Numerical Study On Cross-shaped Stainless Steel Core Plate Wall

Chaithanya
M. Tech Student
Department of Civil Engineering
Government College of Engineering Kannur
Kannur, India

Nijesh C.
Assistant Professor
Department of Civil Engineering
Government College of Engineering Kannur
Kannur, India

***Abstract*—Shear wall systems has been in application as lateral force resisting system in a number of high-rise buildings. Stainless steel core plate wall (SSCPW) is such an innovative type of structural element that has emerged recently. Use of stainless steel has gained acceptance over traditional steel due to its properties like light-weight, durability and corrosion resistance. The SSCPW consists of stainless-steel plates connected each other by orthogonally placed stainless steel core tubes by welding. According to the various combinations adopted, the SSCPW can be used as beam, columns, floors, walls and other structural elements. Various cross-sections of SSCPW can be used. In this study, cross-shaped SSCPW are used. They are subjected to axial and eccentric compression. Finite element software ANSYS Workbench 2022 R2 was used for analysis and to study the influence of various parameters on the load carrying capacities.**

Keywords—Stainless steel core plate wall; axial compression; eccentric loading; load carrying capacity; ANSYS Workbench 2022 R2

I. INTRODUCTION

Stainless steel core plate wall (SSCPW) is a recent type of structural component used recently in civil engineering. It has a structure resembling the honeycomb sandwich structure. They can be employed in prefabricated buildings as special shaped columns which conform to the various building layouts consisting of T-shape, L-shape and cross-shape. The arrangement of flat type SSCPW perpendicularly in different patterns can be used to form these shapes. T-shaped walls can be used both in the exterior and interior of buildings. L-shaped walls can be used at the corner of buildings. Also, cross-shaped walls can be used in the interior as well as the exterior of irregular shaped buildings. In this study, the cross-shaped SSCPW subjected to axial compression is examined. Studies have been conducted on different sandwich structural elements and also on this new type of system under different loading conditions. With the help of experiments and FE analysis, Shu et al. investigated the load-carrying capacity of T-shaped SSCPW subjected to axial compression [1]. Shu et al. also studied the failure mechanism of L-shaped SSCPW when subjected to axial compression using both experimental and numerical methods [2].

A. Construction of Stainless Steel Core Plate

Thin-walled stainless steel core plate is constituted by two stainless-steel plates and a number of stainless-steel core tubes. The plates and the interior core tubes are connected by using brazing copper. The connection is made at elevated temperature. The copper-based brazing alloy is used as filler material for the connection. It is highly economical. This technique of joining SSCP differs from conventional welding technology. Initially, the copper-based filler was added on to the top and bottom ends of the stainless-steel tubes. Then, the stainless-steel plates and tubes were just spot welded in order to establish the location of each core tube. Later, these assembled parts are entered into a hot wind brazing furnace. In the furnace, a very high temperature (about 1030 ºC) inert shielding gas was blown for brazing. The copper-based fillers have a melting point that is lesser than that of stainless steel. The temperature of the shielding gas is regulated in order to reach the copper-based filler's melting point. This makes sure that the stainless-steel plates and tubes do not melt while the copper-based fillers do. By capillary action, the melted filler enters the void between the plates and tubes. In order to ensure this, the shielding gas temperature was sustained for a particular time period. Finally, by gradually lowering the gas temperature to permit connectivity and cooling crystallization between the fillers and weldments, a satisfactory brazing joint was achieved.

B. Advantages

- This system has shown advantages like good corrosion resistance, fire resistance and sound insulation properties.
- SSCPW shows good resistance to lateral loads. They can therefore enhance the seismic performance of buildings.
- They also help in increasing the net area of the building while reducing the cost of construction.
- The smaller cross-section and variable shape of steel plate wall (SPW) system provide improved architectural features which saves space, guarantees versatility and increase efficiency of indoor space when compared to reinforced concrete (RC) shear walls which occupies larger area.
- Because SPWs are substantially lighter than RC shear walls, there is less stress placed on the columns and foundations and less seismic load, which is directly related to the mass of the structure.
- SPWs can be assembled much more quickly than an RC structure, which shortens the construction period and lowers the cost of the project as a whole.

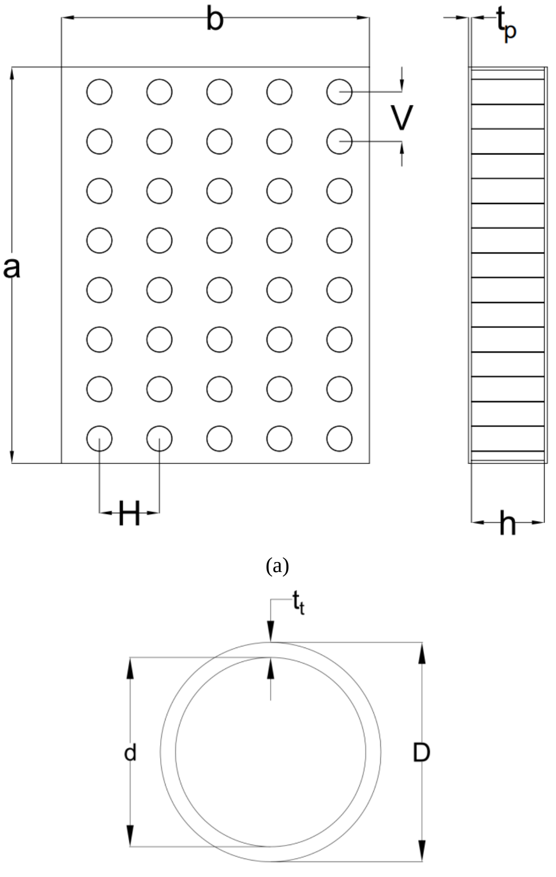
- A properly designed SPW system, has comparatively high energy dissipation capacity and can be used in high-risk earthquake zones.
- In the SPW system, the web tension field functions similar to a diagonal brace, which provides comparatively high initial stiffness, and makes it efficient in limiting wind drift.
- SPWs are often significantly simpler and quicker to install than reinforced concrete shear walls in seismic retrofit applications, which is an important factor to take into account when building occupancy should be continued throughout the construction phase.
- Replacement and repair of steel plates are easier when compared to RC structures.

II. Numerical Modelling

The numerical modelling of the cross-shaped stainless steel core plate wall was done using ANSYS Workbench 2022 R2. The modelling was done by adopting the material properties of the specimen from the experimental study conducted by Shu et al. (2021).

A. *Geometrical modelling*

The geometry of the basic model used for study are given in Fig. 1. Its dimensional details are given in Table I. Various dimensions of this basic model were changed accordingly to conduct different parametric study.



(a)

(b)

Fig. 1. Geometry of specimen: (a) Plate, (b) Tube.

TABLE I. Details of Basic Model

Geometric parameters	Dimension (mm)
a	3000
b	1000
h	147
t_p	2.5
d x t_t	50 x 0.5
V x H	100 x 121

B. *Material modelling*

The material properties adopted for parametric study are given in Table II. All the panels and core tubes of cross-shaped SSCPW were made of austenitic S30408 stainless steel. Fig. 2 shows the stress–strain curve obtained by Shu et al. (2021).

TABLE II. Material Properties

Properties	Value
Young’s modulus	193949 MPa
Poisson’s ratio	0.3
Yield strength	328 MPa

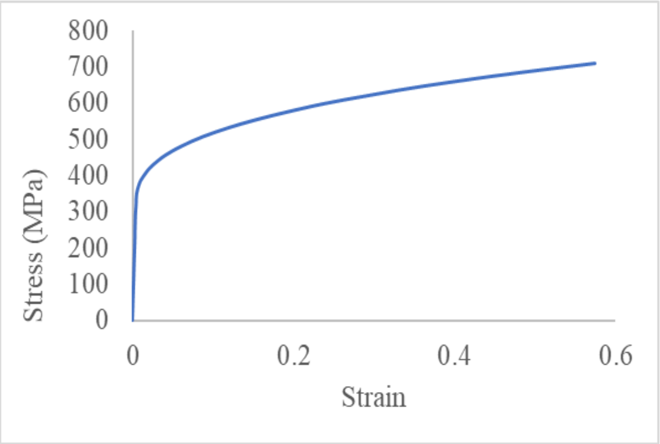


Fig. 2. Stress–strain curve. [1]

C. *Finite Element Modelling*

The finite element (FE) model was created in ANSYS Workbench 2022 R2. Fig. 3 shows the FE model of cross-shaped stainless steel core plate wall obtained from software. The boundary conditions of the FE model were given as hinged at the top and fixed at the bottom. The horizontal degrees of freedom in the x and z directions at the top were restricted, whereas all degrees of freedom at the bottom were restricted. The loading was given as displacement-controlled at the top end till failure occurs.

Shell 181 and Beam 188 were the elements used for meshing the steel plate and the steel tubes respectively. Shell 181 is a four-node element with six degrees of freedom at each node. Beam 188 is a linear, quadratic, or cubic two-node beam element in 3-D which has six or seven degrees of freedom at each node. Based on mesh convergence study, 25mm size mesh was selected to model the element.

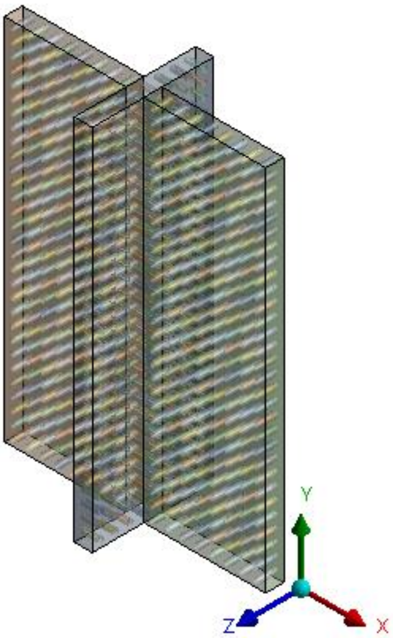


Fig. 3. FE model of cross-shaped stainless steel core plate wall.

III. PARAMETRIC STUDY

The parametric study was done using cross-shaped stainless steel core plate wall. The study included the effect of plate slenderness ratio, internal diameter to thickness ratio of tubes and effect of eccentric loading. For studying the effect of these parameters, the height of the specimen, shape of the specimen and direction of loading in corresponding study were kept constant.

A. Effect of plate slenderness ratio

Plate slenderness ratio is the width by thickness ratio of the plate. Keeping all other properties of the specimen constant, the thickness of the plates was changed. 1.5mm, 2.5mm, 4mm, 6mm and 8mm were the thickness chosen. As a result, the slenderness ratio varied from 666.67 to 125. It was observed that the plate slenderness ratio had significant effect on the capacity of the specimens in terms of peak load. Strength decreased with increase in slenderness ratio. The load-carrying capacity of the specimens increased significantly by 95.16% as thickness of plate increased from 1.5mm to 8mm as represented in Fig. 4. A substantial increase in stiffness was also evident with decrease in slenderness ratio. The peak loads in each case are tabulated in Table III.

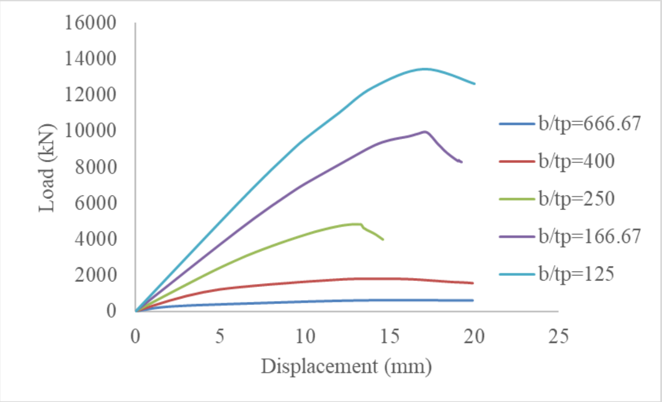


Fig. 4. Load-displacement graph for different plate slenderness ratio

TABLE III. VARIATION OF PEAK LOAD WITH PLATE SLENDERNESS RATIO

b/t_p	Peak load (kN)
666.67	650.88
400	1831.3
250	4839
166.67	9929.2
125	13453

B. Effect of internal diameter to thickness ratio of tubes

The internal diameter of the tube was kept constant as 50mm and the outer diameter was changed in order to change the thickness of the tubes as 0.3mm, 0.5mm, 0.8mm and 1mm. Thus, the internal diameter to thickness ratio of tubes varied from 166.67 to 50. The initial elastic region of the load-displacement graph obtained from study was almost unaffected due to the variation in internal diameter to thickness ratio of tubes. The load-carrying capacity increased slightly by 1.02% with decrease in internal diameter to thickness ratio from 166.67 to 50 as represented in Fig. 5. This could be due to the increase in support provided by core tubes to the plate. The peak loads in each case are tabulated in Table IV.

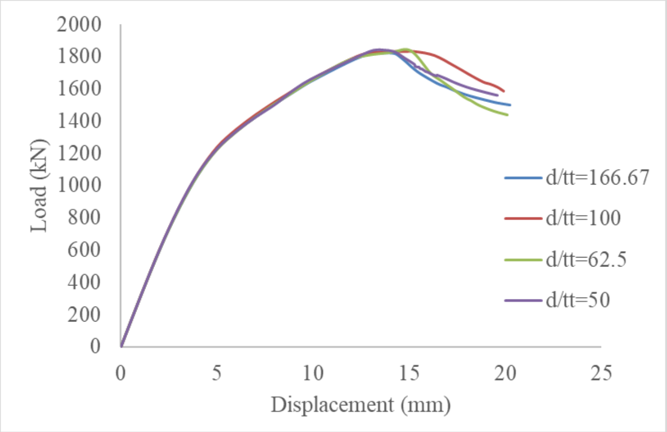


Fig. 5. Load-displacement graph for different internal diameter to thickness ratio of tubes

TABLE IV. VARIATION OF PEAK LOAD WITH INTERNAL DIAMETER TO THICKNESS RATIO OF TUBES

d/t_t	Peak load (kN)
166.67	1825.5
100	1831.3
62.5	1838.3
50	1844.388

C. *Effect of eccentric loading*

In order to study the influence of eccentric loading on cross-shaped stainless steel core plate wall, eccentricities along both z-direction and x-direction were considered. Deviation in load-carrying capacity with change in eccentricity from 0mm to half-length on both directions were noted for study.

1) *Effect in z-direction*

Eccentricity in loading changed from 0mm to 250mm in z-direction. A decrease in peak load with increase in eccentricity could be observed. Load-carrying capacity decreased by 3.83% as eccentricity increased from 0mm to 250mm as represented in Fig. 6. Stiffness of specimens seemed unchanged. The peak loads in each case are tabulated in Table V.

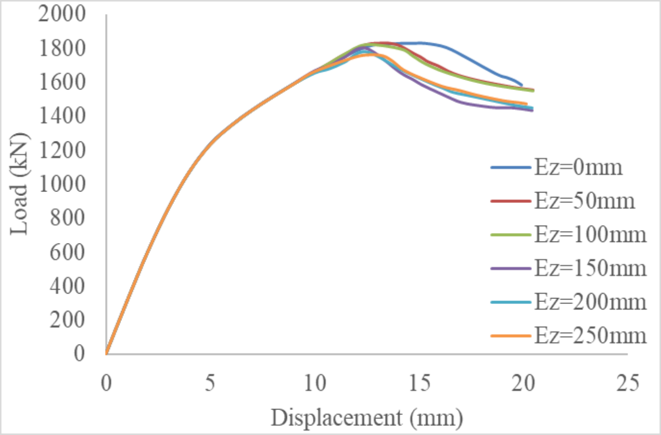


Fig. 6. Load-displacement graph for different eccentricity in z-direction

TABLE V. VARIATION OF PEAK LOAD WITH ECCENTRICITY IN Z-DIRECTION

Eccentricity in z-direction, Ez (mm)	Peak load (kN)
0	1831.3
50	1830.9
100	1822
150	1801.824
200	1781.82
250	1761.1

2) *Effect in x-direction*

Eccentricity in x-direction was considered to vary from 0mm to 500mm. Load-carrying capacity decreased remarkably with increase in eccentricity in x-direction. From 0mm to 250mm, a reduction of 22.56% in peak load was obtained. This was much higher than that observed in z-direction. Also, the reduction was noted to be about 35.73% when eccentricity changed from 0mm to 500mm as represented in Fig. 7. Thus, it was evident that eccentricity in x-direction had more effect than that in z-direction. The peak loads in each case are tabulated in Table VI.

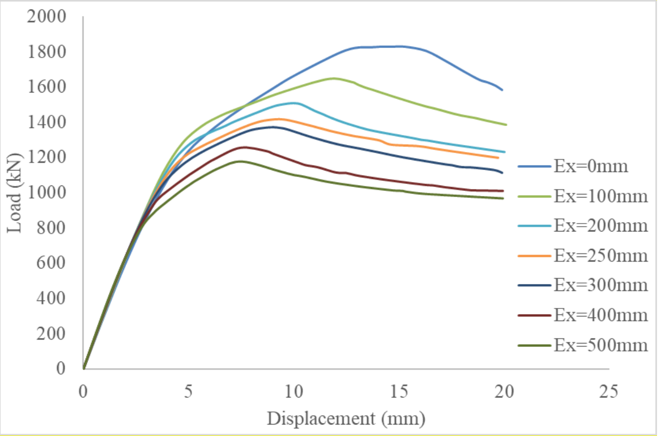


Fig. 7. Load-displacement graph for different eccentricity in x-direction

TABLE VI. VARIATION OF PEAK LOAD WITH ECCENTRICITY IN X-DIRECTION

Eccentricity in x-direction, E_x (mm)	Peak load (kN)
0	1831.3
100	1647.8
200	1506.9
250	1418.1
300	1370.3
400	1255.2
500	1177

IV. CONCLUSIONS

The parametric study on cross-shaped stainless steel core plate wall was completed. The obtained results were analyzed and the following conclusions were arrived upon completion of the study:

- Plate slenderness ratio had significant effect on load-carrying capacity.
- Load-carrying capacity increased by 95.16% as thickness of plate increased from 1.5mm to 8mm.
- Decrease in internal diameter to thickness ratio of tubes led to an increase in support provided to the plates but only a slight increase of 1.02% could be observed in peak load.

- Eccentricity in x-direction had more effect than that in z-direction.
- Load-carrying capacity decreased by 3.83% and 22.56% as eccentricity in z-direction and x-direction increased from 0mm to 250mm respectively.

REFERENCES

[1] Xing-Ping Shu, Su Yan, Yi Li and Bei-Rong Lu, “Strength design of T-shaped stainless steel core plate wall under axial compression,” Journal of Constructional Steel Research, vol. 186, 2021.

[2] Xing-Ping Shu, Huai-Bing Wang, Yi Li, Zhi-Shen Yuan and Ke Li, “Study on the bearing resistance of axially compressed L-shaped stainless steel core plate wall based on the stability loss,” Engineering Structures, vol. 249, 2021.

[3] Yiwen Wu, Shenggang Fan, Hang Zhou, Yang Guo and Qixun Wu, “Cyclic behaviour of diagonally stiffened stainless steel plate shear walls with two-side connections: Experiment, simulation and design,” Engineering Structures, vol. 268, 2022.

[4] Ke Wang, Wenyuan Zhang, Yong Chen and Yukun Ding, “Seismic analysis and design of composite shear wall with stiffened steel plate and infilled concrete,” Materials, vol. 15, 2021.

[5] Jing-Shen Zhu, Yan-Lin Guo, Meng-Zheng Wang, Xiao Yang and Yong-Lin Pi, “Seismic performance of concrete-infilled double steel corrugated-plate walls: Experimental research,” Engineering Structures, vol. 215, 2020.

[6] Meng-Zheng Wang, Yan-Lin Guo, Jing-Shen Zhu, Xiao Yang and Jing-Zhong Tong, “Sectional strength design of concrete-infilled double steel corrugated-plate walls with T-section,” Journal of Constructional Steel Research, vol. 160, 2019.

[7] Xianggang Liu, Chuangze Xu, Jiepeng Liu and Yuanlong Yang, “Research on special-shaped concrete-filled steel tubular columns under axial compression,” Journal of Constructional Steel Research, vol. 147, 2018.

[8] Xing-Ping Shu, Ke Li, Yi Li, Zhi-Qi Xiong, Yi-Heng Huang and Shi-Jie Li, “Experimental investigation on brazing residual stress distribution in 304 L stainless steel core plate,” Journal of Constructional Steel Research, vol. 193, 2022.