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STUDY OF STEEL PLATE SHEAR WALL UNDER PROLONGED SEISMIC EXCITATION

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Abstract – *A Steel plate shear walls are widely used nowadays because of the attracting resistance to cyclic loading. This system offers several advantages as compared to the other usual lateral load resisting systems. Steel saving, speed of erection, reduced foundation cost, and increased usable space in buildings are some apparent advantages of the steel plate shear walls. Steel plate shear walls also provide major stiffness against building drift for the hi-rise buildings. Steel plate shear walls are capable of remaining stable under seismic loading due to their satisfactory hysteretic performance. However, since the thin steel web infills within these walls only yield under tension and in most cases exhibit no significant compressive resistance, their behavior is uncertain under long duration of shaking. The scope of this research is to investigate whether there is a point in time where the steel plate shear wall behavior becomes that of its own bare frame when subjected to excessive shaking, which would indicate that the steel web plates no longer contribute to response. This study is an investigation on the performance and behavior of steel plate shear wall under prolonged seismic waves. Modelling and analyzing of steel plate shear walls will be done by using ANSYS.*

Key Words: **steel plate shear wall, corrugated steel plate, perforation, seismic analysis, deformation, shear stress, energy absorption, stiffness**

1. INTRODUCTION

A steel plate shear element consists of steel infill plates bounded by a column-beam system. When these infill plates occupy each level within a framed bay of structure, they constitute a steel plate wall (SPW). Its behaviour is analogous to a vertical plate girder cantilevered from its base. Similar to plate girders, the SPW system optimizes component performance by taking advantage of the post-buckling behaviour of the steel infill panels. An SPW frame can be idealized as a vertical cantilever plate girder, in which the steel plates act as the web, the columns act as the flanges and the cross beams represent the transverse stiffeners. The theory that governs plate design should not be used in the design of SPW structures since the relatively high bending strength and stiffness of the beams and columns have a significant effect on the post-buckling behaviour.

In the past two decades the steel plate shear wall (SPSW), also known as the steel plate wall (SPW), has been used in a number of buildings in Japan and North America as part of the lateral force resisting system. In earlier days, SPSWs were treated like vertically oriented plate girders and design procedures tended to be very conservative. Web buckling was prevented through extensive stiffening or by selecting an appropriately thick web plate, until more information became available on the post-buckling characteristics of web plates.

Although the plate girder theory seems appropriate for the design of an SPW structure, a very important difference is the relatively high bending strength and stiffness of the beams and columns that form the boundary elements of the wall. These members are expected to have a significant effect on the overall behavior of a building incorporating this type of system and several researchers have focused on this aspect of SPWs. The energy dissipating qualities of the web plate under extreme cyclic loading has raised the prospect of using SPSWs as a promising alternative to conventional systems in high-risk seismic regions.

2. AIM

To evaluate the performance of corrugated steel plate shear wall with different size of perforations.

3. OBJECTIVES

- To study the variation of cyclic response of SPSW with geometric perforations and corrugations based on prolonged seismic loading.
- To compare and discuss the energy absorption behavior and stiffness of CSPSW based on the analyzed perforation.

4. SCOPE

Investigation on the fundamental behavior of ideally ductile SPSWs to determine how they can possibly achieve satisfactory seismic response throughout seismic excitation given that the tension-only hysteretic behavior of the infill plate is believed to dominate this hysteretic response. This is achieved by using progressively longer synthetic ground motions.

5. MODELLING

5.1 Model for Numerical Study

Corrugated Steel Plate Shear walls with perforations of different shapes such as circular, diamond and triangular shapes, SPSW with different corrugations such as sinusoidal and trapezoidal corrugations were modeled. The validated finite element model is used for the modeling and analysis of the entire geometrically different steel plate shear wall. Trapezoidal and sinusoidal corrugated steel plate shear walls with perforations are studied and analyzed with the finite element package ANSYS Workbench 16.0. Circular, triangular and diamond perforations are used whose size varying from 500mm, 650mm, 800mm and 950 mm. The models were meshed and then fixed support condition was given and then the cyclic load was applied for the analysis. Shell element is used for the analysis of thin to moderately thick shell structures and also suitable for linear and large strain nonlinear applications.

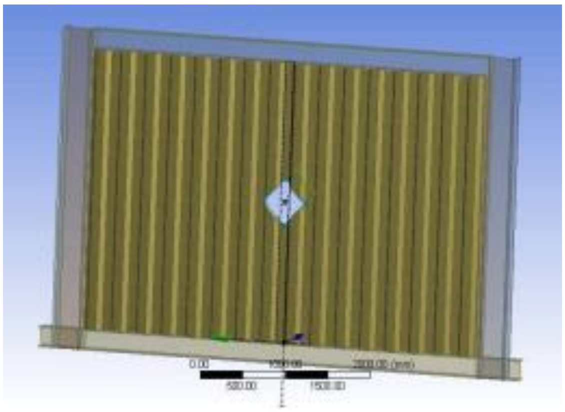

Fig-1: Corrugated steel plate shear wall with 500mm diamond opening

The height and length of the story panel are 3.2 m and 4.8 m, centerline to centerline, respectively, simulating the conventional residential building. The moment frame is modelled as rigid frame construction with regard to girder-to-column connections. The Steel plate Shear Wall (SSW) and Corrugated Steel plate Shear Wall (CSSW) without openings are designed based on the PFI method in which the plate–frame interaction is precisely considered; thus, the effect of vertical load was ignored. The girder is modelled as laterally braced against the out-of-plane movement, simulating commonly observed construction conditions. Total 24 models were analyzed.

5.2 Boundary Condition and Material Properties

Boundary conditions are provided according to the experimental setup. The beams to column connections are moment resisting, therefore all intersecting shell elements are directly connected. The steel shear wall is connected directly and continuously to the columns and girder. Material properties are given in the table below:

Table -2: Material Properties

Sl.No.	Properties	Values
1	Modulus of elasticity (Pa)	2.1e+11
2	Yield strength (Pa)	3.1e+08
3	Ultimate strength (Pa)	4e+08
4	Poisson's ratio	0.3
5	Density (kg/m^3)	7850
6	Bulk modulus (Pa)	1.6667e+11
7	Shear modulus (Pa)	7.6923e+10
8	Tangent modulus (Pa)	6e+08

5.3 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 applied by subjecting the model at the upper girder to monotonically increased lateral displacement.

6. RESULTS AND DISCUSSIONS

The cyclic response of CSPSW with different geometric perforations with two different corrugations were studied. During a severe earthquake the structure is likely to undergo inelastic deformations and has to rely on its absorption capacity and ductility to avoid collapse. The results of nonlinear static analysis of corrugated steel plate shear walls under cyclic loading condition are presented here. In the given charts;
SC- sinusoidally corrugated circular perforation,
SD- sinusoidally corrugated diamond perforation,
ST- sinusoidally corrugated triangular corrugation,
TC- trapezoidally corrugated circular perforation,
TD- trapezoidally corrugated diamond perforation and
TT- trapezoidally corrugated triangular perforation.

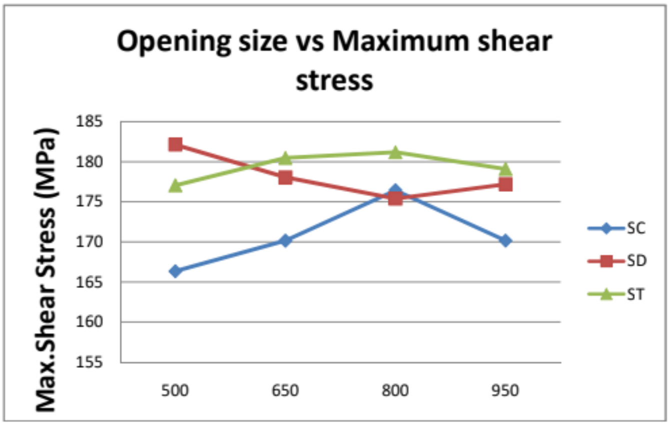

Chart-1:opening size vs maximum shear stress for sinusoidally corrugated SPSW

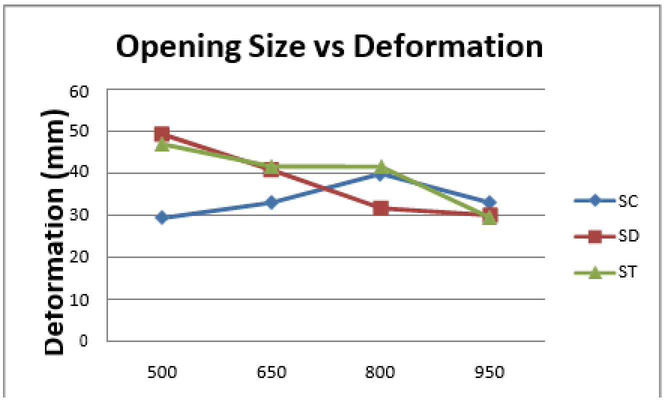

Chart-2:opening size vs total deflection for sinusoidally corruated SPSW

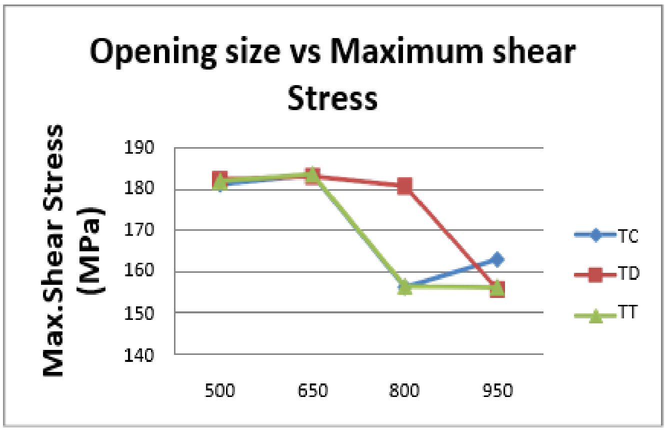

Chart-3:opening size vs maximum shear stress for trapezoidally corrugated SPSW

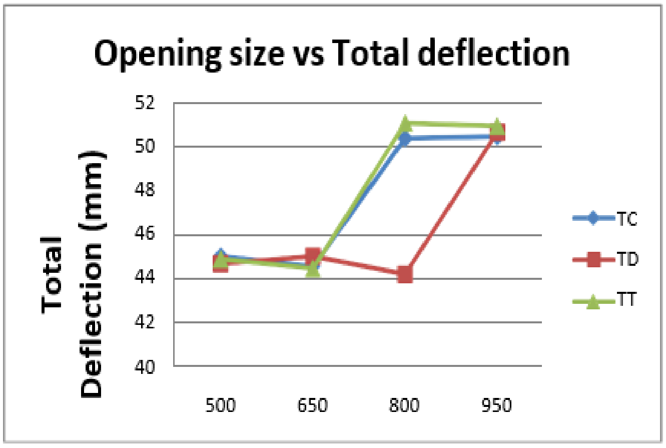

Chart-4: opening size vs total deflection for trapezoidally corrugated SPSW

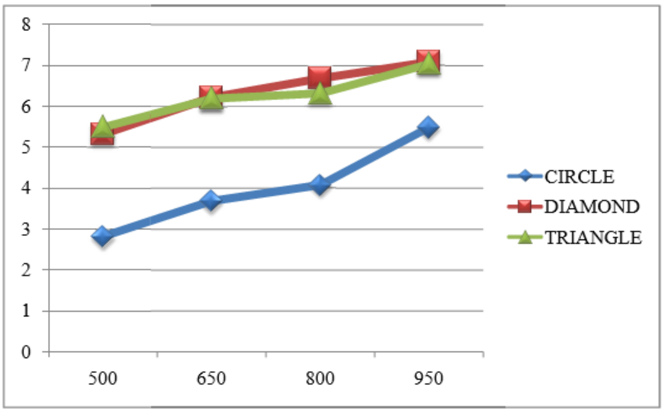

Chart-5:energy absorption graph for different perforation in sinusoidally corrugated SPSW

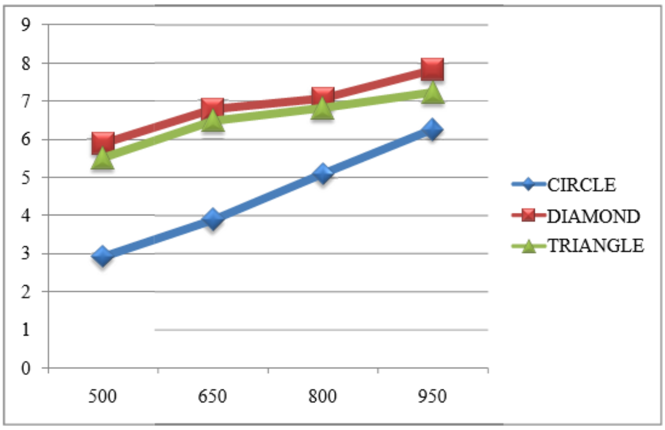

Chart -6: energy absorption graph for different perforation in trapezoidally corrugated SPSW

7. CONCLUSIONS

The following observations and conclusion can be drawn based on the analytical results of the study.

Circle and triangle shapes have more deformation when compared to diamond. Diamond shape is having the maximum area and each interior angle is 90^0 hence diamond 950mm shape is more effective. The comparison of deflection pattern with sinusoidal and trapezoidal corrugation indicates that trapezoidal corrugation gives the better results. Trapezoidal corrugation gives maximum shear stress values. In terms of stiffness results, sinusoidally corrugated shear walls are good when compared to trapezoidally corrugated shear walls. Trapezoidal corrugations have more ductility and more energy dissipation andit yields under plastic hinge formation. The corrugated steel plate shear wall with diamond and triangle perforation gives almost similar energy absorption than circular shape perforation.

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