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Research Article

Bioinspired Sandwich Structure in Composite Panels

Deepak Sampathkumar,[1] **Ashokkumar Mohankumar**,[2] **Yuvaraja Teekaraman**,[3] **Ramya Kuppusamy**,[4] **and Arun Radhakrishnan**[5]

[1]*Department of Mechanical and Automation Engineering, Agni College of Technology, Talambur, Chennai 600130, Tamil Nadu, India*
[2]*Department of Mechanical Engineering, Government College of Engineering, Bargur 635104, Tamil Nadu, India*
[3]*School of Engineering & Computing, American International University (AIU), Jahra, Kuwait*
[4]*Department of Electrical and Electronics Engineering, Sri Sairam College of Engineering, Bangalore 562106, India*
[5]*Faculty of Electrical & Computer Engineering, Jimma Institute of Technology, Jimma University, Jimma, Ethiopia*

Correspondence should be addressed to Arun Radhakrishnan; arun.radhakriahnan@ju.edu.et

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The phenomenon of separation into constituent layers connecting the core and laminate of a composite sandwich complex is a vital complication that leads to early failure of such material. The direction of the sandwich construction's exfoliation rigidity is increased between interlaminar low fiber augmentation. The bioinspired technique of hybrid material layers was used on an aluminium face sheet with an interlayer composition of PET foam core and glass fabric of a material that appears to have greater potential as a flimsy substitute for materials currently used in automotive, aeronautical, and marine applications. This examination seeks to develop the making of such material along the retardation in fibre supplements. Fibre bridging has been recognized as an important appliance in the progress of this operating procedure. Consequently, this method points to promoting the event of fibre bridging by differing aggregates, including the mass and extent of augmented fibres and the quantity of epoxy resin applied. A few advancements were made to the production methods, and though the outcomes for the resisting ability of specimens were found to be indecisive, it was found that the layer separation hardness had even improved. This was confirmed through the operation of scanning electron microscopy and also predicted the mechanically peeled material surfaces which identified the adhesive strength variations with respect to the face sheet surface modified with the sand blasting process. The analysis also revealed the need for further research into optimizing the attachment between aluminium sheet and pet foam and glass fabric based hybrid sandwich panels.

1. Introduction

Composites, the meander materials with elevated strength-to-weight proportion, feathery in nature, and firmness, have induced a long path of substituting traditional materials that include metals and wood. To fully comprehend the role and involvement of composite materials in construction [1], a thorough understanding of the component materials themselves, as well as the numerous ways in which they can be analysed, is required. In most of its common form, a composite indicator [2] is made up of at least two elements that interact together to provide material qualities that are distinct from those of the individual constituents. In applications, many of the composites are made up of a huge amount of stuff (the "matrix") and some form of supplements, which are added to boost the matrix's firmness and rigidity. Typically, this augmentation is performed in the form of fibres. Polymer matrix composites (PMCs) are a type of polymer matrix composite. These are the most prevalent, and they will be the focus of this article. Fibre-reinforced polymers (or plastics) are materials that use a polymer-deployed resin as a matrix and various types of fibres as reinforcement, such as glass, carbon, and aramid [3].

Creation has supplied us with incredible wealth that addresses the outlines of the issues that today's society faces. Multistate architectures motivated by soft-shell turtles are shown to develop composite laminate collision resistance [4]. The goal of this research is to determine the crash reactions and crashworthiness of bioinspired interlaying constructions made of glass fibre augmented plastic (GFRP) panels and aluminium sheets. The impacts of core side dimensions and the influence of velocity on peak load and energy absorption, as well as the crash responses, failure mechanisms, and influence of core side dimensions and collision velocity on peak load and energy absorption, were examined in this paper. The crashworthiness variations in the middle of the GFRP aluminium and the bare GFRP panel were obtained and noted [5–8]. The testing revealed two archetypal load-displacement relationships: single-peak and double-hump bends. The slopes representing nonsuccess models of higher and lower face sheets are more than the failure stage in the energy-displacement curve [9–13], showing that the bare aluminium sheet had poorer energy attainment levels than the GFRP face sheet. In turn, honeycomb infill, on the other hand, was a successful technique to develop the collision resistance of GFRP structures, resulting in a gradual increase in energy absorption and reduced peak load during the influence [14]. The crashworthiness features were likewise shown to be more sensitive to core length compared to core height, with specific energy absorption (SEA) change being minimal as the core height increased. Under high impact velocity, peak load, absorbed energy, and SEA rose notably [15, 16].

The bioinspired sandwich construction on an aluminium face sheet with glass fibre reinforcement, epoxy resin matrix, and pet foam core material is the focus of this research [17–30]. The materials' characteristics were determined experimentally in accordance with ASTM standards [31–40].

The present experimental work on the aluminium face sheet with glass fibre reinforcement, epoxy resin matrix, and pet foam core material-based sandwich composite panels is available for limited studies in the literature. It has many advantages: lightweight, high mechanical strength, chemical, and heat resistance. Limited disadvantages are at the end of their life, and recycling and material separations are difficult.

Furthermore, the experimental results were compared to both the composites and the values used to determine the application.

2. Experimental Study

2.1. Materials. "Skin" is the outer side of the hybrid structure. Aluminium (1100) sheets are employed as the skin material for the improved sandwich composition. The thickness of the sheet is 0.3 mm. By using snipping, the sheet is cut into the required dimension of the skin. Two skins are required to develop one hybrid structure. The matrix material is used to create a bond between the polyethylene terephthalate (PET) foam and the skin materials. As the sandwich matrix material, bisphenol-A (Araldite LY556 resin & Aradur HY951hardnear) epoxy resin is used as the base. It is a very light material, so it is used to reduce the weight of the composite. Abrasive material is used for glass beads and SS beads to improve the surface roughness of the skin material and for uniform binding with the core. Woven glass fibres are employed as a reinforcement material. It is placed in between the PET foam and the face sheets. Table 1 shows the materials required for the fabrication of sandwich panels.

The aluminium1100 grade face sheet property has more correction, heat, and chemical resistance. It helps uniform load transfer to the core material. Energy dissipation in the face sheet for various energies transmitted in the form of quasistatic, tensile, compressive, impact, and dynamic loading has been experimented with by many researchers. The bisphenol-A (Araldite LY556 & Aradur HY951) epoxy resin has low viscosity, long shelf life, good fibre impregnation, and better mechanical, thermal, and chemical properties. The core structural thermoplastic PET foam (thermo-formable closed cell structure) core material is ideal for a variety of sandwich applications that require increased performance while reducing weight. Its properties are better chemical resistance, thermal resistance, sound insulator, very low water absorption, better resin bonding, and screw retention capability. The material has a density range (ISO 845) of 75–85 kg/m^3, a thermal conductivity of 0.033 W/(m-K), a compressive strength (ASTM D 1621) of 0.8–1 MPa, and a compressive modulus (ASTM D 1621 B-73) of 65–80 MPa. There are various grades of glass fibres available. The E-glass fabric is the general purpose low-cost material and also has ASTM standard specifications for characteristics such as high mechanical strength, heat resistance, good water resistance, heat insulation, and better process ability.

2.2. Methods. The main objective of our project is to manufacture a composite material using an aluminium face sheet of 0.3 mm thickness, epoxy resin, glass fibre, and PET foam.

To get a good result, primary work has to be carried out on aluminium sheets. It contains oily layers. An acetone solution is used to remove the oily surface of the sheet completely. Preparing the aluminium face sheet is carried out before going into the process.

2.2.1. Preparation Steps for Sandwich Composite Panels. The following steps are for preprocessing work. Step 1: cut the aluminium sheet to dimensions of $20 * 30$ cm; Step 2: remove any moisture and rust from the aluminium sheet; Step 3: blast the aluminium sheet at the appropriate pressure (3, 5, 7 bar); Step 4: combine the epoxy resin and hardener in a 10 : 2 ratio; Step 5: cut the glass fibre into 25×35 cm pieces. Step 6: the glass fibre with PET foam must be free of moisture and air. This is the preprocessing work that has to be performed to avoid failures that have happened in the final product.

2.2.2. Fabrication Process. After performing the preprocessing (cleaning the face sheet) work, the material is put into the fabrication process. Before moving to the process,

Table 1: Materials required for the fabrication of sandwich panels.

Material	Description	Dimension/grade
Face sheet	Aluminium sheet	0.3 mm thickness & 20×30 cm
Matrix (resin)	Epoxy + hardener	10 : 2 ratio
Core material	PET foam	25×35 cm
Reinforcing material	Glass fabric	E-glass

we ensure the material is free from dust and moisture, and also ensure the quality of the material. To get a better result, we maintain the room temperature at around 30°C. Hand gloves and a face mask are worn during the process for safety.

The schematic representation of the hybrid sandwich panel preparation process is shown in Figure 1, and its process steps are as follows: Step 1: the aluminium sheet (0.3 mm thick) is blasted using various methods (sand blast and glass blast) at various pressures, such as 3 bar, 5 bar, and 7 bar, and a mixed (10 : 2) ratio of epoxy resin with hardener. Step 2: glass fibre is cut into the required dimensions and placed on the aluminium sheet. Spread the epoxy resin evenly over the glass fabric. Now, we take the pet foam (core material) and cut it into dimensions of 25×35 cm that should be placed on the glass fibre. Step 4: the process is repeated until the sandwich structure of two required composite materials is obtained. Step 5: the compression moulding process is used to fabricate the hybrid sandwich panel. The fabrication of control samples is the same as the above procedure, except for aluminium face sheet surface blasting (step 1).

The Araldite LY556 resin is preheated at 30 to 50°C before adding the Aradur HY951 hardener to improve the performance of the matrix preparation process. There are many accelerators available to improve the performance of matrices. The premixing of the hardener and accelerator can allow the use of two-component mixing; it has a longer self-life for several days of usage. The processing of the total matrix mixing system shows the best results at 30 to 40°C.

2.2.3. Design Considerations. It is confirmed that a prepared sandwich panel construction has the ability to accept the structural loads along with design life. It maintains its systemic probity in service conditions in favour of experimental calculation.

The face sheets are provided with essential rigidity so as to withstand the tensile, compaction, and shear strains for applied loads. The core is present to provide the necessary firmness to withstand the shear strains caused by the application of loads. The core has the eligible shear modulus to resist complete buckling of the interlaying composition under loads. The firmness of the core and the compliant solidity of the face sheets should be sufficient to resist the crinkling of the face sheets under applied loads. The core cells are precise enough to avert intercell buckling of the face sheets under modelling loads. More compressive solidity is required in the core to prevent suppression caused by applied loads reacting normally to the face sheets or by suppressing pressure generated by flexure. The sandwich construction has essential flexural and shear firmness to resist additional deviations under given loads. Sandwich stuff (face sheet, core, and adhesive) must support constructional coherence during in-service conditions. Based on this design consideration, the sandwich panel is fabricated as shown in Figure 1.

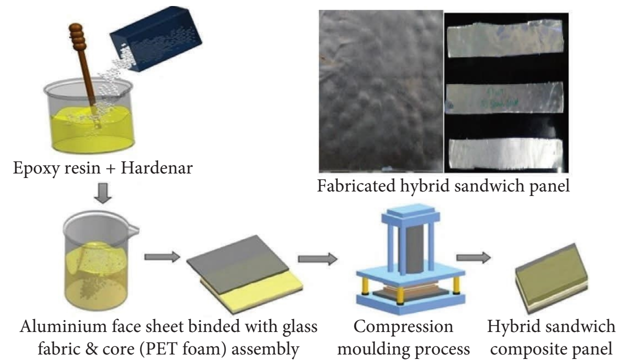


Figure 1: Preparation process for the hybrid sandwich panel.

2.3. Characterization Techniques Used. The fabricated panels are characterised using an artificial environmental weathering test, which is conducted with accelerated weathering equipment. It has a programmable low-temperature humidity control range of −20°C to 50°C as well as a programmable high-temperature humidity control range of −70°C to 150°C. The peeled sandwich composite surfaces were analysed using a Hitachi S-4700 scanning electron microscope (SEM) operated at an accelerating voltage of 10 kV. The optimization of blast pressure using a sand/glass blasting machine, abrasive Eco blast, make: sandstorm, model: SEC-SB-12090, up to 10 bar pressure. The blast surface damage is analysed using vision measurement equipment, make: OPUS, lens magnification: 0.75–4.5 X, high-resolution multicolor CCD camera inbuilt. The peel testing is carried out using a universal testing machine (UTM), make: Instron, model: 3328, up to a 100 kN capacity.

3. Results and Discussion

3.1. A Weathering Trail Is Conducted for Prepared Samples. The completely cured sandwich composite materials are placed in the weathering chamber under the following conditions shown in Table 2 and Figure 2.

Table 2 shows the test conditions programmed in the weathering chamber. Three standard test conditions are selected to evaluate hybrid sandwich panels. For all the conditions, the temperature and test timing are constant, while the humidity value is varied with respect to predicting the sandwich panel face sheet and core bonding damage with respect to time and temperature. UV radiation is present in the outdoor environment. It contains temperature and humidity differences with time and temperature. So, it is the most important damaging component; it changes the chemical structures of the materials. The weathering test is the very important parameter to determine the prepared composite sandwich panel's bonding performance.

Table 2: Weathering test conditions for sandwich panels.

Target samples	Temperature (°C)	Humidity (%)	Time (hrs)
Control sample	60	100, 95 & 85	72
Hybrid sandwich panel 1	60	100	72
Hybrid sandwich panel 2	60	95	72
Hybrid sandwich panel 3	60	85	72

Figure 2: Prepared sandwich composite panels in artificial weathering chamber.

The standard test parameters are set in the weathering chamber. The obtained test results recommend the prepared hybrid sandwich panels 1, 2, and 3 where there is not much material or chemical damage predicted on visual inspection. But the control samples are all three conditions. Natural peel occurred at the end corners of the panels due to the lack of surface roughness. The material bonding strength was affected. These weathered samples are further tested for various characterizations and a mechanical peel test.

3.2. Scanning Electron Microscopy. Weathering samples, peeled sandwich composite surfaces with sand blast and without sand blast specimens, are shown in Figure 3(a). The PET foam is bonded with epoxy resin and compressed with blasted aluminium sheet at an optimised pressure of 5 bar. The surfaces are distinctly transparent. The depth of this surface damage, however, appears to vary with an aluminium exterior. The film is thick and essential to some extent so that it completely wraps around the resin on the surface, and the nonhomogeneous powder mixture is visible, as shown in Figure 3(c). The fully compressed PET foam surface morphology is clearly visible in Figure 3(d). In additional areas, the peeled PET foam surface is much thinner, and the cured adhesive bonding is still distinctly visible, see Figure 3(b).

3.3. Optimization of Blast Pressure. The blasted exterior was pacified for surface rigidity computation and vision quantification analysis so as to examine the effects of blasting on external rigidity and surface patterning. During blasting, due to molecular interactions, the exterior layer is subordinated to abrasiveness and generates crudeness. However, blasting compression plays a key role in creating the desired firmness. Figure 4 illustrates the difference in surface firmness for numerous blasting influences. It is apparent from the figure that mean surface roughness (Ra) increases with an increase in blast pressure. The surface indentation observed was to be increased up to 5 bar of blasting pressure using both glass and SS sand, as well as increasing the pressure that showed a decrease in exterior roughness. The measured surface roughness values are shown in Table 3. And it was measured using a surface roughness tester, Mitutoyo, SJ210 model, Tokyo, Japan.

3.4. Blast Surface Damage Analysis. Surface blasting was done through a blasting machine setup, make: OPUS, vision measuring instrument, CIPET, Chennai, India. The failure modes of the blasted aluminium surface vary with pressure difference, blasting specimen handling, or holding position in the blasting machine, and material damage also occurs due to abrasive material selection. Proper rectifying of the FML materials via fabrication was required to achieve fine structural equities [15]. Figure 5 depicts the failure of the sandwich composite skin structure's aluminium sheet sandblasted face sheets.

3.5. Peel Test Results. The peel strength increased from the original value due to the various surface roughness. Due to abrasive molecular collusion in the blasting nozzle, the peel strength will drop after a certain pressure limit, the surface roughness value will decrease, and the adhesive strength will also decrease. For the 5 bar glass blast and SS sand blasting, the optimal value was recorded. In both glass and SS sand abrasives, inadequate adhesion strength suggests pressures of 6 bar and 7 bar. However, as the alumina/PET foam adhesion was enhanced, there was a greater potential for unstable crack propagation.

Figure 6(a) shows the force-displacement curve of peel resistance of an artificial weathered sample. Peel resistances are measured between the aluminium face sheet reinforced with glass fabric and the PET foam core. This complex binding cross section (aluminium sheet/glass fabric/PET foam) may fail at any time with respect to critical atmospheric weathering conditions. So, the peel resistance test is the most suitable test method to identify the target samples' peak force, crack point, crack path, and fracture energy. The peel resistance test is conducted with the universal testing machine (UTM) as shown in Figure 6(b), and sample dimensions are shown in Figure 6(c). The samples are fixed in T-shape. 180° peel-off was carried out in tensile mode with a cross-head speed of 2 mm/min. The peel test load vs. displacement graph is plotted with the average of five sample values. The obtained graph shows that there are not many variations in the hybrid sandwich panels 1, 2, and 3 weathered samples fracture energy. But the control sample performance is poor in fracture energy, as shown in Table 4.

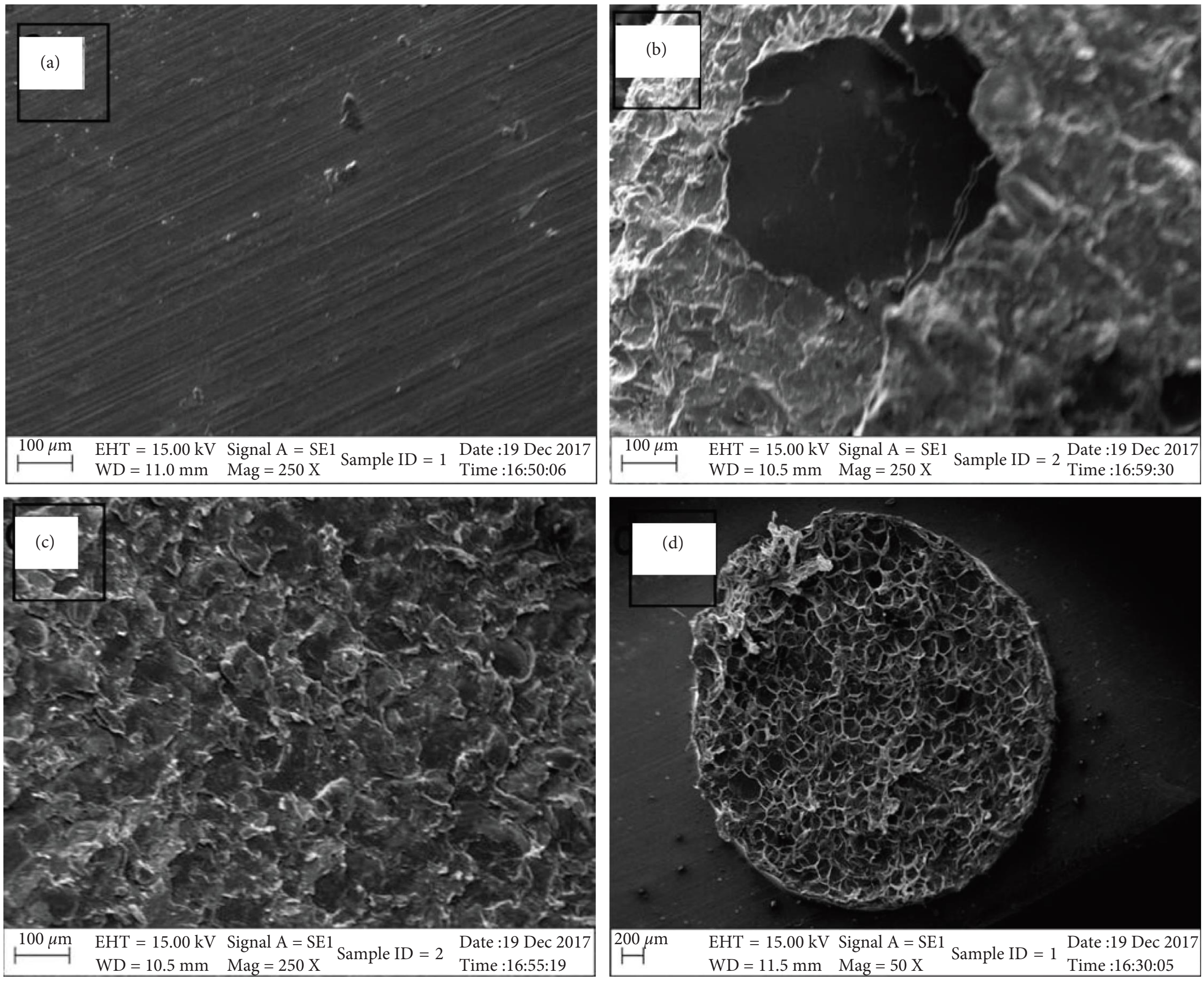


FIGURE 3: (a) Aluminium sheet with e-glass epoxy coated surface; (b) aluminium sheet with 5 bar SS sandblasted and resin coated peeled surface; (c) peel surface with cured resin and coating; and (d) PET form compressed with a fully peeled surface.

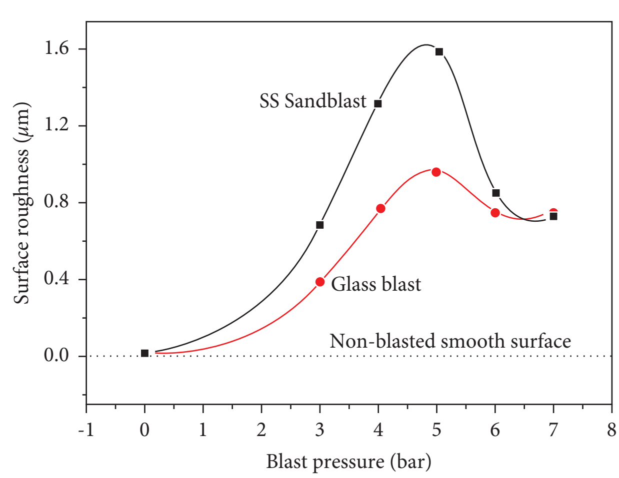


FIGURE 4: Surface roughness for different blasting pressures.

Table 3: Surface roughness for blasted aluminium skin.

Pressure	Glass blast	SS sandblast
Plain sheet roughness (μm) control sample	0.0169	0.0175
3 Bar (μm)	0.39	0.6865
5 Bar (μm)	0.9627	1.319
6 Bar (μm)	0.7519	0.8560

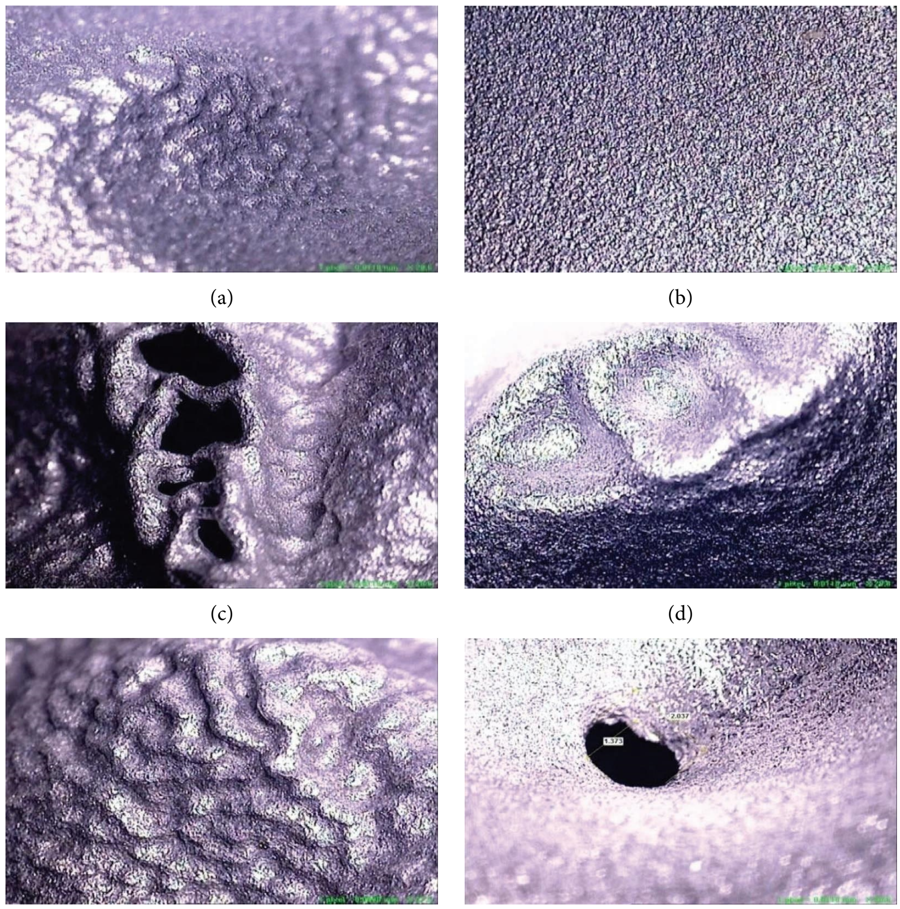
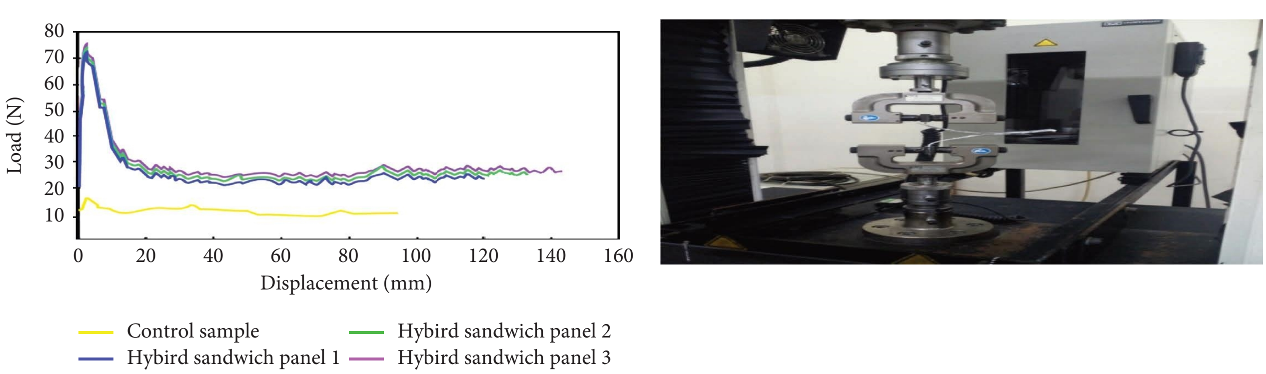
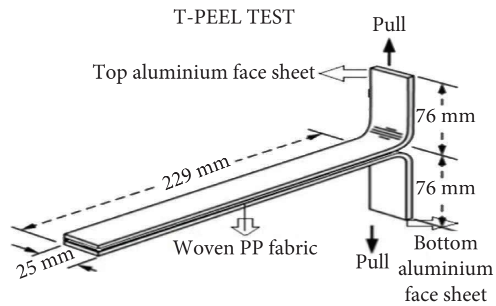

(a) (b) (c) (d) (e) (f)

Figure 5: Maximum blast damage predicted for glass and SS sand blasting on aluminium surface. (a) Glass blast 5 bar pressure, (b) SS sand blast 5 bar pressure, (c) glass blast 6 bar pressure, (d) SS sand blast 6 bar pressure, (e) glass blast 7 bar pressure, and (f) SS sand blast 7 bar pressure.



(a) (b)

Figure 6: Continued.



(c)

Figure 6: (a) Load vs. displacement curve for hybrid sandwich panels, (b) peel test setup in universal testing machine, and (c) schematic representation of peel test sample.

Table 4: T-peel experimental test results.

Target samples	Peak load (N)	Displacement (mm)	Crack formation before complete delamination (mm)	Fracture energy (J/m^2)
Control sample	18	94	6	211
Hybrid sandwich panel 1	75	120	6.5	535
Hybrid sandwich panel 2	76	136	6.9	537
Hybrid sandwich panel 3	78	142	7	540

4. Conclusions

The glass and stainless-steel sandblasted performance of the sandwiched hybrid laminate was expanded using aluminium as the skin and an epoxy/glass fabric/PET foam composite as the core. It could be investigated at various surface roughness, peel strength, and surface damage levels, as well as tested in real-time artificial weather conditions in a test chamber. The aluminium skin surface was modified by blasting (glass and SS sand) at various blast pressures. The peel strength of the tested laminate could be optimised as a result of the surface roughness. The adhesive strength of the laminate was estimated. The surface roughness is high at 5 bar of blasting without any defects. The adhesion strength is also observed to be high at 5 bar pressure blasted laminates. The various blasting defects are described in detail; the proper optimization of blast pressure will reduce the surface damage in aluminium skin material. In future work, the corona treatment increases the surface energy of aluminium skin and the adhesion of core materials. The fabricated target samples are best suitable for humid atmospheres.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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