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Seismic analysis of corrugated steel plate shear wall with opening

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Abstract— Cold –formed corrugated steel plate shear wall (CSPSW) construction is a newly accepted and efficient lateral force resisting system. This system offers several advantages as copared to the other lateral load resisting system. Its consist of corrugated thin infill plate that attached to the horizontal and vertical steel beams in building structurel frame. It offers various advantages over flat plate including ductility. Large initial stiffness,improving buckling stability,high level energy abasorption capacities,and ability to accomadate openings. The openings may be created within the corrugated infill plate to accommodate for architectural purposes, passing utilities, and structural resons. On this bases, this paper investigates the initial stiffness, and energy absorption capacities of CSPSW with and without opening. To this end, numerous finite elemenet models with various geometrical properties are developed and analyszed under cyclic loading. Results and findings of this study are indicate of effectiveness of the thickness, opening size of the infiil plates on the hysteretic performance of corrugate and perforated steel steel shear wall system.Optimal and proper selection of the oforementionedgeometrical parameters can results in CSPSW system with desirable structural behavior and seismic performance.

Keywords— buckling behavior, Corrugated steel plate shear wall, energy absorption Openings, Seismic Performance, stiffness, thickness, opening area.

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1 Introduction

Steel shear walls are widely utilized as an efficient latera force resistance system in areas with high hazard seismicity. This structural system with significant strength and ductility and initial stiffness has been implemented in a number of high-rise buildings as an economical way of providing more space, considerable strength, faster speed of construction, better quality control and lighter structures are the primary motivation for the construction type.

A steel plate shear wall consist of infill plate connected to the surrounding horizontal and vertical beams (HBE and VBE).These columns and beams are rigidly connected to form a moment resisting frame with infill steel plate. The moment resisting frame coupled with the steel plate shear wall increases both redundancy and ductile behavior of the system. Compared to reinforced concrete shear walls, the corrugated steel plate shear walls are much lighter, which ultimately reduces the demand on columns and foundations, and reduces the seismic load. Steel plate shear wall resist lateral loads and dissipate seismic energy through the yielding and buckling of the infill plates. Steel plate shear walls have high elastic stiffness, large displacement ductility, and stable hysteretic behavior and high energy dissipating capacity.

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Corrugated Steel Plate Shear wall is a relatively new system,the corrugated infill plate gives the significant ininitial stiffness. It is a new type of lateral load resisting system.the corrugated steel plate shear wall compared with the unstiffened plate shear walls,CSPSW have greater elastic buckling capacity and more resistince to the gravity loads transferred to the wall panel or nearly avoid them,depending on the direction of the corrugation.

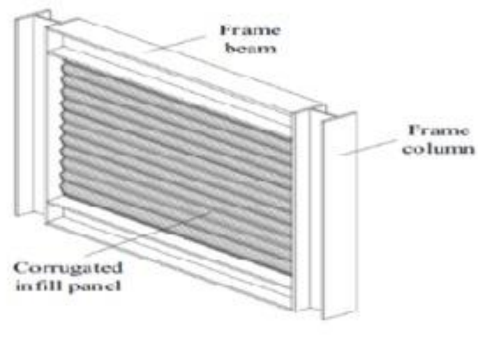

Fig Steel plate shear wall

2. OBJECTIVES AND SCOPE OF THE STUDY

2.1 Objectives of this study,

1. To conduct a nonlinear finite element analysis of perforated corrugated steel plate shear walls under cyclic loading.
2. To study the behavior of the corrugated steel shear

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walls in the bases of, plate thickness, and size and position of the shear wall with and without rectangular openings.

3. Prediction of initial stiffness, deformation, and energy absorption as a function of shear wall geometry are sought.

2.2 Scope of the study are,

Steel shear walls are widely utilized as an efficient lateral resistance system in areas with high hazard seismicity. This structural system with significant strength and ductility has been implemented in a number of high-rise buildings as an economical way of providing more space, considerable strength, faster speed of construction, better quality control and lighter structures.

1. This research is limited to the investigation of the behavior of stiffened CSPSWs with openings on the infill plate under cyclic loading. The parameters are mainly effected the behavior of the system (angle of corrugation, thickness , size of openings and their position). All analyses are performed using the finite element software ANSYS 16.1.

2. Under the current research, there is scope to address these difficulties by limiting the formation of tension fields within the plate by using openings in the infill plate attached to the boundary elements.

3. PARAMETRIC STUDY DESIGN

The overall seismic performance of the corrugated steel plate shear wall depends upon the geometrical properties of the boundary element as well as the infill plate. In this work for detailed investigation on the seismic performance of the CSPSW system, parametric studies are performed by changing the properties of the infill plate. Parameters considered including thickness of infill plate, opening size.On this two basis 21 models are considered. The specification chart for the models is given in table 1

TABLE 1
PARAMETRIC STUDY DETAILS

Model name	Thickness (mm)	Opening size	Function
CSPSW	1.6,2,2.5,3.25.4	NA	
CSPSW	1.6,2,2.5,3.25.4	1000X1600	Window
		1000X2290	Door
		1800X1600	Window
		1800X2290	Door

4. ANALYTICAL INVESTIGATIONS

The non linear analysis of corrugated steel plate shear walls are undertaken by using the commercially available finite element package of ANSYS 16.2

The finite element model of corrugated steel plate shear walls model was constructed by using the two type of elements. The shell element SHELL 181 and the solid element SOLID 186. The SHELL 181 is defined by four noded shell element translation in the x, y, and z direction, and rotation about the x, y, and z- axes. The shell element that is capable of large displacement, no linear behavior and large rotation. The SOLID 186 is defined by 20 nodes having three degree of freedom translation in nodel x, y, and z direction. Solid element that is capable of large deflection, large strain and stress stiffening. And also its exbits quadratic displacement behavior.

4.1 Boundary Condition and Material Properties

Corrugated Steel Plate Shear walls with perforations of different size of rectangular openings 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 was provided as boundary condition at bottom of the shear wall. And the cyclic loading was provided in lateral direction. The load was provided at the top of beam in displacement control and in incremental manner(ATC 24). This work is carryout by providing boundary element as Indian standard ISWB 150 was selected as beam and column element. The beams to columns were moment resisting, therefore all intersecting shell elements were directly connected. And also the box selection 120mmX60mmX3.6mm provided entire the openings. The panel size selected as 3300mmX2700mm. In this work modeling was done by changing of corrugated thickness of trapezoidal corrugated steel plate shear walls, by providing different size of rectangular openings (door and window). The material properties and specimen details are illustrated in table 2

TABLE 2
MATERIAL PROPERTIES

TYPE	Tensile yield strength (GPa)	YOUNG'S MODULUS (MPa)	POISSON'S RATIO
PLATE	207	210	0.3
BEAM	288	210	0.3
COLUMN	300	210	0.3

4.2 Loading Program

The loads are provided in the basis ATC24 protocol. The loading history is conducted on the bases of the displacement (Δ_y). The cycles are $0.25\Delta_y$, $0.50\Delta_y$, $0.70\Delta_y$, Δ_y, $1.5\Delta_y$, $2\Delta_y$, $4\Delta_y$, and $5\Delta_y$. The yielding displacement is equal to the yielding loading p_y, which is equal to the $.7P_{uc}$. The Puc is the estimated ultimate load bearing capacity.

TABLE 3
CYCLIC PROPOTOCOL

Sl no	Displacement(Δ_y)	Displacement (mm)
1	$0.25\Delta_y$	.805
2	$0.50\Delta_y$	1.61
3	$0.70\Delta_y$	2.25
4	Δ_y	3.22
5	$1.5\Delta_y$	4.83
6	$2\Delta_y$	6.44
7	$3\Delta_y$	9.66
8	$4\Delta_y$	12.88
9	$5\Delta_y$	16.1

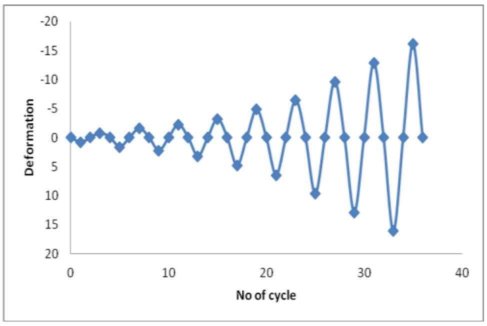

Fig 2 cyclic displacements controlled loading graph

4.3 Modelling

The behavior of the corrugated steel shear wall with openings are investigated under cyclic loading, vertical shear walls with openings are consider for the investigation. The height and length of the story panel are 3m and 3.6m respectively.

The trapezoidally corrugated steel plate shear wall with 1.6 mm thickness, 20.5mm rib height and horizontal and inclined part is 100mm and 22.8mm respectively, and also 64^0 angle of corrugation were consider for the study. Different numerical models used for the study are illustrated in fig 3-8

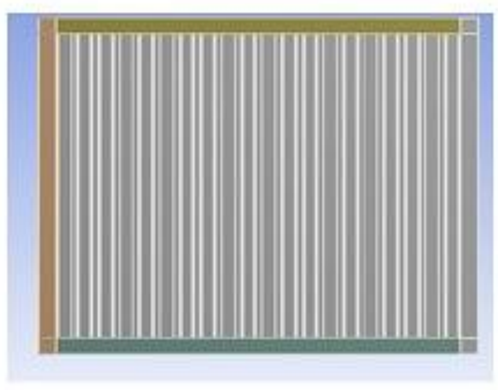

Fig-3 Vertically corrugated steel plate shear wall

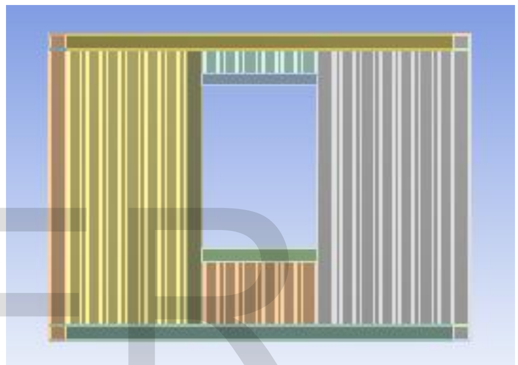

Fig-5 Corrugated steel plate shear wall with window opening W1

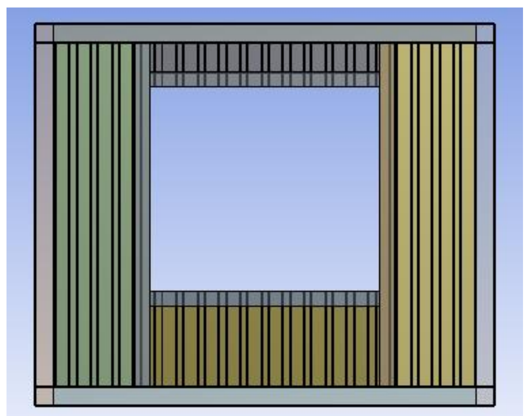

Fig-6 Corrugated steel plate shear wall with window opening W2

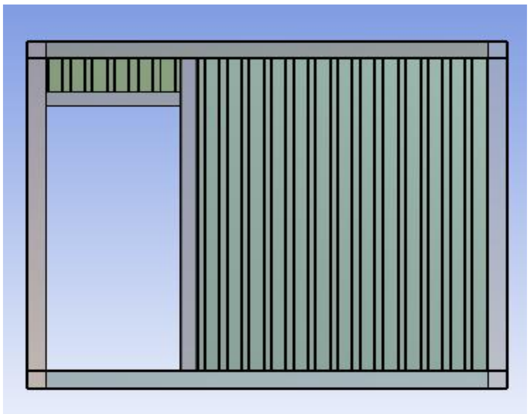

Fig-7 Corrugated steel plate shear wall with door opening D1

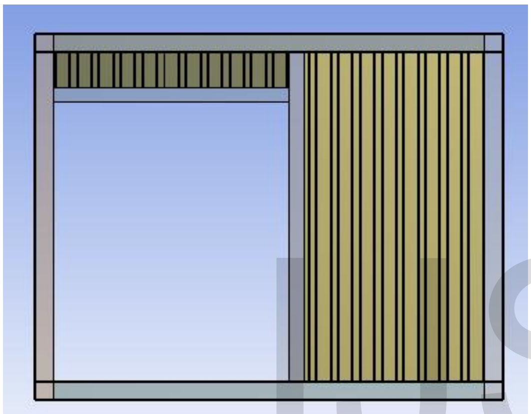

Fig-8 Corrugated steel plate shear wall with door opening D2

5. RESULTS AND DISCUSSIONS

In this part analysis and discuss the behavior and performance of the corrugated steel plate shear wall with and without opening, in the case of a vertically allied corrugated steel plate.

In the case of a vertically allied corrugated steel plate shear wall with and without opening, The size of the wall is 3600 x3000 mm. The analysis gives the equivalent stress effect of the corrugated shear wall without opening and also the hysteresis graph gives the maximum load carrying capacity of the system and deformation of the corrugated steel plate shear wall. The Equivalent Von-Mises stress, Hysteresis behaviour and stiffness of the CSPSW under cyclic loading are shown in below.

TABLE 3

ENERGY ABSORPTION, STIFFNESS AND TOTAL DEFORMATION OBTAINED BY CSPSW WITH AND WITHOUT OPENING

shape	Thickness (mm)	Ultimate strength (KN)	Deformation (mm)	Stiffness (KN/mm)
Shear wall without opening	1.6	683	16.19	42.18
	2	983	16.20	60.67
	2.5	1032	16.31	63.27
	3.25	1300	16.46	78.97
	4	1519	16.65	91.23
Window1 opening	1.6	485	17.06	28.42
	2	583	17.34	33.62
	2.5	695	17.60	39.48
	3.25	831	17.85	46.55
	4	929	17.88	51.95
Window2 opening	1.6	231	16.40	14.08
	2	391	16.79	23.28
	2.5	451	16.88	26.71
	3.25	535	16.88	31.69
	4	608	16.89	35.99
Door1 opening	1.6	317	16.46	19.25
	2	589	17.43	33.79
	2.5	701	17.76	39.47
	3.25	839	18.11	46.32
	4	945	19.90	47.48
Door2 opening	1.6	219	16.45	13.31
	2	327	17.42	18.77
	2.5	422	17.50	24.11
	3.25	487	17.7	27.49
	4	539	17.94	30.04

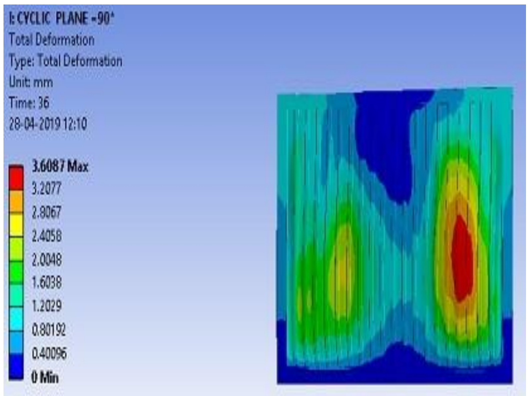

Fig-9 Total deformation of the trapezoidaly corrugated steel plate shear wall without opening

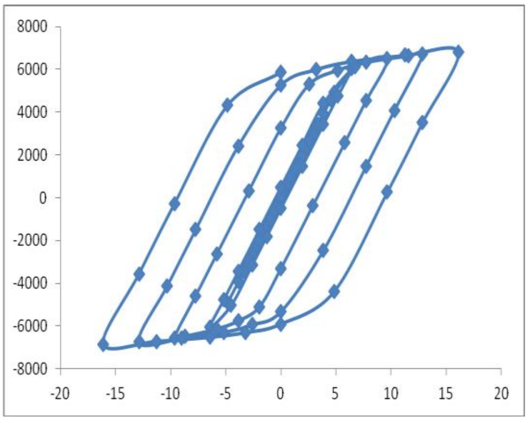

Fig-12 Hysteresis curve of CSPSW without opening

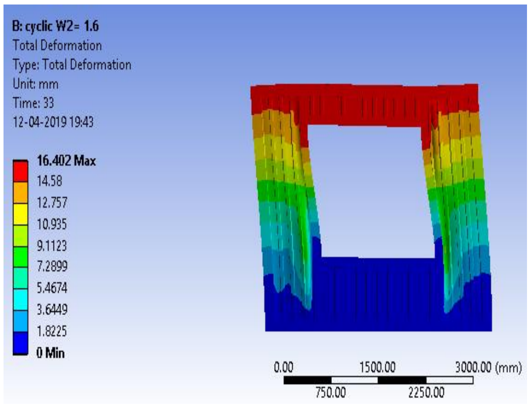

Fig-9 Total deformation of the trapezoidaly corrugated steel plate shear wall with w2 opening

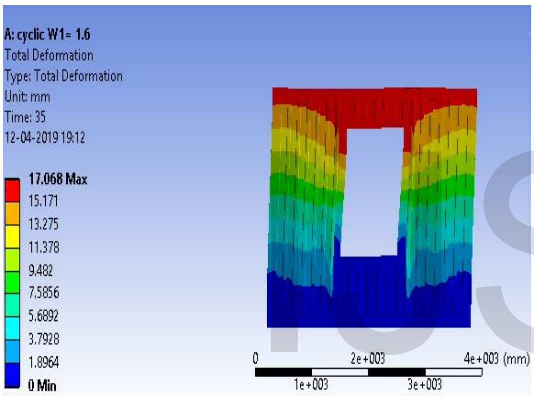

Fig-9 Total deformation of the trapezoidaly corrugated steel plate shear wall with W1 opening

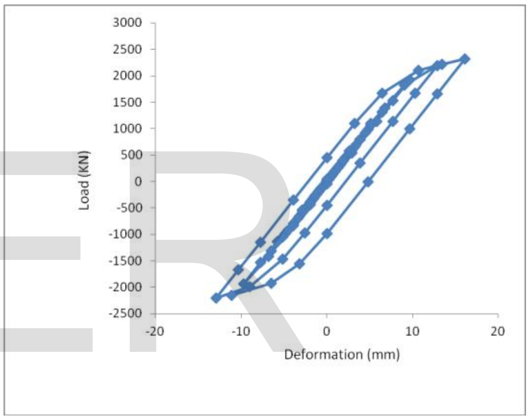

Fig-12 Hysteresis curve of CSPSW with W2 opening

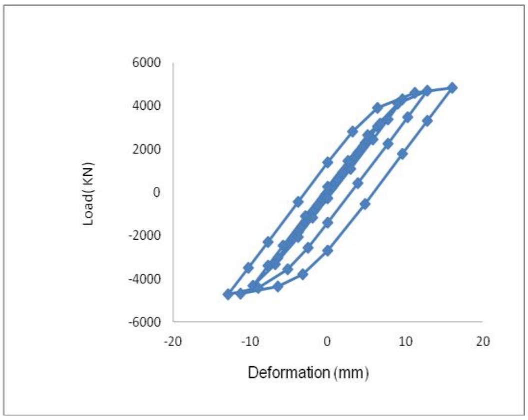

Fig-10 Hysteresis curve of CSPSW with W1 opening

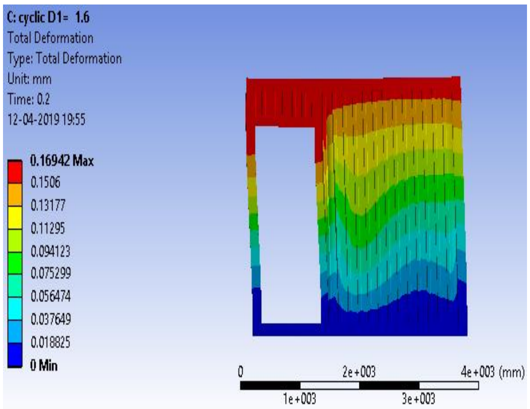

Fig-13 Total deformation of the trapezoidaly corrugated steel plate shear wall with D1 opening

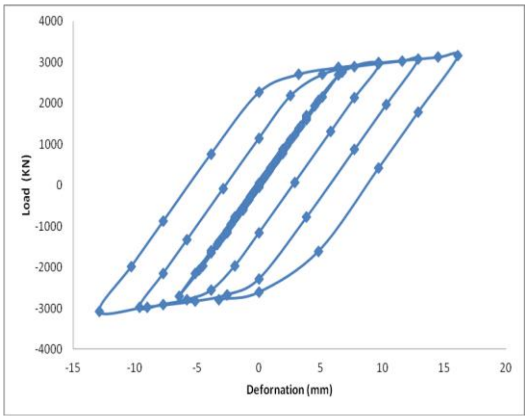

Fig-14 Hysteresis curve of CSPSW with D1 opening

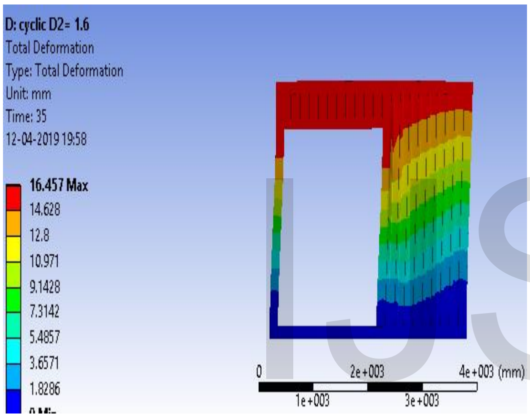

Fig-15 Total deformation of the trapezoidaly corrugated steel plate shear wall with D2 opening

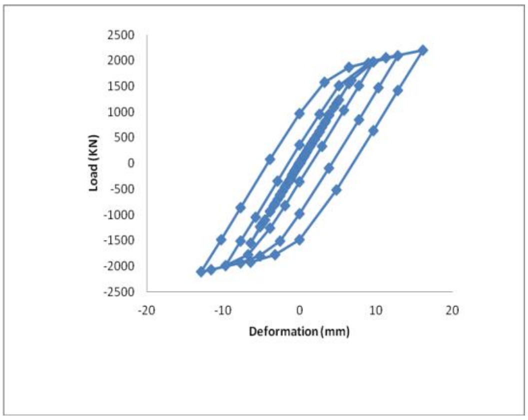

Fig-16 Hysteresis curve of CSPSW with D2 opening

The figure shows that the ultimate load carrying capacity and deformation of the corrugated steel plate shear wall. The ultimate load carrying capacity of the vertically allied corrugated shear wall without opening was 683KN in thickness 1.6mm that was increases up to 1519KN in thinkness 4mm. so the thickness is a important factor of the performance of the system.

The behavior of the corrugated plates without openings is superior to that of shear wall with openings. When we provide a openings of the corrugated steel plate shear wall the load carrying capacity decreased and deflection of the shear wall increases and also decresing the stiffness of the structure.

The infill plate thicknes found to be an important geometric property of shear wall system. Increase in thickness in small range will leads to a large increase of stiffness of the shear wall system. This behavior of shear wall can reduce non-structural damage of the structure under earthquake. Introduction of web plate perforation and increasing of percentage of opening shown to have detrimental effects by reducing ultimate load and stiffness of the shear wall system.

The opening size also the main factor of the performance of the system, the opening size increases also decreasing the ultimate load carrying capacity and deformation. And also the position of the openings also a important factor, the center openings has more damage and less load bearing capacity as compare to the center opening.

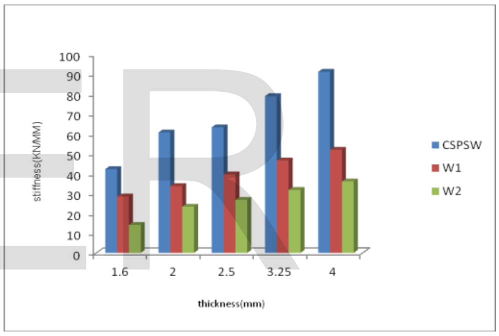

Fig-17 comparison of stiffness of CSPSWs with and without opening(W1 and W2)

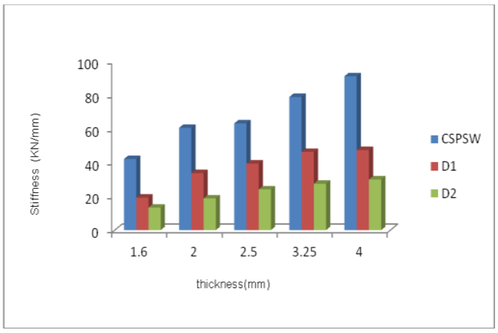

Fig-17 comparison of stiffness of CSPSWs with and without opening(D1 and D2)

6. CONCLUSIONS

In this study of behavior of corrugated steel plate shear wall with different thickness, with and without openings have been investigated using Finite Element Analysis software ANYSIS 16.1. The models were considered based on the infill plate thickness and opening size. Under the scope of the work following observations and conclusions are drawn from the present study. The infill plate thickness is the most important property of the shear wall system. Increasing the thickness of the infill plate its increasing the load carrying capacity and decreasing the deformation of the system. And also the opening size increases its decreasing the load carrying capacity of the system.

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