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Investigation Of behaviour of Double Skin Composite Wall under Compressive Loading

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Abstract

When it comes to construction, double skin composite walls can provide high capacity and stiffness. This type of wall can also provide high strength and cost-effectiveness while improving construction convenience. Double skin composite wall with great potential for use in high-rise buildings and nuclear power plants where the effect of wind and seismic force is very high, as well as in industrial equipment to avoid heat loss. Under compressive force, the interrelation bonding between the steel plate and the core concrete is critical for double skin composite walls. A lack of discretion between the steel and the core concrete may result in local buckling of the steel plate. As a result, the steel and core concrete surfaces split up under high compression.Thin plate can cause local buckling, reducing axial load capacity. The steel truss made of two angles serves as the interface connector. In this study, DSCWs are tested experimentally and analytically under compressive loads using Abaqus software to investigate the seismic behavior of composite walls. Taking into account the thickness of the steel plate, the spacing between the connector and the steel truss, and the thickness of the connector. The load-displacement curve, buckling modes, and stress distributions are all used to evaluate the structural behavior of the walls. The effects of steel plate thickness on structural stability were thoroughly discussed.

Keywords: Double skin composite wall, L-shaped connector, Steel truss, compression.

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I. INTRODUCTION

One of the most critical difficulties in civil engineering applications is the urban population density is increasing rapidly with the increasing economic growth. Progressively high-rise buildings have been built to accommodate and for industrial activities which leads to increasing the population of the world. In recent years, many high-rise steel residential apartments have emerged, which have excellent seismic behavior, short construction time, and recycling potential. The common construction system for steel apartments includes a steel frame system and a steel frame support system. However, with the increasing height of steel apartments, the steel frame system may not always meet seismic code requirements. Double skin composite walls have been acting lateral load resisting system in rise and tall buildings. In recent year researches the has paid the attention to the composite walls made of flat steel plate and concrete. The layout of the steel frame support system would affect the position of the doors and windows. In case of provide openings in DSCWs to improves the efficiency of a structural member. To improve the seismic performance of a high-rise steel apartment, a double skin composite wall (DSCW) could be employed within a steel frame system to enhance the lateral force resisting behavior. Double skin composite wall is a vertical structural element. It will resist the horizonal forces. It is the types of shear wall. DSCWs is a two thin steel plate connected by a tie bar and the spacing between them filled with concrete. The infill concrete can prevent premature local buckling of steel faceplates. The composite shear wall had shown high ductility and good lateral load resisting property.

At the same time, the ductility and compressive strength of concrete can be improved greatly due to the confinement effect of the steel plates.DSCW has many advantages, including large lateral stiffness, high bearing capacity, and good integrity under seismic loading, as well as reduced self-weight and overall thickness over a conventional reinforced concrete shear wall.Researchers have carried out multiple experiments to investigate the seismic behavior of DSCWs, and various types of composite walls were designed during the process. And however, most of the researches are focused on the rectangular section with uniform axial compression.This type of composite walls will offer structural performance over conventional walls. Which has a higher compressive strength and higher stiffness. Moreover, the steel plates are carried out the formwork for the concrete filling and provide internment to the concrete, which increases the compressive strength of concrete.Furthermore, according to the new design regulations, a substantial number of structures built in the past utilizing previous design codes in various regions of the world are structurally unsafe. This work proposes to investigate the seismic behavior of double skin composite wall under compressive load by experimental study and in analytically using ABAQUS finite element (FE) software.

According to the literature, extensive research on the double skin composite wall was carried out. All studies, in particular, are focused on the seismic and axial compressive behaviour of a double skin composite wall [2]. The axial compression is highly dependent on the interface bonding between the steel plate and the concrete core. Experiments are being conducted to investigate the uniaxial behaviour of a double skin composite wall. As a result, the confinement effect increased the compressive strength of DSCWs [1]. In order to promote the use of DSCWs as bearing, retaining, and shear walls in the field of structural engineering, the static and dynamic behaviour of DSCWs has been studied in recent years. The structural performance of DSCW systems under compressive load.It was discovered that the failure of inner concrete, as well as the failure of inner concrete to prevent the inward buckling of steel plates. The compressive behaviour of DSCW with different thicknesses of steel plates. As a result, it was determined that steel plate thickness has a significant influence on the local buckling behaviour of DSCW. The compressive test was carried out to investigate the buckling behaviour of DSCW. Studied the seismic resistance of composite wall by analyzing deformation capacity, material properties and interaction of geometry. The established simplified formulas based on the geometric and material inputs for calculating the ultimate curvature associated with a percentage loss in moment capacity.That can be used to calculate the drift capacities and ductility of composite walls. A model for finding the effective shear stiffness of the composite wall is derived, and it is predictions correlate well with the test results. Also investigated a high strength concrete filled double skin composite wall system to improve the ductility of the core wall in super high-rise buildings. Twelve wall specimens were tested under large axial compressive force. All the specimens exhibited good energy dissipation capacity and deformation capacity with full hysteresis curves and large ultimate drift ratios, thereby good potential for the system in seismic resistant structures.

Extensive studies have been conducted on double skin composite wall using L shaped connector. There is different type of connectors but in L shaped connector had a good bearing capacity and deformation capacity is higher. Using connectors, the ultimate bearing capacity of the specimen more. and the local buckling degree of the steel faceplate was less. The energy dissipation capacity was slightly increased.Parameters used for compressive test and cyclic loading on various literatures are studied.

1.2 Applications of Double skin composite wall

- Used in submarine immersed tube tunnels
- Nuclear containment shells
- Oil and gas storage structures
- Explosion proof structures which comprise two steel plates, core concrete, and connectors.
- In high – rise buildings and nuclear power plants where the wind force and seismic force is more

1.3 Composite action between steel plate and concrete core

DSCWs with different connectors are proposed to improve the composite action.

1. The headed stud shear connector:It could not provide out-of-plane stiffness to the steel plate before the core concrete hardened. Which lead to the premature buckling of the steel plate and greatly reduced the bearing capacity of the wall.
2. Angle connector: This connector will Easy to separate from the core under the impact.
3. Bi-steel Connector: This connector is Increase the out of plane stiffness. Connector is only less than 200mm thick wall.
4. J-hook connector & L connector: In these two connectors has requires high precision, which increases the difficulty of construction.

1.4 Types of connectors

1.T - Shaped connector

In L- shaped connectors long flange wall also has a higher shear strength. But the ductility, energy dissipation capacity, and shear deformation proportion are small. Failure is happening when insufficient flexural strength of the boundary member.

2.L- shaped Connectors

In L-shaped specimen with a protracted flange wall also features a higher shear strength The ductility, energy dissipation capacity, and shear deformation proportion are higher. Local bucking of plate is a smaller amount occurred. Bearing capacity is high during this type.

3.C-Shaped Connector:

In C shaped connector had better energy dissipation than DSCW-L specimens. However, there was no obvious correlation between equivalent viscous damping coefficient and low axial compression ratio.

1.5Steel Truss

Steel truss is analogous to channel members with web perforation. It is often easily located and connected to the steel plate without high precision requirements. The waveform steel bars as web members won't cause difficulty in concrete casting or change the shear mechanism of core concrete walls. Besides, with the aid of a special welding manipulator, the wall thickness can be easily controlled below 200 mm. Steel trusses can provide strong out-of-plane restraint for plates and make two steel plates and concrete work together. The steel truss effectively connects the steel plates and provides them with external restraint. Increasing the spacing to thickness ratio will weaken the external restraint effect. which can cause premature buckling and bearing capacity reduction or possibly premature failure of the composite shear wall. It is recommended that the spacing to thickness ratio mustn't exceed 50mm**.**

A new type of truss was proposed by the authors to act because the intermediate fastener. The truss is made by two angles serving as chord members and kinked rebar serving as web member. The angles are filleted welded to the steel plates by an automatic machine within the factory. This connector is believed to be ready to provide color force bonding between the two materials, and it also helps the steel plates on two opposite sides work together. It should be noted that the steel truss during this paper is essentially in line with the stiffened truss. However, extensive studies and experimental data are needed before this kind of connector could also be applied to composite walls in practice.Furthermore, composite walls with binding bars or headed studs are suffered from separation between the steel faceplates and the concrete core because of the insufficient pull-out strength of those connectors. It's also difficult to well locate the 2 opposite steel faceplate before casting the concrete, since the interface connectors aren't connected inside. On the opposite hand, the applying of embedded steel tubes has the disadvantage that the thickness of the wall shall be thick enough to permit the arrangement of steel tubes.

One another essential factor that influences the axial behavior of double skin composite wall is that the thickness of plate. Due to the restraint provided by concrete, the steel plates in double skin composite walls tend to be thinner. However, this might cause the local buckling of steel plates even when the axial loading is kind of low. The buckling of steel plates will lead to imperfect bonding between the concrete core and also the steel plates, which consequently reduces the confinement to the concrete and reduces the axial load carrying capacity. This paper investigates the double skin composite wall which utilizes steel truss as interface L -shaped connector. Full-scaled tests with compression loading capacity were conducted on specimens to analyze the basic behavior of walls under compression, which is one in every of the characteristics of this experiment comparing with the present research. The effect of plate thickness on the axial performance of walls was evaluated in details.

1.6Experimental study

1.6.1 Material testing

Material is tested for casting the double skin composite wallsuch as specific gravity testing, sieve analysis and slump is conducted.

Table 1: Specific gravity test

Material	Specification	Specific gravity
Cement	PPC 53 Grade	3.15
Fine Aggregate	M – Sand passing through 4.75 mm sieve	2.54
Coarse Aggregate	Retained on 20 mm sieve	2.7

Table 2: Sieve Analysis

Material	Fineness Modulus
Fine Aggregate	3.11
Coarse Aggregate	5.10

Table 3:Slump Test

Slump Value	72 mm

1.6.2 Design Criteria for a specimen

Literature review shows that the bulk of the work on axial behavior focuses on small-scaled test specimens. The length to thicknessratios of most tested specimens were lessthan 4. This implies the specimensare classified into short wall category and also the failure of the specimenis expected to be governed by the cross-sectional capacity. However,for composite walls in real projects, the slenderness ratio is generallymuch larger than 8, Length to thickness ratio is less than 4mm.

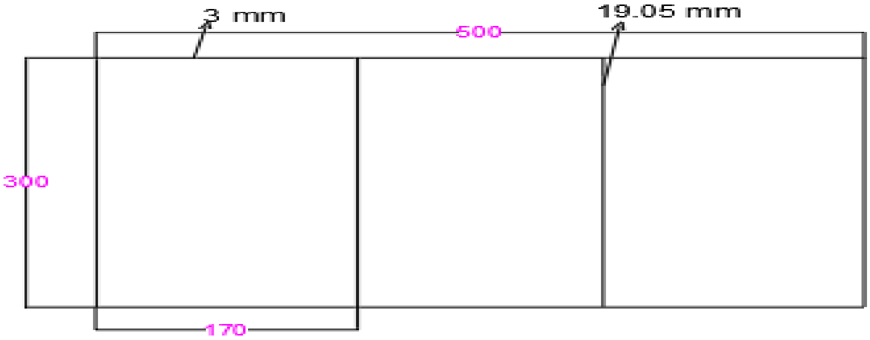

Fig.1 Detailing of Specimen

Table 3: Design of wall

Specimen	h_w mm	b_w mm	t_w mm	t_c mm	t_s mm	Truss size	Spacing
DSCW -1	500 mm	300 mm	150 mm	19.05	3	8	170

1.6.3 Quantity of materials

- M25 Grade concrete is used
- wet volume – 0.0225 m^3
- Dry volume - 0.03465 m^3
- Cement – 10.67 kg
- Sand – 12.6 kg
- Aggregate – 28.05 kg

1.6.4 Test specimen

The specimens used in this study were designed to simulate full-scaled load-bearing walls in engineering applications. To evaluate the behavior of the double skin composite wall specimens were tested under axial compressive force.The height, width, and thicknessof the walls are 500 mm, 300 mm, and 150 mm, respectively (Table.3). L- shaped connector and steel truss is made by drilling. Also,these are fixed to the steel plate wall by drilling. All test specimens are filled with concreteinside.

Fig.2 Connector

Fig.3 Steel truss

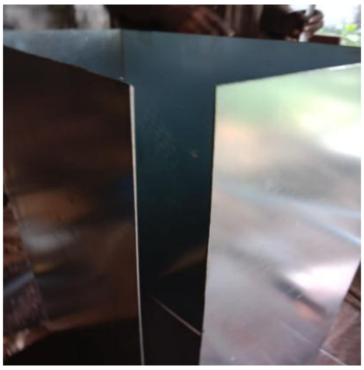

Fig.4.Bending the steel plate


Fig.5.Fixing the connector by drilling


Fig.6 concrete placing & compaction

1.6.5 Test setup


Fig.7 specimen on the testing mechine


Fig. 8 Gauge fixing

The specimen is placed on the universal testing machine. Top of the wall is covered with steel plate. The dial gauge is fixed the side of the wall. Loading the specimen between two plates. To ensure that the axial compressive loading was applied uniformly all across the entire cross-sectional area of the specimen. To prevent the beam from lateral displacement during the compressive strength test. Then apply a force to the specimen by moving the crossheads. During the test, specimen is compressed and buckling is formed. Concrete is crushed in the top of the wall.

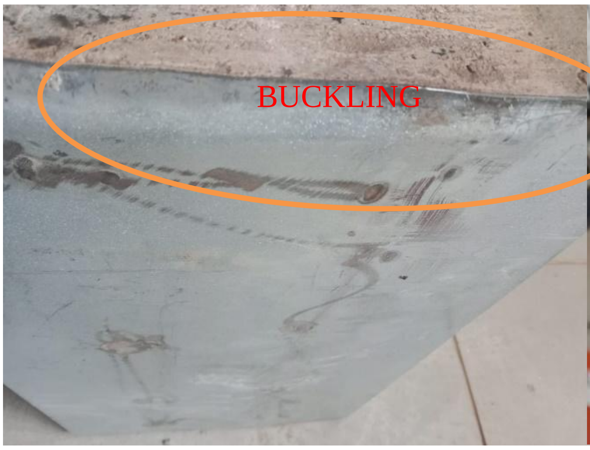

Fig.9 Buckling formed in the wall

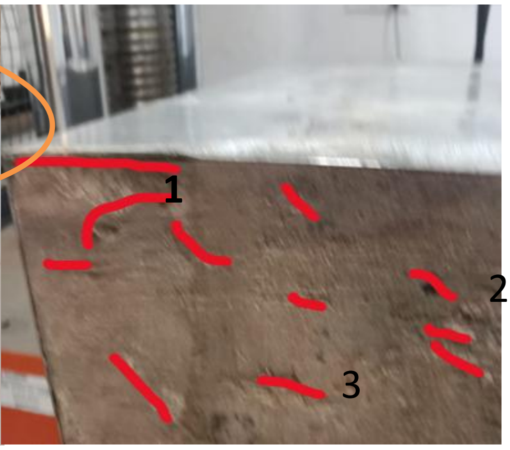

Fig.9 Concrete damage

1.6.6 Test obsevation

During the loading process, the specimen acted smoothly. As thecompressive loading increased, the deformation increased gradually. There was no visible physical phenomenon until the axial load reached 800.04 kN.As the load reached 800.04 kN, slight but dense buckling waves were observed on the side, covering a distance of 10 mm to 20 mm from the top of the wall. As the loading level increased, the buckling became more visible. When the load reached 1015.93 kN, local buckling occurred on the top of the wall (Fig.12). The top was severely buckled, with a clear sound emitted from the specimen, indicating the crushing of infilled concrete (Fig.13). Different types of cracks are formed in the concrete that are vertical crack (2), Horizontalcrack (2), shearcrack (3).

1.6.7 Result & Discussion

1.6.7.1 Failure Mode

According to the test results, specimens under compression have two basic failure modes. Local buckling of the steel faceplate is the first mode of failure, followed by crushing of the infilled concrete. The stress and strain of the steel plate increased as the compression increased during the loading process. The steel plate began to buckle between the adjacent trusses when the stress reached a critical level. The buckled steel plate became loose from the infilled concrete as the lateral deformation progressed. The steel plate's compressive load was gradually transferred to the concrete core, resulting in concrete crushing. When the specimen reached its maximum load, large plate deformation was observed. There was no visible physical damage during the test.Because of overall deformation, the specimen failed. Steel plate local buckling can be avoided by increasing plate thickness, which reflects the limitations on width-to-thickness ratios (Fig.12). When the limit values are met, the entire cross-sectional area of composite walls is considered effective.

1.6.7.2 Load vs displacement response

Figure 14 depicts the load versus axial displacement curves for all test specimens. The load-axial displacement behavior of the specimens is similar. The curves steadily and linearly climb up during the first stage of loading before steel plate buckling occurs, indicating that the specimens are in the elastic range. Following that, the stiffness of the specimens gradually decreases, indicating that plate buckling or possible concrete crushing is developing in the specimens. The specimens then reach their peak load, which is followed by overall wall buckling and severe local buckling. Following that, the load begins to decrease while the axial displacement increases.

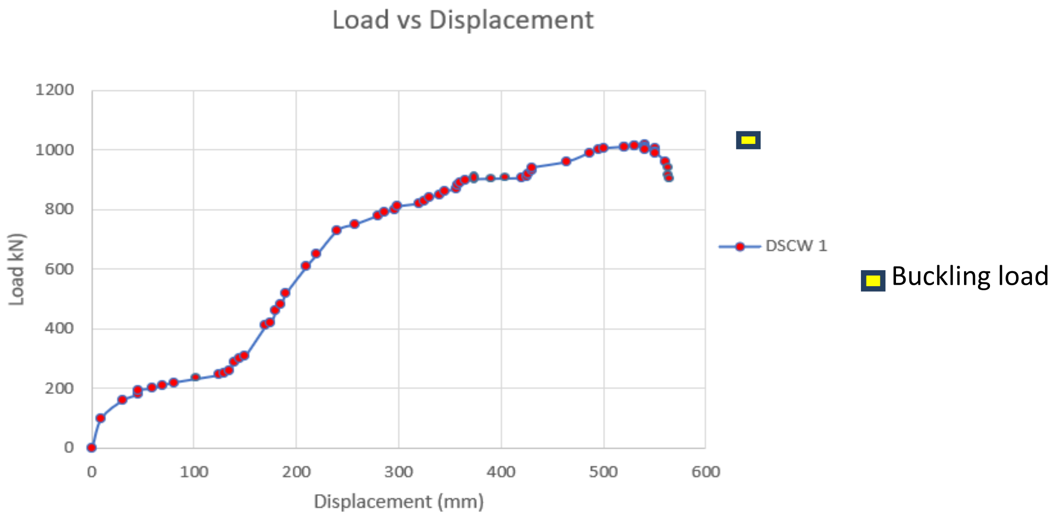

Fig.14. Load vs Displacement

1.6.7.3 Buckling load

Local buckling occurred on the steel plates between the two adjacent trusses when the composite walls were subjected to compressive loading. The steel plates buckled outward in half-waves due to the support provided by the infilled concrete core. Despite the use of gauges to record the stress applied to the specimens, determining the related buckling stress of the specimens remains difficult. This is because the gauges were not always placed precisely where local buckling began to develop.

1.7 Experimental validation

Validation is done by using ABAQUS software.To accurately simulate the seismic performance of the DSCW structure. The specimens are varying with different; Thickness of steel plate, Thickness of steel connector and steel truss spacings.

Table.4 Specimen parameters

SI.no:	h_w mm	b_w mm	t_w mm	t_s mm	t_c mm	spacing	Grade	n	Aspect ratio
DSCW1	1000	1020	150	4	3	240	M25	0.5	2.5
DSCW2	1000	1020	150	5	4	180	M25	0.5	2
DSCW3	1000	1020	150	4	3	240	M20	0.5	2.5
DSCW 4	500	300	150	3	19.05	170	M25	0.5	2

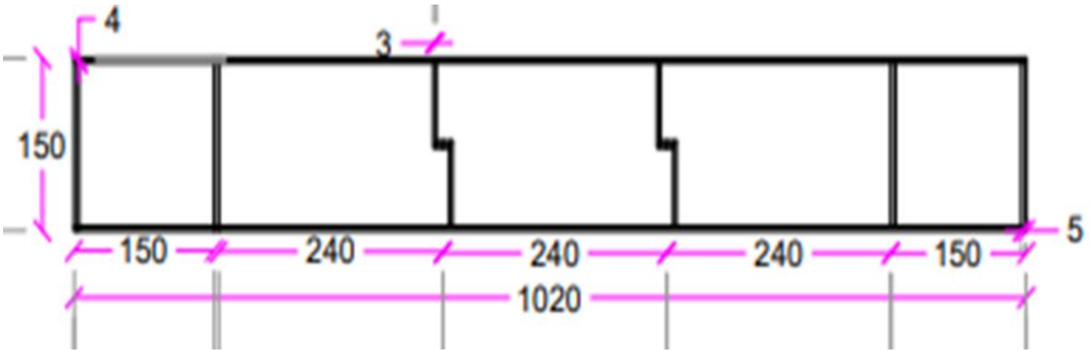

Fig.16 Detailing of DSCW 1

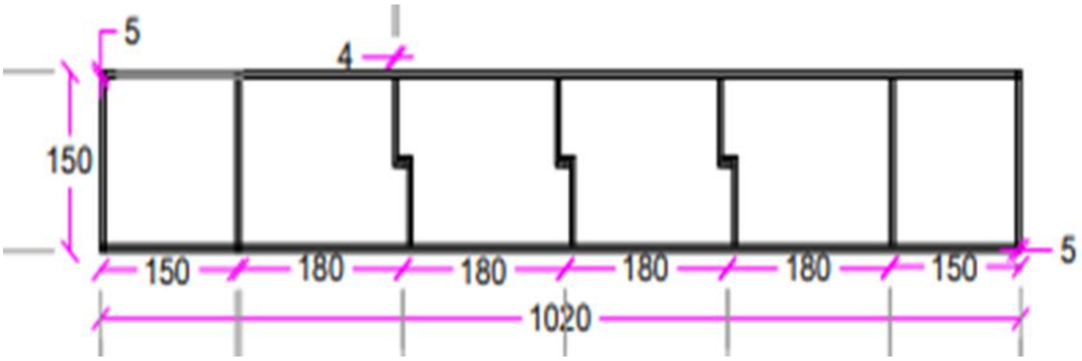

Fig.17 Detailing of DSCW 2

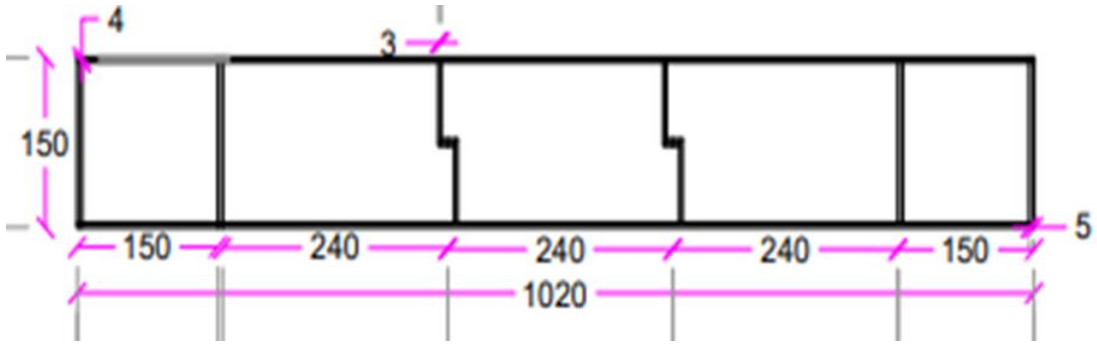

Fig.18 Detailing of DSCW 3

Table.5 Material properties used in software

Concrete		Steel			
Plasticity model			f_y (MPa)	f_u (MPa)	E (MPa)
Poisson's ratio	0.2	Steel	309.4	400	1.95x10^3
Compressive strength	25.5 MPa	Angle steel	325	400	1.84x10^3
Tensile strength	35 MPa	Steel bar	365	500	1.98x10^3
Modulus of elasticity	2.1x10^5 Pa				

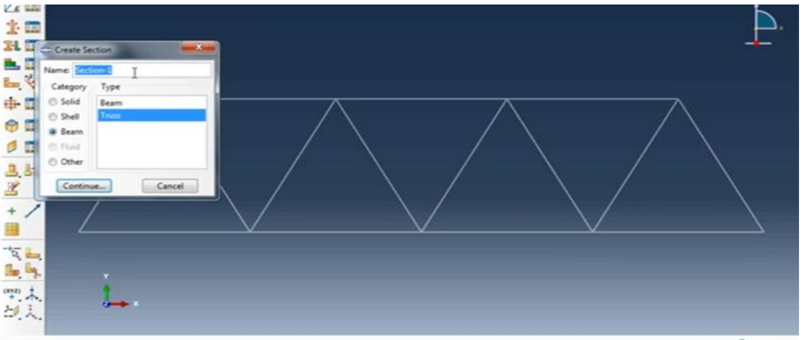
Create Section
Name: Section-1
Category: ○ Solid ○ Shell ● Beam ○ Fluid ○ Other
Type: Beam, Truss

Fig.19. Connector & truss

L-Shaped connector and the steel truss properties are defined in software.

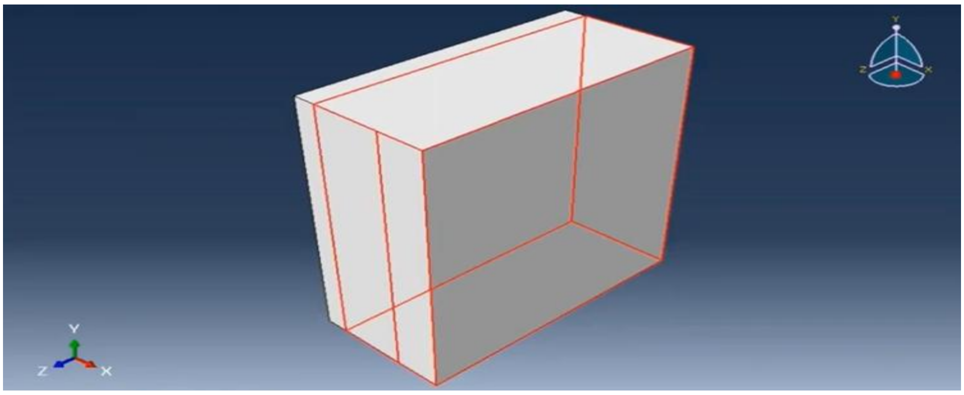

Fig.20 Geometry

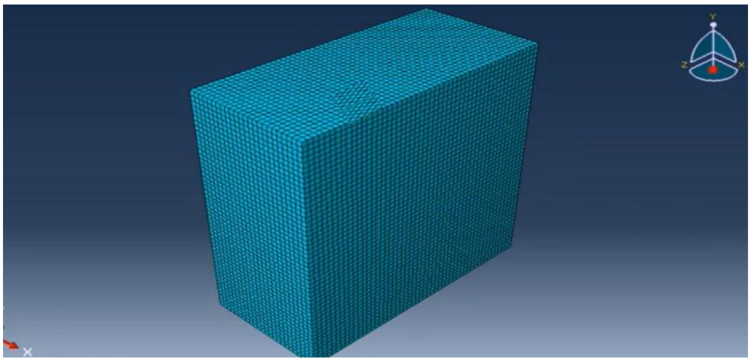

Fig. 21Mesh on Specimen

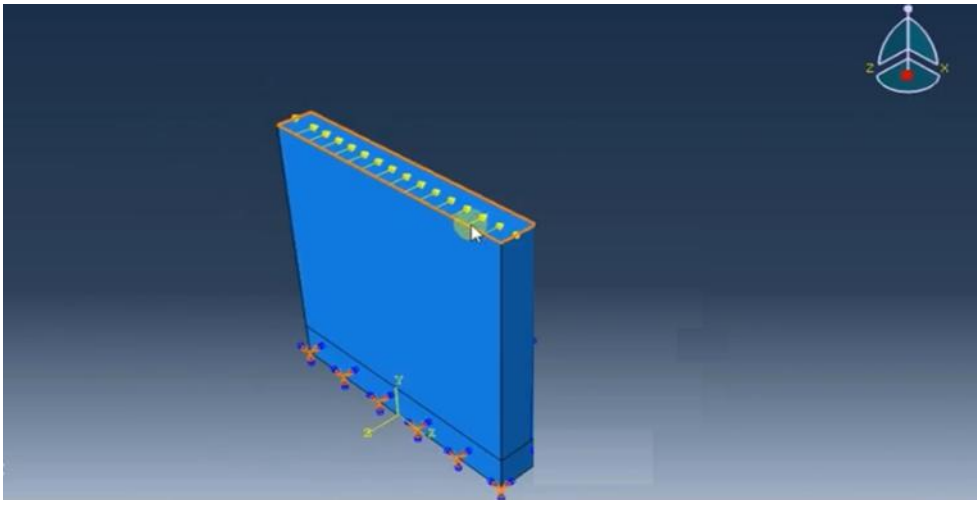

Fig.22 Compressive load is applied

1.7.1 Result & discussion

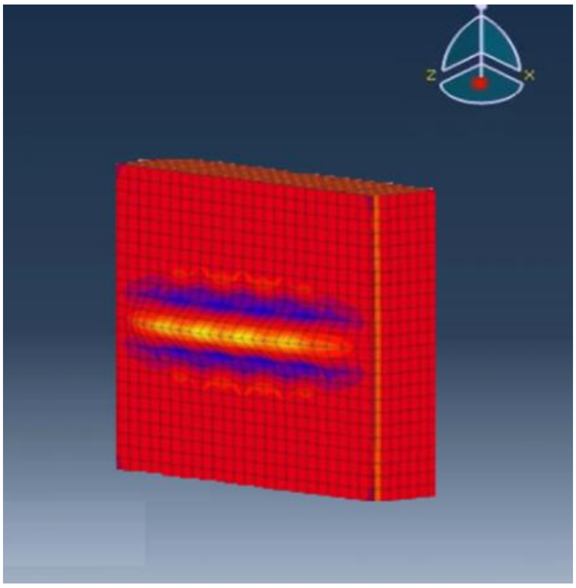

Fig.23 Buckling type 1

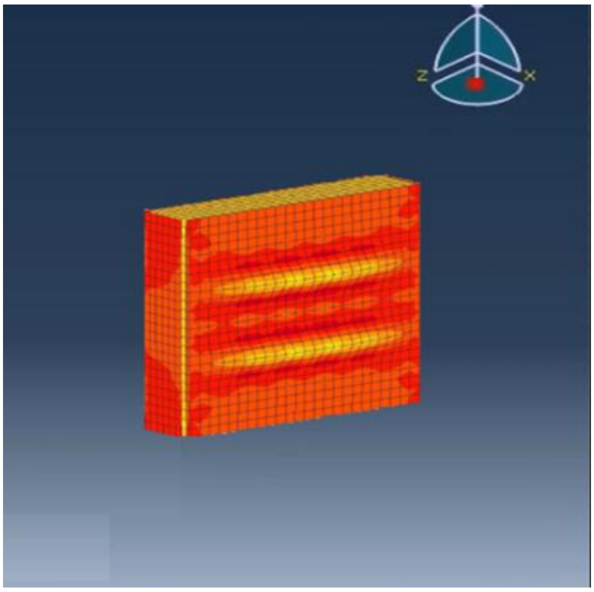

Fig.24 Buckling type 2

Buckling is formed in the specimen at center in various type. The distance between buckling point is keep a distance that is 15-25mm.

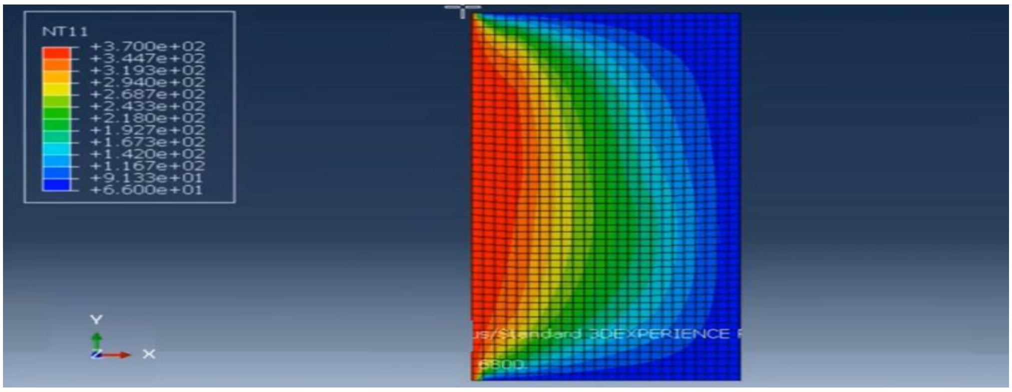

Fig.25 Deformation

From the contour figure obtained ,the maximum deformation values at the center of the wall.

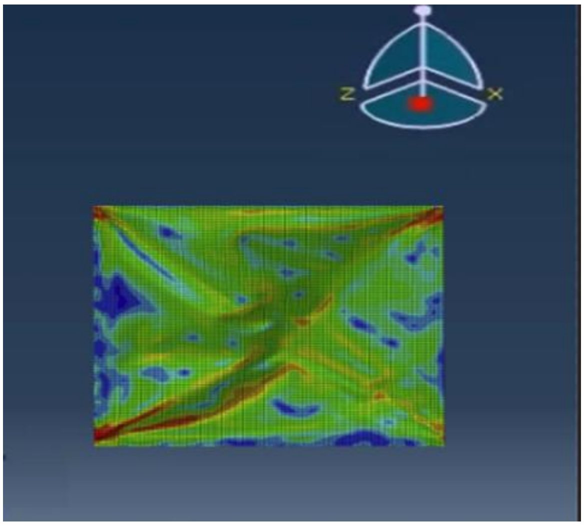

Fig.26 Stress nephogram 1

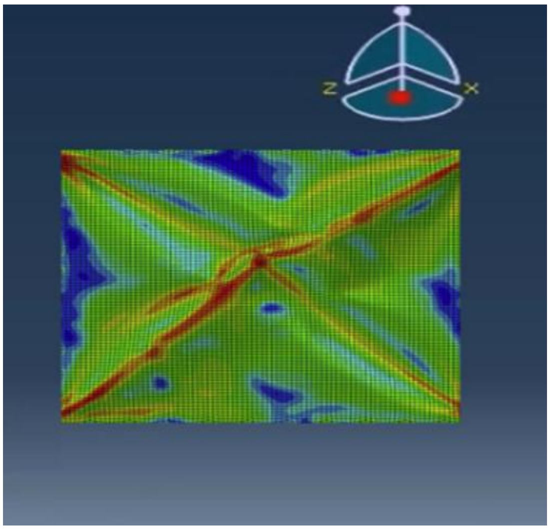

Fig.27 Stress nephogram 2

The stresses in the specimen are formed from corners of the wall. All the corners are contact with the infill concrete.

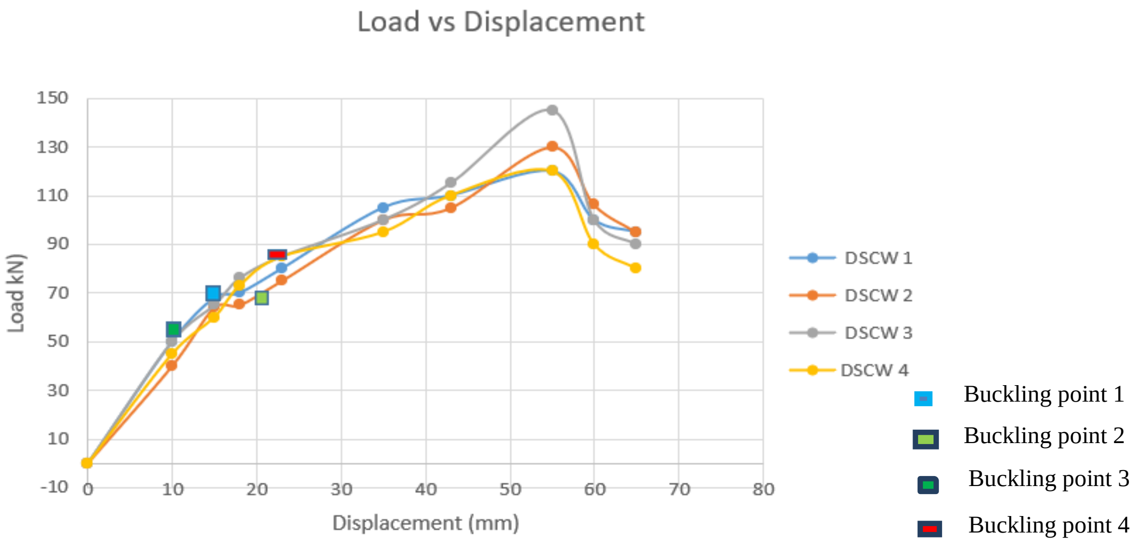

Fig.28 Load vs deformation

II. CONCLUSION

The seismic performance of double skin composite wall structures with connections was investigated in this study using a compressive test and finite element analysis. The behavior of connections between steel plate and frame was studied in particular. The loading capacity of DSCW was also investigated with the proposed connections corresponding to different failure modes. Based on the findings and discussions, the following conclusions are reached:

1. The buckling of the specimen became more apparent as the load increased. During each loading level, the axial deformation increased rapidly as well. The peak load is 1015.93KN.
2. There is no failure that occurs during the loading stages when the peak load is reached. For specimen with a lower spacing to thickness ratio, the buckling amplitude is lower. It is found that the L-Shaped connector resist the buckling of the steel plate.
3. Increasing the compressive load could improve the specimens load carrying capacity. The specimen with the lower spacing to thickness ratio carried more load.
4. The aspect ratio has a significant impact on the seismic behavior of the specimens. When the aspect ratio increases, the cross-sectional area decreases. As a result, the wall's strength and stiffness are greatly reduced.When the aspect ratio exceeded 2.0, the specimens experienced failure with a new type of failure characterized by lateral cracks on the core concrete.

5. Axial compression has a minor positive effect on strength because it delays the development of cracks in core concrete. However, greater axial compression raises the cumulative specimens are damaged
6. The buckling occurs more in the central region with a distance.

REFERENCES

[1]. Chao-QunYuJing-Zhong Tong (2020) “Compressive behavior of slender profiled double-skin composite walls” Journal of Constructional Steel Research volume 182, 106657.

[2]. Jiafe, Jiang, JieLuo Weichen Xuebc Xiang Huc Dua (2021) “Experimental study on hysteresis behavior of precast concrete double skin shear wall with horizontal loop connection and spiral-confined vertical lap connection”, Journal of Building Engineering Volume 45, January 2022, 103526.

[3]. Jianhong Han, Ganping Shua, Ying Qin, Guangen Zhou, Xiongliang Zhou (2021) “Experimental seismic behavior of T-shaped double skin composite wall with steel truss” Journal of Constructional Steel Research 184 (2021) 106776.

[4]. KaiQian, PanHe, Ning Deng Hongh Lid (2021) “Impact of concrete strength on seismic behavior of T-shaped double-skin composite walls” Engineering Structures Volume 236, 112039.

[5]. JunShi, Lanhui, Guoshan, Gao Zhiguo (2021) “Buckling behavior of double skin composite walls under axial compressive load” Construction and Building Materials Volume 321, 126345.

[6]. JunShi,ShanGao,Lanhui Guo (2021) “Compressive behavior of double skin composite shear walls stiffened with steel-bars trusses” Journal of Constructional Steel Research Volume 180, 106581.

[7]. Lihua Chen, Chao Yin, Chenggang Wang, Yuming Liu (2021) “To investigate the Experimental study on seismic behavior of double-skin composite wall with L-shaped connectors. Journal of Constructional Steel Research 174 106312.

[8]. LihuChen, ShiyeWang, YuLoubDengrongXi (2020) “Seismic behavior of double-skin composite wall with L-shaped and C-shaped connectors” Journal of Constructional Steel Research, volume160, Pages255-27

[9]. Lihua, hena, SongBaia, Lujie Zhoua, Zhoua (2021) “Experimental study and numerical simulation on seismic behavior of double-skin composite wall” Journal of Constructional Steel Research volume 187, 106935.

[10]. S. Huang (2020) “Experimental study on axial compression behavior of Double steel plates composite shear wall with L-shaped connectors”. Journal of Constructional Steel Research, Volume 124.

[11]. Xiaomeng, ZhangaYing,QinaZhihu, Chenab Jie (2021) “To investigate the experiment behavior of innovative T-shape-composite shear walls under in-plane cyclic loading”. Journal of Constructional Steel Research, Volume 120, Pages 143-159.

[12]. Y. Qin, Z.H. Chen, J.J. Bai, Z.L. Li, Test of extended thick-walled through-diaphragmconnection to thick-walled CFT column, Steel Compos. Struct. 20 (2016) 1–20

[13]. Y. Yang, J. Liu, J. Fan (2021) “Buckling behavior of double-skin composite walls: an experimental and modeling study”, J. Constr. Steel Res. 121, 126–135

[14]. Yangqin, Ga-pingShuaGua-GenZhoubJian, HongHann (2021) “To investigate Compressive behavior of double skin composite wall with different plate thicknesses”. Journal of Constructional Steel Research Volume 157, Pages 297-313.

[15]. Yongqian, ZhengCunhu, WangManying Chen (2020) “Flexural strength and stiffness of circular double-skin and double-tube concrete-filled steel tubes” Marine Structures Volume 81, 103126.

[16]. Zongping Chena, Yuhan Liang, Xiang Liu, Jingming Cai (2021) “Experimental study on the hysteresis behavior of L-shaped double-skin composite wall with concrete-filled steel tubes” Engineering Structures Volume 245, 112965