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Influence of Post Curing on the Flexural Properties of a Rigid Polyurethane or Polyisocynurate Foam-Glass/Epoxy Face Sheet Sandwich Composite

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Abstract: Room temperature curing epoxy matrix materials are used in this investigation to fabricate sandwich composites consisting of glass fabric/epoxy matrix skin and a rigid polyurethane or a rigid polyisocynurate foam. These epoxies can be post cured at an elevated temperature to improve their mechanical properties by increasing the degree of cross linking due to post curing. Whether this improvement translates into improved mechanical properties for the sandwich composites or not is investigated here. This investigation proposes to evaluate the flexural properties of above said composites before and after post curing. The evaluated flexural properties are compared and a more suitable fabrication method suggested for the sandwich composites.
Keywords: glass/epoxy skin; sandwich composites; polyurethane rigid foam; polyisocynurate rigid foam; flexural properties, post curing.

Introduction

Polyurethane and polyisocynurate belong to a class of thermosetting polymers and have the advantages of low density, excellent insulating properties, excellent bonding with matrix materials, high abrasion resistance and shock absorption. Sandwich composites with polyurethane or polyisocynurate foams are a special class of composites manufactured by attaching thin skins to thick and stiff cores to obtain high bending stiffness at a low density. Sandwich panels are gaining popularity in many structural applications such as floor and roof panels and cladding walls for buildings. Sandwich panels with FRP as the skin have been investigated by many researchers. Froud [1] presented how the sandwich composites are designed to obtain high bending strength or stiffness in his article named “Your sandwich order sir?”. Johnson and Sims [2] Reis and Chaves [3] and Christoph and Czaderski [4] studied some of the aspects of strength, stiffness and curing in sandwich composites. The present investigation aims at fabricating glass fabric-epoxy polyurethane foam and poly isocynurate foam sandwich composites and investigating the improvement in mechanical properties due to post curing as in the case of epoxy systems. Parameters like flexural rigidity, shear deflections, bending and normal stress produced, shear strain, shape factors were studied and compared for both the normal and post cured specimens. R.M.V.G.K Rao *et al* [5] showed that the optimum honeycomb core to skin weight ratios for maximum stiffness and strength of the sandwich panels could be experimentally determined.

Experimental Details

The matrix used was composed of epoxy resin and hardener in 2:1 ratio. The resin used was GY 257 with AARADUR 140 as the hardener. The density of epoxy system was 1.2 gm/cc. Glass fabric of 280 GSM areal weight, $0/90^0$ weave (600 X1000 mm, 8 layers) was used as the reinforcement material. Longitudinal elastic modulus of skin (glass fabric-epoxy system) was assumed to be 11500 MPa for a skin volume fraction of fibres as 0.3. Polyurethane foam and polyisocynurate foam were used as core materials for fabrication of sandwich composites whose density was 125 kg/cu.m.. Figure 1 shows vacuum bagging technique for fabrication of sandwich composites. Same procedure was followed with polyisocynurate foam as core material instead of polyurethane foam to make sandwich composites. The standard specimens were made using jig-saw machine for comparison and the influence of post curing. The samples were post cured at 70^0 C for 1 hour in an electrical industrial oven and later cooled for a day. Flexural properties were determined as per ASTM test methods [6,7,8]. Three point bending tests were performed on a UTM as shown in figure 2 . A strain rate of $0.01s^{-1}$ was maintained.

Result and Discussion

Flexural parameters were calculated for each specimen and the average of four specimens were tabulated as shown in Table 1 for glass/epoxy–PUF sandwich composite and in Table 2 for glass/epoxy PIR sandwich composite. For glass/epoxy-PUF sandwich composite the following changes were observed; At 16:1 span to depth ratio the flexural parameters changed marginally after post curing. At 21:1 span to depth ratio after post curing, the flexural rigidity increased by 69%, bending stresses decreased by 33.37%, normal stresses decreased by 33.37% and shape factor for stiffness decreased by 23%.

For glass/epoxy-PIR sandwich composite the following changes were observed; At 16:1 span to depth ratio the flexural rigidity increased by 24% after post curing and the other flexural parameters marginally changed after post curing. At 21:1 span to depth ratio after post curing, flexural rigidity increased by 24%, bending stresses decreased by 20.9%, normal stresses decreased by 21%, shape factor for stiffness decreased by 8% while the other flexural parameters change marginally after post curing.

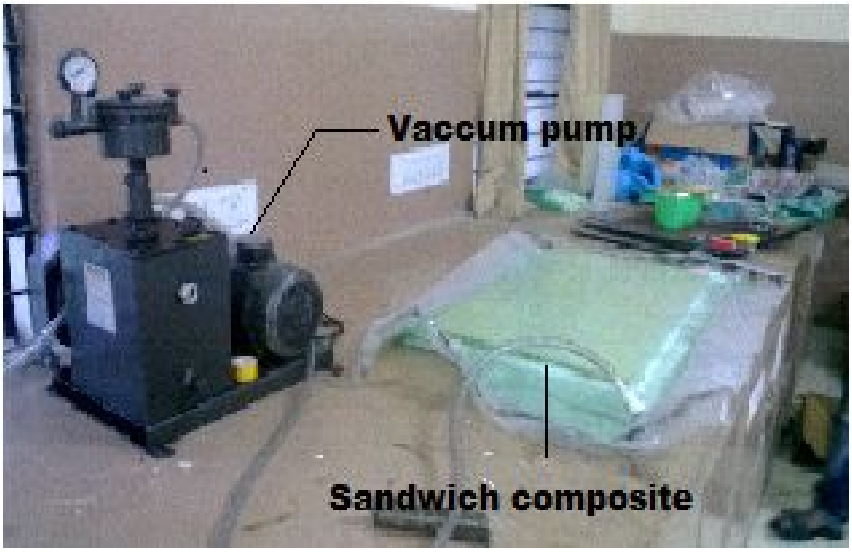

Figure 1. Vacuum bagging technique for fabrication of sandwich composites.

Figure 2. Three point bending test in a UTM for 21:1 span to depth ratio

Table I. Average values of flexural properties of glass/epoxy-PUF sandwich composites.

Specimen	Flexural Rigidity (N/mm^2) X10^6	Shear Deflection (mm)	Bending Moment (N-mm) X10^3	Bending Stress N/mm^2	Shear Stress N/mm^2	Shear strain	Normal Stress N/mm^2	Bending Shape Factor for Stiffness	Bending Shape Factor for Failure
Span to depth ratio 16: 1									
Non-post cured	512.6	7.04	57.5	21.17	0.139	0.0328	21.13	12.02	0.954
Post cured	558.25	6.83	54.62	20.64	0.134	0.0320	20.61	12.20	0.950
Span to depth ratio 21:1									
Non-post cured	569.59	9.14	78.15	25.92	0.13	0.0323	25.88	11.24	0.895
Post cured	963.15	8.38	76.25	17.27	0.12	0.0307	17.29	8.60	0.623

Table II. Average values of flexural properties of glass/epoxy-PIR sandwich composites

Specimen	Flexural Rigidity (N/mm^2) X10^6	Shear Deflection (mm)	Bending Moment (N-mm) X10^3	Bending Stress N/mm^2	Shear Stress N/mm^2	Shear strain	Normal Stress N/mm^2	Bending Shape Factor For Stiffness	Bending Shape Factor for Failure
Span to depth ratio 16: 1									
Non-post cured	569.74	5.605	90.252	34.234	0.215	0.0260	34.185	12.156	0.987
Post cured	707.42	5.9708	98.713	31.490	0.227	0.0281	31.428	10.705	0.841
Span to depth ratio 21:1									
Non-post cured	684.39	6.1667	114.071	37.308	0.199	0.0245	29.738	11.017	0.869
Post cured	853.42	5.3471	106.591	29.502	0.178	0.0225	29.428	9.798	0.744

As flexural rigidity is denoted by the stiffness of the sandwich beam, post curing improves the degree of cross-linking and the elastic modulus of the epoxy resin, thereby causing an increase in the skin stiffness. Stiffness and strength changes in the foam due to a heat treatment at 70º C are also possible depending upon the thermal stability of the foam at a given temperature. PIR is thermally stable up to ~200º C but PUF is not stable beyond 100ºC. So a post curing temperature of 70º C causes more stiffening in the PUF than PIR. So the mechanical property changes in the foam are reflected in the sandwich properties. Also it is observed that the shape factor for stiffness and the shape factor for failure in bending exhibit a reduction after post curing due to the skin contraction and dimensional changes in the foam. Further, as the flexural rigidity is higher for longer spans as dictated by the modified sandwich beam equations, the effect of post curing is also more for the longer span .

Conclusions

Parameters like flexural rigidity, deflection, shear and bending stress, normal stress, and shear strain were determined and a comparison was made between the normal and post cured specimens. It was observed that there is an appreciable increase in flexural rigidity and a general decrease in the other flexural properties with post curing. The reasons are due to an increased degree of cross-linking of the epoxy resin, dimensional and mechanical property changes in the foam due to post curing.

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