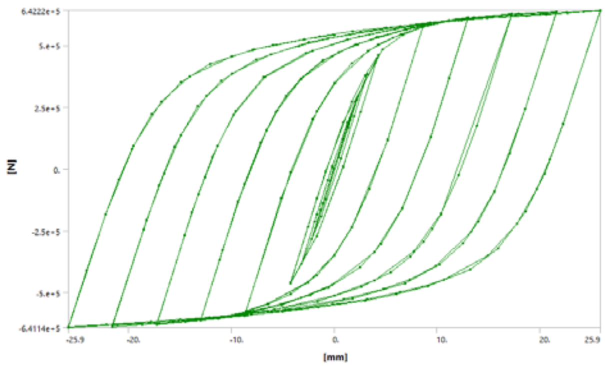

Fig 20 Hysteresis curve with of CSPSW with 200mm circular diameter opening

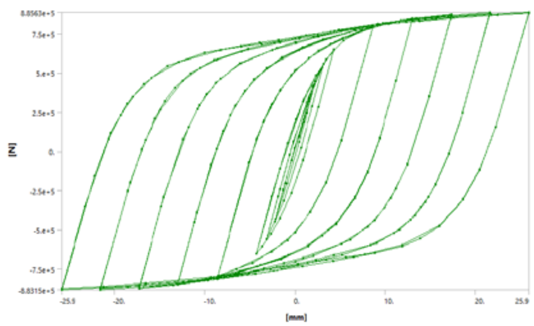

Fig 21 Hysteresis curve with of CSPSW with 200mm and 150mm circular diameter opening

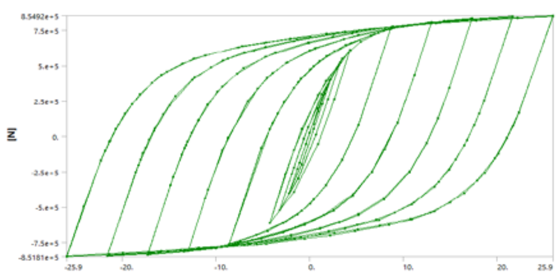

Fig 22 Hysteresis curve of CSPSW with diamond shape inscribed in 200mm diameter opening

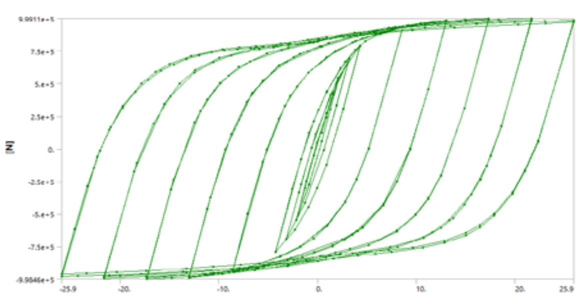

Fig 23 Hysteresis curve of CSPSW with diamond shape inscribed in 150mm diameter opening

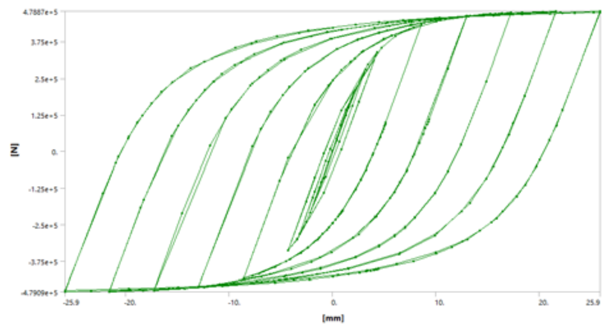

Fig.24 Hysteresis curve of CSPSW with square shape inscribed in 200mm diameter opening

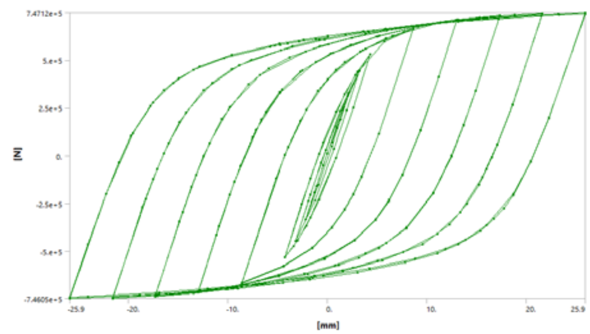

Fig.25 Hysteresis curve of CSPSW with square shape inscribed in 150mm diameter opening

The total energy absorption, stiffness and total deformation of various models are illustrated in table 3. The area under the hysteresis curve gives the total energy absorption.

Table 3 Energy Absorption, Stiffness and Total deformation Obtained by CSPSW with Different Perforation Shape

Shapes	Diameter (mm)	Energy absorption (Nmm)	Total deformation (mm)	Stiffness (N/mm)
Circle	200	2.82E+08	37.953	24796.2
	150	4.08E+08	60.479	34194.2
Diamond	200	3.86 E+08	49.039	33008.5
	150	5.32 E+08	98.531	38001.5
	200	2.10 E+08	39.572	23060.2
Square	150	3.30 E+08	37.274	28846.3

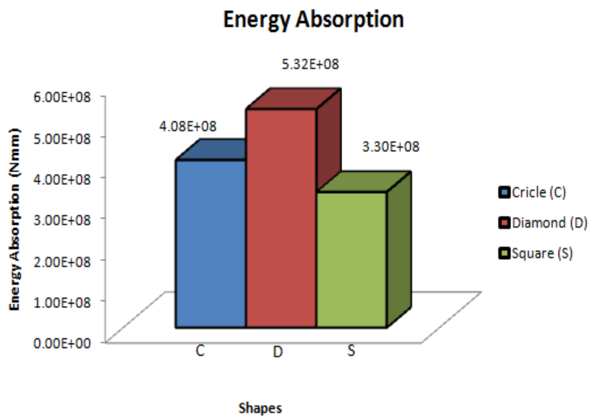

Fig 26 Comparison of Energy Absorption obtained from CSPSW with Different Shapes

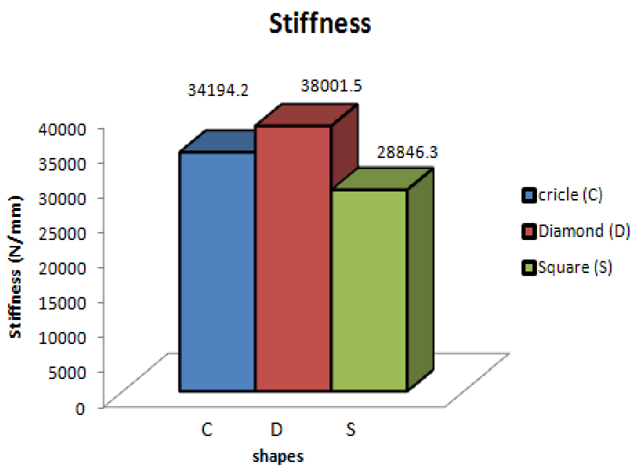

Fig 27 Comparison of stiffness obtained from CSPSW with Different Shapes

Conclusions

The Corrugated steel plate shear wall has been given a new modification by providing perforation with different diameters in the steel plate. The corrugated steel plate shear wall was providing perforations in order to reduce the wastage of the material and to inhibit the energy dissipation. The perforations of different shapes are arranged in horizontal strips. The CSPSW is subjected to cyclic loading based on ATC 24 loading protocol. After the cyclic analysis of CSPSW it is seen that the CSPSW with diamond shape shows more energy absorption and gives more stiffness than other shapes. Hence we can recommend using CSPSW with, diamond shape inscribed in 150mm diameter opening which has energy absorption and stiffness more than that of CSPSW with other opening.

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