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Investigation On The Effect Of Thickness Ratio On Performance Of Curved Beam Sandwich Structure

Saudamini Deshmukh[1], Ashwini Khanaware[2], Vaibhav Badhe[3],Avinash Tade[4]
[1,2,3,4] Department of Mechanical Engineering JSPM's Rajarshi Shahu School of Engineering, Narhe, Pune
Corresponding Author: Saudamini Deshmukh

***Abstract**: In this project the effect of core thickness and facesheet thickness on flexural strength and elastic modulus is investigated for Polyurethane core glass/epoxy sandwiched structures. The face sheets of glass/ epoxy were prepared using hand layup and vacuum bag moulding technique. In order to interpret the effect of variable ANOVA is used. From the results of ANOVA it is found that, the face sheet thickness is most significant variable for flexural strength and for elastic modulus core thickness. The images of the fractured specimens showed, crack propagation starts from the interface between the core material and facesheet and moves towards the center of the core to the lower face of the facesheet.*
***Keywords:** Glass/Epoxy Polyurethane foam, Flexural Strength, Elastic modulus,Ansys,Finite Element Simulations.*

I. Introduction

Improving the performance of any structural material for a specific applications like aerospace, marine, automobile and civil engineering is of prime concern to designers. The designers strive to build the structural materials which are light with improved performance. The major factors contributing to the improved performance in these applications have been advanced materials and new structural concepts. New materials such as composites and structural concepts such as sandwich construction have resulted in lighter structural designs with superior performance. The sandwich structure consists of relatively two thin face sheets of composite material in which a core material is sandwiched. Core materials refer to the central component of a sandwich structure like honeycomb, balsa or foam cores. The purpose of sandwich structure is to achieve a stiff and simultaneously light component. A sandwich structure is designed to make sure that it is capable of taking structural loads throughout its design life. In addition, it should maintain its structural integrity in the in service environments. Sandwich composites fabricated with rigid foam core - PUF, PIR glass epoxy face sheet using vacuum bagging technique are more popular and economically viable thanthose with honeycomb cores. Finite element simulation and analyses are carried for the experiments conducted and results compared withexperimental values. A design study is carried out for evaluation of percentage influence of parameters on the strength of sandwich panels and optimized results presented in finite element simulation.

II. Background

Investigative studies on foam core sandwich constructions in the last two decades have shown significant results for applications. Optimum values of core thickness, face thickness and core density were obtained from analyses. Stiffness per unit weight measurementswere taken on sandwich panels with polyurethane foam cores. In the current study axial,shear and flexural properties of vacuum bagged glass fabric/ epoxy facesheet and foam core sandwich panels have been evaluated. Axial properties of foam were evaluated by conducting tension and compression tests with few modifications in ASTM standards. Shear properties of glass fabric/epoxy skin PUF, PIR foam core sandwich panels evaluated in conditions of single lap, double lap adhesive joints.

III. Literature Review

Sr. No.	Name of Author and Title of Paper	Experiments Conducted	Parameters	Conclusion (Result)
1.	Experimental study on the mechanical properties of polymer matrix composite sandwich structures. (Roshni N.M.,Sandeep M.B)	Testing flexural strength of sandwich structure , Effect on thickness of elastic modulus.	Facesheet thickness,Core thickness,Flexural Strength,Elastic modulus,Foam density,Mathematical model.	The maximum value of flexural strength can be achieved for the sandwich structure having greater facesheet thickness lower core

				thickness values.
2.	The stress and strain concentrations in curved beam of finite stiffness with end moments. (Ling zhang, jian hou)	Testing the curved beam of finite thickness with different curvatures using FEM.	Elastic stress and strain fields in the curved beam of finite thikness and end moment	For a curved beam of finite thickness,the through-thickness distributions of the stress concentration factor and the strain concentration factor are not uniform.
3.	Experimental analysis of bending stresses and deflection in curved beam made of laminated composite material. (Assma Hassan Ismail)	Experimental study of finite element analysis method using ANSIS	Curved beam theory,Composite material,Strength of materials,Finite element method.	The middle layer is subjected to less stress because the moment center pass through it where the resultant stress is zero.
4.	Finite Element Analysis of Axial,Shear and Flexural Behaviour of Rigid Foam Core-Glass Fabric Epoxy Face Sheets Sandwich Composites. (Saraschandra M, Ramya. M, Suresh. E and Padmanabhan. K)	Finite Element Modeling.	Finite element simulations, Stress analysis, Sandwich composites, Design optimization,Ansys.	The axial,shear and flexural behaviour of structure changes according to stress and composites.
5.	Bending of curved sandwich beams. (Sture Smidth)	St. Verant's principle. Thin and thick face theory for straight beam. FEM calculations. AIRY'S stresses function in cylindrical co-ordinates, isotropic case , cylindrical orthographic case ,hooks law, parameter study ,elasticity solution, plain strain	Cylindrical and orthographical model, FEM model, computer solution, stress ,strain	Solving system equation on computer they are compared with simple analytical calculation geometrical parameter are chosen to represent common sandwich structure member
6.	Experimental evolution of strength and stiffness of fibre reinforced composite under flexural loading(G.Rathnakar, H.K.Shivannm)	Vacuum bagging process, three point method, visual inspection.	Fabrication of specimen and graphite fibre laminates support span, speed of loading	Effect of thickness on flexural strength and thickness under flexural loading condition .Three point bending method provide better estimation. Graphite Laminated improved in strength and stiffness than glass. Deflection is more in glass as compared to graphite
7.	Effect of the fibre geometry on flexural properties of reinforced steel fibre reforming concrete(Abdelaziz meddan, larbi belangrad, miloud beddas)	Determine their flexural strength band stiffness.	flexural loads deflection curve using similar ASTM relation.	Increases the aspect ratio. fibre length increase is less remarkable
8.	Free vibration of curve beam with varying curvature and tapper	Natural frequency of curve beam with varied tapper ratio	Free vibration curved beam finite element curvature, tapper ratio	Curvature ratio increase the length of the curved beam

	ratio(Mohamed J. Al Robaiy,mohummed al shjary and Mohamed Al januh)			decrease the natural frequency at same taper ratio
9.	Fabrication and evalution of multilayer polyurethane foam core sandwich panel for static flecture stiffness (vijay kumar ,bhimsen sorogan)	3 point bending test. 4 point bending, digital flexural testing	Stiffness and strength fracture mode determine	Analysis of stiffness at length, scope in future
10.	Fabrication and mechanical testing of glass fiber entangled sandwich beam (amir shahdin Laurent mezeix)F	3Point bending test, vibration test.	Foam sandwich beam,honey comb sandwhich and entangled sandwitch compression	High damping in entangled sandwitch structure
	Evaluation of sandwitch panel with various polyeutheren foam cores and ribs(Hesham tuwair matthew hoppkinson,Jeffery volz)	3 point bending test ,4 point bending test, Flatwise compressive test and tensile test .flexural test	Displacement ,speed, thickness,MTS -880 testing machine ,electrical strain gauges.	The structure behaviour three different core alternatives for GFRP foam infill sandwitch panel was investigated.the FEM allowed to accurately predict behaviour of beam
12.	Impact responce of sanwitch beams with various curvature and debonds (Buket Okutan Baba)	Instrument droping impact test ,debonded between top and bottom of face sheet and core, impact tests,energy absortion	Force,time,cuvature angle,displacement, Upper debond, lower debond, no debond,impact faces,cract propogatuion.	Investigate the impact behaviour of curved sandwitch composite beam with debond.With maximum contact debond decreases
13.	Bending and buckling of sandwitch beam(N.J.Hoff ,S.E.Mautner)	Compression test,bending test, buckling test.	Corethickness, slenderness ratio,extensional and shearing deformation	The analysis was carried out for a sandwich beam whose core is weak as compared to its face so that the bending movement resist by faced alone
14.	Test method for measuring strength of a curved sandwich beam (Adrew M.Layne and Leif A.Carlsson)	Strength gauge instrumentated sanwitch in test,sandwitch beam testing.	Glass fabric, polyester resin, catalyst vacuumed bagging material.	The good agreement observed lends confidence to the test procedure and ability to produce pure bending loading of curved beam.
15.	The stress and strain concentration in curved beam of finite thickness with end moments (ling ling zhanga, zheng yang, jian hou, zhiqian wang)	Timoshenko's elasticity space approach, winkle's theory ,3D FEA, FEM, mesh conversion test.	Stress concentration factor ,finite thickness, stiffness, stress-strain concentration factor,	Distribution of stress and strain concentration factor are not uniform and they are depends on thickness and radius of curvature.

IV. Objective

The objective of this paper is to introduce the specimen and fixture, evaluate the ability of the fixture to achieve the desired state of pure bending in the curved region, and evaluate the failure mechanism and strength of a curved sandwich beam.It is found that the flexural strength of sandwiched polymer matrix composites are depending on the foam density, composition of the facesheet and the bond strength between the core and facesheet. So, there is scope for further investigation on the sandwich structures. Hence, the objective set for this project is to study the effect of core thickness and facesheet thickness on the flexural strength and elastic modulus of glass/epoxy polyurethane sandwiched polymer matrix composite at fixed density of core i.e 300 kg/m3 .

V. Experimental Procedure

5.1 Methodology:

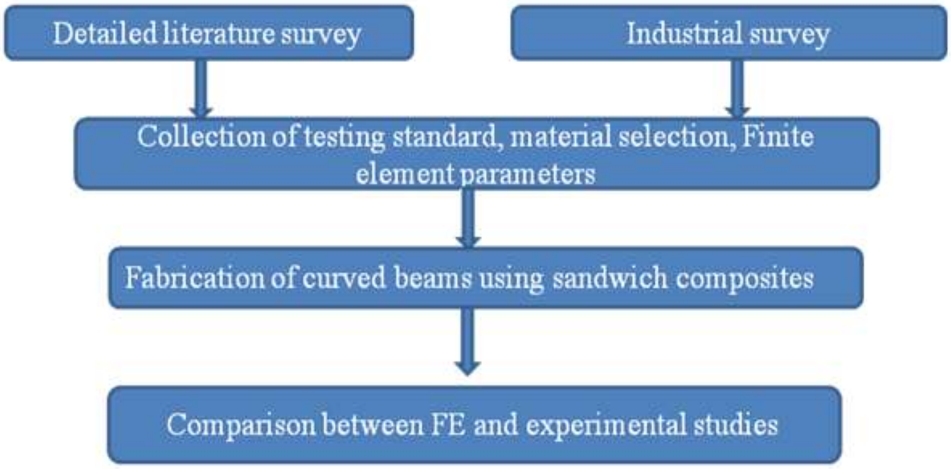
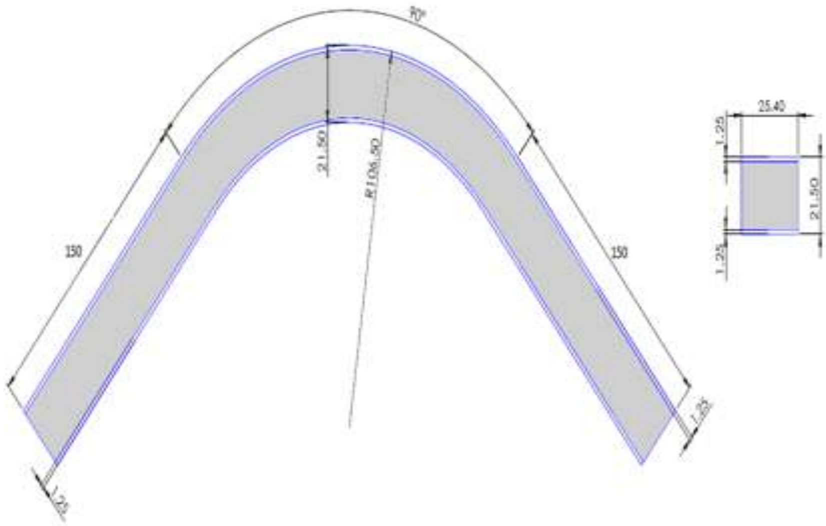


Fig: Flow chart of research methodology

5.2 Fabrication:



One of the initial objectives of the project was to fabricate the test specimen and conduct bending test. So the first step was to fabricate test specimen. The geometry and loading set up was adopted from [1]. The curved sandwich beam consisting E-glass/epoxy face sheets and a polyurethane foam core was fabricated having the following dimensions. The inner radius was 85mm, thickness of face sheets was 1.25mm each side and the core was 19mm thick. The width of the beam was 25.4mm. The specimen was a continuous beam consisting a central circular 90-degree region connected to straight legs. The straight legs of the beam were 150mm long. Methylene diphenyl di- isocyanate (MDI) and polyol were taken in required amounts, considering the volume of expansion. Following this, both the constituents were mixed and stirred continuously until uniformity in the solution was achieved. The mould was prepared using Plaster of Paris (POP). Plaster of Paris was selected for its quick setting property and its ability to taken any shape. The mould was supported with wooden fixtures at all four sides. The solution obtained after mixing was poured in the mould. After few seconds, the mixture began expanding in the confined shape. In order to achieve uniform density and properties throughout the specimen, uniform pressure was applied on top.

Fig. 60/40 ratio of two chemicals

5.3 Finite Element Analysis

The specimen modelling and finite element analysis was carried out as described in the following steps.

Step1: Add the Material data separately for the core and face sheet with the help of material model in the pre-processor section.

Step2: Draw the inner edge of the specimen in the x-y plane using create option in the modelling section of the pre-processor.

Step3: Extrude the inner edge along the z-axis for the determined thickness.

Step4: Mesh the model into finite elements using mesh tool option. The width of the specimen is divided into 20 elements and the length of the specimen is divided into 150 elements using the mesh. The quad element and free mesh option were checked in the mesh tool window.

Step5: The model was constrained at a predetermined distance from the free edges. The model constrained in three axes namely X, Y, Z axes. The specimen was supported by a roller support in the reference , hence the model was constrained along a line for three degrees, leaving the model free to rotate in three degrees.

Step6: The model was loaded, again, at a predetermined distance from the centre of the model. The specimen was loaded using a cylinder similar to the support in order to avoided indentation of the specimen . Hence load was applied along a line.

Step7: The finite element model is now complete and hence, the solver is run.

Step8: The desired properties are extracted using the post processor tree. The properties extracted are vonMises stress, Shear stress in the XY, YZ, and the ZX planes and the resultant total displacement.

Step9: Using the path operations, the variation of the above properties along the length of the specimen was found.

VI. Development of Experimental Plan

In this project the parameters selected for the study are facesheet thickness and the core thickness at constant density of core at 300 kg/m3 .The list of parameters and their levels are shown in table.

Table: Selected parameters and their levels

Parameters	Levels		
	1	2	3
Facesheet thickness, mm	2	4	6
Core thickness, mm	10	20	30

Using design of experiment (DOE) approach, the minimum number of experiments to be conducted are 5.A varying specimen shapes and sizes can be used for this test, but the most commonly used specimen size for ASTM D790 is 3.2mm x 12.7mm x 125mm. Three-point bending tests were performed in a servo controlled UTM machine having a load cell capacity of 5kN. At least 5 specimens were tested for each thickness of laminate. The crosshead speed was maintained at 2mm/min. The tested specimens were examined through visual inspection for failure of fibres and matrix.

VII. Results

Flexural strength of the polyurethane core sandwiched glass/epoxy laminate samples were tested according to ASTM standard D790. In this test, the specimens were loaded in a three point bending fixture of computer controlled UTM of 5 kN capacity.Effect of Core Thickness and Facesheet Thickness on the Flexural Strength: The effect of PU core thickness and facesheet thickness on the flexural strength of PU/glass/epoxy sandwich structure is shown in figure 6.1 & 6.2. From the graph 6.1 it is observed that, the flexural strength decreases with increase in core thickness. That is, flexural strength is inversely proportional to the core thickness.

VIII. Conclusion

From the experimental results of flexural strength of PU core sandwiched glass/epoxy composite structure following conclusions are drawn.

1. The most significant factor for flexural strength is facesheet thickness contributing 61.53% of influence and for elastic modulus is core thickness contributing 49.2% of influence.
2. The maximum value of flexural strength can be achieved for the sandwich structure having greater facesheet thickness lower core thickness values. In this project the maximum value of flexural strength achieved is 192.5Mpa.
3. The maximum elastic modulus can be achieved for the greater thickness of core and in this project 31.72 Gpa elastic modulus is achieved for 30 mm core thick sandwich structure.
4. During the flexural loading, the complete load is first taken by the facesheet and gradually transferred to the core material.

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