iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 4 **Issue:** X **Month of publication:** October 2016

DOI:

Volume 4 Issue X, October 2016
ISSN: 2321-9653

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Behavioural Comparison of Geometrically Different Steel Plate Shear Walls

Amrutha Rajeev[1], Boby Jacob[2], Sibin Muhamed[3]
[1]P.G Scholar, Dept of Civil Engineering, Kothamangalam, Ernakulam, Kerala, India
[2]Assistant Professor, Dept of Civil Engineering, Kothamangalam, Ernakulam, Kerala, India
[3]Research Scholar, Dept of Ocean Engineering, Indian Institute of Technology, Madras, India

Abstract— Steel Plate Shear Walls (SPSWs) have been used as efficient and widely constructed primary lateral force resisting system particularly in areas of high seismic hazard in several modern and important structures. Significant strength, ductility and initial stiffness at relatively low cost and short construction are the primary motivations for the construction type. This paper is an investigation on the behavioural comparison of geometrically different SPSWs under quasi static cyclic and monotonic loading condition. The overall seismic performance of a Steel Plate Shear Wall depends upon geometrical properties of the boundary elements as well as the infill plates. Here a Parametric study conducted on geometrically different Steel Plate Shear Walls for the detailed investigation on the seismic performance of the SPSW system by changing the geometric properties of the infill plate. Geometric differences are provided by using unstiffened steel plate, stiffened steel plate, unstiffened shear panels with openings and stiffened shear panels with openings as infill plate and providing different configuration of stiffeners for the Steel Plate Shear Walls system.

Keywords— ***Steel Plate Shear Walls (SPSWs), Unstiffened Steel Plate Shear Walls, Stiffened Steel Plate Shear Walls, Unstiffened Steel Plate Shear Walls with Openings, Stiffened Steel Plate Shear Walls with Openings, Configuration of Stiffeners, infill plate, ultimate load, ductility, stiffness.***

I. INTRODUCTION

Since 1970's, Steel Plate Shear Walls (SPSWs) have been used as efficient and widely constructed primary lateral force resisting system particularly in areas of high seismic hazard in several modern and important structures. The seismic behaviour of them is not as well as understood as other commonly used systems, such as concentrically braced frames and moment frames as there are a limited number of buildings with SPSW lateral systems that have been subjected to large earthquakes. Significant strength, ductility and initial stiffness at relatively low cost and short construction are the primary motivations for the construction type. Much lighter weight, faster erection process, much easier and faster retrofit applications are the other major advantages of the Steel Plate Shear Wall system. The main function of the shear wall is to resist horizontal story shear and overturning moment due to lateral loads. In general, Steel Plate Shear Wall system consists of a steel infill plate or wall plate, two boundary columns and horizontal floor beams. Steel Plate Shear Walls can be constructed in two types: unstiffened and stiffened. In unstiffened walls, a series of flat plates with light thickness is used for utilizing the post-buckling field under overall buckling. In stiffened Steel Plate Shear Walls, a belt series or steel profiles are utilized as stiffeners with different arrangements: horizontal, vertical and diagonal – on one side or both sides of the wall until the energy dissipation, stiffness and ultimate bearing are increased; this method is economical and quite effective. In the case of SPSWs with openings, openings are provided on its infill plates, it is also an attraction of SPSWs that is the easiness of opening application in the infill plate which is sometimes required for passing the utilities, architectural purposes, or structural reasons.

The objectives for the present study are, prediction of ultimate load, ductility and stiffness as function of shear wall geometry and then evaluate and compare the behaviour of geometrically different Steel Plate Shear Walls on the basis of analysis result obtained which includes, effect of different thicknesses, effect of different opening percentages and effect of configuration of stiffeners. Failure modes and buckling analysis are out of scope of the study. A detailed finite element analysis has been conducted on 33 models of Steel Plate Shear Wall which includes, Unstiffened Steel Plate Shear Walls, Stiffened Steel Plate Shear Walls, Unstiffened Steel Plate Shear Walls with Openings, Stiffened Steel Plate Shear Walls with Openings and Steel Plate Shear Walls with different Configuration of Stiffeners. In the execution of parametric study, infill plate thickness, opening percentages and stiffeners configurations are included.

II. VALIDATION FOR THE FINITE ELEMENT ANALYSIS

To establish the accuracy of the numerical modelling methodology, finite element model of tested specimen of Corrugated Steel

Volume 4 Issue X, October 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Shear Wall is developed and compared it with a well established laboratory test, for this Vertically Corrugated Steel Plate Shear Wall tested by Emami and Mofid was considered [5].

A. Experimental Program Details

In experimental research trapezoidal vertically Corrugated Steel Shear Wall is constructed in half scale, one story and single bay. The shear panel was 2000mm wide and 1500mm height and with thickness of 1.25mm. For the boundary frame of the specimen, the top beam section is HE-B 140, the bottom beam section specimen is HE-B 200 and section of column is HE-B 160, which is connected to the strong floor beam of the laboratory. Where HE- B is I shape wide flange according to the European standard. The connection of each column to the bottom beam and the top beam to the columns were developed utilizing complete penetration groove welds of its flanges and fillet weld of its web, i.e., this connection was fully moment-resisting. The shear panel was connected to the surrounding frames by fish plates. Fish plate-to-shear panel connection was simultaneously performed by welds and bolts.

Fig. 1 Experimental Setup of Specimen

To implement lateral load and to investigate the behaviour of the specimen in lab, quasi- static cyclic load is applied by two horizontal hydraulic jacks on both side at top beam level using AC protocol. In this study loading was conducted as displacement controlled and gravity loads were not applied [5]. The experimental setup of the specimen is shown in Fig 1.

B. Numerical Model Details

The simulations were undertaken using the commercially available finite element package of ANSYS 16.2. As described, numerical model according to the as-built dimension of the tested specimen was modelled and analysed in ANSYS 16.2. The model was constructed using the general purpose four node shell element that is capable of large displacement and non linear behaviour.

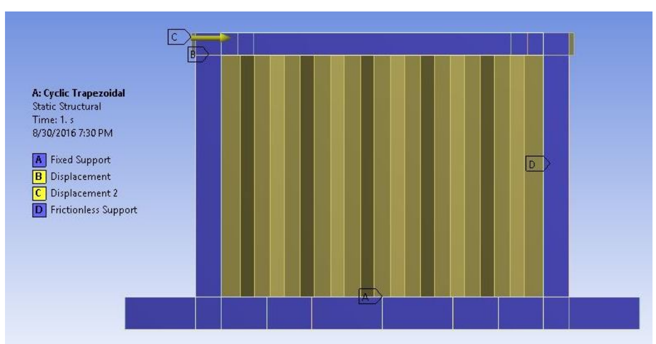

Fig. 2 Numerical Model

The shell element was used for all components of the structure including the standard rolled section. The beams to columns were moment resisting, therefore all intersecting shell elements were directly connected. The steel wall is connected directly and continuously to the beams and columns as suggested by Emami and Mofid [5]. The numerical model of the specimen is shown in Fig 2. Young's modulus of elasticity and Poisson's ratio are considered to be 200GPa and 0.3 for all steel material. The yield

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

strength of plate, beam and column are 224 MPa, 254 MPa and 280 MPa respectively.

C. Validation of Modelling

For the validation of finite element modelling, the hysteresis curve of quasi- static cyclic loading generated from the finite element analysis is compared with the experimental test result. The simulations were performed under displacement controlled loading with the aid of a non - linear static procedure. The hysteresis behaviour of tested specimen and numerical models are shown in Fig 3 and 4.

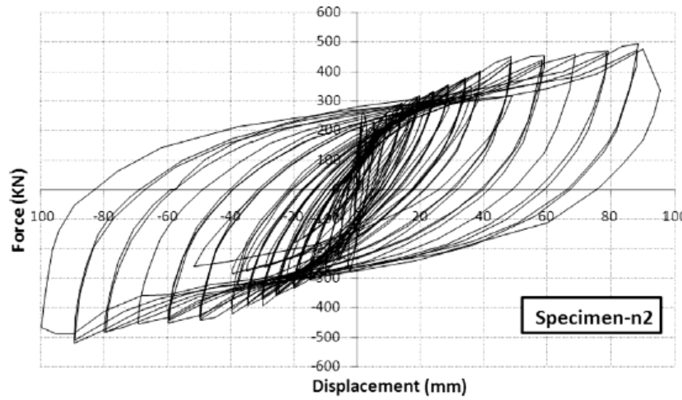

Fig. 3 Hysteresis Behaviour of Tested Specimen

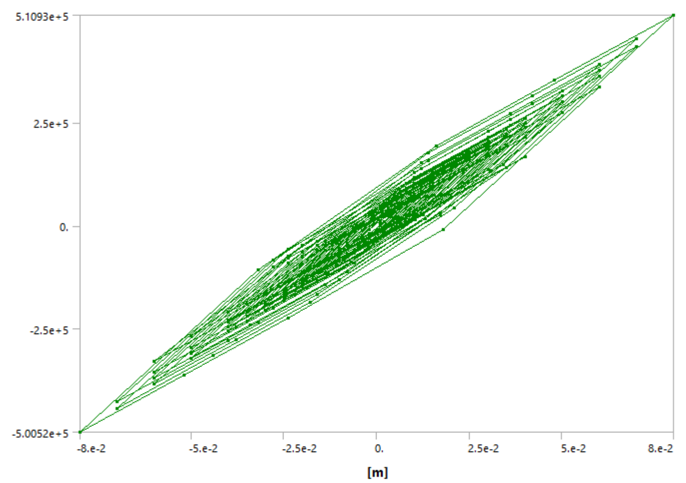

Fig. 4 Hysteresis Behaviour of Numerical Model

Excellent agreement is observed between analysis and experimental results. For the numerical model of Corrugated Steel Plate Shear Wall the peak load observed during the test is underestimated only by 4% as shown in Fig 3-4. Minor differences in the result of comparison presented are due to the type of verification.

III.PARAMETRIC STUDY DESIGN

The overall seismic performance of a Steel Plate Shear Wall depends upon geometrical properties of the boundary elements as well as the infill plates. In this work for the detailed investigation on the seismic performance of the SPSW system, parametric studies are performed by changing the geometric properties of the infill plate. Parameters considered including thickness of infill plate, opening percentage, and stiffeners configuration. On this basis 33 models are considered. The specification chart for the numerical models is given in Table I.

Volume 4 Issue X, October 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

TABLE I

SPECIFICATION CHART FOR NUMERICAL MODELS

Model Name	Parameters		
	Thickness [A] (mm)	Opening Percentage[B]%	Stiffeners Configuration [C]
ST [A]	1.5,2,2.5, 3.25,4	NA	NA
ST[A]OP[B]	1.5, 2, 2.5, 3.25,4	5,10,15,25	NA
ST[A][C]	1.5	NA	E,ED1,ED, ED3
ST[A]OP[B][C]	1.5	5	E,EOD1,EOD, EOD3

Here S indicates Steel Plate Shear Wall. As it is seen in Table I, SPSW models are labelled such that the infill plate form and geometrical properties of each model can be identified from the label. Here A, B and C represents parameter thickness, opening percentage and stiffeners configuration. For instance, label ST [A] indicates that, the model is a SPSW with thickness A. A can be of values1.5mm,2 mm, 2.5mm, 3.25mm and 4mm. ST1E indicates that, the model is a SPSW with thickness 1.5mm and also this plate is stiffened with edge stiffeners. ST [A]OP[B][C] indicates that the model is a SPSW with thickness A, it has an area equal to B percentage of the infill plate area and this model is stiffened with C configuration of stiffeners.

A. Parametric Study on Thicknesses

Thicknesses of the infill plates are found to be an important parameter for SPSW system. Parametric study in thickness was conducted to investigate the influence of the different thicknesses of infill plate on the behaviour of Steel Plate Shear Wall. Five different plate thicknesses are considered based on common values mentioned in the published literatures. Thicknesses are 1.5mm, 2mm, 2.5mm, 3.25mm and 4mm respectively.

B. Parametric Study on Opening Percentages

Easiness of opening application in the infill plate is one of the advantages of the SPSW system. Openings are unavoidable in some situations where it is required for passing the utilities architectural purposes or structural reasons. Also as per the design considerations shapes, sizes and locations of openings can be varying. To investigate the effect of introduction of openings and variation of openings sizes, different opening percentages are provided in the infill plate. Four different opening percentages are considered for the study. Opening percentages taken as an area equal to 5%, 10%, 15% and 25% of the infill plate area. These models consist of a 200 mm filleted rectangular perforation or opening in its infill plate centre. Details of opening percentages and opening dimensions are illustrated in Table II.

TABLE III

DETAILS OF OPENING PERCENTAGE AND OPENING DIMENSION

Opening Percentages (%)	Dimension of Openings (mm)
5	1050 X 600
10	1450 X 450
15	1664 X 1100
25	2000 X 1516

C. Parametric Study on Configuration of Stiffeners

Stiffeners can improve the seismic performance of the SPSW system. To investigate the influence of the different configuration of stiffeners on the characteristics of the SPSWs this parametric study is conducted. Assumptions for this parametric study are: stiffeners are of size 120mm X 20 mm, provided on both side of the infill plate. Different configurations provided are illustrated in Table III.

Volume 4 Issue X, October 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

TABLE IIIII
DETAILS OF STIFFENERS CONFIGURATIONS

Configuration of Stiffeners	Combination of Stiffeners
0	No stiffeners
E	Edge alone
ED1	Edge and diagonal
ED2	Edge and diagonally inclined (same configuration in both side)
ED3	Edge and diagonally inclined (different configuration in both side)
EO	Edge and around opening
EOD1	Edge, around openings and diagonal
EOD2	Edge, around openings and diagonally inclined (same configuration in both side)
EOD3	Edge, around openings and diagonally inclined (different configuration in both side)

IV. NUMERICAL MODELLING AND SIMULATION

The validated finite element models are used for the modelling and analysis of all the geometrically different Plate Shear Walls. Finite element analysis is more reliable for the analysis of Steel Plate Shear Walls. The simulations were undertaken using commercially available finite element package ANSYS 16.2 Workbench.

A. Geometry

Geometrically different SPSWs used in the study are – Unstiffened Steel Plate Shear Walls, Unstiffened Steel Plate Shear Walls with openings, Stiffened Steel Plate Shear Walls and Stiffened Steel Plate Shear Walls with openings. All these geometrically different Steel Plate Shear Wall have the same boundary conditions and material properties. A total of 33 Steel Plate Shear Walls were modelled. The height and length of the story panel are 3m and 4m respectively correspond to the conventional dimensions of the Shear Wall in the building were assumed.

B. Boundary Conditions

Boundary conditions are provided according to the experimental setup. The bottom edge of the infill panel and the base of the columns were fixed in each finite element models. The beams to column connections are moment resisting therefore the entire intersecting SHELL 181element are directly connected. The Steel Plate Shear Wall is connected directly and continuously to columns and beams. To prevent the out of plane movement of the frame, the beam to column connection of each finite element model were restrained from the global z direction. In each model the top beam section is HEB 280, the section of column is HE B 160 and the bottom beam section is HEB 400. As per the test specimens, plate sections of sizes PL 224 X 137 X 10 mm, PL 280 X 153 X 10 mm, PL 352 X 195X 10 mm were provided inside the top beam, columns and bottom beam respectively as stiffeners. Boundary element dimensions are illustrated in Table IV.

TABLE IVV
BOUNDARY ELEMENT DIMENSIONS

Design of specimen	Profile	Web Height (mm)	Web thickness (mm)	Flange Width (mm)	Flange thickness (mm)
Top Beam	HEB 280	280	10	280	18
Columns	HEB 320	320	11	300	20
Bottom Beam	HEB 400	400	13	300	24

C. Loading Program

To simulate earthquake load and further to investigate the behaviour of Steel Plate Shear Wall two types of loading programs were

Volume 4 Issue X, October 2016
ISSN: 2321-9653

employed that is quasi static cyclic loading and monotonic loading. Quasi static cyclic load simulations were performed under displacement controlled loading. In the case of monotonic loading, loading was applied up to specimens ultimate load were reached

D. Material Properties

Material properties of each steel material are shown in Table V.

TABLE V

MATERIAL PROPERTIES

Type	Young's modulus (GPa)	Poisson's Ratio	Tensile yield strength (MPa)	Tensile ultimate strength (MPa)
Plate	200	0.3	224	315
Beam	200	0.3	254	383
Column	200	0.3	280	423
Stiffener	200	0.3	313	490

E. Numerical Models Used For the Study

For the investigation of the behaviour of Steel Plate Shear Wall s under lateral loading, Unstiffened Steel Plate Shear Walls, Stiffened Steel Plate Shear Walls, Steel Plate Shear Walls with Openings are considered. Different numerical models used in the study are shown in Fig 5- 17.

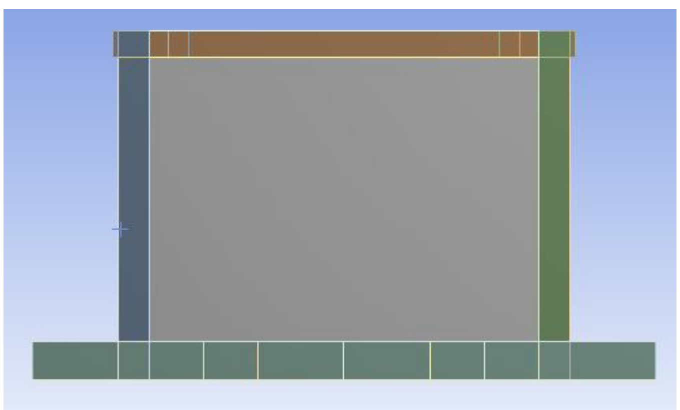

Fig. 5 Unstiffened Steel Plate Shear Wall (SPSW)

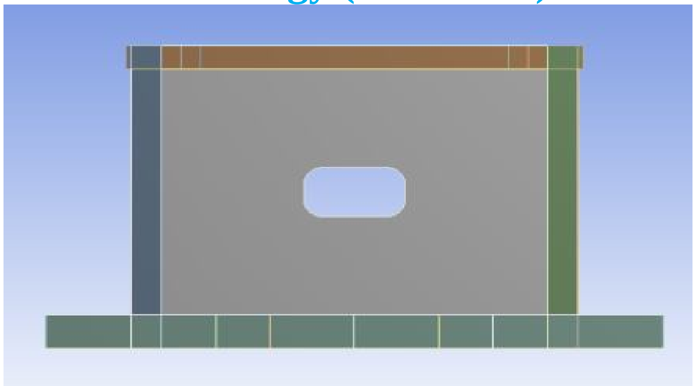

Fig.6 Unstiffened SPSW- 5% Opening

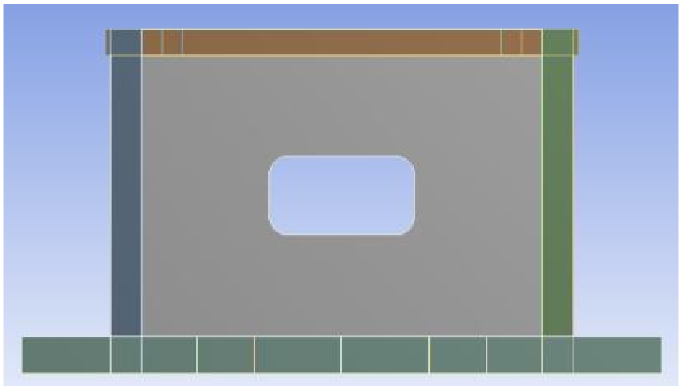

Fig.7 Unstiffened SPSW -10% Opening

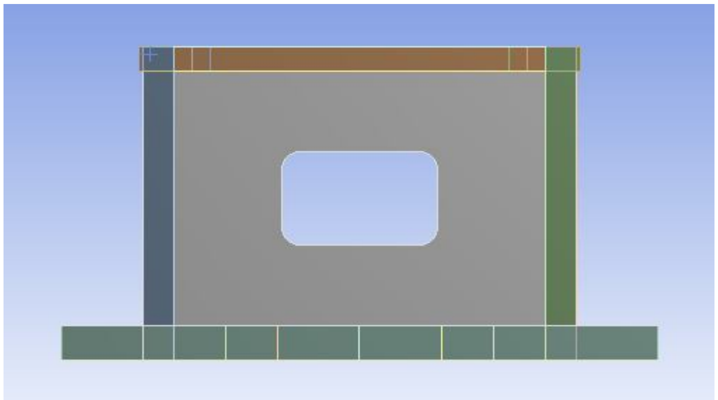

Fig. 8 Unstiffened SPSW -15% Opening

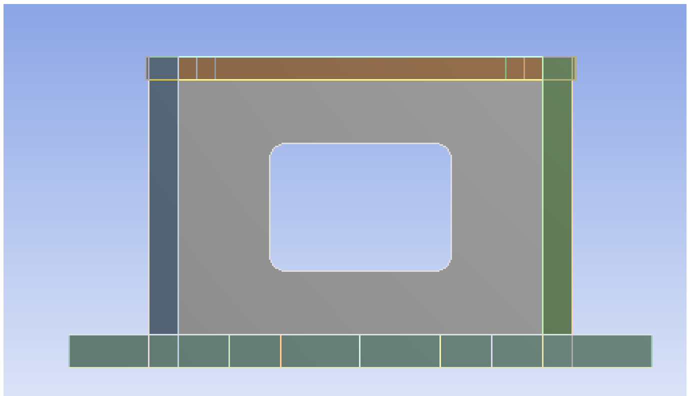

Fig. 9 Unstiffened SPSW -25% Opening

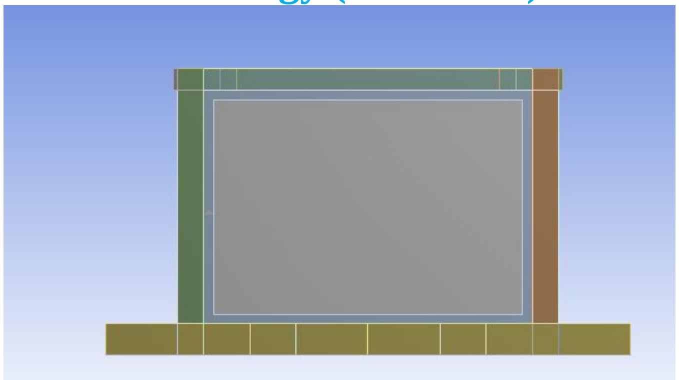

Fig.10 Stiffened SPSW with Stiffeners Configuration E

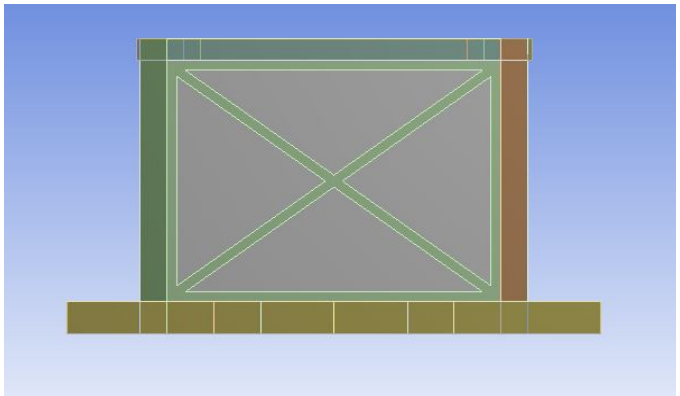

Fig. 11 Stiffened SPSW with Stiffeners Configuration ED1

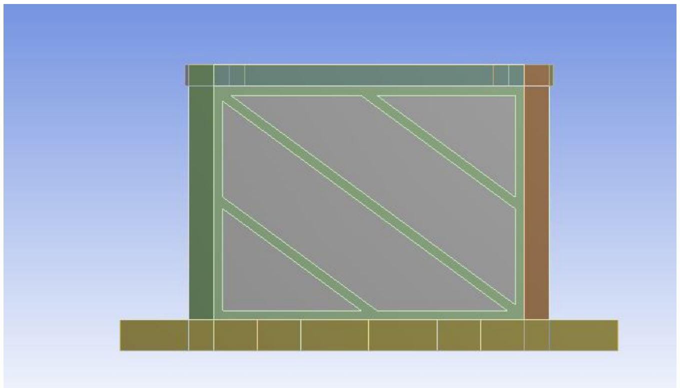

Fig.12 Stiffened SPSW with Stiffeners Configuration ED2

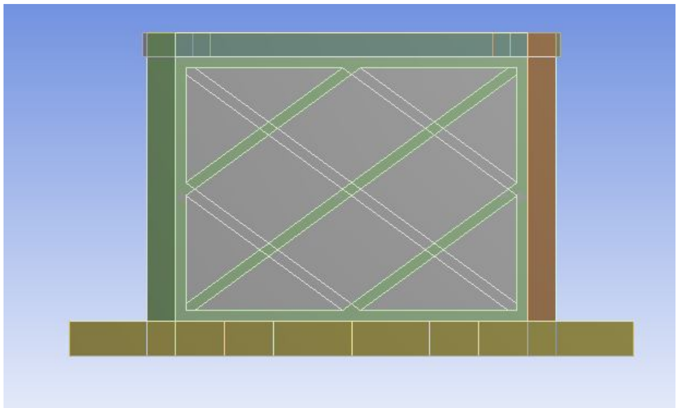

Fig .13StiffenedSPSW with Stiffeners Configuration ED3

Volume 4 Issue X, October 2016
ISSN: 2321-9653

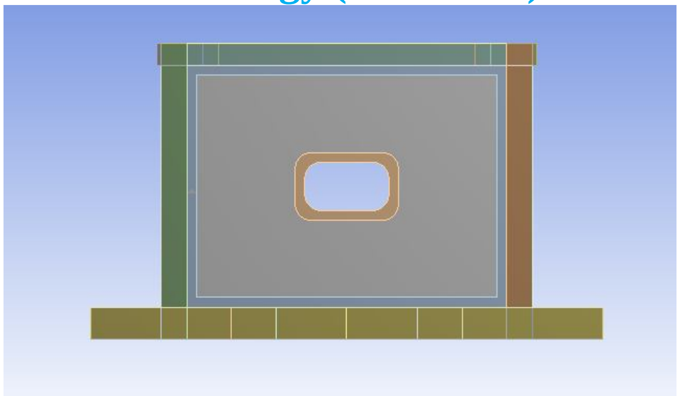

Fig.14 Stiffened SPSW with Opening and Stiffeners Configuration EO

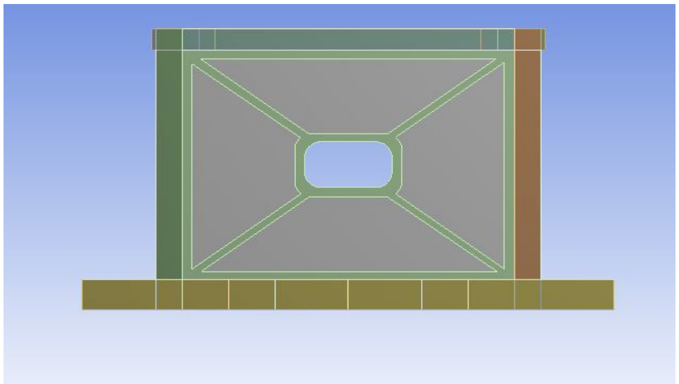

Fig.15 Stiffened SPSW with Opening and Stiffeners Configuration EOD1

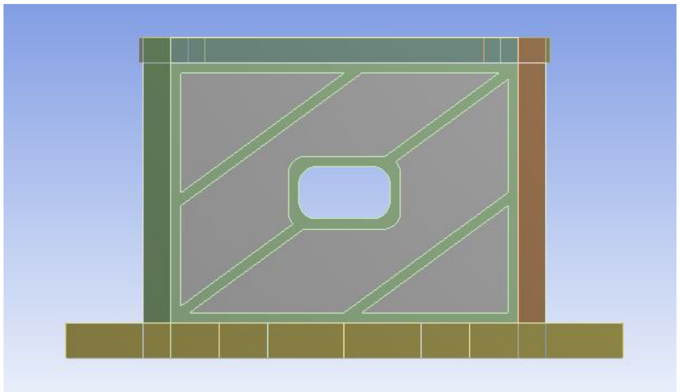

Fig.16 SPSW with Opening and Stiffeners Configuration EOD2

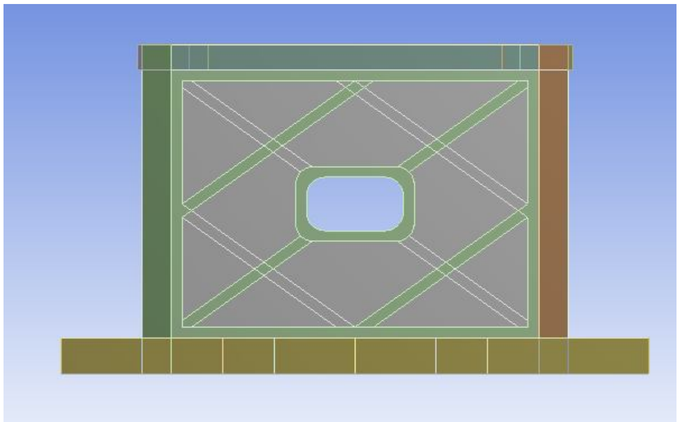

Fig.17 SPSW with Opening and Stiffeners Configuration EOD3

V. NON- LINEAR STATIC ANALYSIS OF SHEAR WALLS UNDER MONOTONIC AND CYCLIC LOADING

Variation of stiffness, energy dissipation capacity, ductility and ultimate strength are the main characteristics which affects the seismic performance of the Steel Plate Shear Wall. Considering the significance of these characteristics of lateral force resisting system, the performance of SPSW models in terms of stiffness, ultimate load, and ductility are find out through the assessment of numerical results from non- linear static analysis of models under monotonic and cyclic loading.

VI. EVALUATION OF PARAMETRIC STUDY RESULTS

The results of nonlinear static analysis of Corrugated Steel Plate Shear Walls under monotonic loading condition are presented here. For the easy way to understanding, evaluation results are presented in the form of two different sets. Details of each set are given below. In each set ultimate load, ductility and stiffness performances are evaluated for corresponding SPSW system.

A. Case 1: Unstiffened Steel Plate Shear Walls

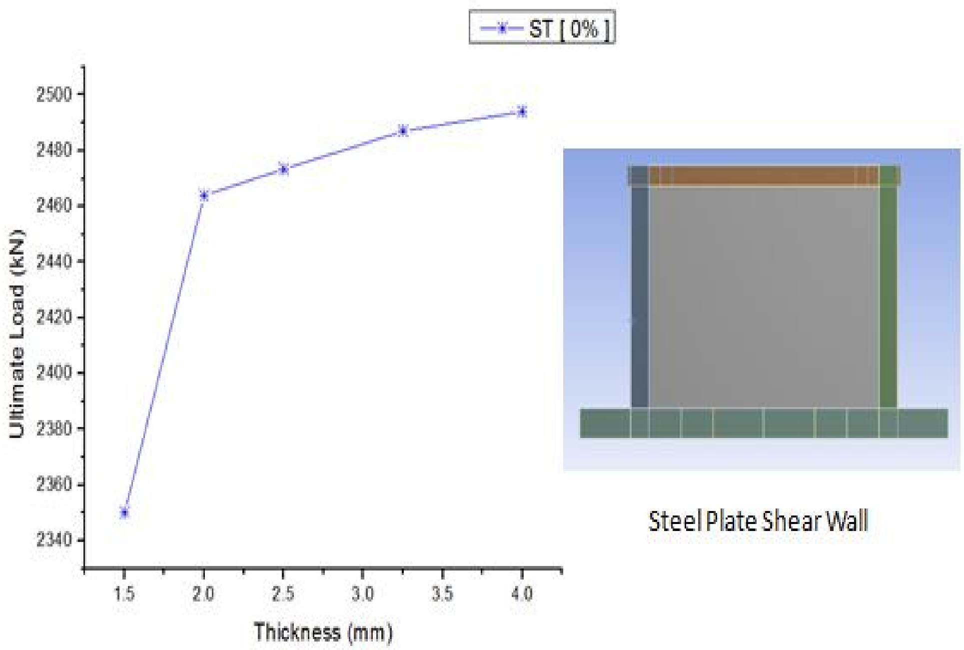

Fig.18 Ultimate Load Performance of Unstiffened Steel Plate Shear Walls as a function of Thickness

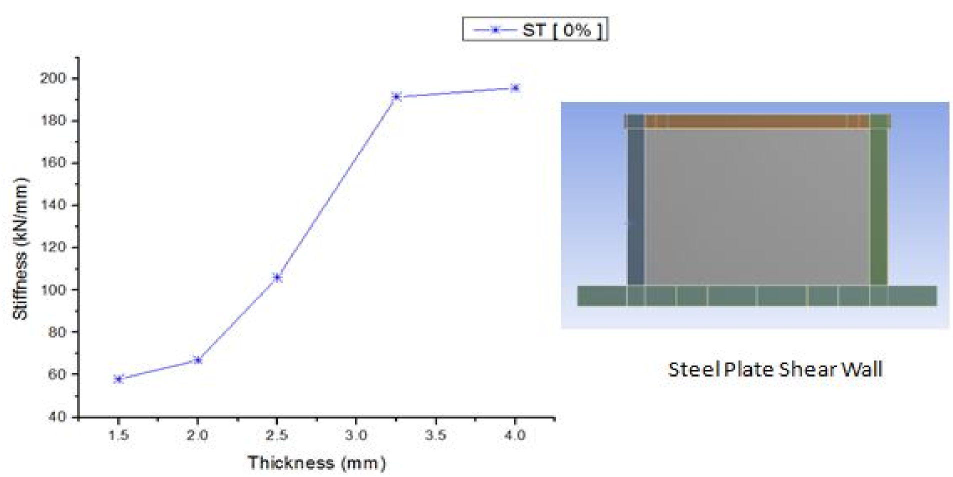

Fig.19 Stiffness of Performance Unstiffened Steel Plate Shear Walls as a function of Thickness

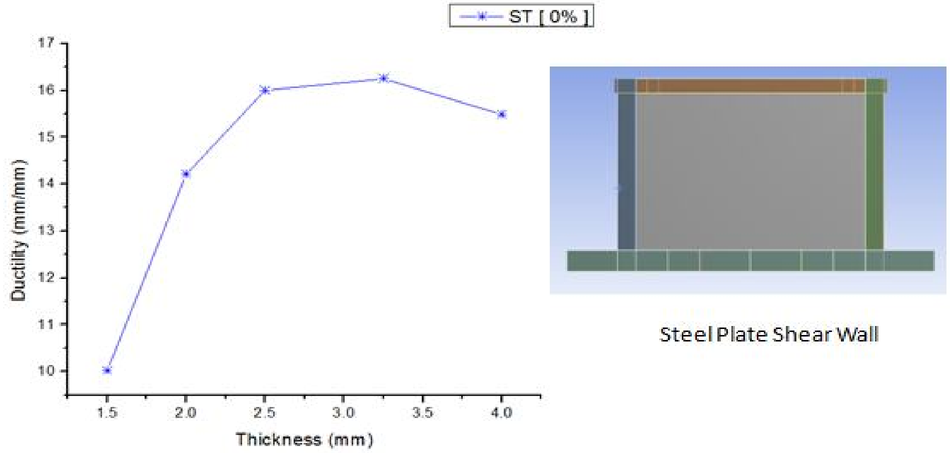

Fig. 20 Ductility Performance of Unstiffened Steel Plate Shear Walls as a function of Thickness

B. Case 2: Unstiffened Steel Plate Shear Walls with openings.

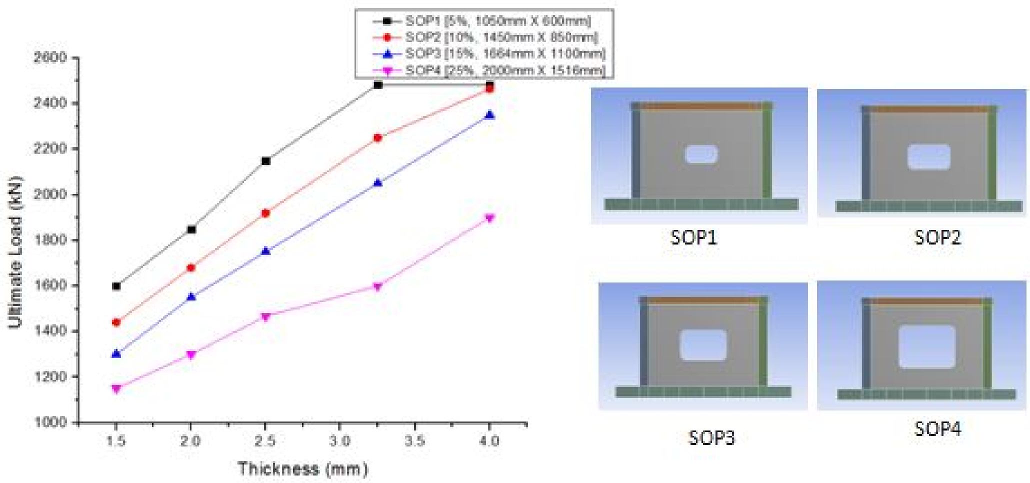

Fig. 21Ultimate Load Performance of Unstiffened SPSWs with Openings as a function of Thickness

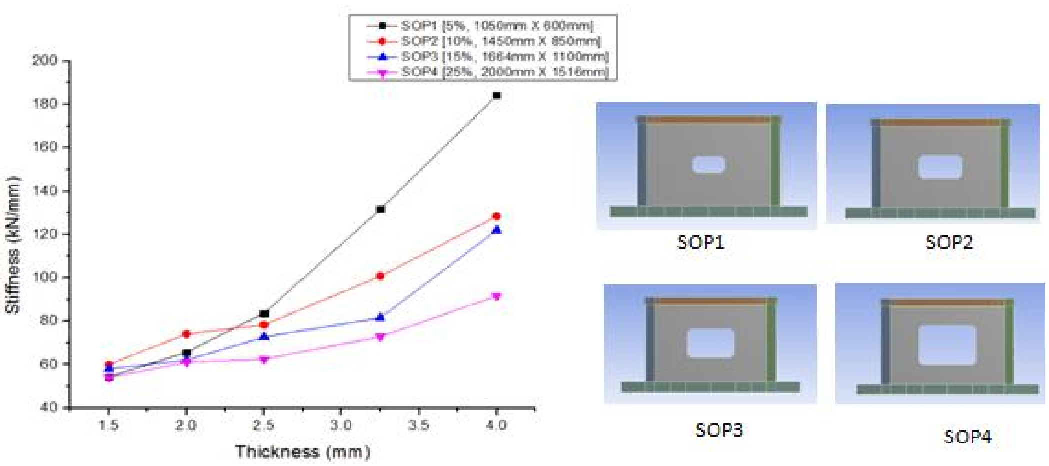

Fig. 22 Stiffness Performance of Unstiffened SPSWs with Openings as a function of Thickness

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

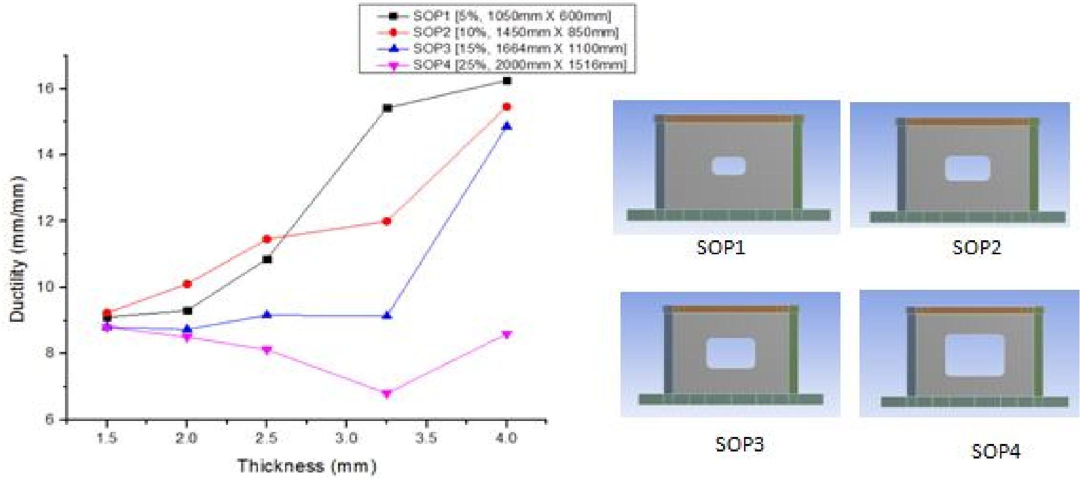

Fig. 23 Ductility Performance of Unstiffened SPSWs with Openings as a function of Thickness

C. Case 3: Stiffened Steel Plate Shear Walls.

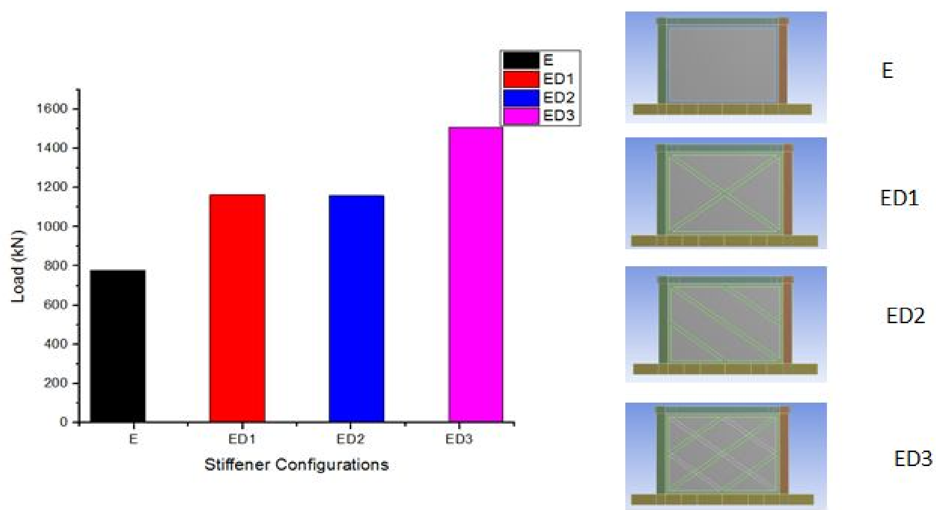

Fig. 24 Load Performance of Stiffened SPSWs without Openings as a function of Stiffener Configurations

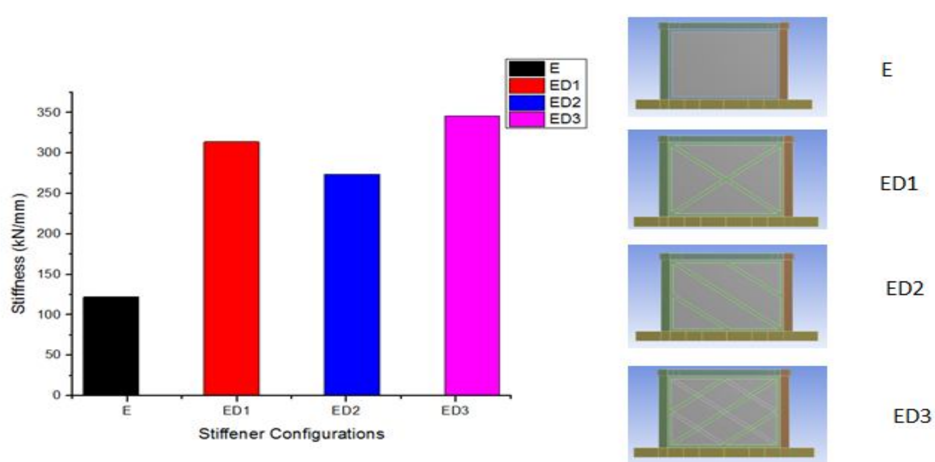

Fig. 25 Stiffness Performance of Stiffened SPSWs without Openings as a function of Stiffener Configurations

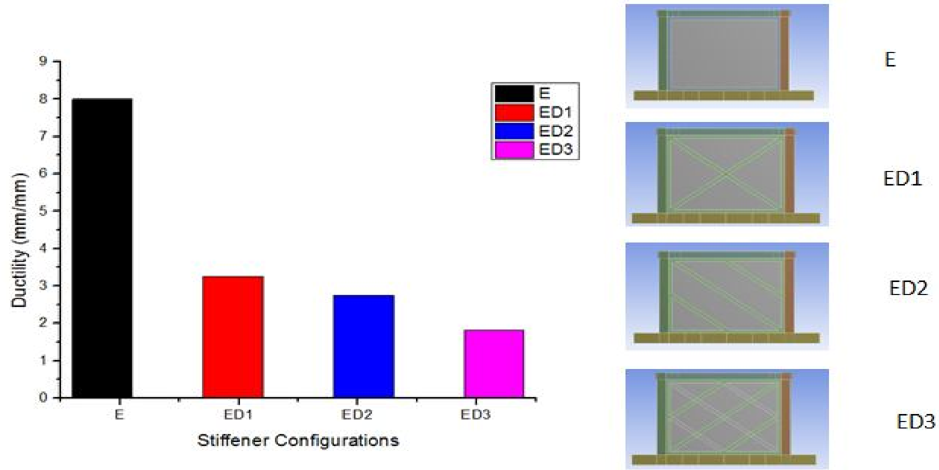

Fig. 26 Ductility Performance of Stiffened SPSWs without Openings as a function of Stiffener Configurations

D. Case 4: Stiffened Steel Plate Shear Walls with openings

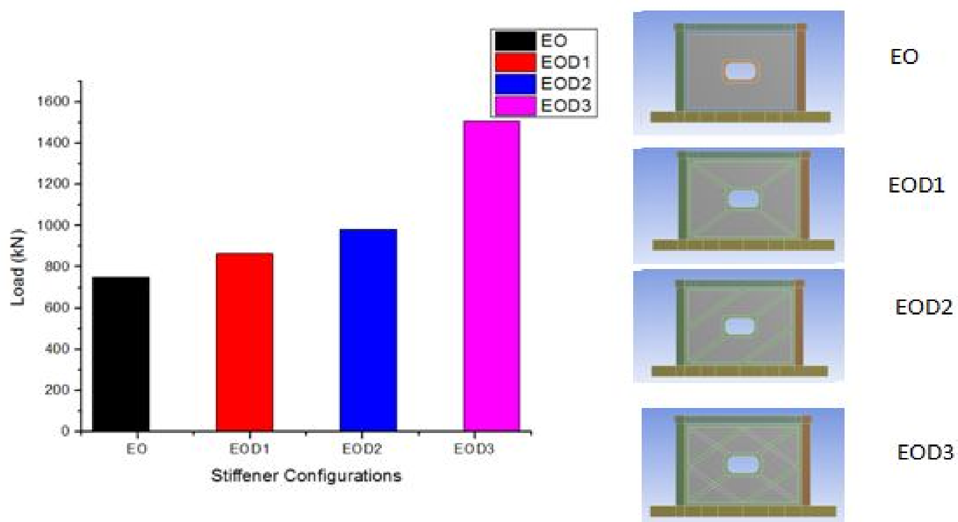

Fig. 27 Load Performance of Stiffened SPSWs with Openings as a function of Stiffener Configurations

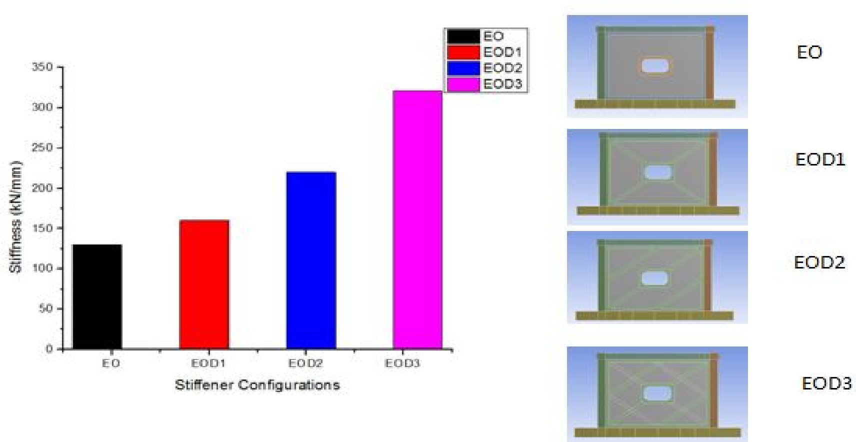

Fig. 28 Stiffness Performance of Stiffened SPSWs with Openings as a function of Stiffener Configurations

Volume 4 Issue X, October 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

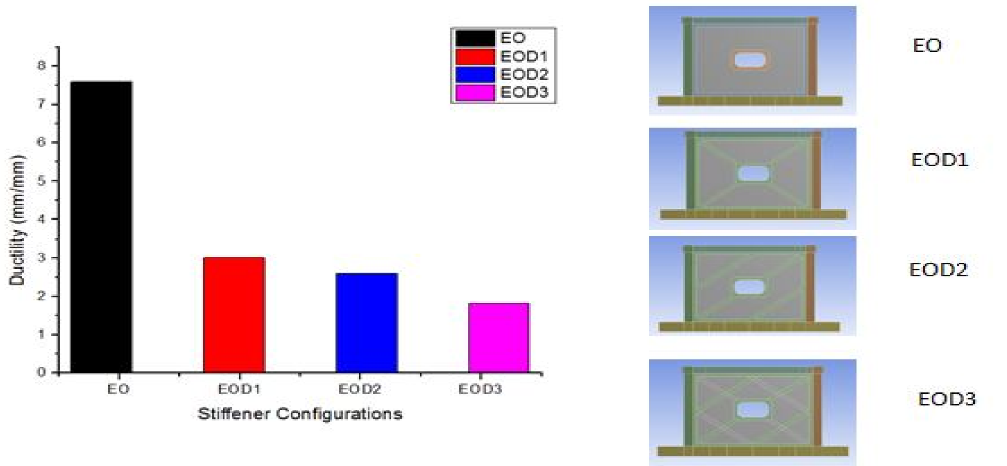

Fig. 29 Ductility Performance of Stiffened SPSWs with Openings as a function of Stiffener Configurations

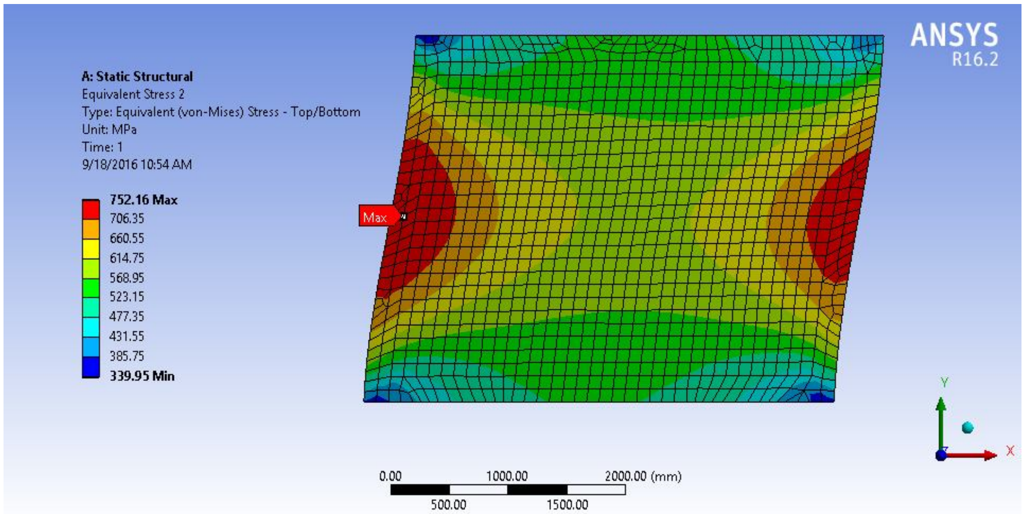

Fig.30 von Mises Stress Contour Plot of Unstiffened Steel Plate Shear Panel

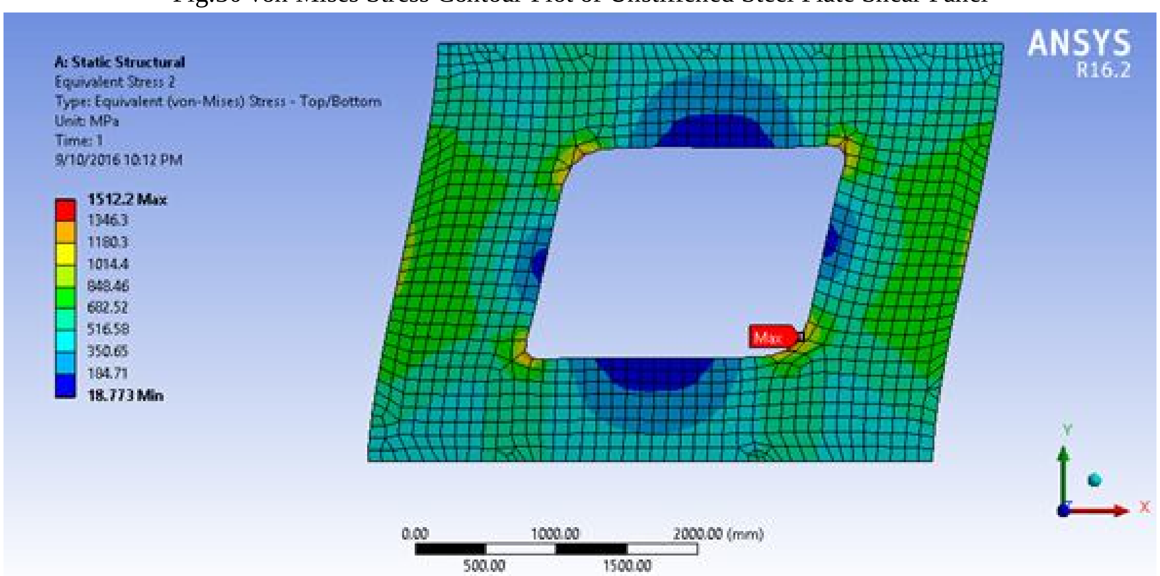

Fig. 31 von Mises Stress Contour Plot of Unstiffened Steel Plate Shear Panel with 25% Opening at Centre

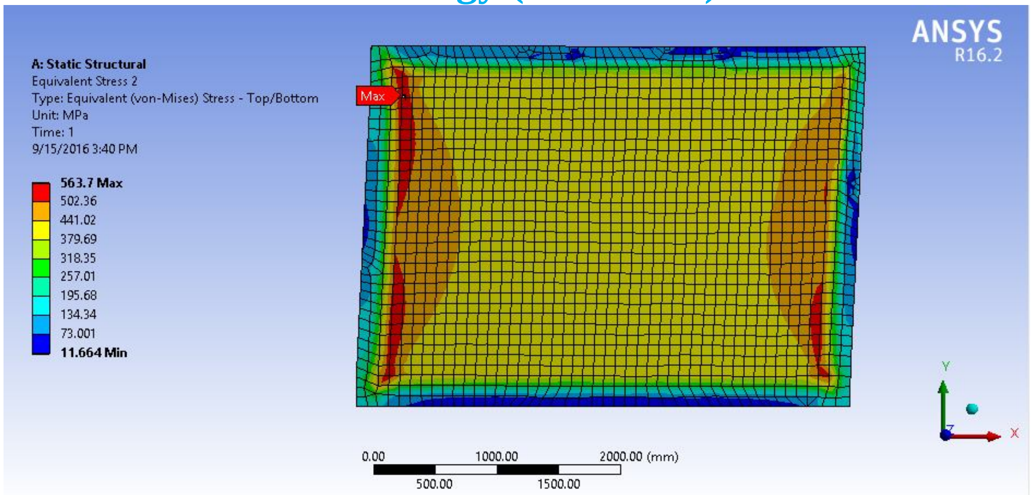

Fig. 32 von Mises Stress Contour Plot of Unstiffened Steel Plate Shear Panel with Stiffener Configuration E

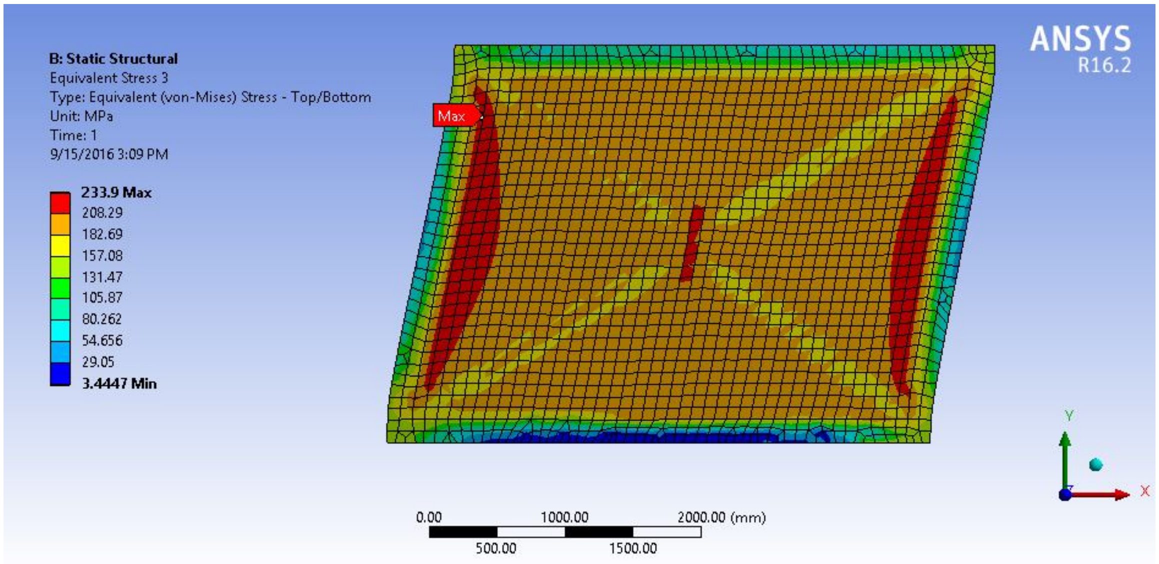

Fig.33 von Mises Stress Contour Plot of Unstiffened Steel Plate Shear Panel with Stiffener Configuration ED1

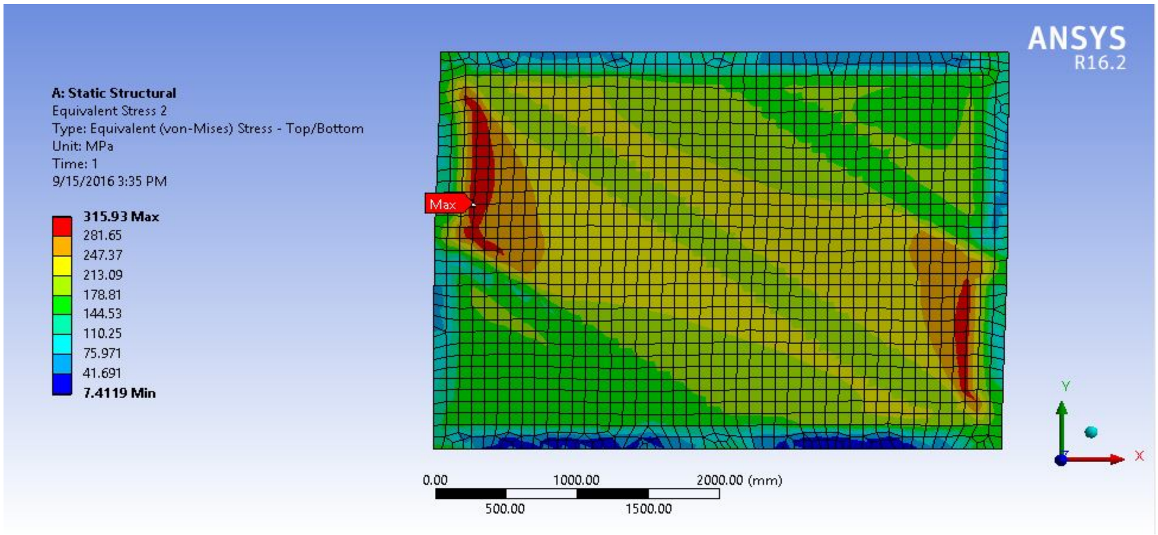

Fig. 34 von Mises Stress Contour Plot of Unstiffened Steel Plate Shear Panel with Stiffener Configuration ED2

Volume 4 Issue X, October 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

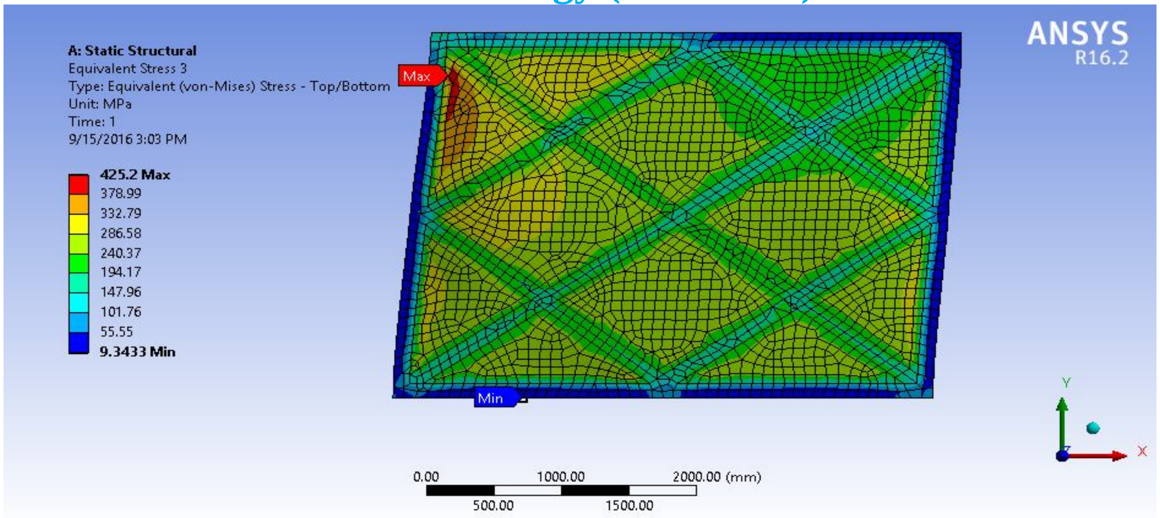

Fig. 35 von Mises Stress Contour Plot of Unstiffened Steel Plate Shear Panel with Stiffener Configuration ED2

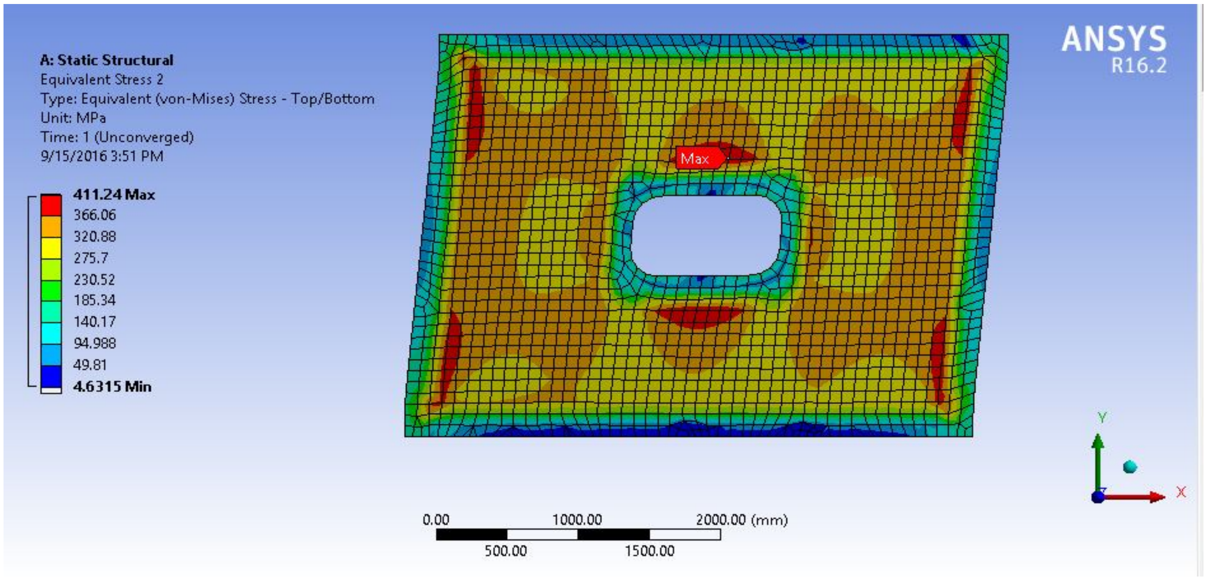

Fig. 36 von Mises Stress Contour Plot of Unstiffened Steel Plate Shear Panel with Opening and Stiffener Configuration E

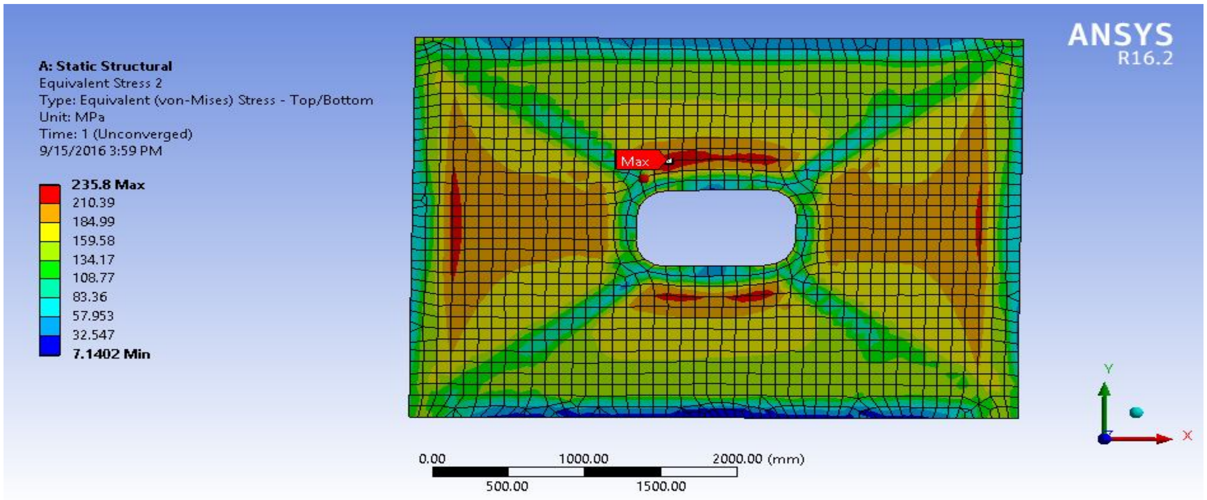

Fig. 37 von Mises Stress Contour Plot of Unstiffened Steel Plate Shear Panel with Opening and Stiffener Configuration ED1

Volume 4 Issue X, October 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

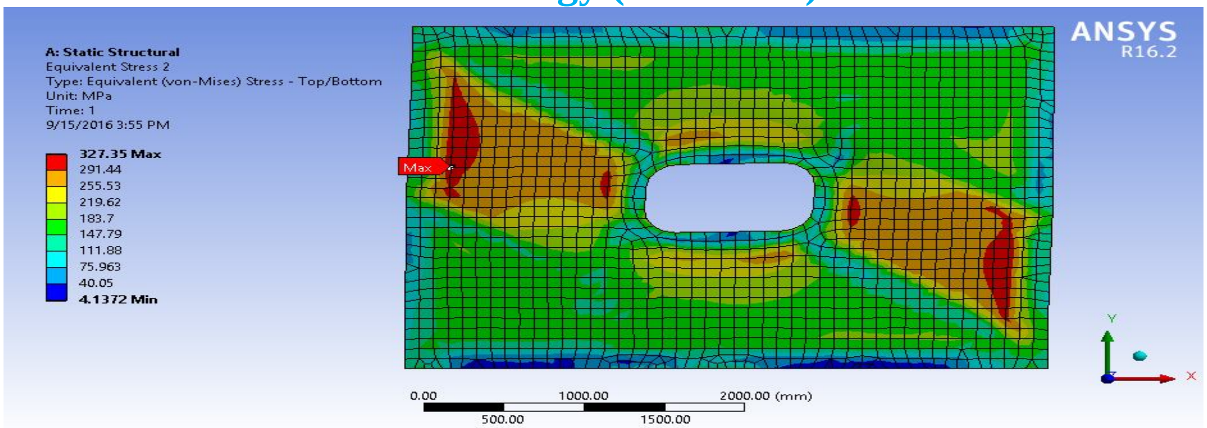

Fig38 von Mises Stress Contour Plot of Unstiffened Steel Plate Shear Panel with Opening and Stiffener Configuration ED2

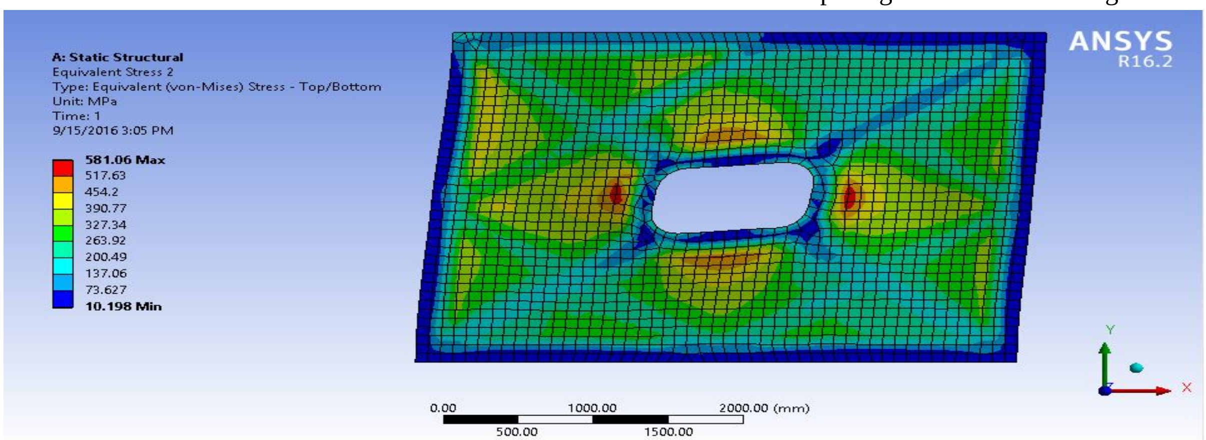

Fig. 39 von Mises Stress Contour Plot of Unstiffened Steel Plate Shear Panel with Opening and Stiffener Configuration ED3

VII. COMPARISON OF PARAMETRIC STUDY RESULTS

Based on the results of different parameters on the behaviour of Steel Plate Shear Walls in this part, comparisons are carried out for the Steel Plate Shear Walls with similar geometrical status

A. Case 1 : Comparison of Unstiffened Steel Plate Shear Walls With and Without Openings

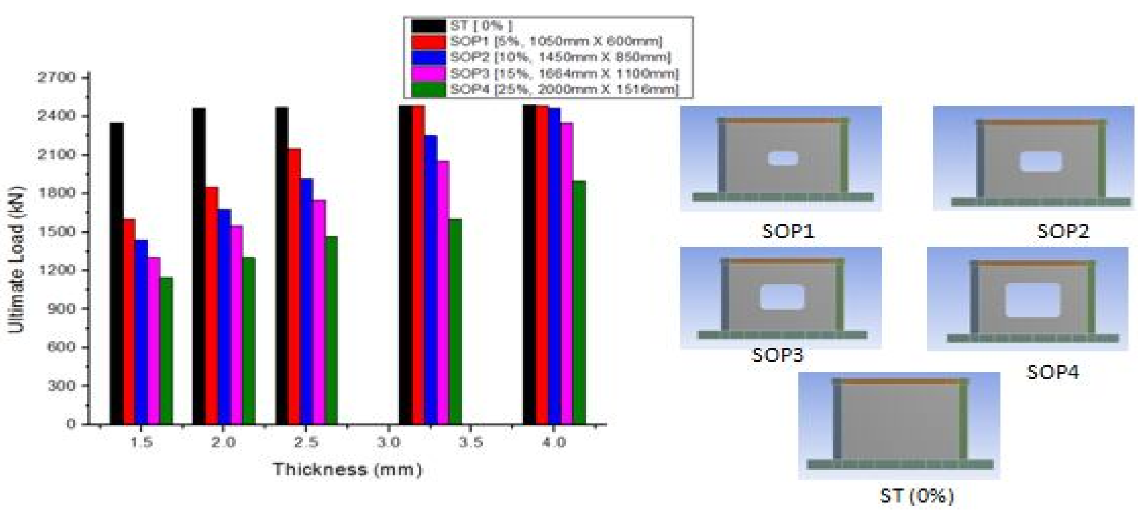

Fig.40 Comparison of Ultimate Load Performance of Unstiffened SPSWs With and Without Openings as a function of Thickness

Volume 4 Issue X, October 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

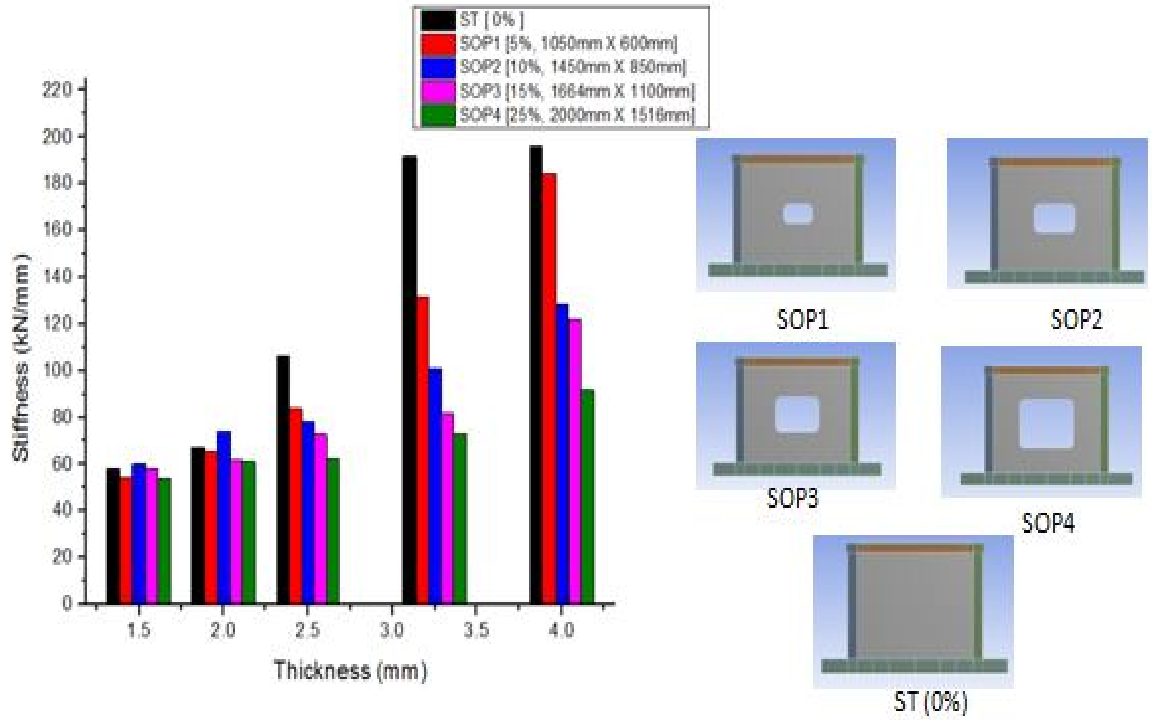

Fig. 41 Comparison of Stiffness Performance of Unstiffened SPSWs With and Without Openings as a function of Thickness

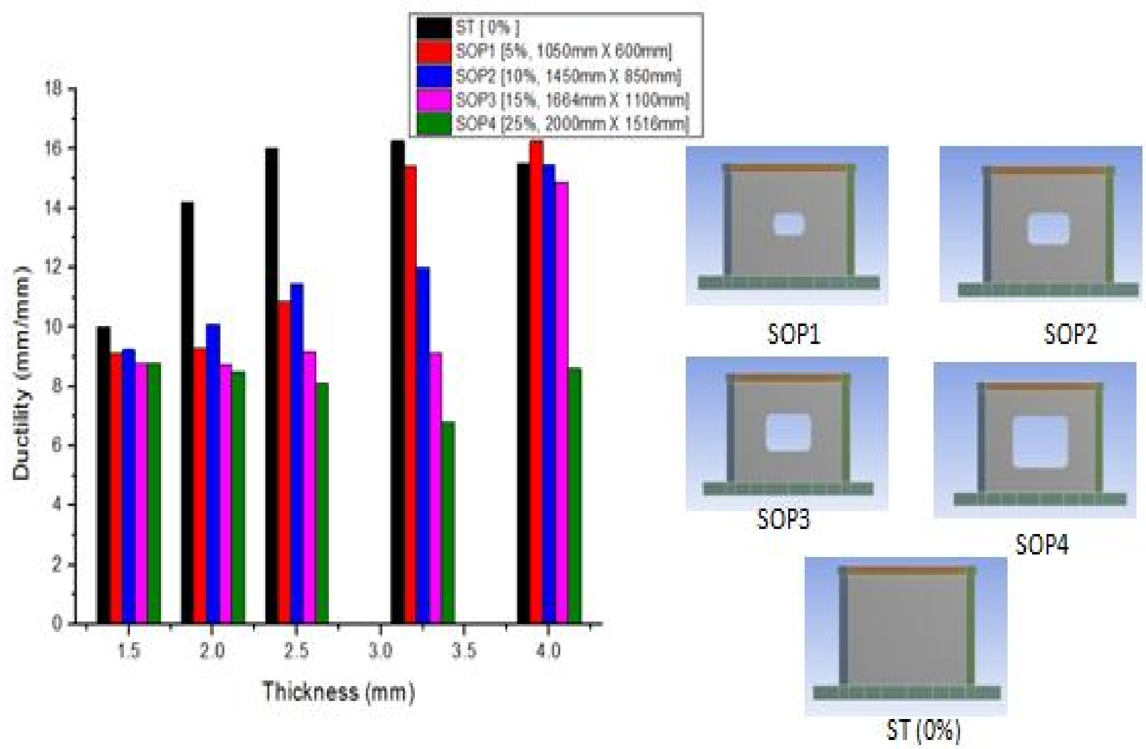

Fig. 42 Comparison of Ductility Performance of Unstiffened SPSWs With and Without Openings as a function of Thickness

Volume 4 Issue X, October 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

B. Case 2: Comparison of Stiffened Steel Plate Shear Walls With and Without Openings

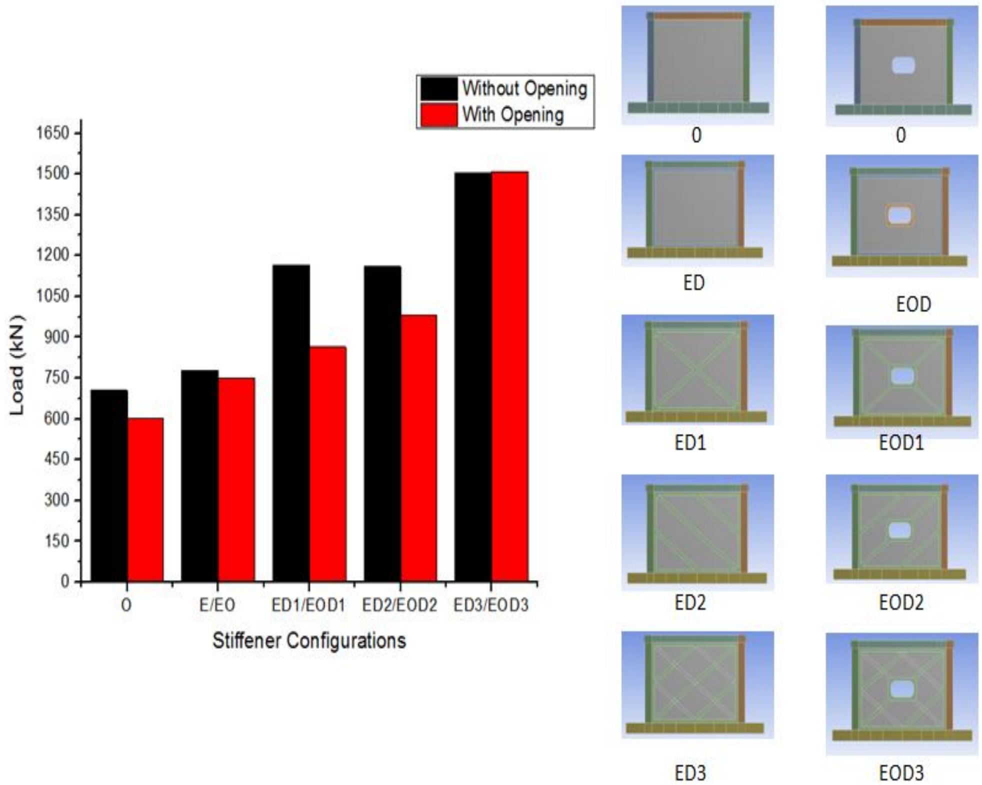

Fig. 43 Comparison of Load Performance of Stiffened SPSWs With and Without Openings as a function of Stiffener Configurations

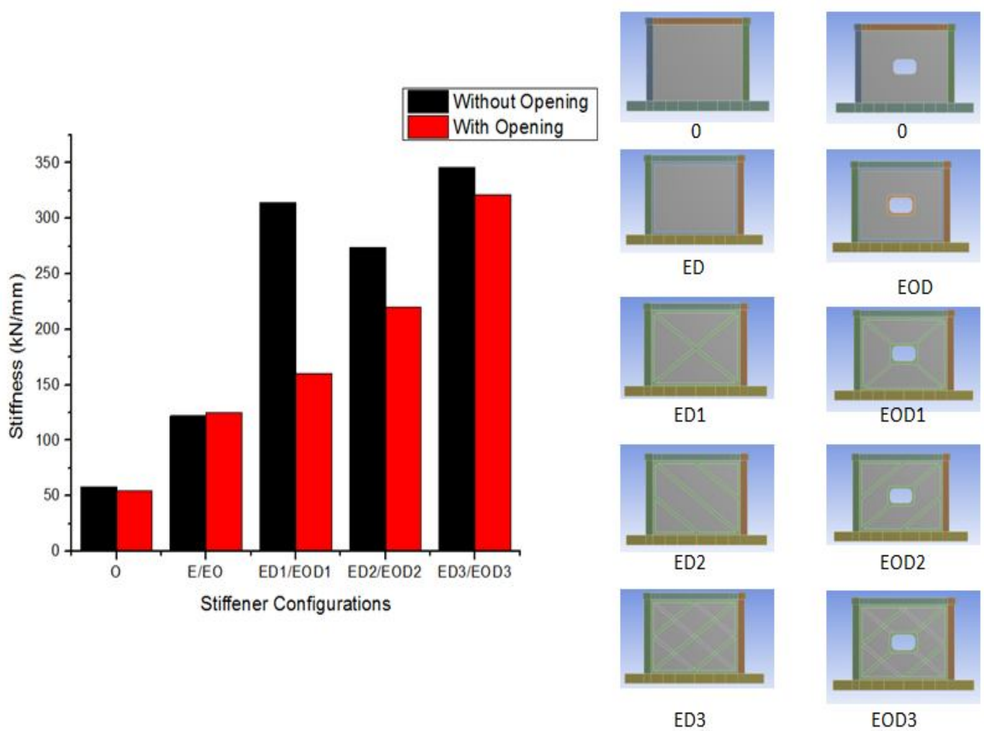

Fig. 44 Comparison of Stiffness Performance of Stiffened SPSWs With and Without Openings as a function of Stiffener

Configurations

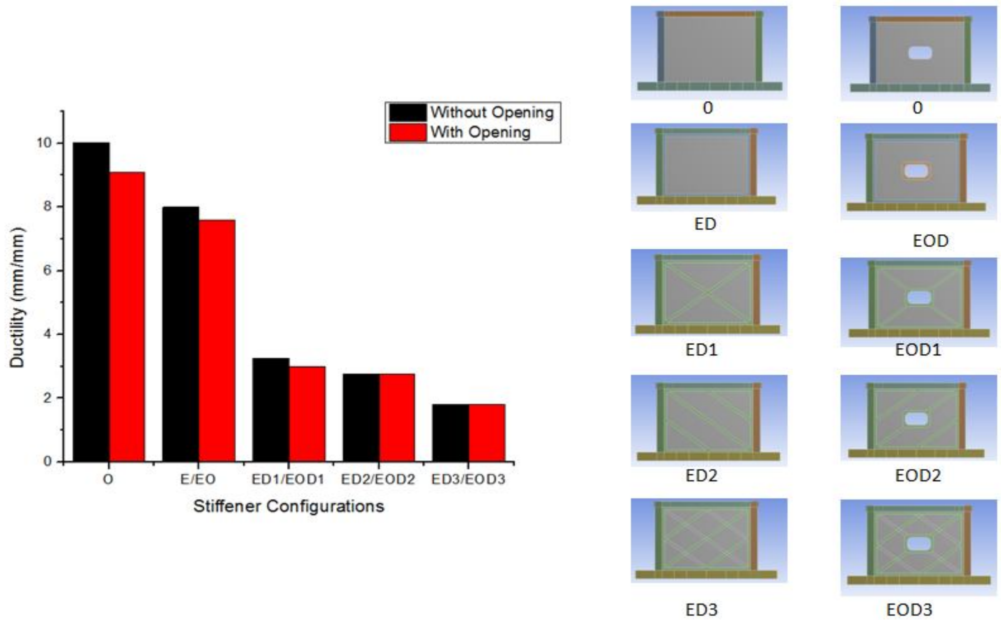

Fig. 45 Comparison of Ductility Performance of Stiffened SPSWs With and Without Openings as a function of Stiffener Configurations

VIII. CONCLUSIONS

In this study the behavior of geometrically different Steel Shear Walls with different thicknesses, with and without openings and with different configuration of stiffeners have been investigated using Finite Element software in ANSYS16.2.Numerous finite element models were considered based on infill plate thickness, opening percentage and stiffener configuration. Under the scope of the work following observations and conclusions are drawn from the present study.

A. To establish the accuracy of the numerical modeling methodology, finite element model of Corrugated Steel Plate Shear Wall is developed and compared it with a well-established laboratory test; excellent agreement is observed between analysis and experimental results. For the numerical model the peak load observed during the test is underestimated only by 4%.

B. Introduction of web plate openings and increasing of the opening size or percentage were shown to have detrimental effects by reducing ultimate load and stiffness of SPSW system while ductility of the system was not affected specifically by the variation of the opening size.

C. Use stiffeners on both sides of the infill panels can improve the strength and stiffness performance of Stiffened Steel Plate Shear Wall system significantly compared to Unstiffened Stiffened Steel Plate Shear Wall.

D. Stiffener configuration ED1 (Edge and Diagonal) is found to be detrimental for Steel Plate Shear Wall with central opening because this can reduce strength performance of the system significantly.

E. Under moderate earthquakes it is better to use stiffener configuration ED1 (Edge and Diagonal) and ED3 (Edge and diagonally inclined (different configuration in both side)) for SPSW system without openings because X or diagonal shaped stiffeners have equal effect in strengthening and stiffening of the panels due to similar geometrical status, leading to less non structural damages for the building equipped with Stiffened SPSW system.

F. During a severe earthquake structure is likely to undergo inelastic deformations, it has rely on its ductility performance to avoid collapse; in such situations it is better to use stiffener configuration E, it has good ductility due to less imperfections created within infill plate due to welding operation are very small

IX. ACKNOWLEDGMENT

This work was supported by the Faculty of MA College of Engineering and Research Scholar of Indian Institute of Technology.

Volume 4 Issue X, October 2016
ISSN: 2321-9653

Their support is gratefully acknowledged.

REFERENCES

[1] Ignasius F Seilie and John D Hopper, "Steel Plate Shear Wall: Practical Design and Construction", North American Steel Construction Conference, Modern Steel Construction April 2005.

[2] Abhishek Verma and P. R. Maiti, "Push Over Analysis of Unstiffened Steel Plate Shear Wall", International Journal of Engineering Research and Development, Vol 1, pp 41- 49, 2012.

[3] Gajendra Kumar Verma and SavitaMaru, "Some Studies on Behavior Of Steel Plate Shear Wall In Earthquake Prone Area: A Review", International Journal of Engineering Trends and Technology, Vol 4, 2013.

[4] Shahin banaee1, Mohammad Hossein Adibradand Armin Roohbakhshan, "Investigate the use of steel plate shear walls in buildings", International Journal of Scientific & Engineering Research, Vol 7, 2016.

[5] Fereshteh Emami, Mahmoud Mofid and A. Vafai, "Experimental study on cyclic behavior of trapezoidally corrugated steel shear walls", **Article** in Engineering Structures, Vol (48),2013, pp.750–762.

[6] Ronny Purba and Michel Bruneau, "Finite-Element Investigation and Design Recommendations for Perforated Steel Plate Shear Walls", American Society of Civil Engineers, 2009.