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FINITE ELEMENT ANALYSIS OF STEEL PLATE SHEAR WALL

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Abstract - *Steel plate shear walls (SPSW) consist of thin infill steel plates that is attached to beams, called horizontal boundary elements (HBEs), and to columns called vertical boundary elements (VBEs) in building structural frames. This system offers several advantages as compared to the other usual lateral load resisting systems. When a lateral load applied on SPSW more demand produced on frames so in order to make it strong we have to require the adoption of large cross-section profiles it will increase the cost. Perforated steel plate shear wall is a relatively new lateral load resisting system used for resisting wind and earthquake loads. This paper it shows the advantage of using perforated steel plate, when a perforation given on the steel plate the tension field will reduce which will limit the demand on surrounding frames. A parametric study FEM analysis on perforated panels by changing its thickness of plate, aspect ratio of plate, number of holes, pattern of holes, diameter of holes. Finite element (FE) models of this system were developed and analyzed in ANSYS. From the obtained results estimate the strength and deformation of perforated shear plate.*

***Key Words*: Horizontal boundary element, Vertical boundary element, Perforated, Lateral load, Demand**

1. INTRODUCTION

Steel plate shear walls (SPSW) have been used, as the primary lateral force resisting system in buildings for more than three decades. A steel plate shear wall consist of three components, namely the steel infill plate, the beams which are referred to as horizontal boundary elements (HBE) and the columns which are referred to as vertical boundary elements (VBE). The vertical steel infill plates are typically connected to the surrounding beams and columns. Compared to reinforced concrete shear walls, SPSWs are much lighter, which ultimately reduces the demand on columns and foundations, and reduces the seismic load.

The steel infill panels in SPSW system can be either stiffened or unstiffened. SPSWs have high elastic stiffness, large displacement ductility, and stable hysteretic behavior and high energy dissipating capacity. Since 1970, steel shear wall systems as the choice among lateral load-resisting systems has been used in several modern and important buildings. During the 1970s, the steel shear walls were used in Japan for new buildings and in the United States to improve the seismic rehabilitation of existing buildings.

The main duty of steel shear walls is to resist horizontal load and overturning moment caused by the lateral loads, respectively. Energy dissipation and ductility during seismic events is principally achieved through yielding of the web plates along the diagonal tension field. They have been used in the structural design and retrofitting of existing buildings with different configurations, with thick steel plate, stiffened or un-stiffened thin steel plate. In unstiffened openings, tension is induced in the center of the plate due to buckling. The interaction between the opening and the tension field caused a decrease in stiffness and strength

The objectives of this study are to conduct a nonlinear finite element analysis of perforated steel plate shear walls under monotonic lateral loading and to study the influence of aspect ratio, plate thickness, number and diameter of holes on the behavior of unstiffened spsw.

A detailed finite element analysis has been conducted on Steel Plate Shear wall with and without opening. The parametric study includes; infill plate thickness, aspect ratio, number and diameter of holes.

2. VALIDATION

To establish the accuracy of the numerical modeling methodology, finite element model of steel plate shear wall in ANSYS is compared with A. Formisano et al. Specimen which is implemented in ABAQUS for simulating the behavior of shear panels under monotonic loading.

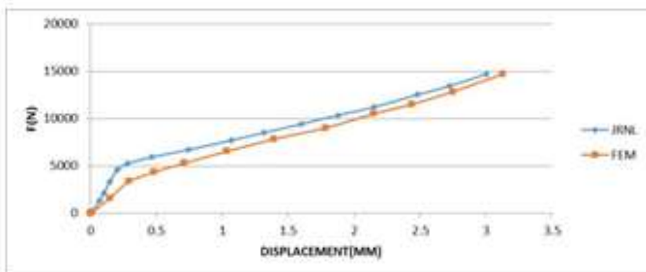


Fig 1: Validation graph

Displacement mm		
JOURNAL	FEM	ERROR %
3	3.12	4

3. PARAMETRIC STUDY

For the detailed investigation on the seismic performance of the steel plate shear wall system, parametric studies are performed by changing the geometric properties of the infill plate including thickness of infill plate, number and diameter of holes, and aspect ratio of the SPSW.

Table 1: Specification Chart for Numerical Models

specimen	Thickness of plate(mm)	diameter of holes	number of hole	Pattern of holes
SPSW T1	0.37mm	-	-	-
SPSW T2	0.7mm	-	-	-
SPSW1 T1D1	0.37mm	75mm	1	
SPSW1 T2D1	0.7mm	75mm	1	
SPSW1 T1D2	0.37mm	100mm	1	
SPSW1 T2D2	0.7mm	100mm	1	
SPSW2 T1DI	0.37mm	75mm	2	
SPSW2 T2D1	0.7mm	75mm	2	
SPSW2 T1D2	0.37mm	100mm	2	
SPSW2 T2D2	0.7mm	100mm	2	
SPSW2 T1DI -v	0.37mm	75mm	2	
SPSW2 T2D1 -v	0.7mm	75mm	2	
SPSW2 T1D2 -v	0.37mm	100mm	2	
SPSW2 T2D2 -v	0.7mm	100mm	2	
SPSW4 T1DI	0.37mm	75mm	4	
SPSW4 T2D1	0.7mm	75mm	4	
SPSW4 T1D2	0.37mm	100mm	4	
SPSW4 T2D2	0.7mm	100mm	4	
SPSW4 T1DI -v	0.37mm	75mm	4	
SPSW4 T2D1 -v	0.7mm	75mm	4	
SPSW4 T1D2 -v	0.37mm	100mm	4	
SPSW4 T2D2 -v	0.7mm	100mm	4	

Parameters considered including thickness of infill plate, aspect ratio, number and diameter of holes. The specification chart for the numerical models is given in Table 1. Two different plate thicknesses are considered. Thicknesses are 0.37mm, 0.7mm. Aspect ratios are taken as 1.5, 1, and 0.6. One, two and four holes in spsw are considered aligned in two different patterns.70mm and 100 mm diameter holes are considered.

4. NUMERICAL MODELING AND SIMULATION

This section describes investigation on the behavior of perforated SPSW using the finite element software ANSYS. Several key features of assembling a comprehensive finite element model, such as modeling process, element definitions, and material definitions, are concisely discussed first. After evaluating the accuracy and convergence of the resulting finite element model, perforated strips 500 mm wide with 100 mm diameter holes are first examined and results are presented in terms of stress-strain distributions throughout the strip section as well as in terms of global deformations. The model is then modified to consider various perforation diameters, boundary conditions, and material idealizations. These studies are intended to develop an understanding of the behavior of individual perforated panels as a fundamental building block in understanding the behavior of complete SPSW in the next section.

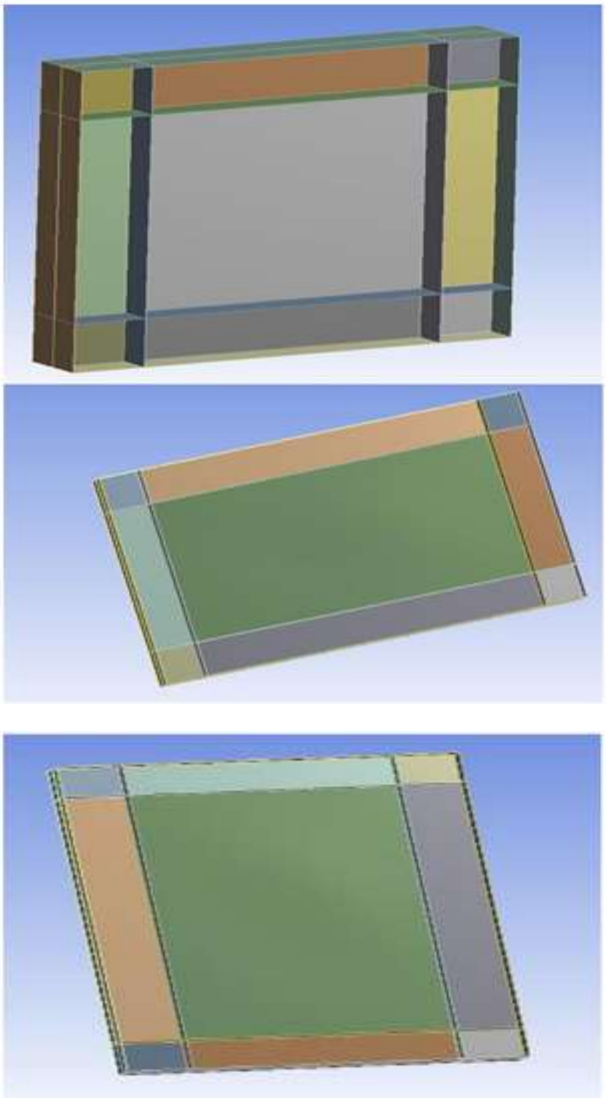


Fig 1 spsw with different aspect ratios

Table 2 Comparison of spsw with two thicknesses

Specimen	Thickness	Deformation	Load
SPSW T1	T1	20.1402	30226.5
SPSW T2	T2	30.0467	44599.3

Table 3 : Variation of deformation and load spsw with one hole

SPECIMEN	Thickness	Deformation	Load
SPSW1T1D2	T1	19.5327	25087.1
SPSW1T1D1	T1	22.2897	32230
SPSW1T2D2	T2	29.2056	35714.3
SPSW1T2D1	T2	24.56012128	39538.39

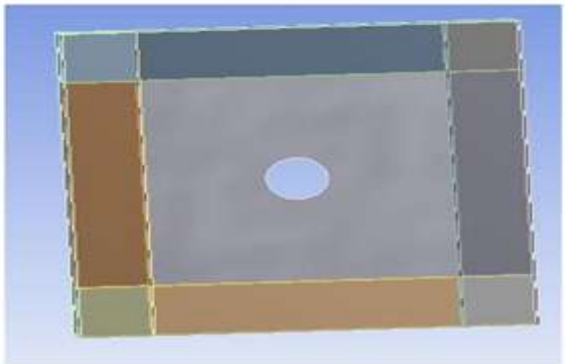


Table 4 : Comparison of for 75mm, 100mm and 0.37mm0.7mm (horizontally oriented)

SPECI MEN		D=100		D=75	
	Thickn ess	Deforma tion	Load	Deforma tion	Load
SPSW2	T1	37.570	1935 0.9	45.3254 5	15523 .8
SPSW2	T2	37.529	3721 7.4	48.2456	33214 .25

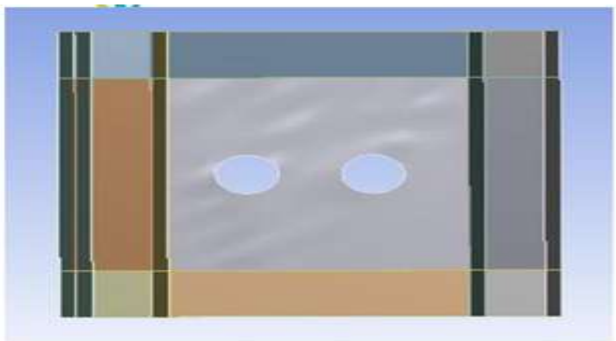


Table 5 comparison of 75mm, 100mm and 0.37mm, 0.7mm (vertically alligned)

		D2=100		D1=75	
speci men	Thickn ess	Deforma tion	Load	Deforma tion	Load
SPSW 2_v	T1	38.0374	1866 1.3	49.0457	14859 .21
SPSW 2_v	T2	37.5758	3434 7.8	43.4576	30124 .53

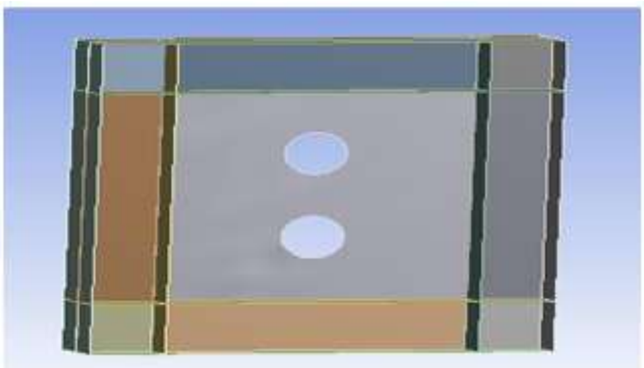
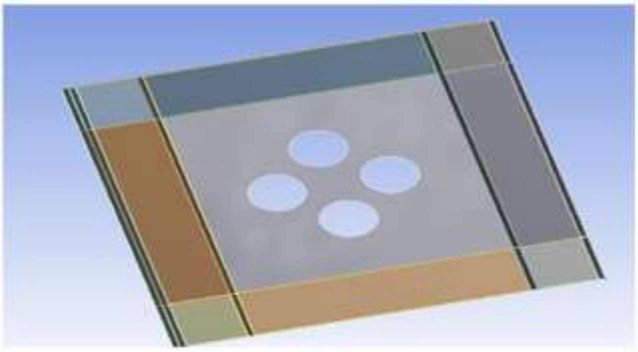


Table 6 : Comparison of 75mm, 100mm and 0.37mm, 0.7mm (vertically aligned)

		D=100		D=75	
	Thickness	Deformation	Load	Deformation	Load
SPSW 4_V	T1	37.429	17606.5	46.241	16475.45
SPSW 4	T1	38.224	16308.3	48.215	13452.48
SPSW 4_V	T2	37.557	31826.1	37.453	27546.45
SPSW 4	T2	37.529	30000	40.756	24457.27



FOR ASPECT RATIO1

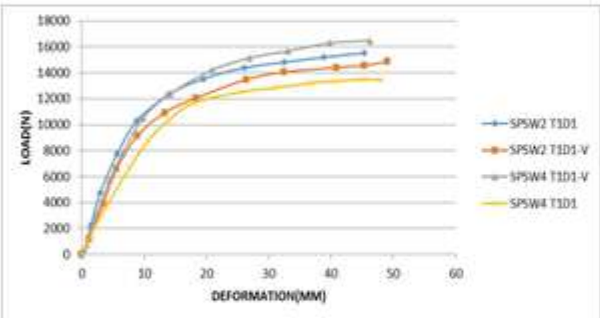


Fig 5: Load-Displacement curveor holes with different patterns of T1 thickness 75mm dia

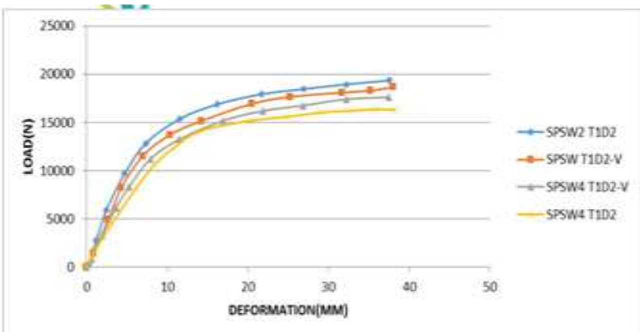


Fig 6 : Load-Deformation curves for holes with different patterns of T2 thickness 75mm dia

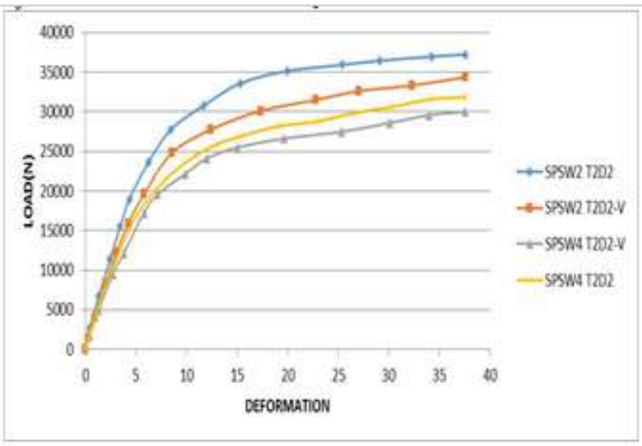


Fig 7: Load-Deformation curves for holes with different patterns of T2 thickness 100mm dia

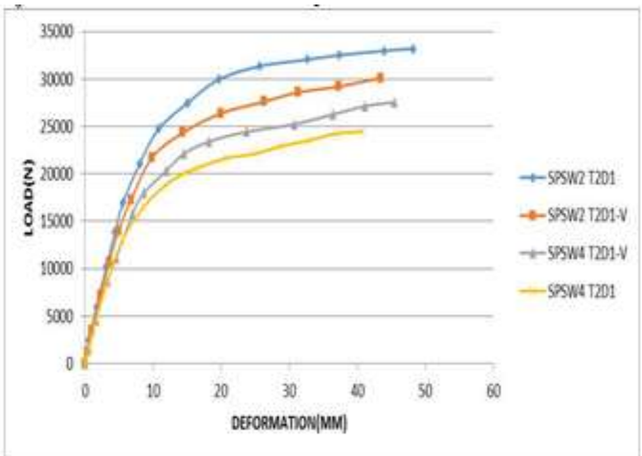


Fig 8: Load-Deformation curves for holes with different patterns of T2 thickness 75mm dia

FOR ASPECT RATIO 1.5

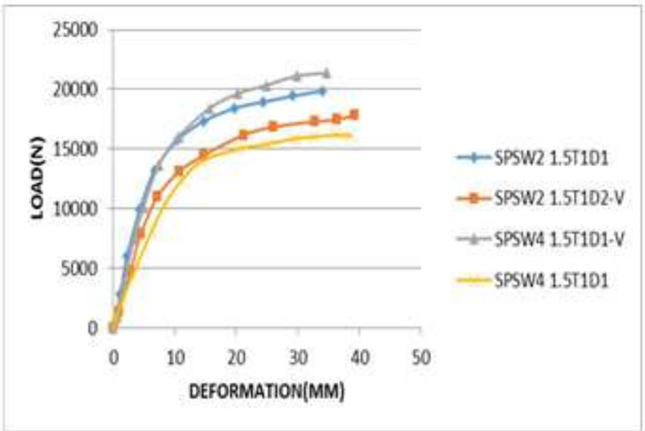


Fig 9 : Load-Deformation curves for holes with different patterns of T1 thickness 100mm dia

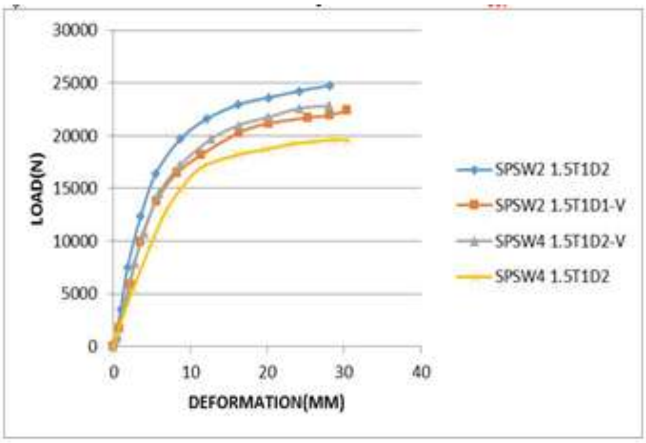


Fig 10: Load-Deformation curves for holes with different patterns of T1 thickness 75mm dia

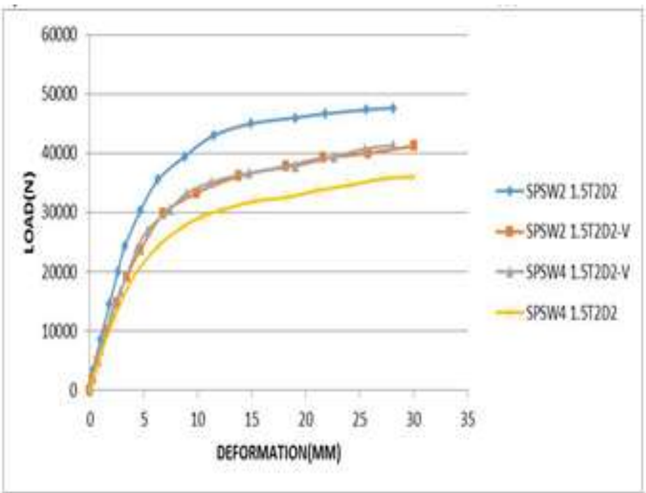
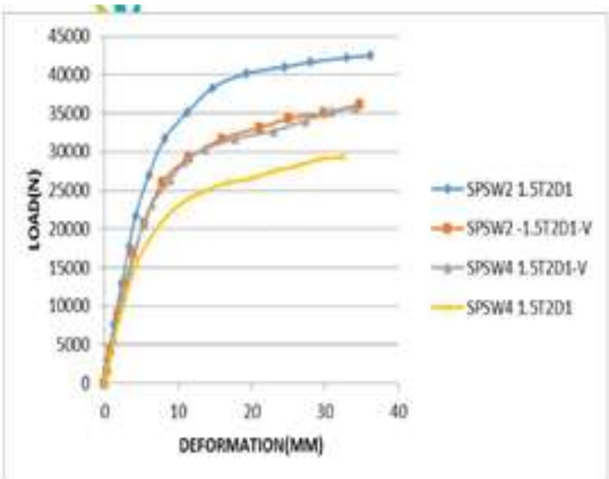


Fig 11: Load-Deformation curves for holes with different patterns of T2 thickness 100mm dia

FOR ASPECT RATIO 0.6



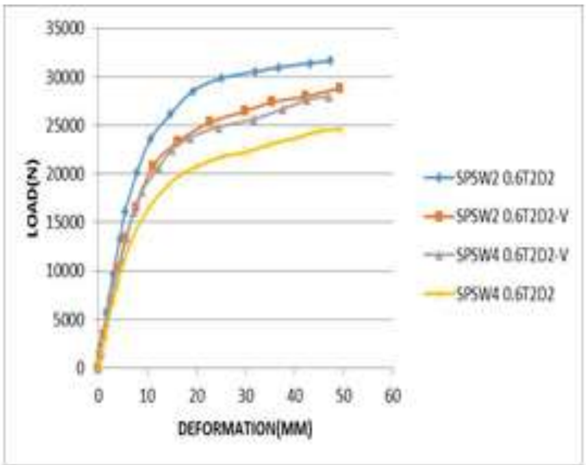


Fig 12: Load-Deformation curves for holes with different patterns of T2 thickness 100mm dia

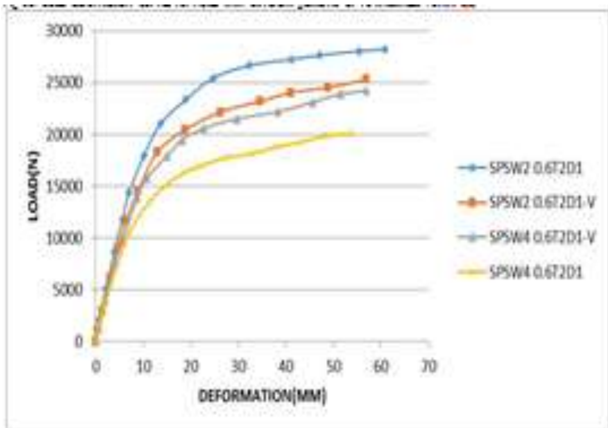


Fig 13: Load-Deformation curves for holes with different patterns of T2 thickness 75mm dia

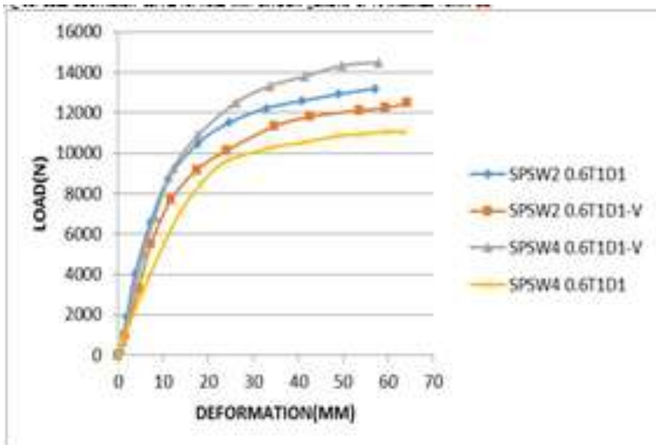


Fig 14: Load-Deformation curves for holes with different patterns of T1 thickness 75mm dia

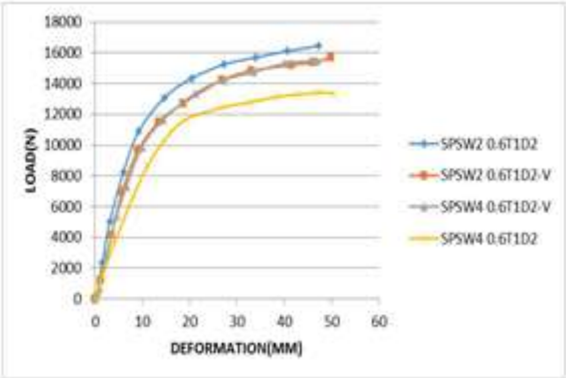


Fig 15: Load-Deformation curves for holes with different patterns of T1 thickness 75mm dia

5. CONCLUSIONS

In this study the behavior of Steel plate Shear Walls with different thickness, different aspect ratios, different number and diameter of holes have been investigated using Finite Element software in ANSYS18.1. Under the scope of the work following observations and conclusions are drawn from the present study.

Spsw with high thickness plate has more deformation and shear load rate than the low one. In two hole case Horizontal hole shows highest load and medium deformation. As the hole diameter increases the maximum shear load decreases and the lateral deformation increases. In four hole case Vertical type shows the highest load and least deformation.

As the height of the frame increases the shear load value decreases and the deformation rate increases.

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