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Effect of Soft Core Thickness with Composite Face Sheets on Sandwich Panel Beyond Its Yield Limit

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Abstract

Various industries have used sandwich panels in a vast array of applications. It is the composition that makes them unique; a low density core material, placed in between two high modulus face sheets creates an ultra-light weight structure providing extraordinary stiffness. The inner, generally softer than the face sheets has been widely studied in elastic range with metal faces often used. This study also makes a unique contribution in that it explores the impact of varying thickness of light core on the behavioral changes seen among sandwich panels after yield stress. Load grows gradually in a quasi-static process until vanishingly close to the yield point. Through using of a finite element analysis package, particularly ANSYS model this panel acquires simply supported boundary conditions on all sides. The accuracy of the developed model is proved by detecting careful comparisons with available numerical and experimental cases described in literature, demonstrating a strong concordance with previous works. Challenging conventional wisdom, this study highlights an intriguing revelation: It shows an upward variation beyond the yield strength of this central material. Interestingly, when the thickness of core increases, there is an increase in transmitted load to face sheets. Instead, a decreasing core thickness makes the sandwiched panel performance similar to that of orthotropic composite plate approaching yield before faces do.

Keywords: performance, decreasing, yield, orthotropic

Introduction

In detail, the test was conducted on carbon fiber-reinforced polymer structures to cover composite sandwich construction. Significantly, the cores A plane compression had better mechanical properties than those in which they were W ,Y and X shaped(X. Gu,2023). This led to the use of ideal designs for multi-span sandwich panels with slightly contoured steel skins and PUR. The strength/failure characteristics of a new core design for sandwich composite structures were presented through three point bending test[R. Studziński,2009].

The core and face sheets were made of E-glass fiber reinforced epoxy resin[A. Uzal]. The field of such study was low-velocity behavior for sandwich composite panels, their experimental and numerical modeling. The difference in structural and damage responses was large between small-span sandwich panels to a big span(D. Feng, 2022). A modular sandwich panel system designed for interior applications of wall partition was also introduced, comprising an extruded polystyrene board core and offering three face sheet options. These are gypsum plasterboard, fire-resistant gypsum plaster board and magnesium oxide boards(S. Ferreira et al, 2023).A densification strain change equation was implemented to model the quasi-static compression stress of a gradient foam material. In addition, a two-field displacement model was formulated for the compression of negative gradient foam material under spherical indentation(X. Xiao, 2018). The evaluation of the 2D FE model's performance for sandwich panels with bi-directional flax fiber reinforced polymer faces and dual aspect ends under concentrated loads was carried out(D. Betts, 2023).Facade sandwich panels used for building construction were studied experimentally, whereby polyurethane cores as well supported the panel through its structural profile. Through finite element analysis, the effects of plate thickness and stacking sequence played in producing maximum deflection under heating conditions were identified(G. Stanisavljević, 2023).Using 3D finite element methods to perform free vibration analysis of a thick rectangular plate made up from isotropic and orthotropic materials leads to obtain boundary limits for the period under investigation(S. Akour, 2019). Convergence results were compared with known analytical solutions. Furthermore, the three dimensional finite element process was supplemented by thickness isotropic and anisotropic material tests on experimental modal analysis (K. SRIVIDYA, 2022).

A number of rubber foam surface material SIPs have been proposed(N. Thongcharo,2021). Sandwich structure GFRP composites filled with rigid PU foam were defined, and significant attention was paid to the number of variants between face layer GFRPS and core material epoxy resin in terms of mechanical properties(S. Rohman, E. Kalembang, 2023).In this numerical experimental study, the aluminum foam sandwich panel doubly curved surfaces plastic deformation was presented. Having developed a microscopic 3D Voronoi model to describe the morphology of close-cell aluminum foam(X. Zhang, 2021), we have predicted face sheet/core delamination failure in plastic forming process of sandwich panels with such foams numerically(X. Zhang, 2023). The history, process and materials used in SIP manufacturing were reviewed ,The findings of most recent SIP investigation were researched depending on application and its restraints to direct wrongdoings for architects(M. Panjehpour, 2012).The proposed modification to improve the fracture properties for a medium-density fiberboard is inserting and glass fibers between two layers using hand layup. A study on the delamination of face sheet–core separation to core material in a sandwich medium density fiberboard(M.K.Hassan, 2017).In this, theoretical modelling and double cantilever tests are utilized to characterize mode I face-core interfacial debonding of an all composite sandwich beam with a hexagonal honeycomb carbon fiber–reinforced polymer core. A theoretical model was developed combining Timoshenko's face sheets theory and High Order Sandwich Panel for structural applications that involved elastic layer lightweight composite panel(P. Xue, 2022). Four independent set of face-sheet reinforcement sequences is selected, including kenaf-kenaf; glass–glass whereas mechanical characteristics and types of failure are well explained (O.A. Afolabi, 2023).

To analyze face sheet–core debonding, a proposed two-node spectral finite element for sandwich panel with thirteen degree of freedom was developed. The use of the spectral element formulation resulted in an exact dynamic stiffness matrix for the element(M.V. V. S. Murthy, 2022).In order to ensure simply supported boundary conditions along all edges of the square, showing that thickness C core affects behavior under Sandwich Panels beyond yielding metal face sheets, Hydromat Test System for two-dimensional panel testing is adapted. The study of the core thickness involved a univariate search optimization technique(S.Akour, 2011).

Physical Model and Geometry

Two composite material layers marked t create a sandwich panel, with the flexible core denoted by thickness c positioned between them. The core mostly is foam, which has softer characteristics than face sheets. In figure 1, the panel is shaped like a square with size of 'a'. The total thickness h refers to parameter 'h'. The assigned values for a, t, and c are as follows: With 610mm, t=2.54 mm and c can be from height of 39 inches to one inch high.

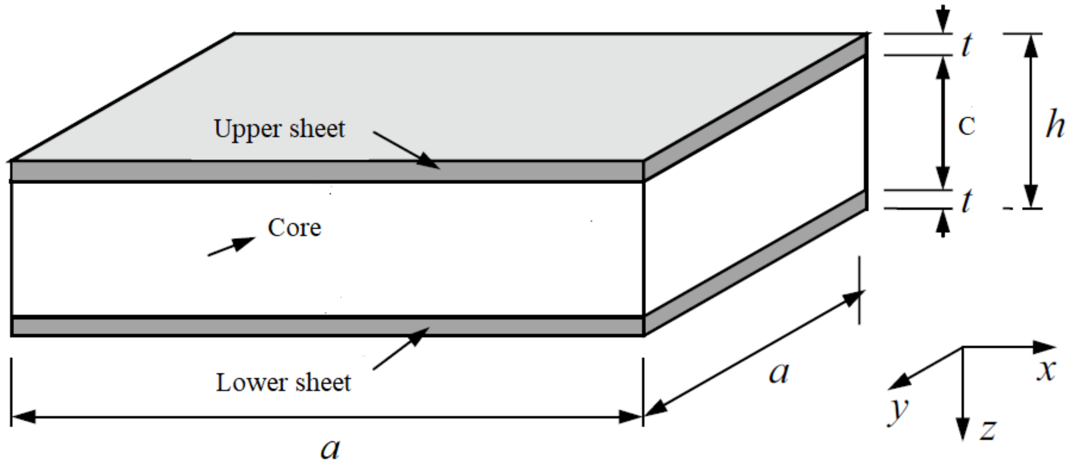

Fig 1 illustrates sandwich panel geometryUnderlying Assumptions

This research considers material nonlinearity, adding some simplifications to the model without losing its physical integrity. The following assumptions provide a framework for this approach:

Full Bonding: The face sheets and core are considered fully bonded, preventing the occurrence of delamination between these layers.Elastic Face Sheets: All face sheets are elastic. This assumption is based on the significant variances in yield strength and modulus between the face sheet's subfloor, and core. As a result, it is argued that the face sheets maintain elasticity throughout the process of loading such that when yield occurs in these face sheets; analysis terminates.Simply Supported Boundaries: All four edges of the panel are simply supported, enabling an efficient simplified structural layout. Core Material Nonlinearity: The core material's nonlinearity is taken into consideration in the analysis, which accounts for deviations from linear behavior during load cases.

Conditions within the boundary and material properties:

The sandwich panel is developed as a square in form. In terms of shape, the loading area is also a square that has an edge length of 610mm. The panel walls are simply supported (i.e. they're free to rotate and have no moment resistance)

Table 1: Core material properties (*R.F. Gibson, 2016*).

Material	Property Source	Young's Modulus (MPa)	Poisson's ratio	Shear Modulus (MPa)	Shear Strength (MPa)	0.2% offset Yield strength (MPa)	Strain at yield point (mm/mm)
AirexR63.50	Rao,2002	37.5	0.335	14.05	0.45	0.637	0.019

Table 2: Fiber material properties (https://www.matweb.com).

Material	Modulus of elasticity X-Direction	Modulus of elasticity Y-Direction	Poisson's ratio	Shear Modulus
Structural	151 GPa	10.3 GPa	0.3,0.59	7.2 GPa
	Modulus of	**Fiber volume**	**Poisson's ratio**	

	elasticity	fraction		
Fiber	230 GPa	0.785 GPa	0.22	
	Yield tensile	**Yield compression**	**Elongation**	
Carbon Fiber	945 (MPa)	686 (MPa)	1.5%	
Epoxy	79.6 (MPa)	108 (MPa)	14.6 %	

In load increments to the upper face sheet, the applied till it reaches maximum yield strength at panel. Figure 4 shows a distribution region of the distributed load that extends across all upper face sheet plate surface. The loading region, which refers to the center section of the upper surface panel, is square. Yet, in the case of a sandwich structure's performance environment, core thickness takes on criticality. These are as outlined in Table-1 according to the core thickness varying from (15mm, 20mm; 30mm), and maximum value of so, this pertains on mechanical properties material face sheet candidate, thereafter concerning core. Figure 2 presents the stress-strain curve of core material. So, we chose these materials because they are field-ready. Figure 3 shows a symmetric cross-ply laminate surface for sheet element.

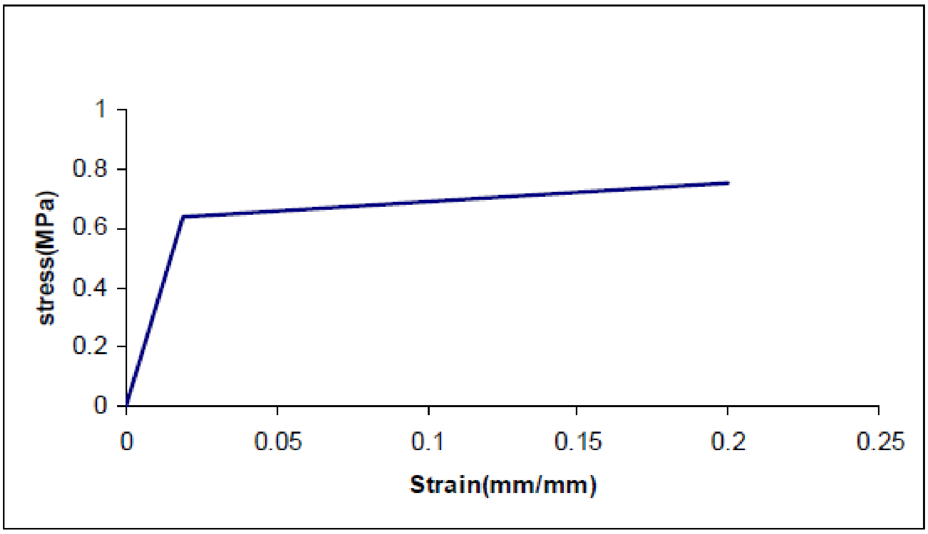

Fig.2: The Stress Strain Curve

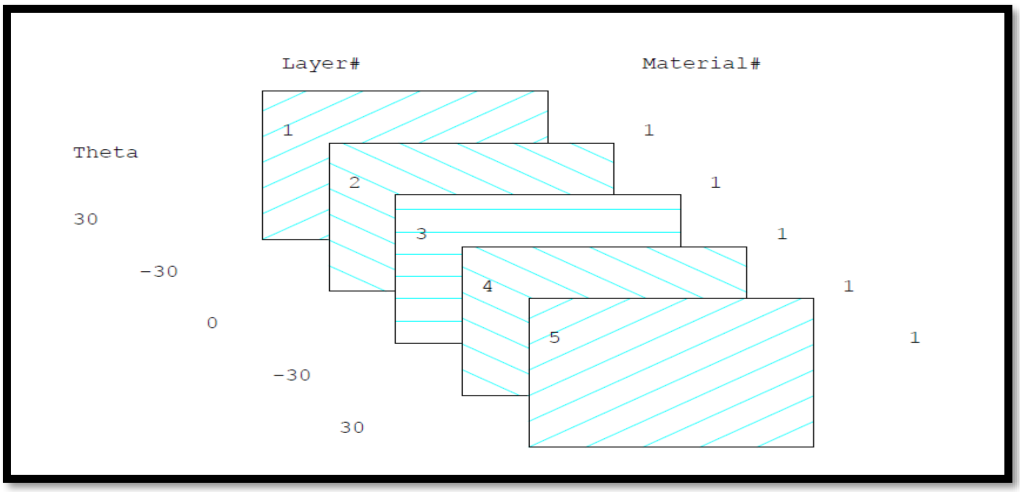

Fig 3: The upper and lower face sheet composite material and stacking

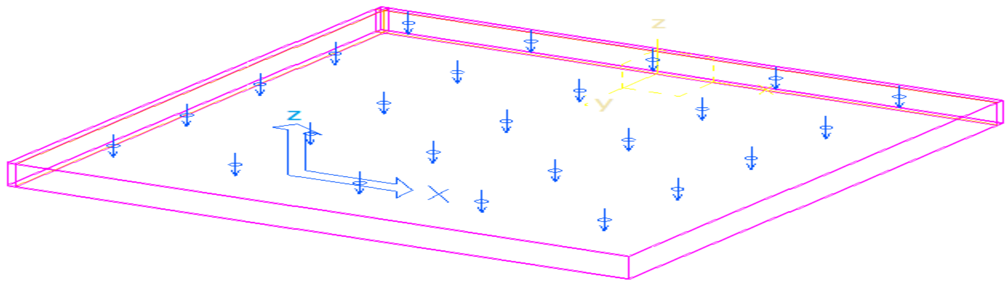

Fig 4 The load distributed on the upper face sheet

Finite Element Model

In order to predict the mechanical properties in sandwichmaking process, ANSYS commercial program was used. The evolution featured 3D linear FEA models of sandwich panels with the variations in core thickness. Four-node SHELL 281 and eight node solid 186 elements were employed to represent skins and core material, respectively. The ANSYS–APDL numerical analysis was achieved with the meshes SOLID 186 elements as sandwich core shear surface. Shell 281 elements were used to mesh the upper and lower faces of sandwich panel. The subsequent section contains the discussion of these parts in detail according to ANSYS Manual. Figures 5 and6 present the meshed FE models for face sheet elements and core. This method proved effective in thin to moderately thick shell structures. The SHELL 281 Shell Element used in the analysis has six degrees of freedom at each node that represent translations along X-, Y, and Z-axis directions as well as rotation around three coordinates. However, the benefit of using PLANE elements is clearly seen in modeling yielding and forming plastic hinge due to their relatively long stress/strain profile through plate thickness. However, stress results appear clearer to interpret and shell elements require less computational time with fewer convergence problems than plane ones. However, shell models require subsequent processing after the analysis to understand and interpret obtained results. The SOLID 186 element is used for the three-dimensional modeling of solids, that has twenty nodes with six degrees freedom—nodal translation along x, y and z-axis. This element shows plastic creep, swelling stress stiffening behavior and large deflections as well. The sandwich panel is carefully developed by the finite element program ANSYS involving two-dimensional and three-dimensional models. Compatibility is verified by a convergence test.

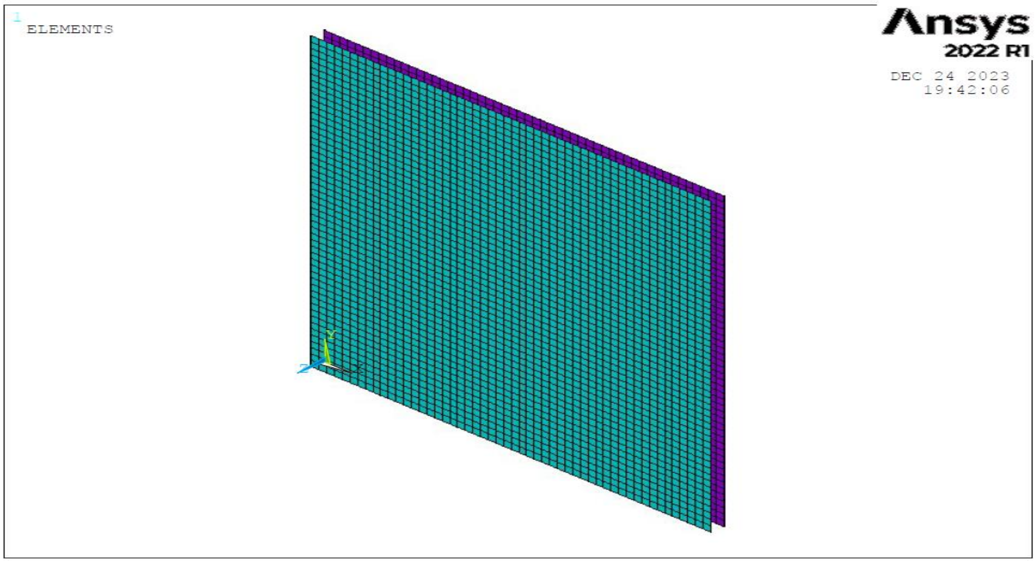

Fig.5: upper and lower face sheet of sandwich panel

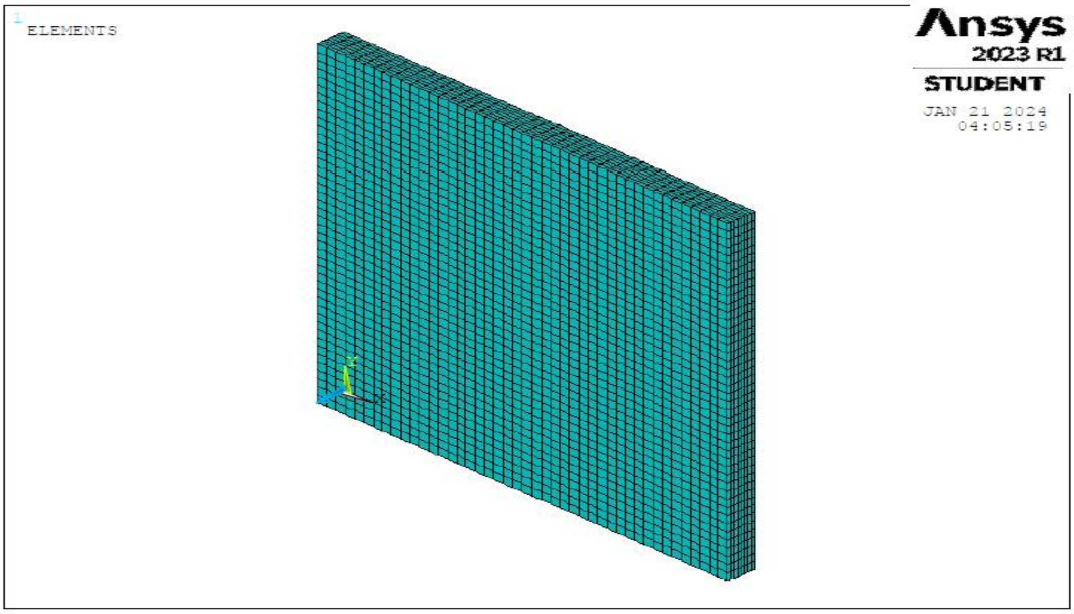

Fig. 6: FEM mesh for core of sandwich panel

Model Verification

One scenario that has been mimicked in the existing literature using FE model is absolute difference of less than one percent. In order to strengthen the trust in FE model and its forecasts, other experimental validation were conducted. Therefore, the experimental study was based on an AirexR63.50 and Face sheet Aluminum 3003-H14 sandwich panel. The mechanical properties of both the core and sheets were determined experimentally based on ASTM Designation. As shown in Fig. 6, relationship between the applied load and displacement at center of specimen is depicted for experimental tests as well as FE modeling cases In particular; there is a significant consensus among the results. The relative deviation does not exceed 6 percent. The findings below show repeated trials that exceed two but plotted as means (Figure 7). These initiatives additionally reinforce the reliability of the FE model and consistency with actual experimental information.

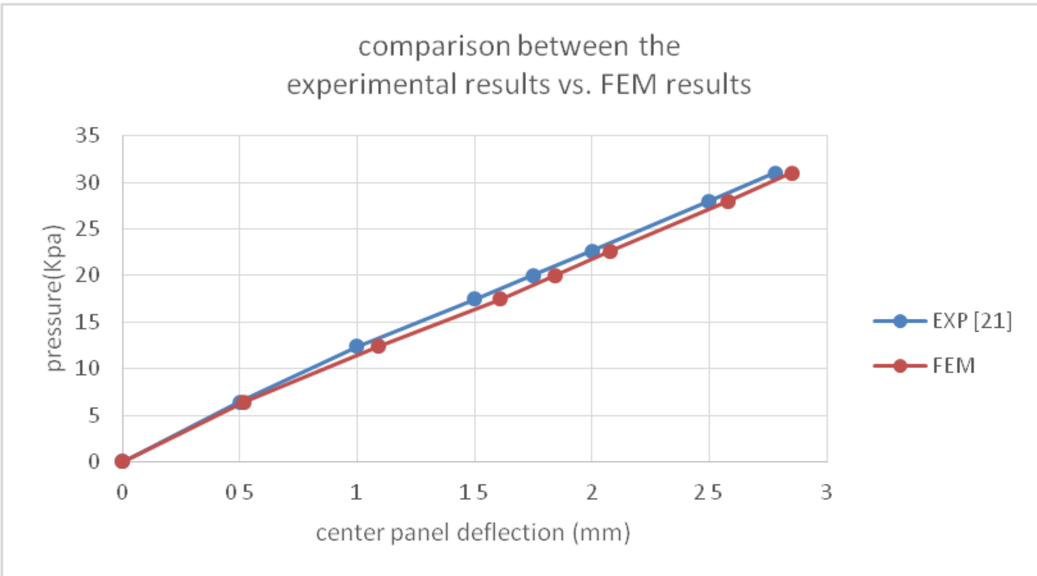

Fig 7: load vs. middle bar deflection curve Results and Discussion

The study analyzes why thickness has an influence on the behavior of sandwich panels that is beneficial for design engineers in determining parameters, which can suit their designs. One of the notable features for this study implementation is that it utilizes ANSYS software program to consider material nonlinearities, stress and its components inclusive plastic strain. The results of this study indicate differences in the performance of the sandwich panels. In particular, plastic deformation is recorded in the vicinity of panel support in accordance with defining boundary conditions. This is also in accordance with the physical situation treating to effect, which brings about conversion of distributed pressure into impact loads when boundary conditions are simply supported.

The adopted loading criterion corresponds to the start of yielding in any one of the face sheets, which is aligned with a designer's intention of limiting permanent panel deformation. The beginning of permanent deformation marks the start of face-sheet yielding, and such results are at slightly below this initiating level. Sample outputs are presented to demonstrate the performance of sandwich panel's for each parameter. Figure (8) shows the overall deflection at plate center that ultimately tries to show an increase in core thickness reduces sandwich behavior. As there is an increase in the core thickness, it has been shown from Figure (9) that load-carrying capacity also increases. In Figs. (10, 11), we see the effect of panel core thickness on both upper and lower face sheets respectively in that top facing begins to clamp first followed by bottom one. Additionally, the research notes tension stresses in both face sheets consistent with Von Mises theory whereby both faces are under tensile stress and their upper one has a higher value because of direct pressure. Figures (10, 12) illustrate the influence of core thickness on upper face sheet, lower face sheets and correlation with CORE's maximum Von Neumann stress.

Figures (10, 11) have poisoned loading curves because of the change in core materials and both on face sheets are alike. Figure (13) stresses that carbon fiber on face sheets does not significantly change the nature of deformation for deflection contour Figure (14) shows shear stress in the core material at upper rim of the core. Figures (15) and (16), which may be seen as similar to shear stress contours present the von Mises stress for upper face materials and lower limits. As shown in figure (17), minimum Von Mises stresses are noticed at the center of core, because fiber orientation path compensated each other while high-magnitude stress is present near the boundaries where all forces reflected as responses.

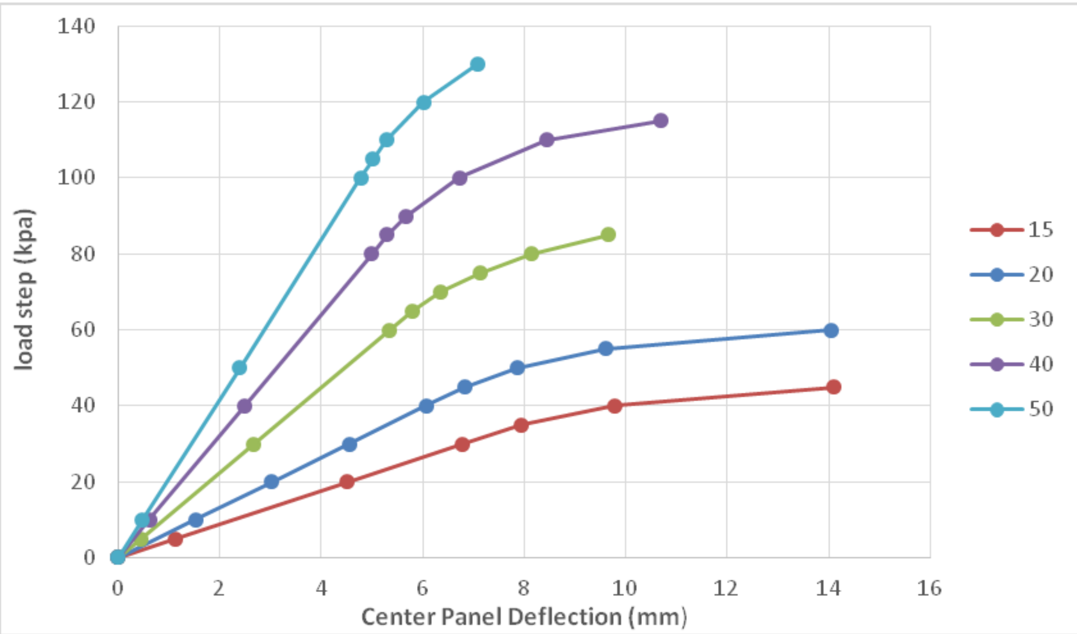

Fig 8 Deflection of center vs. Load Step (KPa)

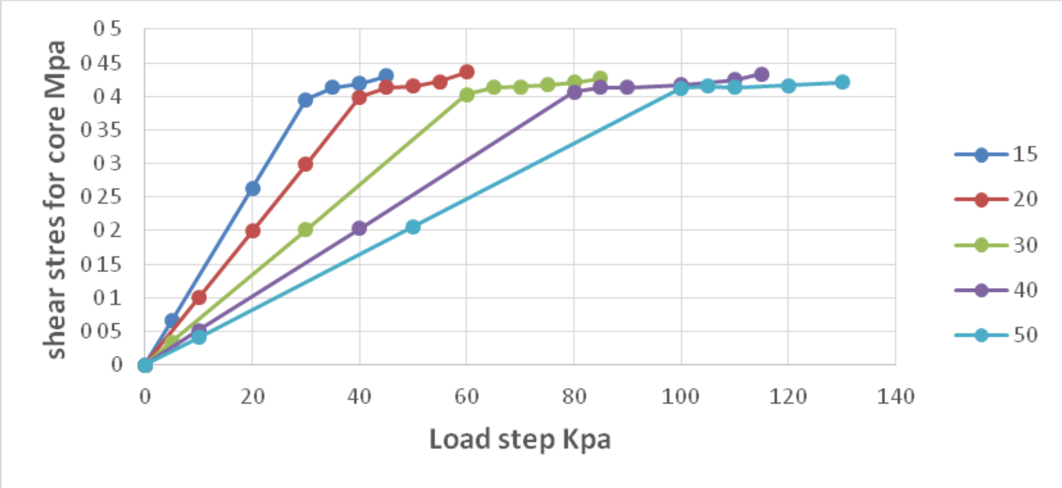

Figure 9: maximum shear stress vs. load step (KPa) for varying core thickness

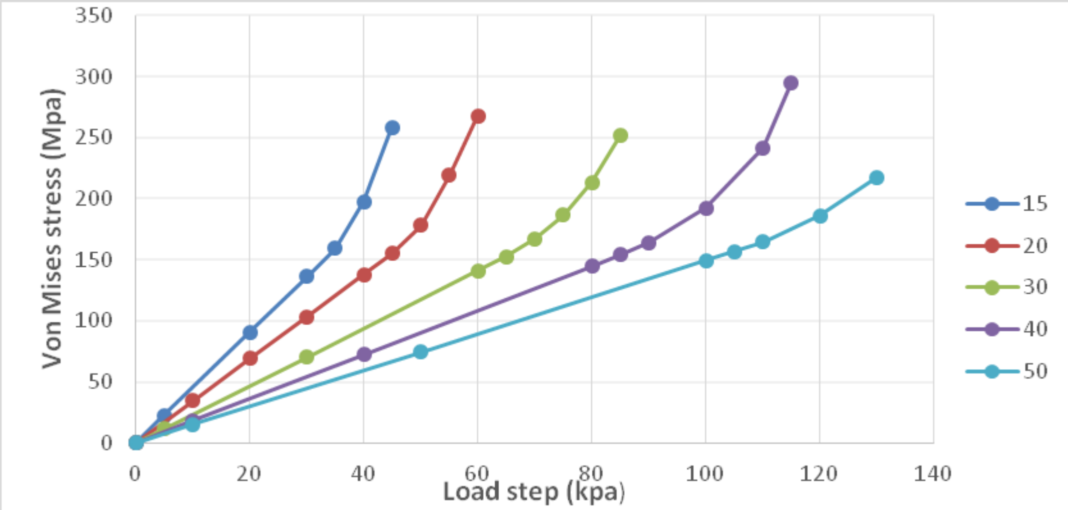

Figure 10: Maximum von Misses stress value (Mpa) vs. load step (KPa)

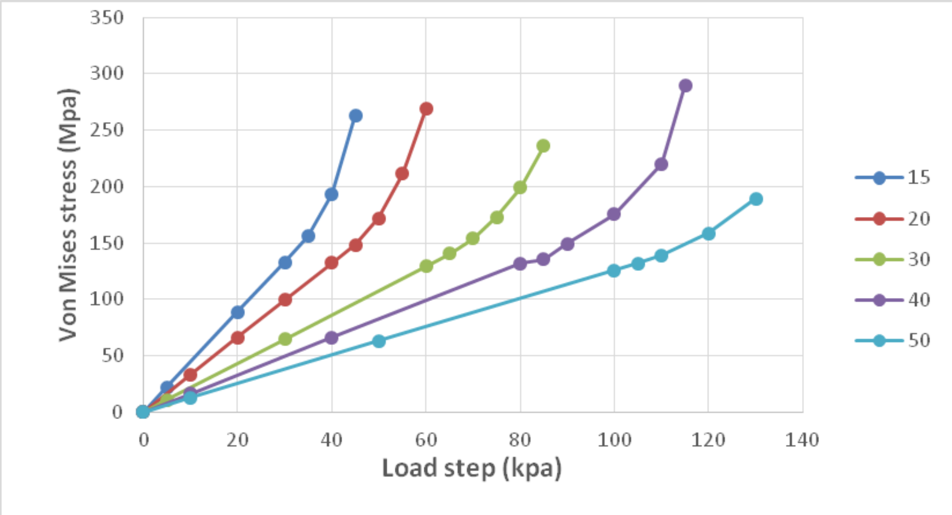

Fig 11 Maximum von Mises stress valuevs. load step for varying core thickness

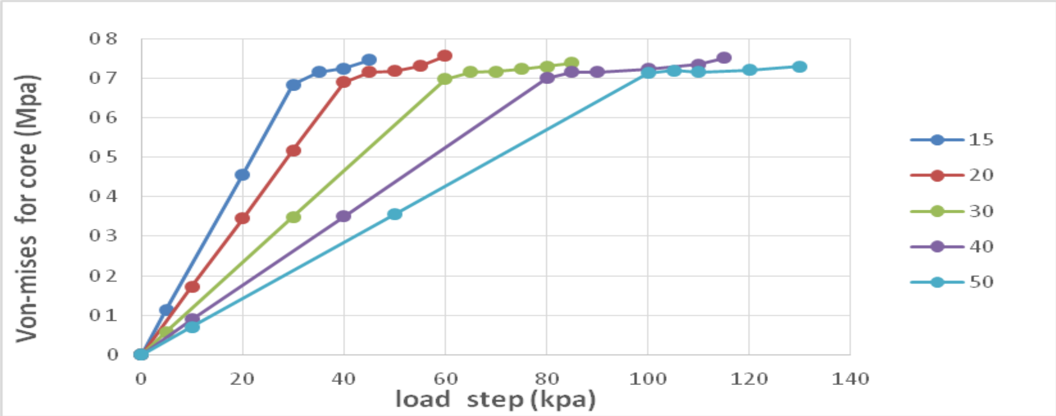

Fig 12 Maximum von Mises stress value (MPa) vs. load step (kpa) for varying core thickness

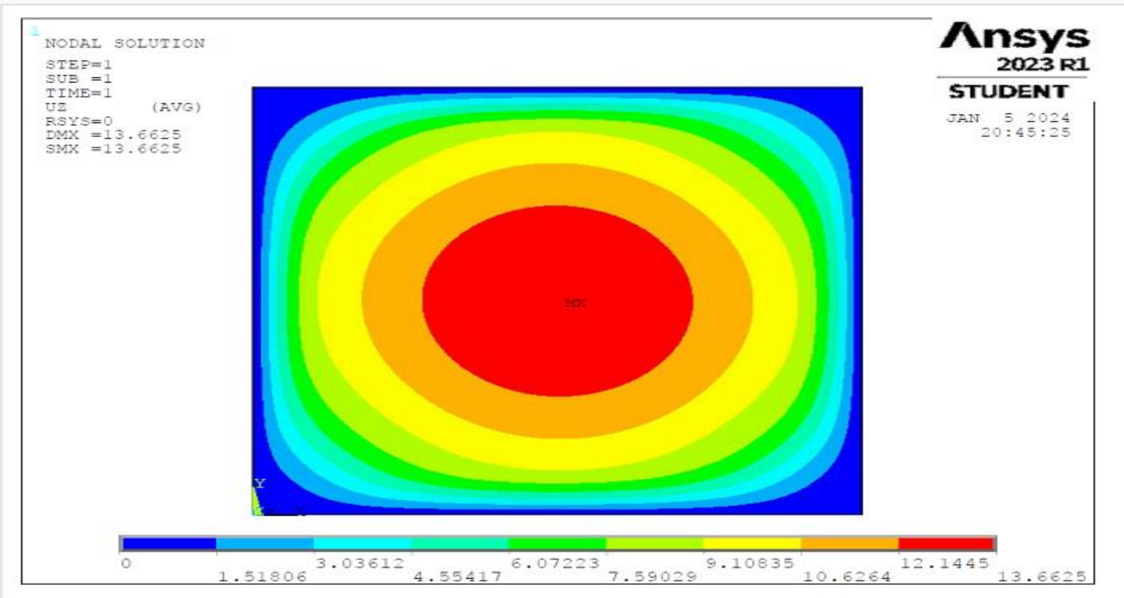

Fig 13 contour deflection for whole panel 20mm and load 60kpa

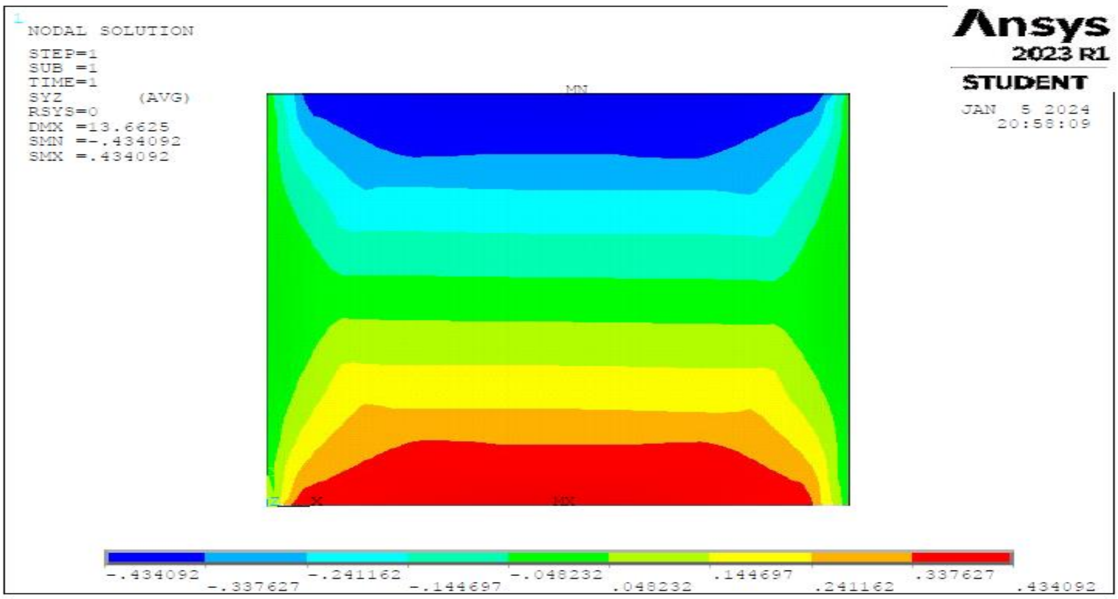

Fig 14: contour of Shear stress for core material at core 20mm

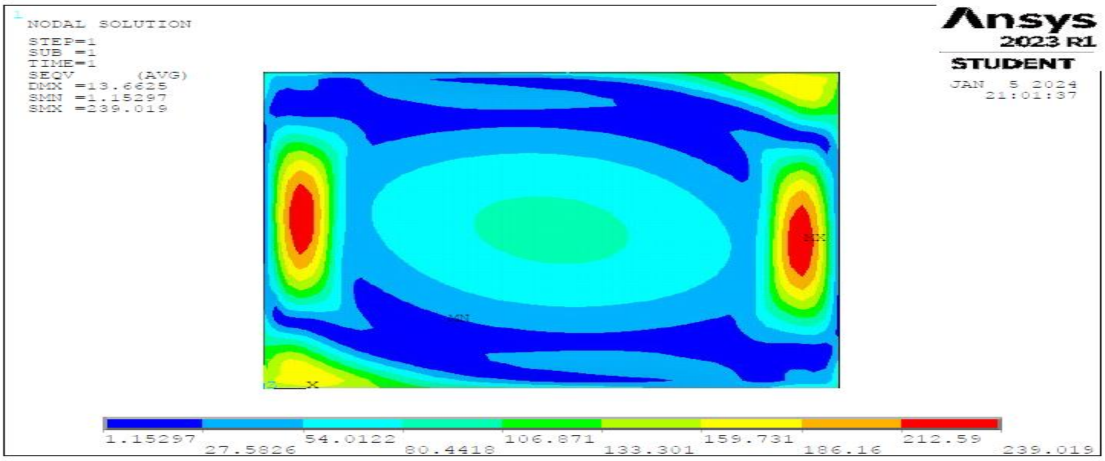

Fig 15: Contour of Von Misses stress for ace sheets, 20mm and load step 60kpa

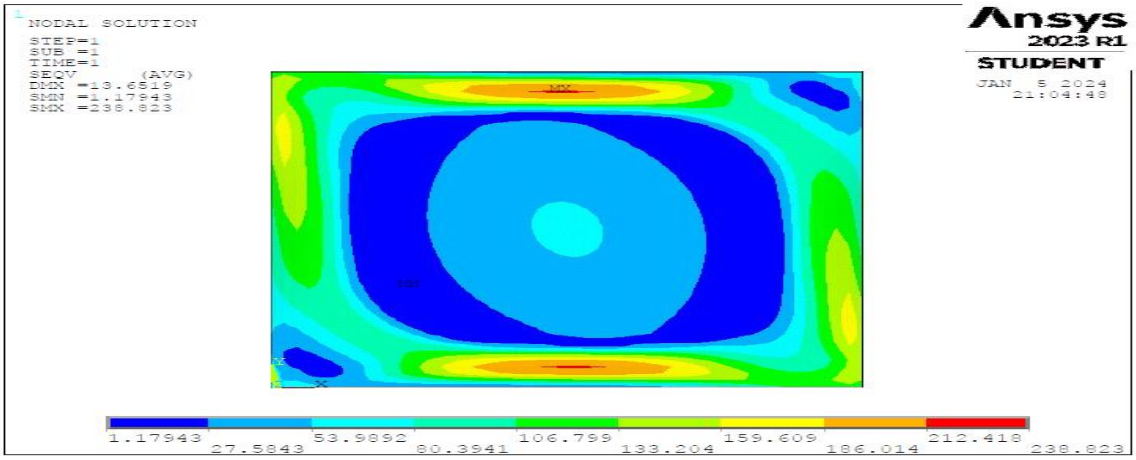

Fig 16: Contour of Von Misses stress for lower face, 20mm and load 60kpa

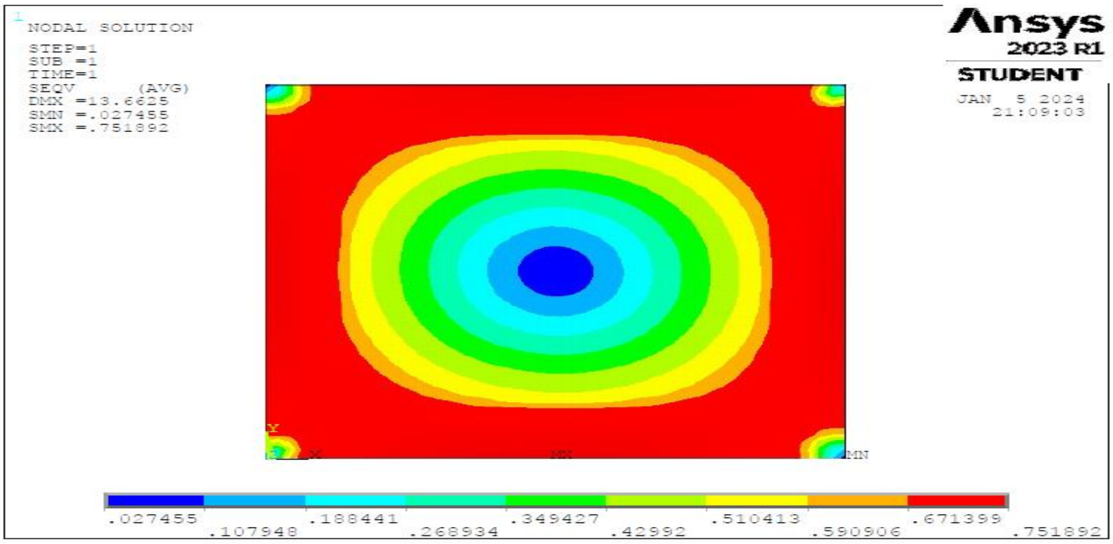

Fig 17: Contour of Von Misses stress for center core, 20mm and load step 60kpa

Conclusion

The investigation is centered on studying how a sandwich panel behaved beyond its core yield point. 'ANSYS' software is employed to generate a comprehensive model of the entire panel including nonlinearity for core material. An analytical check against cases present in available literature is followed by selected experimental validation of the model. The proposed model not only is well consistent with the previous literature but also shows a perfect fitting with experimental data.The load capacity of the panel also shows a considerable rise as the core material exceeds its yield points. This load transfer to the face sheets is responsible for an increase in core thickness augmentation. Design preferences tend to denote that the faces of sheets give in before core material when panel thickness enables yielding, which goes well with an orthotropic composite sheet. This strategic relationship guarantees a desirable performance characteristic which sees the face sheets precede core material in instances of certain conditions.

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