Numerical Analysis of PVC Foam-filled Honeycomb Hybrid Core Sandwich Wall Panels with Aluminium Face Sheets

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ABSTRACT

In this study, a numerical analysis of PVC foam-filled honeycomb hybrid core sandwich wall panels with aluminium face sheets was done. The effect of core thickness, skin thickness, and honeycomb cell size were investigated. The panel combinations of varying core thicknesses of 40 mm, 50 mm, and 60 mm, skin thicknesses of 2.4 mm, 2.6 mm, and 2.8 mm, and honeycomb cell sizes of 40 mm, 60 mm, and 80 mm were analyzed using ANSYS workbench. The panels under both axial loading and eccentric loading were done. The load-carrying capacity of sandwich wall panels under axial load is almost 3 times higher than that under eccentric loading. It was found that the load-carrying capacity of panels increased with the increase in core thickness and skin thickness. Also, the core shear stresses, skin stresses, and total deformations decreased. The panel is compared with a panel without PVC foam. It was observed that the load-carrying capacity of the panel with PVC foam is double of the panel without PVC foam. When the sandwich wall panel of cell size increases from 40 mm to 60 mm, the load-carrying capacity is reduced by one-third.

Keywords: Sandwich panels; Honeycomb core; green materials; hybrid core; ANSYS Workbench

1 Introduction

A structural sandwich is a specific type of laminated composite made up of a combination of various materials that are bonded to one another in order to take advantage of the structural advantages of each individual component [1]. Three main components make up a sandwich, as shown in Figure 1. A thick, light core lies between two thin, stiff, and strong faces. To achieve a load transfer between the components, the faces are adhesively connected to the core [2].

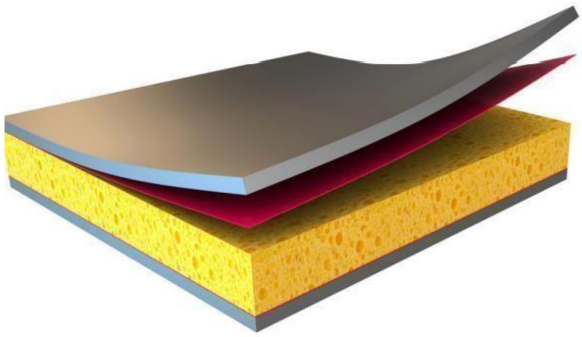

Figure 1: *Sandwich Structure*

1.1 Sandwich wall panels

The advantages of a typical prefabricated sandwich wall panel, such as durability, affordability, fire resistance, huge vertical intervals between supports, and use as shear walls, bearing walls, and retaining walls, are all present in sandwich panels [3]. To accommodate building extensions, they can be moved. In comparison to many alternative wall systems, the insulation offers higher energy efficiency and moisture protection [4].

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2 Methodology

Sandwich wall panel with PVC foam filled honeycomb hybrid core and aluminium face sheet was considered for analysis. Due to its low cost, rapid results, and capacity for in-depth analysis of numerous variables, numerical investigation of structure offers an appealing method of research [5]. As a result, Ansys Workbench, a commercial piece of software, was used to create a three-dimensional non-linear finite element model [6]. For conducting the analysis, the first step was the validation of Ansys software based on data from an experimental analysis. For the fulfillment of the defined objectives, the steps followed were structural modeling, nonlinear static analysis, parametric study, development of load deformation curve, and comparative study [7].

Data regarding material properties for aluminium 6061 and PVC foam was collected for the purpose of material modelling. The material properties are given in the following Table 1.

Table 1: *Material properties of Al alloy 6061 & PVC foam*

Properties	Yield strength	Shear strength	Elastic modulus	Poisson’s ratio
Al alloy 6061	276 MPa	207 MPa	68.9 GPa	0.33
PVC foam	51.6 MPa	5.01 MPa	3.38 GPa	0.32

2.1 Modelling of geometry

The 3D finite element models of bare and PVC foam filled honeycomb sandwich panels were developed by means of ANSYS software (ANSYS Workbench 2022 R1). The FE model consist of three major parts: one core and two outer face sheets. PVC foam-filled honeycomb hybrid core sandwich wall panel with aluminium face sheet was modeled as shown in figure 2 [5]. A total of 12 models were considered for the analysis purpose while varying different parameters such as core thickness, face sheet thickness, and honeycomb cell size. Different combinations of values are adopted for different parameters for each model. The size of the sample panel is fixed as 500 X 1000 mm. The height (H), width (W), core thickness (tc), skin thickness (ts) shown in table 2.

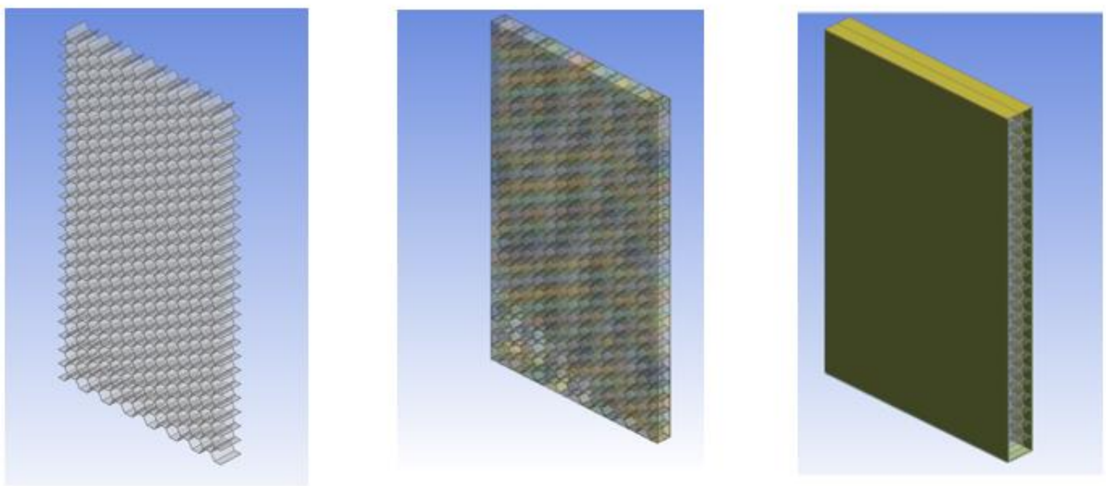

Figure 2: *Modelling stages of sandwich panels* **(a)** *honeycomb core,* **(b)** *PVC foam filled honeycomb core,* **(c)** *PVC foam filled honeycomb core covered with Al face sheets.*

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Table 2: *Specimen parameters*

Group	Specimen	W (mm)	H (mm)	tc (mm)	ts (mm)	S (mm)
A	SP1	500	1000	40	2.4	40
	SP2	500	1000	50	2.4	40
	SP3	500	1000	60	2.4	40
B	SP4	500	1000	40	2.6	40
	SP5	500	1000	50	2.6	40
	SP6	500	1000	60	2.6	40
C	SP7	500	1000	40	2.8	40
	SP8	500	1000	50	2.8	40
	SP9	500	1000	60	2.8	40
D	SP10	500	1000	60	2.8	60
	SP11	500	1000	60	2.8	80
	RSP	500	1000	60	2.8	40

2.2 Loads and Boundary Conditions

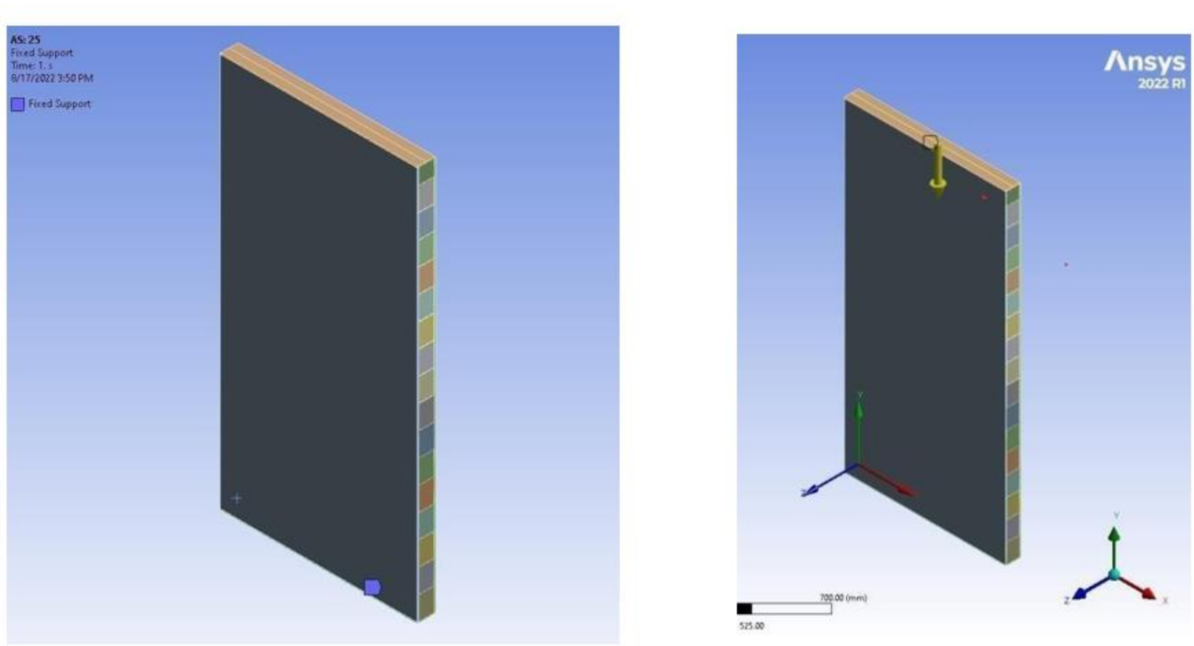

Figure 3: *Loads and boundary conditions for static analysis.*

The bottom of the sandwich panel is fixed. The in-plane axial load is applied quasi statically on the top face of the panel.

3 Results and Discussion

3.1 Load Deformation Curve

3.1.1 Load Deformation Curve under Axial Loads

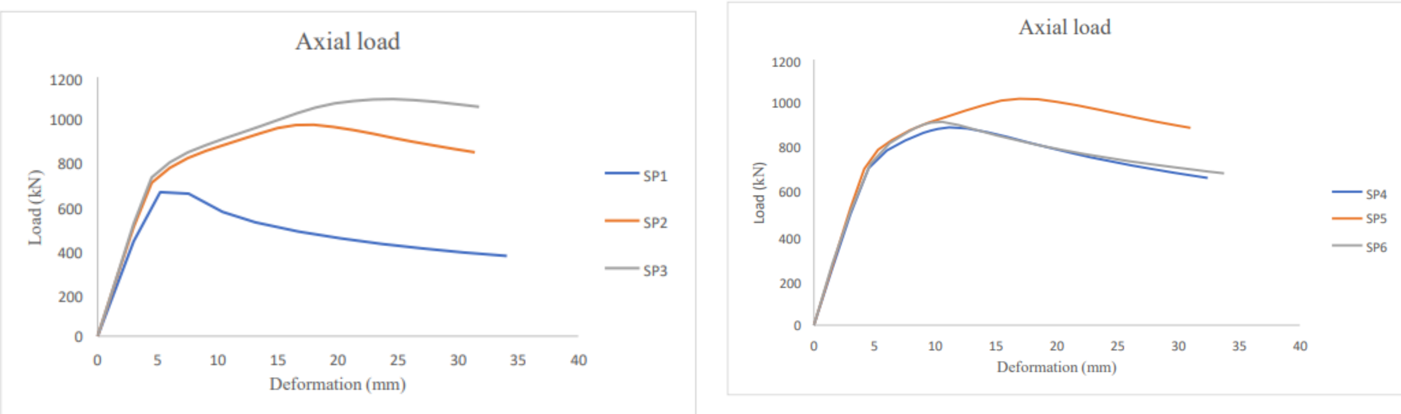

Figure 4: (a). *Load–deformation curve of SP1, SP2 & SP3,* **(b).** *Load–deformation curve of SP4, SP5 & SP6*

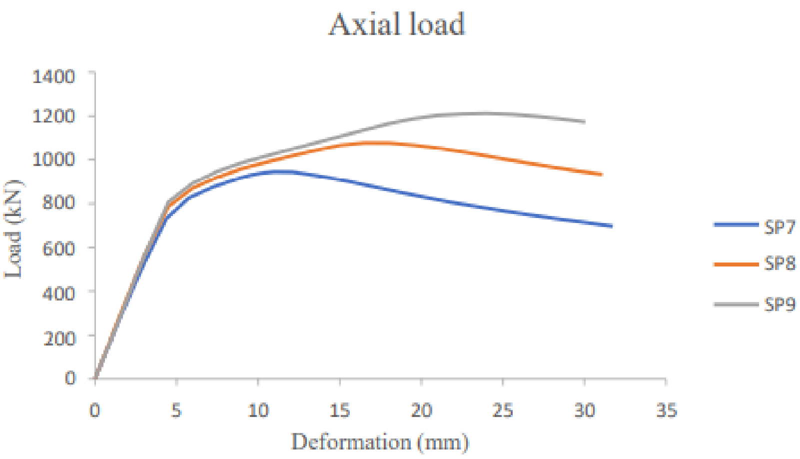

Figure 4: (c). *Load – deformation curve of SP6, SP7 & SP8*

The maximum load that can be carried by SP, SP2, and SP3 were 667 kN, 972 kN, and 1098 kN respectively. The critical loads of SP4, SP5, and SP6 were observed as 904 kN, 918 kN, and 1122 kN. The maximum loads on SP7, SP8, and SP9 were noted as 945 kN, 918 kN, and 1210 kN.

3.1.2 Load Deformation Curve under Eccentric Loads

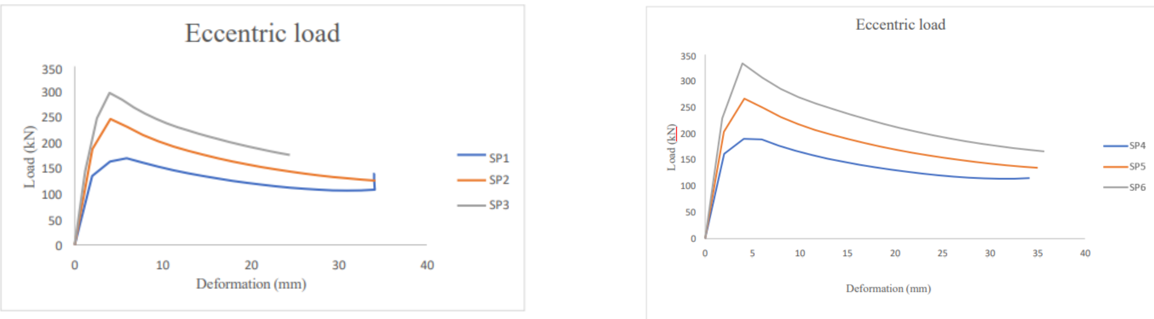

Figure 5: (a). *Load-deformation curve of SP1, SP2, and SP3 under eccentric load,* **(b).** *Load-deformation curve of SP4, SP5, and SP6 under eccentric load*

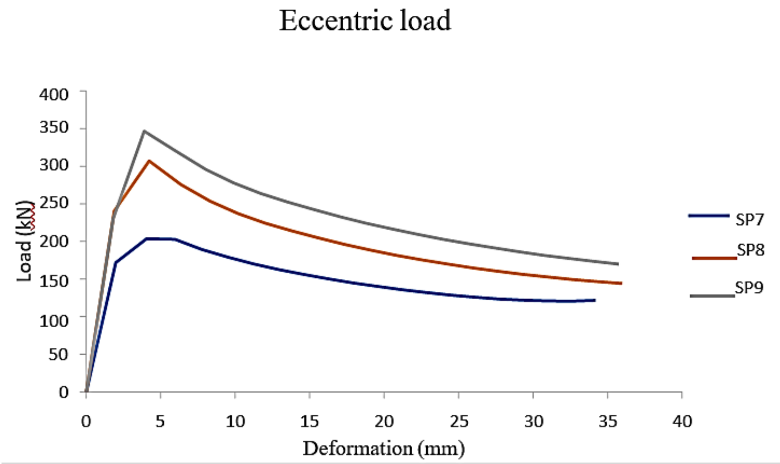

Figure 5: (c). *Load-deformation curve of SP7, SP8, and SP9 under eccentric load*

The critical loads of SP1, SP2, and SP3 under eccentric loads were 169 kN, 247 kN, and 333 kN. The peak loads observed are 187 kN, 266 kN, and 346 kN for SP4, SP5, and SP6. The load deformation curve of SP7, SP8, and SP9 under eccentric load shown in figure 5(c). The critical loads were 203 kN, 306 kN, and 396 kN.

3.2 Effect of Core Thickness

3.2.1 Effect of core thickness on peak load

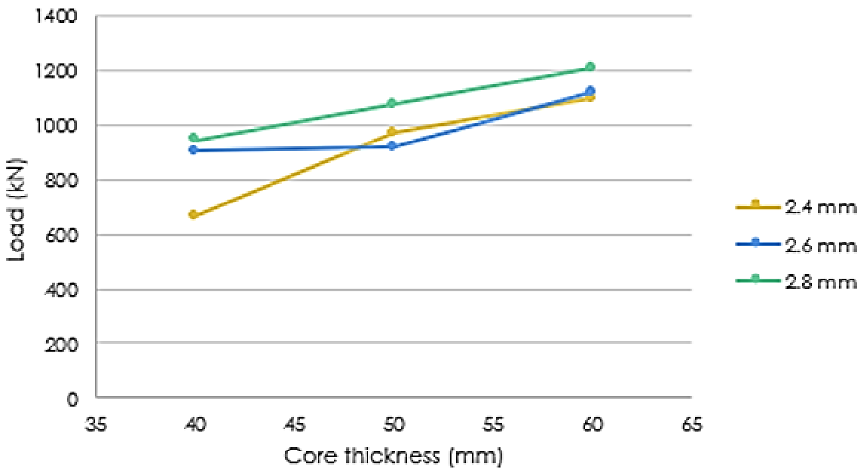

Figure 6: *Graph of critical load vs core thickness*

3.2.2 Effect of Core Thickness on Core Shear Stress

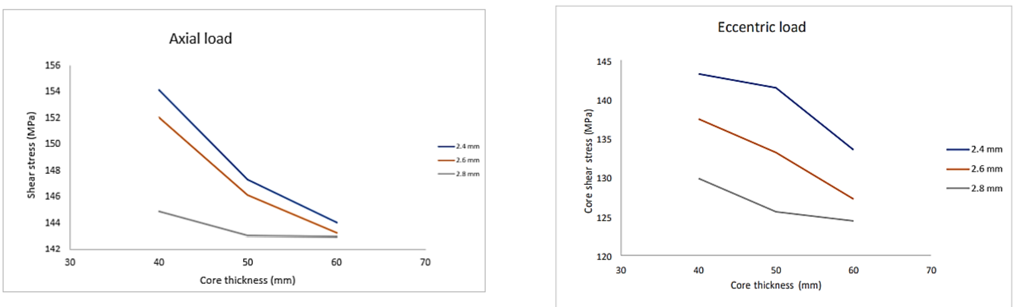

Figure 7: (a). *Graph of shear stress vs core thickness under axial load,* **(b).** *Graph of shear stress vs core thickness under eccentric load*

3.2.3 Effect of Core Thickness on Skin Stress

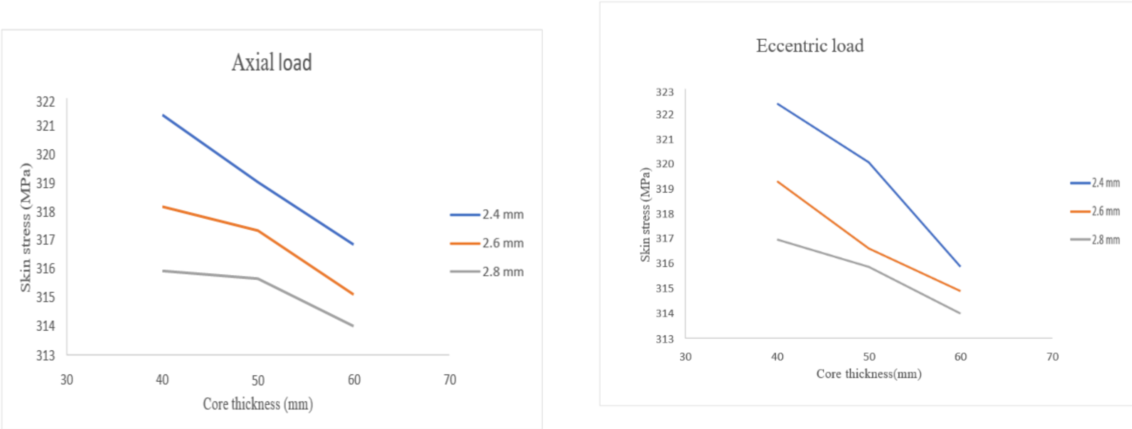

Figure 8: (a). *Graph of skin stress vs core thickness under axial load,* **(b).** *Graph of skin stress vs core thickness under eccentric load*

3.3 Effect of Skin Thickness

3.3.1 Effect of Skin Thickness on Peak Load

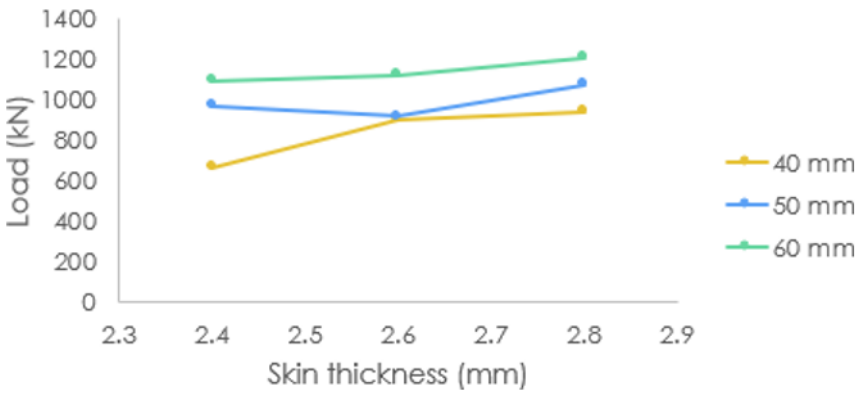

Figure 9: *Graph of critical load vs skin thickness*

3.3.2 Effect of Skin Thickness on Core Shear Stress and Skin Stress

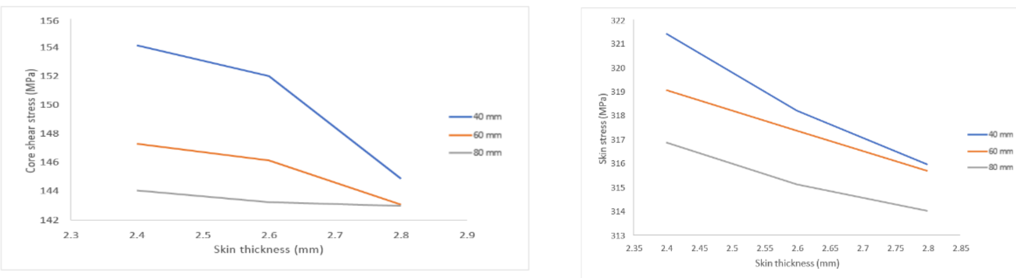

Figure 10: (a). *Graph of core shear stress vs skin thickness,* **(b).** *Graph of skin stress vs skin thickness*

3.4 Effect of Cell Size of Honeycomb

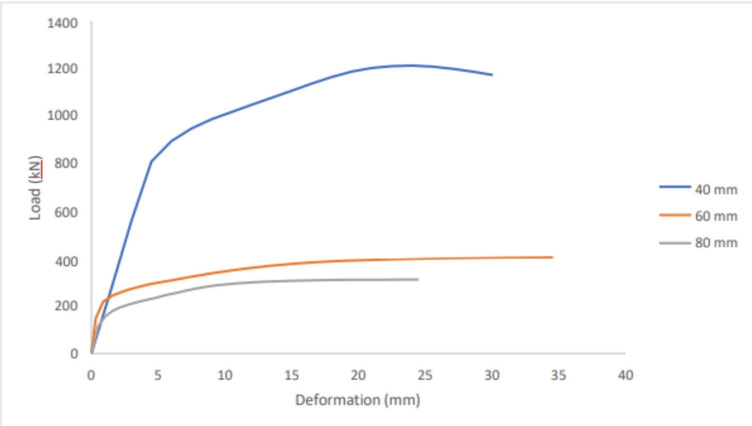

Figure 11: *Load-deformation curve of panels of honeycomb cell size 40 mm,60 mm, and 80 mm*

The maximum loads are obtained as 1210 kN, 400 kN, 245 kN when the cell size increases by 20 mm.

3.5 Comparison of Sandwich Wall Panels with or without PVC Foam

3.5.1 Model after FEM Analysis

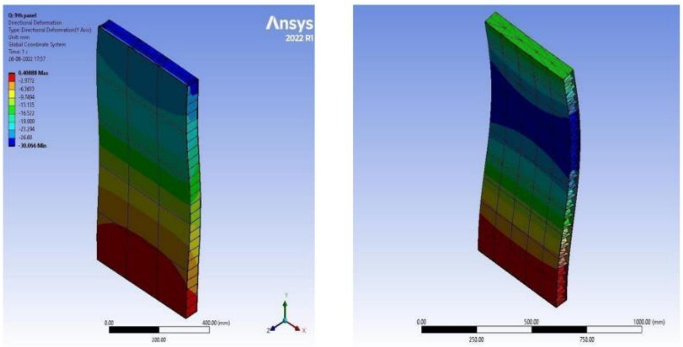

Figure 12: (a) *SP 9 under axial load,* **(b)** *Reference panels under axial load*

The sandwich panel without PVC foam shows large deformations. The sandwich without the PVC foam was found to be buckled more.

3.5.2 Comparison of Peak Loads

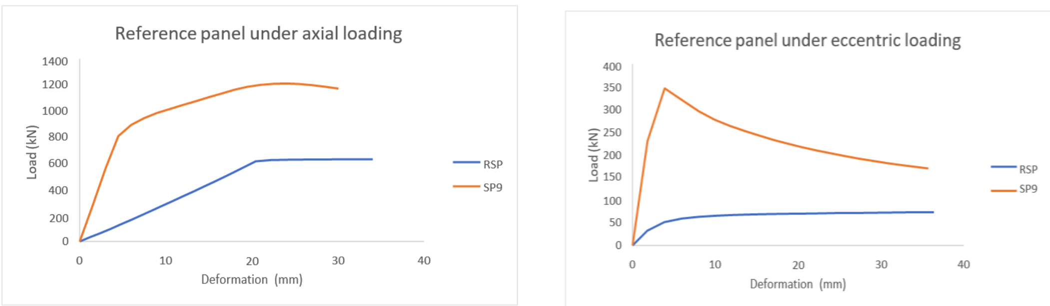

Figure 13: (a) *Reference panel under axial loading,* **(b)** *Reference panel under eccentric loading*

3.5.3 Core shear Stress and Skin Stress

Table 3: *Comparison of sandwich panels with or without PVC foam*

	SP 9	RSP
Critical load	1210 kN	545 kN
Core shear stress	142.28 MPa	394.66 MPa
Skin stress	314.01 MPa	923.5 MPa

4 Conclusions

In this particular study, the numerical analysis of PVC foam filled honeycomb hybrid core sandwich wall panels while varying important parameters were carried out. The performance of the panel was then compared with the honeycomb core sandwich wall panel without the PVC foam. The major findings from the study are following:

- The Sandwich panel 9 (SP9) shows better performance and load carrying capacity among the panels. The load critical load was observed as 1210 kN.
- The load carrying capacity sandwich wall panel under axial load is higher than that under eccentric loading. The load that can be carried by the sandwich panel under eccentric loading was decreased by three times than that under axial loading.
- Core thickness and skin thickness has significant effect on the behaviour of sandwich wall panels.
- As the increase in core thickness as well as the thickness of face sheet, the load carrying capacity improved. The load-carrying capability of the sandwich wall panel doubled when the core thickness went from 40 to 60 mm. When the plate thickness was increased from 2.4 mm to 2.8 mm it was found that the maximum load carrying capacity was improved by more than 3 times.
- Also, the core shear stress and the skin stresses decreased with increase in core thickness and skin thickness.
- Honeycomb cell size should be minimum. Large cell size will cause large deformations and less load carrying capacity. The sandwich wall panel of cell size 40 mm shows maximum load carrying capacity. It was observed as 1210 kN. When the panel of cell size equal to 60 mm, the load carrying capacity reduced by one-third. When the cell size of 80 mm, the peak load reduced again, and it was observed as 245 kN.
- The hybrid core sandwich panel has enhanced properties compared to the sandwich wall panel without PVC foam filled honeycomb core. The load-carrying capacity of the PVC foam-filled honeycomb hybrid core sandwich wall panel was almost 2 times that of the wall panel without the PVC foam. Also, the core shear stress and skin stresses were found very low compared to the reference panel.

5 Publisher's Note

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How to Cite

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