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Mechanical Characterization of FRP using Glass Fiber & its Application for Corrugated Sheet

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Abstract: In this paper, an experimental study was undertaken to characterise the Von-Misses stress and translational displacement behaviour of FRP corrugated sheet. In this work, corrugated sheet of glass fiber reinforced epoxy composites were fabricated. Epoxy resin was used as polymer matrix material and glass fiber was used as reinforcing material. The matrix of FRP composite is epoxy resin and the reinforcement is E-glass. Reinforcement type is surface veil and Triaxial cell fabric. The main focus of this work was to fabricate composite corrugated sheet by the cheapest and easiest way. For this, hand layup method was used to fabricate corrugated sheet glass fiber reinforced epoxy resin composites. The corrugated FRP sheet is manufactured with dimensions 2 mm thickness, 600 mm width and 600 mm length. Moreover, a finite element (FEA) analysis was carried to simulate the Von-Misses stress and translational displacement behaviours of corrugated sheet. The maximum values of both Von-Misses stress and translational displacement were found. They were 9 MPa and 0.2 mm. Based on maximum stress criterion and maximum deflection for static structure, the model is safe.
Keywords: FRP, Corrugated sheet, FEA.

I. INTRODUCTION

In this paper the hand layup process used in FRP manufacturing. Fiber reinforced polymer commonly known as FRP is a composite material made of a polymer matrix rainforest with fiber. Composite Materials are becoming more popular gradually replacing traditional material with additional strength, lighter weight and superior property. Fiber reinforced composites used in water transport, construction industry, toys, instrumentation, medicine etc. Based on application and reinforcement used, there are many ways to manufactures parts with fiber reinforced composites, the fiber is usually glass, carbon or aramid, although other fiber such as or wood or asbestos have been sometime used. FRP are manufactured by two methods: pultrusion and hand lay-up as open mold method. Hand layup is open molding process and it's the oldest moulding process for creating FPR product. Hand layup is simple composite molding method, offering low-cost tooling, simple processing, and wide range of part size.

Today's in the market available of various types of corrugated roofing sheets with different materials such as Steel (G.I. steel), Plastic, Composite materials etc. composite materials of Cement fibrous, Fiber Reinforce Plastic. These different materials of sheets are manufactured by using different manufacturing methods. Like that, for Steel corrugated roofing sheets manufactured process by using roll forming method; for Plastic corrugated roofing sheets manufacturing process by using Extrusion method; for Cement fibrous corrugated roofing sheets manufacturing process by using Hatschek method; for FRP corrugated roofing sheets manufacturing by using Hand Lay-up or Spray Lay-up method. Cement fibrous corrugated roofing sheets like to be fiberglass roofing sheets, the different between both sheets are made from different materials. Cement fibrous sheet is in the used cement materials for bounding the fibers. And FRP sheet is in used the resin for bounding the fiberglass. These both sheets materials group is belong to composite materials. The fiber is used in sheet for increase the strength of sheet. There are different materials of sheets, so different manufacturing methods of these. Hashem Akbari, Ronnen Levinson, and Paul Berdahl [6], they are discussed about the methods for the manufacturing of Residential Roofing materials. Such that, shingles; Clay tiles; Concrete tiles; Metal roofing. In this paper discussed about climate of California, the demand for cooling energy, increasing roof solar reflectance reduces energy consumption in mechanical cooled building, and improves occupant comfort in non-conditioned buildings, with manufacturing methods and innovative methods for increasing the solar reflectance of these roofing materials. In cement fibrous sheets, the major components involved cement, water, silica, lime stone flour and fibers. The cement fibrous corrugated roofing sheets manufacture by different methods,

AL Moselemi [1], to provide an overview of the different technologies that are currently in use to manufactured of cement fibrous sheets, the most popular technology used in fiber cement manufacturing is the Hatschek process and other processes are used such as Extrusion machine, Fourdrinier forming machine, Pour-on Technology, Wounder Board Process, Cement-Bonded particle board, Wood wool Boards, Block and Siabs.

These technologies are currently used for manufacturing of cement sheets in factories. Hatschek process is very old method was developed in 1890's for production of asbestos cement product. Tony Cook [4], describes the details working mechanism about Hatschek machine process for manufacturing of fiber cement sheets. This method is helpful for film formation cement fibrous sheets in uniform thickness and flatness of sheet. S. Delvasto, E.F. Toro, F. Perdomo [2], this are discussed about another technology for manufacturing of corrugated fiber reinforced cementitious sheets using Vacuum forming technology. The machinery used in cylinder forming process is simple; this technology appropriate for small scales of production and it is an environmental friendly low cost appropriate technology that does not need skilled labour. Above manufacturing methods and technology of to produce corrugated fiber cement sheets, these manufacturing technologies will be helping for manufacturing corrugated fiberglass roofing sheets.

This paper presents the characterisation of the mechanical properties of a 2 mm thick corrugated sheet. The main objective of this work is to investigate the behaviour of the FRP sheet under Von-Misses stress and translational displacement. Tests on specimens were undertaken to determine the mechanical properties. Aside from these tests, a finite element analysis (FEA) was carried to simulate the Von-Misses stress and translational displacement behaviours of corrugated sheet. The results obtained from the experiment were compared with those of FEA.

II. EXPERIMENTAL METHODOLOGY

A. Material

The following materials were used for the fabrication of FRP corrugated sheet:

- Resin - Epoxy resin
- Hardener - Epoxy hardener (curing agent of epoxy resin)
- Glass fiber- Triaxial fabric

Hand layup method was used for preparing the laminated composites sample. At first plywood board was taken around 100 mm by 300 mm for making desired pattern. In this work, plywood board acted as open mold instead of metal mold or any other kind of mold. Triaxial fiber was cut according to desired dimension. Triaxial fiber was cut by scissor. Then Triaxial fibers were taken for weighing. Triaxial fibers were weighed by electric weight balance. From Triaxial fibers weight, epoxy resin, hardener and filler material were weighed based on composition. For tensile testing, according to required dimension, 225gm glass fiber taken as 30%. Epoxy resin was taken 429.33gm. Epoxy hardener was mixed with epoxy resin in 10:1 (resin: hardener) ratio. So, 42.933 gm. hardener was taken. After weighing, a layer of Triaxial fibers was placed on the surface of the pattern. Then mixture of epoxy resin and hardener, depending on composition, poured onto the surface of the Triaxial fibers mat. Resin mixture was uniformly sprayed with the help of 2.5 inches brush. Second layer of mat was then placed on the resin mixture surface and compressed by brush with a mild pressure on the mat-resin mixture layer to remove air as well as excess resin present. The process was repeated for each layer of resin plus hardener mixture or resin plus hardener plus filler material mixture and mat, till the required layers were stacked. After achieving desired thickness, the laminated composites were kept for 48 hours at room temperature for curing. After curing, specimens were withdrawn from the pattern. Then samples were cut by grinding machine according to required testing dimensions. Tensile test was carried out using universal testing machine. The testing range of that UTM machine is 20 to 100 KN. For tensile testing, test specimens were prepared according to ASTM D3039 (317×25×4) mm.

The same hand layup method is used for preparing FRP corrugated sheet. Firstly two metal corrugated sheet of 2mm thickness was taken around 2.5 ft by 2.5 ft for making desired pattern. The metal corrugated sheet acted as closed mold instead of any other kind of mold. The process was repeated for each layer of resin plus hardener mixture and mat, till the required layers were stacked. After achieving desired thickness, another metal corrugated sheet was placed on laminated composites with some weights over it and was kept for 48 hours at room temperature for curing. After curing, corrugated sheet was withdrawn from the pattern and cut it with 600 mm by 600 mm in size. The corrugated sheet (Fig. 1) investigated have mass density of 1650 kg/mm3. Table 1 displays the section properties of the corrugated sheet.

Table 1 Section properties of the corrugated sheet

Properties	**Value**
Corrugated sheet thickness, t (mm)	2
Nominal width, w (mm)	600
Nominal length, l (mm)	600

Fig. 1 FRP Corrugated sheet

Fig. 2 Tensile Test

III.EXPERIMENTAL RESULTS AND DISCUSSION

A. *Specimen Testing*

The longitudinal load–displacement and the failure mode of specimen under tensile loading are displayed in Fig. 3. It should be noted that the calculation of tensile stress and modulus values are based from the equations suggested in the corresponding standard. From Fig.3, one can observe that the specimen exhibited an elastic behaviour up to failure. Fig. 3 indicates that the maximum tensile load ranges from 69 to 74 kN (failure stress at 229–242 MPa).

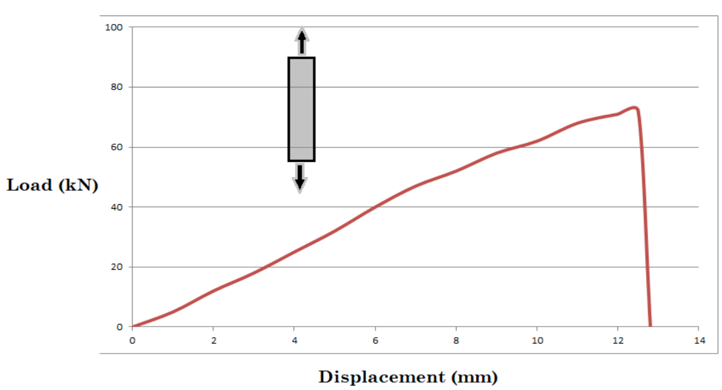

Fig. 3 Load displacement curve

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B. Summary of the mechanical properties

Table 2 summarise the average value of the properties of the laminated composites sample. The results indicated in Table 2 show that the peak tensile stress is 229 MPa.

Table 2 Summary of mechanical properties from actual specimen test

Properties	**Value**
Tensile (MPa)	229
Tensile, elastic modulus (MPa)	30,000

IV. SIMULATION

A. Finite Element Analysis (FEA)

Numerical simulations were performed to compare with the experimental measurements of the Von-Misses stress and translational displacement behaviour. The finite element model was developed whereby the property inputs are based from the material properties derived from specimen tests. Finite element method was conducted simulating the specimen and the loading set-up in the actual experimental conditions to have a reliable result.

Static Structural Analysis

In this study, the 600x600 mm corrugated sheet with a thickness of 2 mm was modelled with mesh size of 5* 5 mm.

A uniformly distributed 100 kg load is applied on entire surface and fixed support is applied at bottom 30 mm offset from opposite sides of resting length 25mm.

Von-Misses Stress = 9 MPa

Displacement = 0.2 mm

B. Preparation of CAD Model Using SOLIDWORKS Software

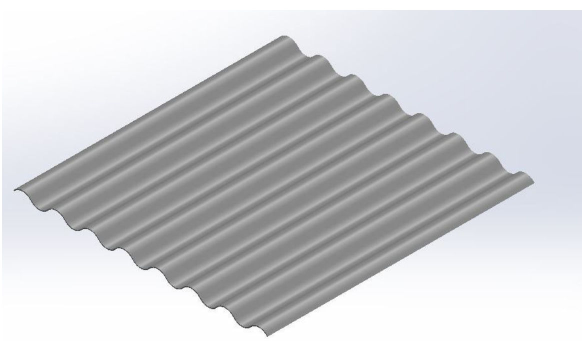

Fig. 4 3D Model

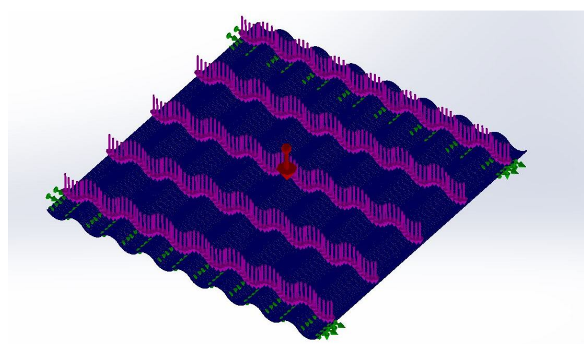

Fig. 4 Meshed Model

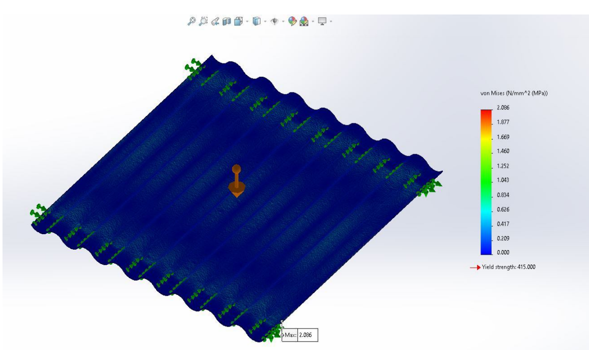

Fig. 4 Von-Misses Stress Plot

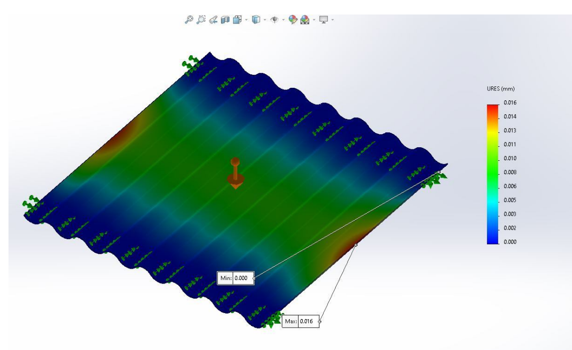

Fig. 4 Displacement Plot

The 100 Kg or 981N uniformly distributed load gave 9 MPa Von-Misses stress and 0.2 mm translational deflection. Maximum von Mises stress is 9 MPa. The stress is low and in the area of maximum stress criterion with strength 229 MPa. The model is safe based on maximum stress criterion when subjected uniformly distributed. Maximum translational displacement is 0.2 mm. The ratio of translational displacement and span length is (0.2)/(600) < 1/100. The model is safe based on maximum deflection when subjected uniformly distributed.

V. CONCLUSION

In this mechanical characterization, tests were carried out on a glass fiber reinforced epoxy resin composites as well FRP corrugated sheet were fabricated using hand layup method. Mechanical properties were investigated. Moreover, an FE analysis was performed to simulate the Von-Misses stress and translational displacement behaviour. The maximum values of both Von Misses stress and translational displacement were found for the uniformly distributed load on corrugated sheet. They were 9 MPa and 0.2 mm (for 100 kg load). The model is safe when simulated uniformly distributed load based on both maximum stress criterion and maximum deflection.

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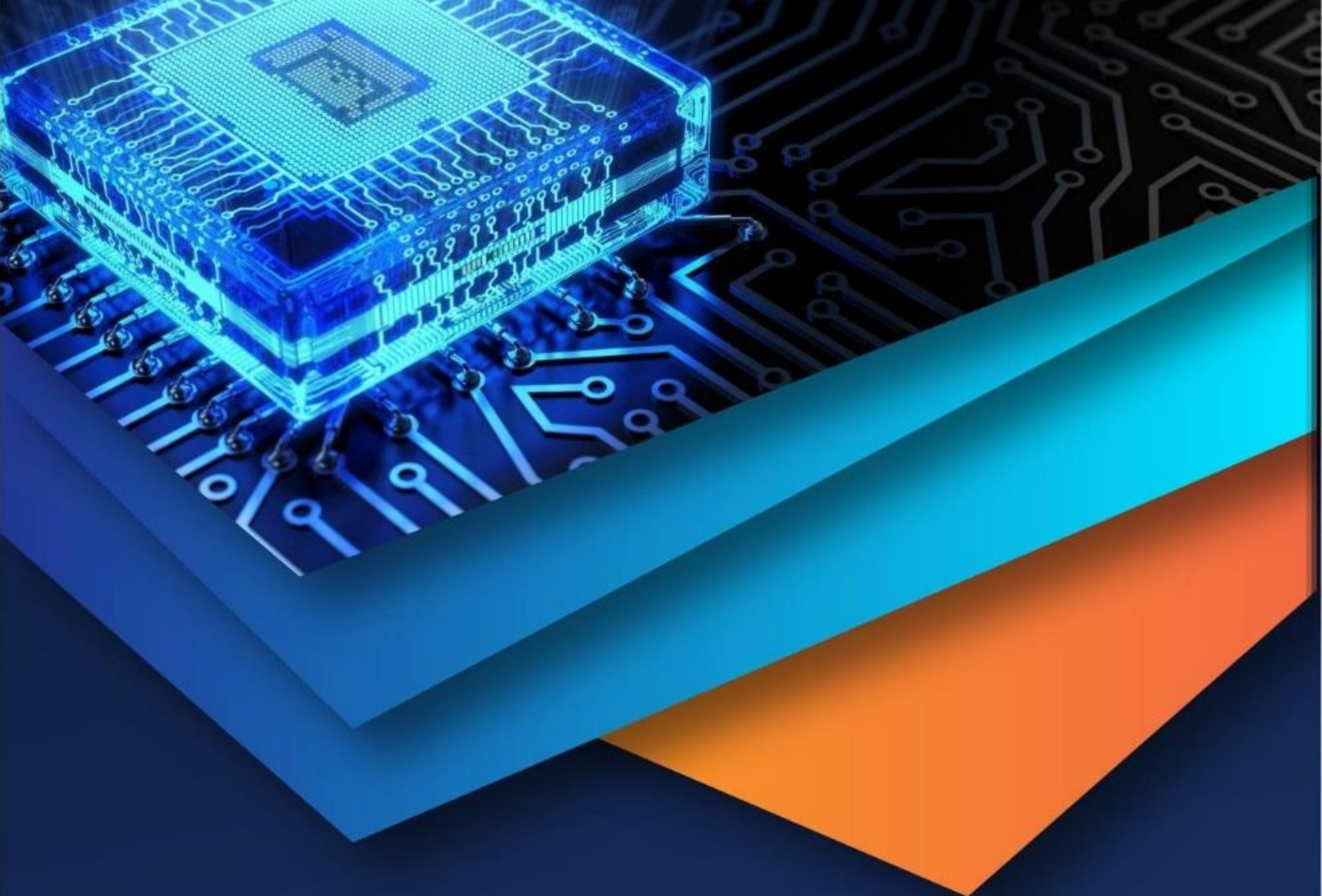

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