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Studies on Flexural Optimization of Glass Fabric-Epoxy Skin/Rigid Foam Core Sandwich Composites

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Abstract: This paper studies the strength and stiffness of rigid polyurethane foam core/glass fabric reinforced-epoxy based -sandwich composites with design optimization in mind. This investigation uses finite element software ANSYS™, an experimental hand lay up technique and mechanical testing in a Universal Testing Machine. The finite element results were compared with results from experimental work that were obtained for flexural strength and flexural rigidity. Testing and analyses were carried out keeping the existing ASTM standard guidelines in mind and design optimization as a study.
Keywords- Sandwich composite, finite element modelling, flexural properties, polyurethane rigid foam core, glass fabric, epoxy resin, design optimization.

Introduction

In the concept of sandwich construction, high modulus facing is combined with thick and light core, suggesting the possibility of designing structures so proportioned that the maximum bending strength and stiffness can be achieved with minimum weight of core and facing material combinations [1]. Froud [2] presented an optimum sandwich design criteria with respect to weight in his article rightly named "Your sandwich order sir?". R.M.V.G.K Rao *et. al* [3] showed that the optimum core to skin weight ratios for maximum stiffness and strength of the sandwich panels could be experimentally determined and optimized in the case of honeycomb panels. Another publication [4] describes the strength and stiffness optimization of rigid PVC core- glass/epoxy face sheet sandwich composites. This investigation aims at modelling E-glass fabric-epoxy/rigid polyurethane foam sandwich composites for superior flexural strength and stiffness at a much reduced weight by utilizing low density polyurethane rigid foams with 64 and 124 kg/cubic meter specifications.

Theoretical Considerations

LJ Gibson has given the optimal stiffness of sandwich composites at a skin weight to core weight ratio of ¼:1 [5]. Froud's theory predicts that, the maximum flexural rigidity occurs when the core weight = 2 times the skin weight [2]. For, maximum bending strength, the core weight = total weight of skins [2]. In this project the designs were made for maximum strength and stiffness using rigid foams of polyurethane core and glass fabric / epoxy face sheets.

Experimental Details

This work consists of sandwich models and panels that are considered for the finite element analysis predictions and experimental validations. As per the required core to skin weight ratios, four sandwich composites were modelled and fabricated with two glass fabric/epoxy – polyurethane rigid foam of 64kg/m^3 density(GE/PU 64 kg/m^3) and two glass fabric/epoxy – polyurethane rigid foam of 124kg/m^3 density(GE/PU 124 kg/m^3) with dimensions of length:1000 mm,breadth:104-108 mm and thickness:52-54 mm, keeping foam thickness as 50mm constantly and adding skin layers symmetrically on either side. For each foam density two sandwich composites were fabricated, one for stiffness optimization and another one for strength optimization according to Froud's theory. The volume fraction of the fabric in the skin of all the four composites was around 0.3 and estimated based on the weight and volume ratios of the resin. A Universal Testing Machine (UTM) was used in testing the sandwich composites in three point flexure [6] but at a span to depth ratio of 16:1 for comparison with the FRP laminates. The strain rate employed was in the static test domain, *viz.* 0.01 s^{-1}. The most observed failure mode, *viz.* the buckling delamination is depicted in Figure 1 for the sandwich specimens.

Fig.1: Buckling delaminations on the compressive face

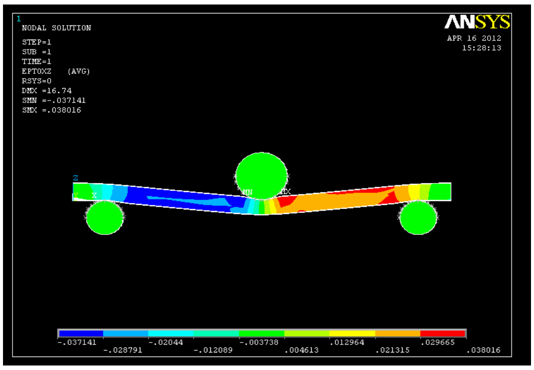

Fig 2: The XZ shear strain in a 124 kg/cu.m Rigid PUF strength panel.

Results and Discussion

The results of the X- direction stress, XZ shear stress, X-direction strain and XZ shear strain values for the sandwich specimens are shown in Table VI. The results of the XZ shear strains of a 124 kg/cu.m sandwich strength optimized specimen shown in Figure 2 reveal maximum values in the compressive region of the skin and core which are the areas where buckling delaminations of the skin occur. From the shear strains the shear stresses could be evaluated. These shear stresses were more than the allowables as per design calculations. Buckling delaminations of the specimens observed in the experiments (Figure 1) could thus be predicted in finite element analysis. There is a fair agreement between the predictions in the FE analyses and the observed experimental data for the normal stresses and the bending stresses for the sandwich specimens, though the shear stresses and the shear strains exhibit a closer fit. The results for other densities and constructions is given elsewhere [7]. Figures 3 a and b indicate that though the stiffness and strength are said to be optimized per unit width, only the optimization of strength appears to be valid where as the optimization of stiffness does not occur as per the dictates of the equations by Froud [2] or Gibson [5] as seen in our investigations. The stiffness of the strength optimized panel was found to be higher than the stiffness of the stiffness optimized panel. The results were uniformly of the same trend for the sandwich composites with foams of 124 kg/cu.m density. Thus, the thumb rules that are applicable to honeycomb sandwich composites do not seem to be valid for rigid foam core composites. The other weight ratios between the skin and the foam core appear to have an influence on the flexural strength and rigidity optimization. Studies regarding this are currently in progress.

Table I. Properties of Sandwich Composites

Specimen	Flexural rigidity x10^9 Nmm^2	Bending stress (MPa)		Shear stress (MPa)		Shear deflection (mm)	Shear strain		Normal stress (MPa)	
		EXP.	FEM X-dir	EXP.	FEM XZ-dir		EXP.	FEM XZ-dir	EXP.	FEM Z-dir
GE-PU-124 kg/m^3 (Stiffness Panel)	1.6935	42.19	50.37	0.106	0.123	8.1136	0.0213	0.0274	44.58	49.545
GE-PU- 124 kg/m^3 (Strength Panel)	2.401	38.82	31.5	0.168	0.179	10.89	0.0336	0.038	47.88	49.54
GE-PU-64kg/m^3 (Stiffness Panel)	1.006	22.4	33.21	0.0302	0.0381	2.802	0.0067	0.0092	21.45	29.279
GE-PU- 64 kg/m^3 (Strength Panel)	2.3329	9.579	9.139	0.0304	0.032	2.784	0.0068	0.0077	9.575	16.31

Conclusions

Design optimization was attempted for maximum stiffness and strength in foam core sandwich composites. The observed buckling delamination failure mode of the specimens also indicate that the true design optimized values for the stiffness were not achieved despite following the rules for design optimization. More insight towards achieving a closer optimization is required.

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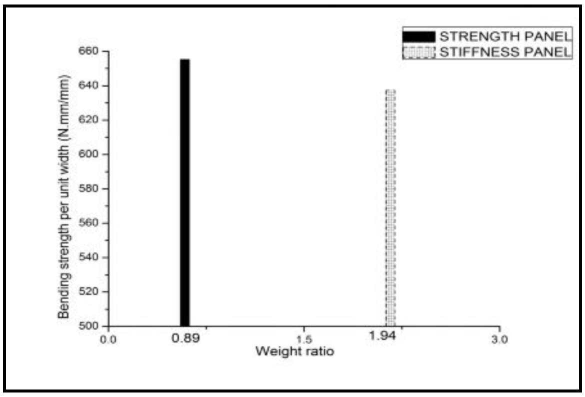

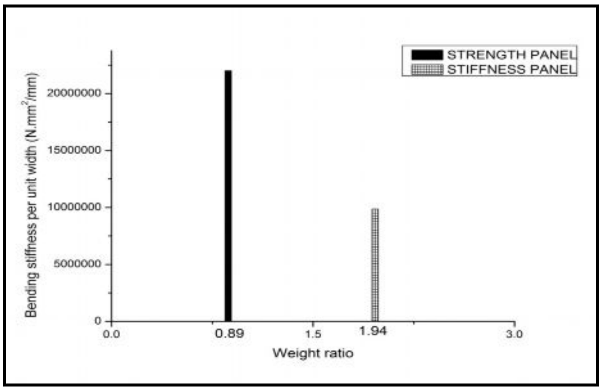

(a) **(b)**

Figures 3a and b showing the maximum bending strength and bending stiffness per unit width of the strength and stiffness optimized panels with 64 kg/cu.m foams

References

1. Noakes K, “Successful Composite Techniques”, Osprey publishing UK, 1989.
2. Froud G.R, “Your Sandwich Order, Sir?”, Composites, July 1980, Vol: 11, p 133,.
3. Murthy O, Munirudrappa N, Srikanth L, Rao RMVGK, “Strength and Stiffness Optimization Studies on Honeycomb Core Sandwich Panels”, Jl. Of Reinforced Plastics and Composites, 2006, vol. 25, No: 6, p663.
4. Theulan JCM, Peijs AAJM, `Optimization of the bending stiffness and strength of composite sandwich panels’, Composite Structures, 1991, Vol: 17, p 87-92.
5. Gibson LJ, Optimization of stiffness in sandwich beams with rigid foam cores, Materials Science and Engineering, 1984, Vol : 67, p 125-135
6. ASTM D7250 / D7250 M-06, Standard practice for determining sandwich beam flexural and shear stiffness. West Conshohocken, PA, 19428-2959 USA.
7. K. Padmanabhan, in the PROCEEDINGS of International Conference on Composites for 21st Century Current & Future Trends ICC-CFT 2011, January 4-11, 2011, IISc, Bangalore, India.

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