International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 03, March-2016

A Theoretical and Experimental Approach for Sandwich Composites

Sathyanarayana V.[1*], Sharath N[2*], Dr. Irfan G[3], Swetadri Srinivasan[4*],
[1,2,3,4] Dept. of Mechanical Engineering,
Akshaya Institute of Technology,
Tumkur

***Abstract* - Sandwich composites are becoming more and more popular in structural design, mainly for their ability to substantially decrease weight while maintaining mechanical performance. This weight reduction results in a number of benefits, including increased range, higher payloads and decreased fuel consumption.**

It has long been known that separating two materials with a lightweight material in between increases the structure's stiffness and strength. So Macro mechanical analysis of sandwich composites is done, Theoretically, modified classical lamination theory (CLT) and mechanics of material (MOM)approach has been used to determine in-plane elastic properties of sandwich composites, Experimentally, sandwich composites were tested to determine in-plane elastic properties, Experimental results are in good agreement with the theoretical values obtained modified CLT and MOM approach.

Keywords: Composites, Elastic Properties, Sandwich

INTRODUCTION

The use of composite sandwich structures in aerospace and civil infrastructure applications has been increasing especially due to their extremely low weight that leads to reduction in the total weight and fuel consumptions. High flexural and transverse shear stiffness and corrosion resistance. In addition, these materials are capable of absorbing large amounts of energy under impact loads which results in high structural crash worthiness. In its simplest form a structural sandwich, which is a special form of laminated composites, is composed of two thin stiff face sheets and a thick light weight core bonded between them. A sandwich structure will offer different mechanical properties with the use of different types of materials because the overall performance of sandwich structures depends on the properties of the constituents. Hence, optimum material choice is often obtained according to the design needs. Various combinations of core and face sheet materials are utilized by researchers worldwide in order to achieve improved crash worthiness.

In a sandwich structure generally the bending loads are carried by the force couple formed by face sheets and the shear loads are carried by the light weight core material. The face sheets are strong and stiff both in tension and compression as compared to the low density core material whose primary purpose is to maintain a high moment of inertia. The low density of the core material results in low panel density; therefore under flexural loading sandwich panels have high specific mechanical properties relative to the monologue structures. Therefore, sandwich panels are highly efficient in carrying bending loads. Under flexural loading, face sheets act together to form a force couple, where one laminate is under compression and the other under tension. On the other hand, the core resists transverse force sand stabilizes the laminates against global buckling and local buckling. Additionally, they provide increased buckling and crippling resistance to shear panels and compression members.

Modeling composite Sandwich Structures

Mechanics can be divided into three major areas

a) Theoretical b) Applied c) Computational

Theoretical mechanics is concerning about fundamental laws and principles of mechanics. Applied mechanics uses this theoretical knowledge in order to construct mathematical models of physical phenomena and to constitute scientific and engineering applications. Lastly, computational mechanics solves specific problems by simulation through numerical methods on computers.

According to he physical scale of the problem, computational mechanics can be divided into several branches:

a) *Nano mechanics and micromechanics b) Continuum mechanics c) Systems*

Nanomechanics deals with phenomena at the molecular and atomic levels of matter and microcechanics concerns about crystallographic and granular levels of matter and widely used for technological applications in design and fabrication of materials and microdevices. Continuum mechanics is used to homogenize the microstructure in solid and fluid mechanics mainly in order to analyze and design structures. Finally systems are the most general concepts and they deal with mechanical objects that perform a noticeable function.

As it is the issue of this study, the modeling of composite materials is more complex that of traditional engineering materials. The properties of composites, such as strength and stiffness, are dependent on the volume fraction of the fibers and the individual properties of the constituent materials. In addition, the variation of lay-up configurations of composite laminates allows the designer greater flexibility but complexity in analysis of composite structures. Likewise, the damage and failure in laminated composites are very complicated compared to that of conventional materials. Due to these aspects, modeling of composite laminates is investigated as macro-mechanical modeling

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 03, March-2016

Macro-mechanical modeling

Classical lamination theory for thick laminates

In the classical lamination theory, it was assumed that the laminate is thin compared to its lateral dimensions and that straight lines normal to the middle surface remain straight and normal to that surface after deformation. As a result, the transverse shear stress $\left(\tau_{xz}, \tau_{yz}\right)$ and shear strains $\left(\upsilon_{xz}, \upsilon_{yz}\right)$ are zero. These assumptions are not valid in the case of thicker laminate and laminates with low stiffness central plies undergoing significant transverse deformations. In the theory discussed below, referred to as first order shear deformation laminated plate theory, the assumption of normality of straight lines is removed, and that is, straight lines normal to the middle surface remain straight but not normal to that surface after deformation.

Figure 5.4 thick sandwich composite plates and E-glass epoxy laminate

Figure 5.5 shows a section of a laminate normal to the y-axis before and after deformation, including the effects of transverse shear. The result of the latter is to rotate the cross-section A by an angle α_x to a location A', which is not normal to the deformed middle surface.

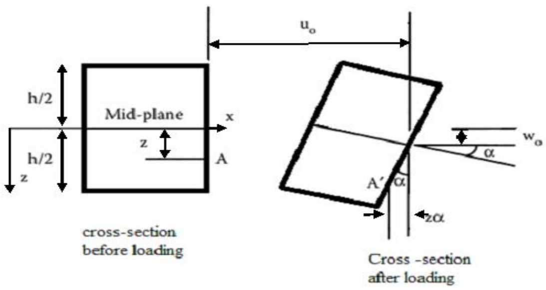


Fig 5.5: The relationship between displacements through the thickness of a plate to midplane displacements and curvatures.

$$E_x = \frac{A_{11}A_{22} - A_{12}^2}{hA_{22}}$$

$$E_y = \frac{A_{11}A_{22} - A_{12}^2}{hA_{11}}$$

E_x = Longitudinal Young's modulus of sandwich composite

E_y = Transverse Young's modulus of sandwich composite

$$\upsilon_{xy} = \frac{A_{12}}{A_{22}}$$

$$\upsilon_{yx} = \frac{A_{12}}{A_{11}}$$

ν_{xy} = Longitudinal Poison's ratio of sandwich composite

ν_{yx} = Transverse Poison's ratio of sandwich composite

$$G_{xy} = \frac{A_{66}}{h}$$

G_{xy} = In plane shear modulus of sandwich composite

Table 5.6 Macro mechanical properties of sandwich composites

Properties	Values
Young's modulus (GPa) E_x	6.246
Young's modulus (GPa) E_y	6.246
Major Poisson's ratio (in-plane) ν_{xy}	0.1539
Minor Poisson's ratio νyx	0.1539
In plane shear modulus (GPa) Gxy	1.6737

Characterization of sandwich composite laminate using mechanics of material approach

Tensile modulus of sandwich composite can be determined by using strength of materials approach.

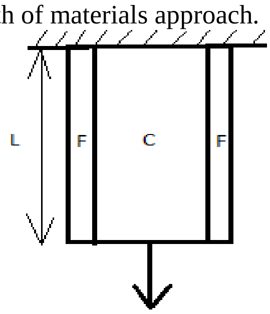


Fig 5.6. Sandwich composite in Mechanics of material approach

$$E_{sandwich} = \frac{2E_f A_f + E_c A_c}{2A_f + A_c} \text{ Or}$$

$$E_{sandwich} = E_{Fs} \times V_{Fs} + E_{Core} \times V_{core}$$

E_f = young's modulus of fiber
E_m = young's modulus of matrix
A_f = Area of fiber
A_c = Area of core
V_{Fs} = Volume fraction of face sheet
V_{core} = Volume fraction of core

Table 5.7 properties of sandwich composites by mechanics of materials approach

Properties	Values
Young's modulus (GPa) E	6.228
Poisson's ratio (in-plane) ν	0.1846

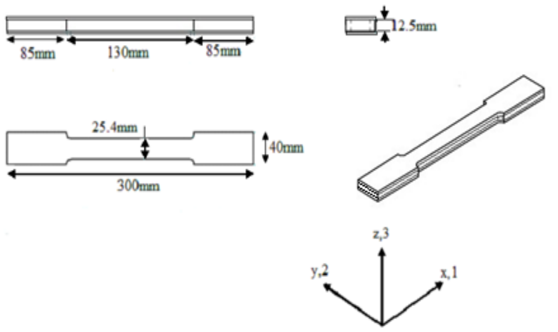
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 03, March-2016

EXPERIMENTAL

3 COMPOSITE SANDWICH STRUCTURE

4.3.1 Tensile test

In-plane tensile tests were conducted to determine the tensile strength and modulus characteristics of the composite sandwich panels. Forth is purpose, tensile test specimens were sectioned from larger composites and wich panel and tests were performed using them echanical (UTM) test machine at a crosshead speed of 0.5 mm/min. Figure 4.18 shows the geometry and test configuration of tensile test specimen Load versus deformation values was recorded during testing.The tensile strength and modulus values were obtained by equations 3. 3 and 3.5 similarly with the face skin material.



(a)

(b)
Figure 4.18 Sandwich test specimen (a) Geometry of the specimen (b) Actual specimen

4.3.2 Shear test

The shear tests were conducted to determine the in plane and out of plane loading effects on shear properties of sandwich composite specimens. The details of the specimen for shear test are shown in figure 4.18. The specimen was loaded in a universal testing machine by shear test fixture at a constant head speed of 1 mm/min. Three for each specimen type were provided with resistance strain gauges oriented at $\pm 45^0$ to the loading axis and bonded in the middle of the specimen to determine its shear response during the entire loading regime. The average shear strain is then determined from the strain gauges using the relation

$$\gamma_{avg} = \varepsilon_{+45} - \varepsilon_{-45} \tag{4.11}$$

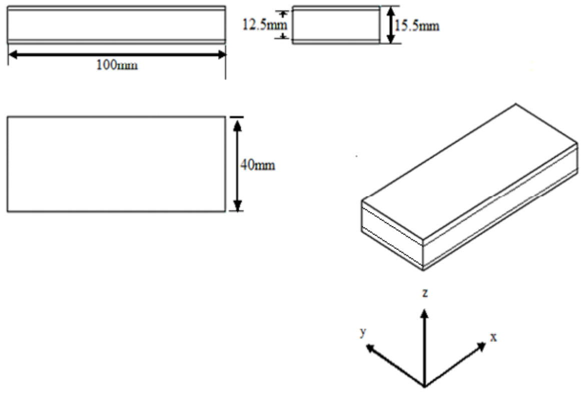
Where the ε_1 and ε_2 is the strain measured by the $+45^0$ gauge and the strain measured by the -45^0 gauge. The average shear stress is then determined by dividing the applied load P by the area of the cross section between the notches.

$$\tau_{avg} = \frac{P}{2A} \tag{4.12}$$

The apparent shear modulus is then calculated by dividing the average shear stress by the average shear strain:

$$G_{avg} = \frac{\tau_{avg}}{\gamma_{avg}} \tag{4.13}$$

Shear block as shown in figure 4.17(a)
Was used for the testing of sandwich composite specimens



(a)

(b)
Figure 4.18 Sandwich shear test specimen (a) Geometry of the specimen (b) Actual specimen

RESULTS AND DISCUSSION

Tensile test of Sandwich composites

The Young's modulus and poison's ratio are obtained from the slope of the initial portion of stress–strain plots and lateral and linear strain plots as shown in figure 6.5 and 6.6. The predicted and experimental values of elastic properties are shown in Table 6.4 and 6.5. The elastic moduli predicted by modified CLT and mechanics of material showed good agreement.

Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 03, March-2016

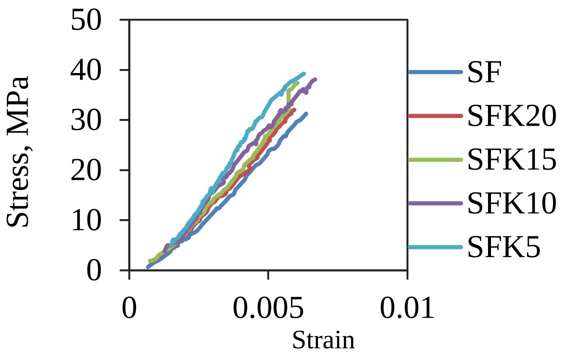


Figure 6.5 Stress versus strain plot of sandwich composite

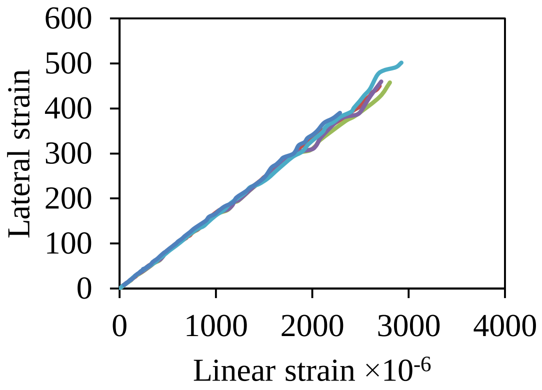


Figure 6.6 Linear versus Lateral strain plot

6.3.1 Failed specimen of Sandwich composite

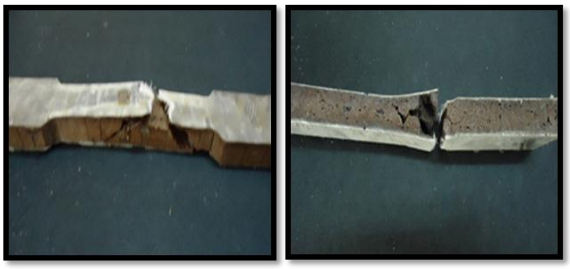


Figure 6.7 Failed specimens of Sandwich composite

Table 6.5 Experimental Results of Sandwich composites

Specimen code	Dimension (mm)			Max Load (kN)	Max stress (Mpa)	Max. strain	Young's modulus 'E' GPa
	L	W	t				
SF	130	25.4	15.5	12.316	31.28	6355	5.747
SFK 20	130	25.4	15.5	12.605	32.018	5934	6.065
SFK 15	130	25.4	15.5	14.715	37.37	6048	6.393
SFK 10	130	25.4	15.5	15.009	38.12	6684	6.798
SFK 5	130	25.4	15.5	15.450	39.24	6275	7.180

Table 6.6 comparing the theoretical results with experimental results of sandwich composites

Sandwich composite (SF)	MCLT Approach	Strength of material approach	Experimental
Longitudinal Young's modulus	6.246 Gpa	6.228 Gpa	5.747 Gpa
Transverse Young's modulus	6.025 Gpa	6.228 Gpa	5.747 Gpa
Poisson's ratio	0.1539	0.1846	0.1588

From the figure 6.5 we can see that as Honeycomb cell size decreases the load taken by the sandwich composite is high. Therefore honeycomb structure and the cell size of that plays an important role in the tensile strength of sandwich composite. Failure occurs in the tensile test causes the cursing of Kraft honeycomb core resulting in delamination at the edges of the sandwich. The maximum average load which can be withstand by sandwich composite is SFK 5 15.450 KN.

In plane shear test on sandwich composite

The shear modulus is obtained from the slope of the initial portion of stress–strain plots shown in figure 6.10. The predicted and experimental values of elastic properties are shown in Table 6.7 and 6.8. The elastic moduli are predicted by modified CLT and mechanics of material showed good agreement.

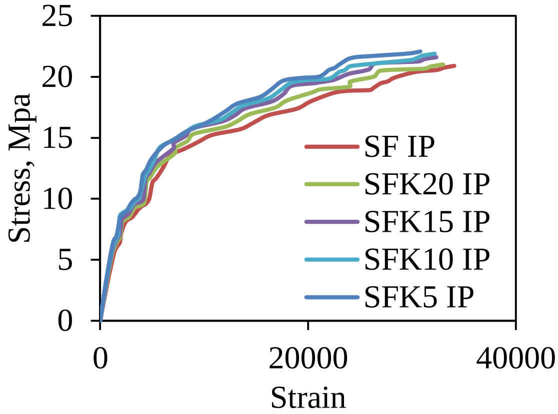


Figure 6.10 Stress versus strain plot of in plane shear test sandwich composite

Figure 6.11 Failed specimen of in plane shear test

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 03, March-2016

Table 6.8 Experimental Results of In plane shear test on Sandwich composites

Specimen code	Dimension (mm)			Max Load (kN)	Max stress (Mpa)	Max. strain in µ	Shear modulus 'E' GPa
	L	W	t				
SF	100	40	15.5	25.930	20.911	34087	1.547
SFK 20	100	40	15.5	26.064	21.019	33000	1.585
SFK 15	100	40	15.5	26.795	21.608	32340	1.663
SFK 10	100	40	15.5	27.156	21.900	32200	1.815
SFK 5	100	40	15.5	27.376	22.077	30800	1.921

Table 6.9 comparing the theoretical results with experimental results

Sandwich composite (SF)	Rule of mixture	MCLT Approach	Experimental
Shear modulus	1.649 Gpa	1.6737 Gpa	1.547 Gpa

The maximum applied load under in plane shear test of composite sandwich is 27.376KN for SFK 5 shows the honeycomb structure and the cell size of that plays an important role in the shear strength of sandwich composite. Table 6.8 summarizes the predicted and the measured Shear modulus of the composite sandwich under In plane shear test. The predicted and the actual Shear modulus of the Sandwich using the in-plane shear equation are nearly equal. The presence of the fibre composite skins adds to the overall strength of the specimen by preventing the widening of the crack in the core material and delayed the shear failure until all the fibres crossing the cracked core failed.

CONCLUSION

1. Modified classical lamination theory was developed for thicker laminate and laminates with low stiffness central plies undergoing significant transverse deformations.
2. Using Modified classical lamination theory, elastic properties of sandwich composites are calculated.
3. The experimental investigations are carried by conducting different test for the Sandwich composite, to find the elastic properties of the material.
4. For Sandwich composite, Experimental results are in good agreement with the theoretical values obtained Modified classical lamination theory and Mechanics of material approach.
5. Therefore, separating two materials with a lightweight material in between increases the structure's stiffness and strength.

REFERENCES

[1] Brian D. Flinn "Fundamentals of Composite Sandwich Panels" Department of Materials Science and Engineering University of Washington, Seattle WA 98195 bflinn@u.washington.edu

[2] Nikhil Gupta and EyassuWoldesenbet, "Characterization of Flexural Properties of Syntactic Foam Core Sandwich Composites and Effect of Density Variation", Journal of Composite Materials, 2005, Vol. 39, No. 24, pp. 2197-2212.

[3] Russo and B. Zuccarello, "Experimental and numerical evaluation of the mechanical behaviour of GFRP sandwich panels",JournalofComposite Structures, 2007, Vol. 81, pp 575–586.

[4] F. Mujikaa,*, J. Pujana, M. Olave, "On the determination of out-of-plane elastic properties of honeycomb sandwich panels" Polymer Testing 30 (2011) 222–228.

[5] A.C. Manalo*, T. Aravinthan, W. Karunasena, "In-plane shear behavior of fibre composite sandwich beams using asymmetrical beam shear test" journal of Construction and Building Materials, pp 1952-1961.

[6] Adams,DonaldF.2006.Sandwichpaneltestmethods.*HighPerformance Composites,* no. 5: 4-6. http://www.compositesworld.com/ (accessed January 21, 2007).