International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2015): 6.391

Corrugated Steel Plate Shear Wall with Opening and Stiffener at Opening

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Abstract: ***The greater increase in the number of tall buildings the effect of lateral loads like earthquake forces creates greater damage to the entire structure. Steel plate shears wall system that is integrated into the frame of a structure that serves to accept and dissipate shearing forces that may be associated with seismic activity. The system consists of boundary elements of horizontal and vertical steel beams and thin web steel plate. The web plate may be flat or corrugated. Web plate remove burden of excessive lateral force generated by an earthquake from the system frame and the overall building frame. Openings may need to be created within the steel corrugated infill plate to accommodate for architectural purposes, passing utilities, and structural reasons. The ultimate strength of shear wall was varying when corrugation angle of panel changed. The strength of shear wall decreases when cutout provided at the center .The strength can be increased by providing stiffeners around the cutout. This paper conducting the study for selecting corrugated steel plate shear wall with higher load carrying capacity from out of these different angles (0º, 30º, 60º, 90º) of corrugation. Corrugation was provided with respect to the x axis. Study was also conduct by providing cutout at the center and stiffener around cutout of corrugated shear wall which carrying greater load carrying capacity.***

Keywords: Trapezoidal Corrugated Plates, Corrugated Angles, Cutout, Stiffener, Ultimate Strength.

1. Introduction

A steel plate shear wall (SPWs) is a lateral-load resisting system consisting of vertical steel plate infill connected to the surrounding beams and columns and installed in one or more bays along the full height of the structure to form a cantilevered wall. SPSW subjected to cyclic inelastic deformations exhibit high initial stiffness, behave in a very ductile manner, and dissipate significant amounts of energy. These characteristics make them suitable to resist seismic loading. In general, the system consists of boundary elements of horizontal and vertical steel beams and an array of thin steel plates, known as web plates .The horizontal and vertical boundary elements form part of the building frame, with the space between each horizontal boundary element being equal to one story of the building. The steel web plates are bolted to the boundary elements and receive energy associated with lateral forces from the building frame. Through development of tension field, the steel web plates consume much of the energy from the shear force and prevent it from destroying the building.

Before the addition of the steel web plates to the SPSW system, the assemblage of the horizontal and vertical boundary elements can be described as a simple Steel moment frame. Steel moment frame resists lateral forces by the yielding under extreme loading and bending of the horizontal and vertical frame elements. In the case of a major earthquake, the frame elements are designed to stretch and dissipate the seismic shearing forces. The steel web plates act as the primary force-dissipating elements in the system. They remove the burden of counteracting excessive lateral force that may be generated by an earthquake from the system frame and the overall building frame. Steel web plate is relatively thin and ductile.

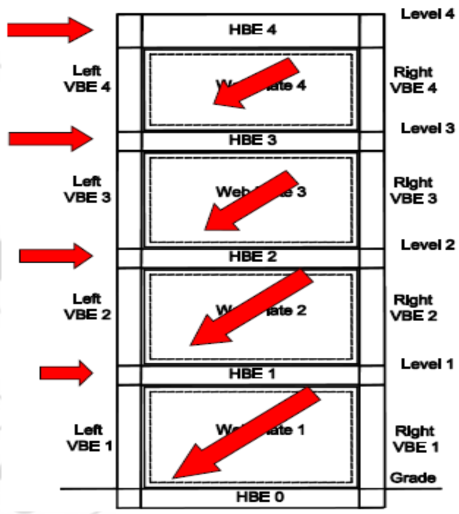

Figure 1: Behaviour of Steel Plate Shear Wall

The benefits the system are high ultimate bearing capacity, perfect plasticity, high energy absorption capacity, appropriate stiffness, reduced structural weight, lower foundation construction costs, better quality and high-speed construction. Corrugated steel plates, due to their ductility and low cost. On the other hand, in corrugate plates, the plates wave function is similar to that of the stiffeners and it has appropriate stiffness too.

2. Scope and Objectives

These are the main scope of the study,

1) Shear wall system are very important in case of tall buildings in earthquake prone areas to resist the lateral loads.

2) Corrugated and non-corrugated steel plate shear walls have become more widespread during these days and are much efficient than RC shear walls.
3) Openings may need to be created within the steel infill plate to accommodate for architectural purposes, passing utilities, and structural reasons.

These are the main objectives of the study,
1) To analyse the single storey trapezoidal corrugated steel plate shear wall,
   - Corrugation angle 0º of infill plate
   - Corrugation angle 30º of infill plate
   - Corrugation angle 60º of infill plate
   - Corrugation angle 90º of infill plate
2) To analyse the single storey trapezoidal corrugated steel plate shear wall with cutout at center.
3) To analyse the single storey trapezoidal corrugated steel plate shear wall with cutout and stiffener at center.

3. Analytical Investigations

3.1 Procedure

SPSWs were modeled and analyzed using ANSYS 16.1 finite element software. Shell element 281 was used for the modeling. This element has plasticity, stress stiffening, large deflection, and large strain capabilities, and is well-suited for modeling shells. In order to ensure high accuracy in modeling and analysis, convergence and mesh refinement studies are performed. A typical finite element model is shown in below. Fixed support was provided as boundary condition at bottom of the shear wall. Monotonic loading was provided in lateral direction. The load was provided at the top of beam in displacement control and in incremental manner. This work is carryout by providing boundary element as Indian standard. ISMB 225 was selected as beam and column element. 1.25mm selected as infill plate thickness. The panel size selected as 2000mmx1500mm. The yield stresses of the plate, beam, and column components are 210 MPa, 300 MPa, and 300 MPa respectively. Young's modulus of elasticity and Poisson's ratio are considered to be 210 GPa and 0.3, respectively for the steel material. Moreover, the von Misses yield criterion is adopted for the steel material yielding. In this work modeling was done by changing of corrugation angle of trapezoidal corrugated steel plate shear wall, by providing opening at the center and by providing stiffener around the opening .Opening size selected for study was 500mmx500mm.

3.2 Trapezoidal corrugated steel plate shear wall

Trapezoidal corrugated steel plate shear wall was created by changing the corrugation angle with 0º, 30º,60º,90º.Angle of inclination changed with respect to x axis .Analysis was done by using a single storey steel plate shear wall. The main purpose of changing angle of corrugation for selecting best angle which carrying higher ultimate strength. Models of different angles are shown below.

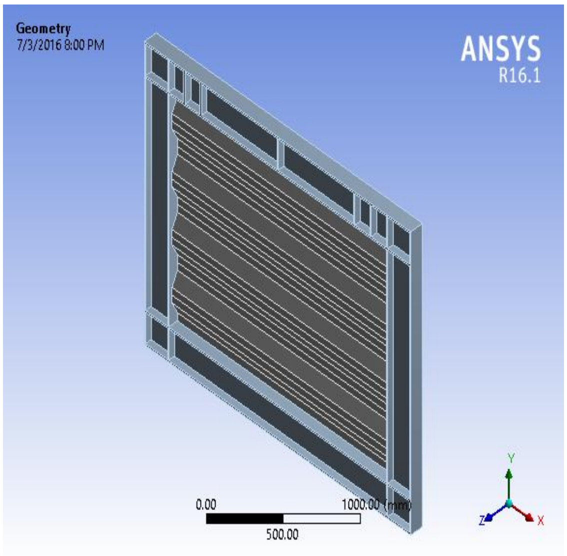

Figure 2: Trapezoidal corrugated steel plate shear wall with 0 º corrugation angle

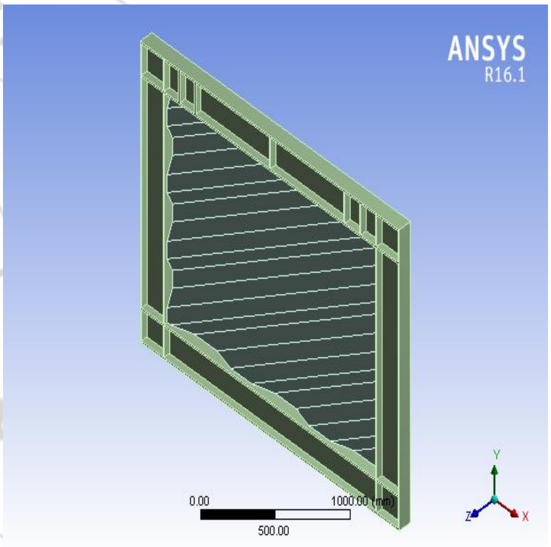

Figure 3: Trapezoidal corrugated steel plate shear wall with 30 º corrugation angle

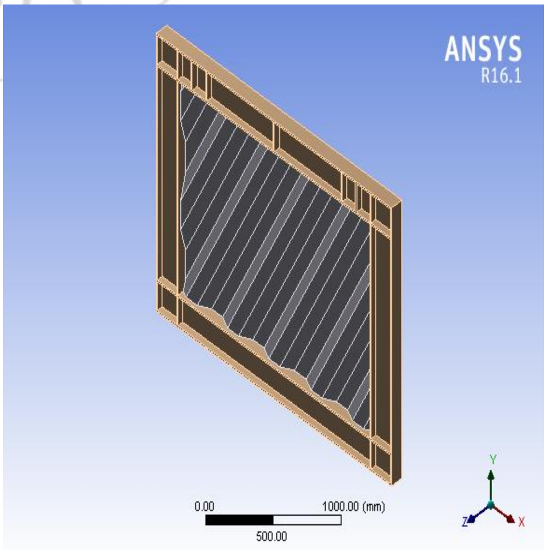

Figure 4: Trapezoidal corrugated steel plate shear wall with 60 º corrugation angle

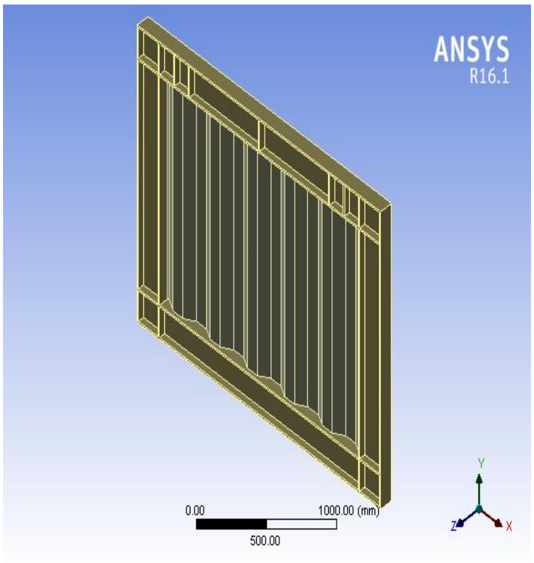

Figure 5: Trapezoidal corrugated steel plate shear wall with 90 º corrugation angle

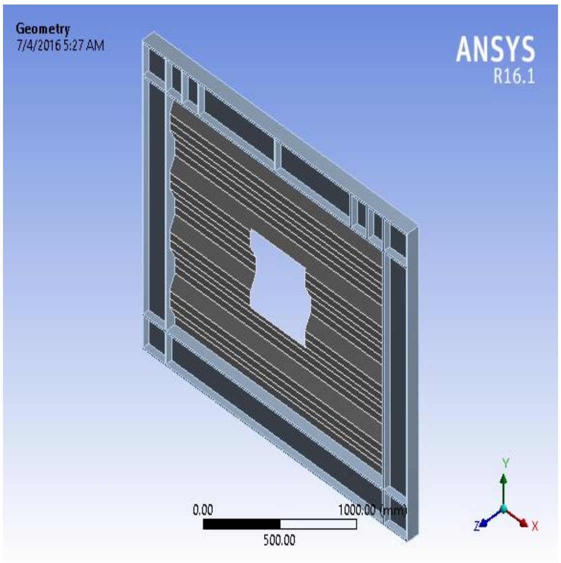

Figure 7: Trapezoidal corrugated steel plate shear wall with cutout

3.2.1 Meshing

Steel plate shear walls with boundary elements were one of the complex models. Therefore getting more accurate results, frame elements and infill plates were meshing separately by using different element size. Frame element was one of rigid body; lateral loads were more affect in the infill corrugated plate. Buckling of steel plate occurs when load was provided on the top of the beam So that meshing size of boundary element kept as 100mm and infill plate mesh sizing kept as 30mm for all models.

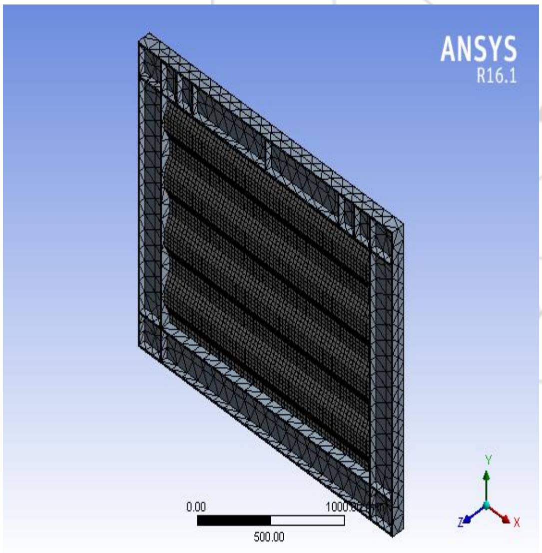

Figure 6: Trapezoidal corrugated steel plate shear wall with meshing

3.3. Trapezoidal corrugated steel plate shear wall with cutout

3.4. Trapezoidal corrugated steel plate shear wall with cutout and stiffener around cutout

Stiffeners are secondary plate or section which are attached to beam webs or flanges to stiffen them against out of plane deformation. Here deformation was most affected around the cutout therefore arresting these deformations a small thickness steel element was providing around the cutout for improving the strength of the load carrying capacity. The size of beam element which provided around the cutout is 0.005mx0.05m (BxH).

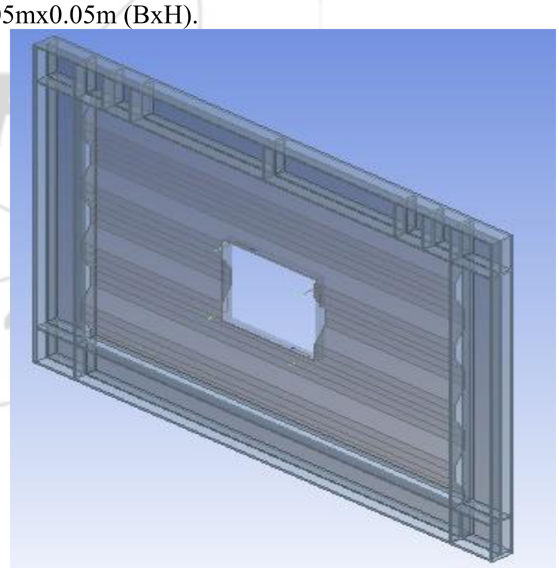

Figure 8: Trapezoidal corrugated steel plate shear wall with cutout and stiffener

4. Results

The ultimate load carrying capacity of each model was different. The ultimate strength of different angle of corrugation of steel plate shear wall was shown in table.

Table 1: Ultimate strength of different angle of shear walls

Angle of trapezoidal corrugated shear wall	Ultimate strength (kN)
0º	573
30º	523
60º	546
90º	547

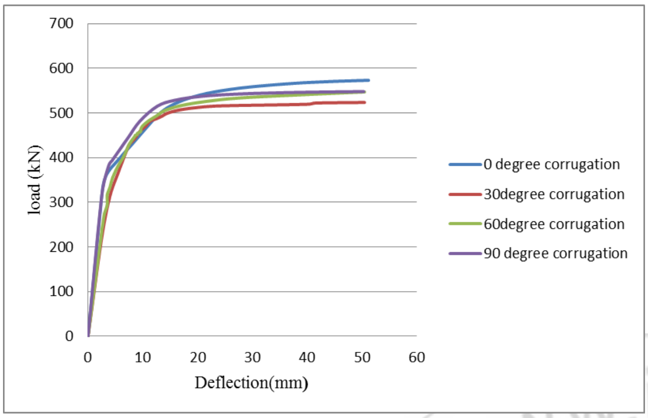

Figure 9: Comparison of results of load vs deflection of trapezoidal corrugated with different angle

The graph showing that when angle is maintained as 0º, it can carry higher load other than remaining angles .The ultimate load carrying capacity of steel plate shear with 0º angle is 573 kN .When angle of corrugation was 90º the ultimate load carrying capacity was 547kN.Ultimate load carrying capacity is very less when corrugation angle is provided in 30º. Therefore from this study the best angle of corrugation is 0º.Steel plate shear wall is mainly using for resisting lateral forces. Here lateral force which was applying parallel to x direction that is in 0º with respect to x axis, the corrugation angle was also in 0º .Therefore it gets more load carrying capacity in other angles. Deflection of all the shear walls was almost similar as per the input.

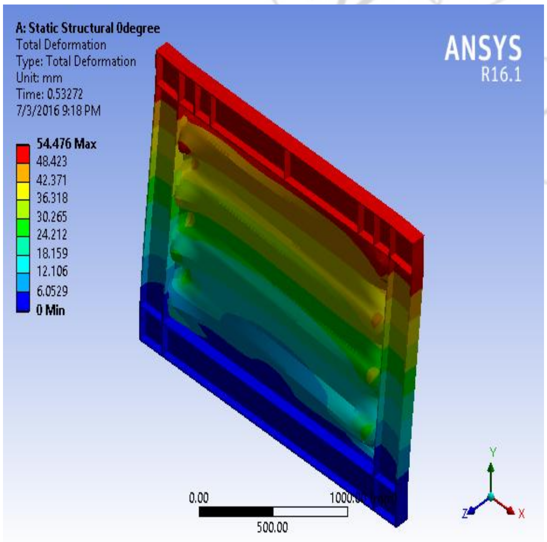

Figure 10: Trapezoidal corrugated steel plate shear wall with cutout and stiffener

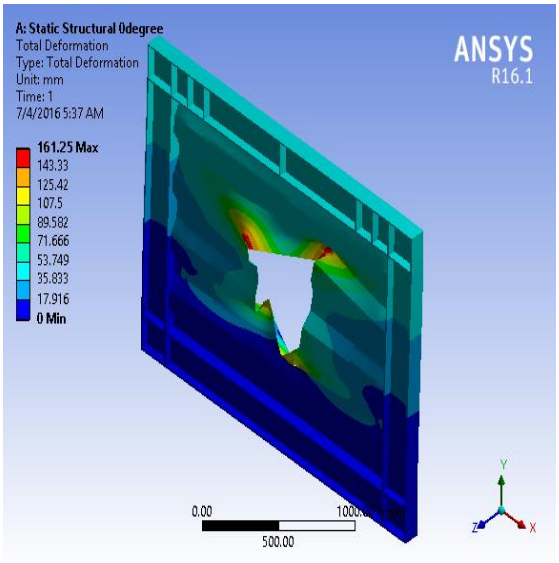

Figure 11: Total deformation of trapezoidal corrugated steel plate shear wall with cutout

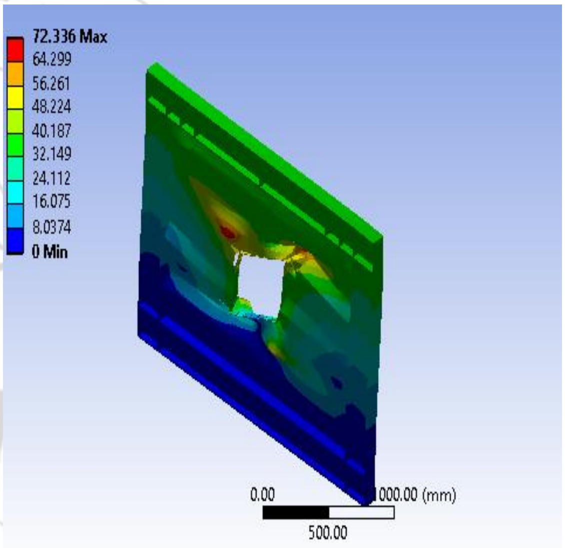

Figure 12: Total deformation of trapezoidal corrugated steel plate shear wall with cutout and stiffener

When we provided a cutout at center of corrugated steel plate shear wall the load carrying capacity decreased and deflection of the shear wall increases. In case of 0º corrugated angle without cutout, the ultimate load carrying capacity was 573 kN but the presence of cutout, the value decrease up to 402 kN. So for improving the load carrying capacity, a rectangular stiffener was provided around the cut out .Therefore the strength increased up to 443 kN.When stiffener was provided around the cutout the deflection decreases than the cutout shear wall model but increase than without cutout shear wall model. In case of without cutout model the deformation was greater at the load applying area. But in case of cutout the deflection is higher at opening area

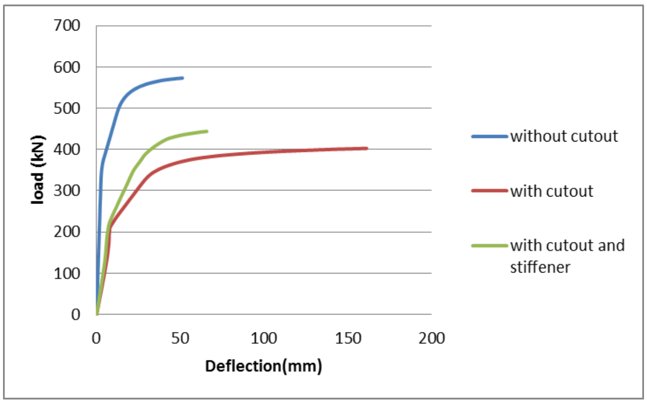

Figure 13: Comparison results of Deflection Vs load of trapezoidal corrugated with different conditions

5. Conclusions

- Steel plate shear wall with 0^0 angle of corrugation of infill plate has greater ultimate strength than other angles and 30^0 angle had less strength.
- Steel plate shear wall with 90^0 angle of corrugation of infill plate shows better result as compared to 30^0, 60^0
- Provision of cutout at center decreased the load carrying capacity of trapezoidal corrugated steel plate shear wall.
- Stiffeners around the cutout gets good results, it increased the strength more than cutout.
- Trapezoidal shear wall had better performance against lateral load.

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