A Study of Corrugated GFRP Composite subjected to Transverse loading

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Abstract— **Now a days, glass fiber reinforced polymer(GFRP) composites became the best alternative to replace the traditional materials due to its superlative properties such as high stiffness to weight ratio, strength to weight ratio & corrosion resistance etc., the present work focuses replacement ship container wall of corrugated structure with GFRP composites. These structures are tested for flexural and bending strength. General purpose (GP) polyester resin is used as matrix and glass fabrics of orientations 0&45 are used as reinforcement to make the two ply corrugated composite& hand lay-up technique is employed.**

Index Terms : GFRP composites, GP Resin, Corrugated Structure, Glass Fabric.

I. INTRODUCTION

Though wide variety of traditional metal materials and alloys are available for different applications, still composites are competing due to its outstanding properties strength to weight ratio, stiffness to weight ratio, corrosion resistance, low density, electrical resistance etc., glass fiber reinforced polymer composites have huge applications in electronics, structural, aviation, navy and automobile fields[1].in composites, reinforcement (fiber or fabric)is major load carriers and where as matrix holds the fibers together, protects from environment effects and transfers the load to the reinforcement. the present investigation is carried out on corrugated composites for structural applications.

Jin Zhang et al.,[2] studied for bending strength, stiffness and energy absorption of corrugated sandwich composite structure for energy absorption in transportation vehicles & they have considered the design parameters to be selection of fiber type, corrugation angle and core-sheet thickness, The results revealed that Increasing the corrugation angle and the core sheet thickness improved the specific bending strength of the sandwich structure, while increasing the bond length led to a reduction in the specific bending strength.

Ziad K et al.,[3] studied Optimum Design of Structural Fiber Composite Sandwich Panel for Flooring Applications based on cost. they have followed Finite Element (FE) and Genetic Algorithm (GA) method to analyze the composite sandwich panel for civil engineering applications. Not only the type of matrix and fabric but also fabric orientation is going to effect the performance of corrugated structures [4,5].

S. C. Mohanty [6] modeled multi-layered symmetric sandwich beam and analyzed using numerical methods and finally suggested that optimization can be done using finite element method for vibration analysis.

ES Kocaman et al.,[7] studied foam core sandwich composites failure modes with the help of Fiber Bragg Grating sensors. They have fabricated using vacuum infusion process and then, composites are subjected to a static and a cyclic loading under the three-point bending. They have found depending up on damage modes, different responses of the Fiber Bragg Grating sensor.

S. Heimbs et al.,[8] followed autoclave technique to fabricate the Folded Structures for the aero space application. They have tested the sandwich structure with a folded core made of carbon fiber-reinforced plastic for compressive strength, shear strength and impact strength based on numerical methods and experimentation. high stiffness and strength values leading to a very localized failure under impact loads and the delamination propagation in the face laminate is limited by the adjacent core cell connections are observed.

Bartolozzi, G et al.,[9] considered sandwich corrugated layers to be orthotropic homogeneous layers and carried out finite element analysis and found experimental and NM results are comparable.

Carlson, L.A et al.,[10] studied deformations and failure modes like global buckling, wrinkling local instabilities, and face/core debonding of sandwich panels subjected different types of loads and given analytical solutions to the corrugated structure. Guru Saiprasad et al.,[11] used simple hand lay-up technique to find the mechanical compressive strength of hybridized sandwich coupons with different combination of reinforcements namely glass fabric, jute fabric and Kevlar fabric by keeping the corrugated angle to constant 45^{0}.results revealed that hybridization can be successfully implemented for better mechanical performance and cost.

The present investigation is carried out to know whether the orientation of reinforcement is effective or not for the corrugated glass fiber reinforced polyester composite.

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II. Materials And Methods

13mill glass fabric (400gsm) of orientations 0&45 and general purpose resin is purchased from Allied agencies, tarbund Hyderabad. mould is required for giving shape to the resin/ fiber combination. A Wooden mould is prepared by using wood router machine as shown in fig - 1. The plain shaped mould is used at the time of assembly i.e., joining of the flat composite with the corrugated composite using the matrix. Cut the E-glass fiber as per the mould dimension. The fiber is marked using scale and then it is cut with a scissor as shown in fig-2.

Fig-1. Wood Mould

Fig-2. Cutting of Glass Fabric

The matrix consists of resin (Polyester resin), catalyst and accelerator. The resin is mixed with the catalyst and accelerator in the ratio given in the table-1.

TABLE-I.
MIXING RATIO OF MATRIX

S. No	Material Name	Volume used	Percentage
1	GP Polyester resin	1 liter	96.153%
2	Catalyst	0.02 liter	1.923%
3	Accelerator	0.02 liter	0.923%

The simplest and oldest technique, used to fabricate the composite laminate is Hand lay-up. In this process successive layers of matrix and reinforcement are manually applied to an open mould for the fabrication of composite laminates. This process is used in making both corrugated and plain composite. The mould releasing agent (i.e. silicon spray) is applied on to the mould surface**.** Then after a few minutes the matrix over the mould is applied and place the fiber and press it with hands using gloves. Rollers are also used for avoiding air bubbles then again apply the matrix and follow the same. Leave the specimen for about 2 hours to dry up. Then, remove the specimen from the mould.

Assembly is the process of joining all component together in order to get the required laminates. Perfect assembly provides strong joining of corrugated shape and plain shaped composite sheets. In perfect assembly, there is no gap at any section of sheets where it is joined. Thus, making the assembly is very strong and reliable. The matrix is applied on the surface of flat shaped specimen and also corrugated shaped specimen. Then the corrugated shaped specimen is placed over the flat shaped specimen, where both the specimen has the same fiber. The complete procedure is shown in figures from 3-5.

Fig-3 Removing the bubbles with a roller

Fig-4 Plain Composite

Fig-5 Removing the Composite from mould

Heavy load is kept on the joined specimen to make the assembly very strong. Finally, load is removed at about 2 hrs and the required assembly is achieved.

TABLE: II
ORIENTATIONS AND NUMBER OF LAYERS

S. No	Fiber orientation (in degrees)	No. of layers of fiber	Thickness in mm
1	0,0	2	2
2	0,45	2	2
3	0,-45	2	2
4	45,45	2	2
5	45,-45	2	2

3-point bend test is carried out to find the flexural strength of the composite at Jyothi spectro analysis laboratories located in balanagar, Hyderabad with universal tensile testing machine. a ball drop impact test setup is made with maximum ball bounce to be 160cm as shown in figures from 6-7, to know the impact strength of the corrugated composite.

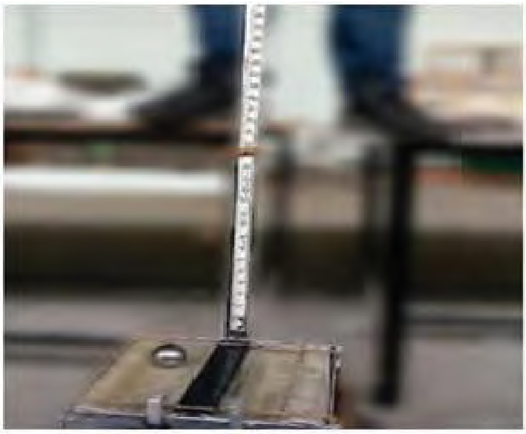

Fig -6 Impact load setup

Fig-7 Bend test setup

III. Results And Discussion

After preparing the specimens, they are tested to know the maximum amount of transverse load and amount of energy it is absorbed. the maximum gradual transverse load to deflection are shown in figures 8-12 for the GFRP composite corrugated beam. The load increases steadily with the displacement up to the highest peak load. There after the wall of core begins to buckle and the load has abruptly decreased. Global failure is observed during bend test before the delamination of layers

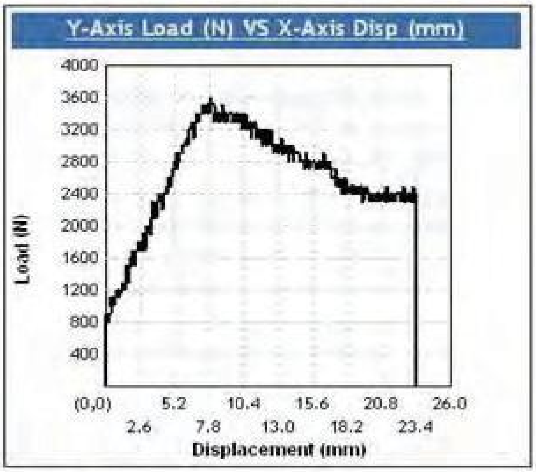

Fig-8 Load vs Defelction graph of (0, -45)

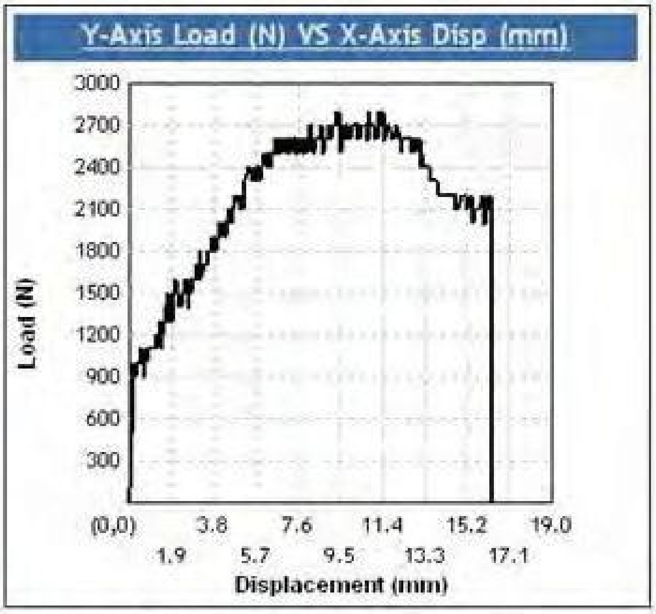

Fig-9 Load vs Defelction graph of (+45, +45)

Ball drop Impact test is conducted to calculate the following and results are tabulated in table III and comparison has made in figures 13-16:

Absorbed energy (AE)
Co-efficient of restitution (COR)
Brinell hardness (HB)

Thus the specimen that absorbs the highest amount of energy is the best among all the specimens.

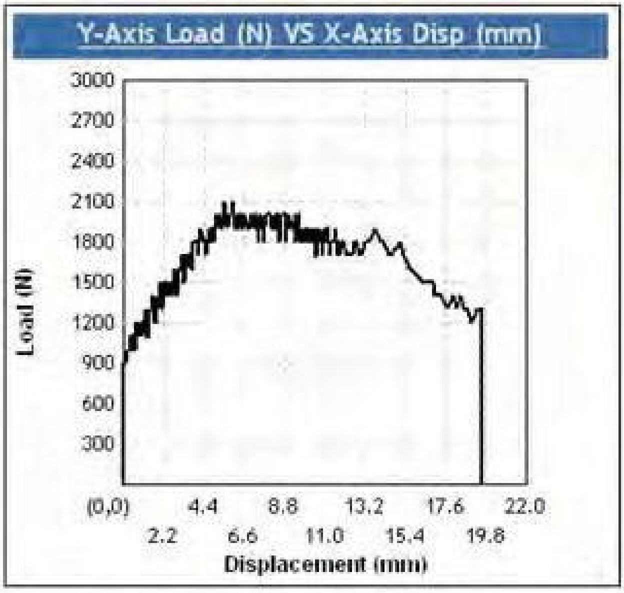

Fig-10 Load vs Defelction graph of (0, +45)

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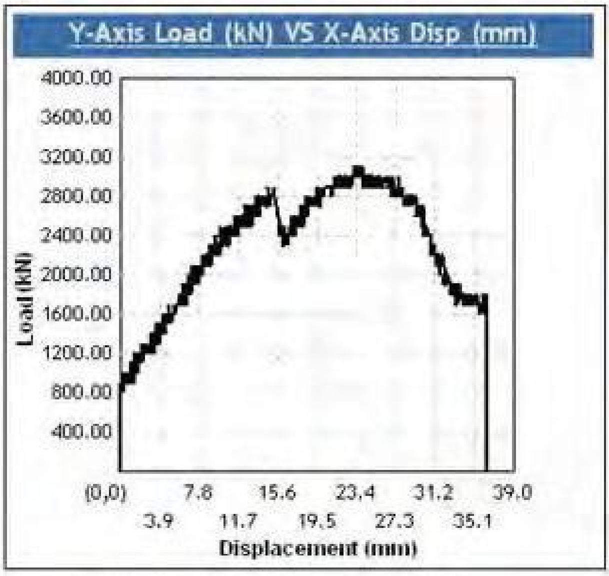

Fig-11 Load vs Defelction graph of (0, 0)

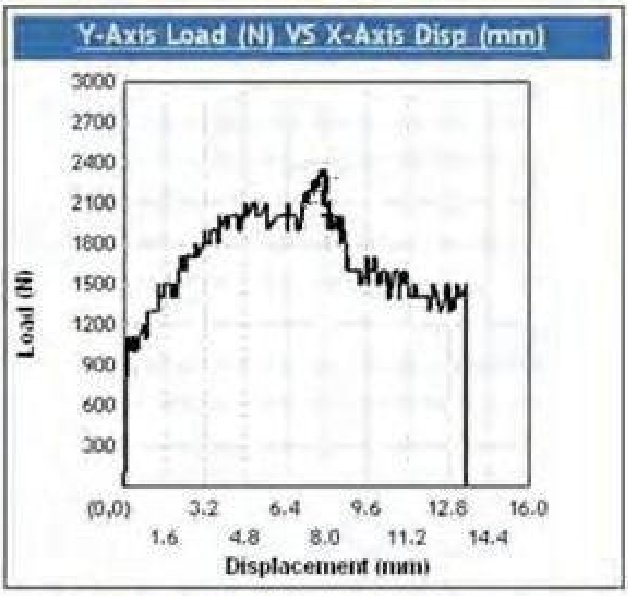

Fig-12 Load vs Defelction graph of (+45, -45)

Formula 1: Absorbed energy(AE) = Total energy–Potential energy

$$AE = \frac{1}{2}mv^2 - mgh$$

m= Mass of the ball in Kg.
v= velocity of specimen in m/s.
g=gravitational constant in m/s^2
h=height of the ball in mm.
Formula 2: Co-efficient of restitution(COR)

COR = coefficient of restitution $c = \sqrt{\frac{h}{H}}$
h = bounce height
H = drop height
D = Diameter of the ball
d = Diameter of the indentation.

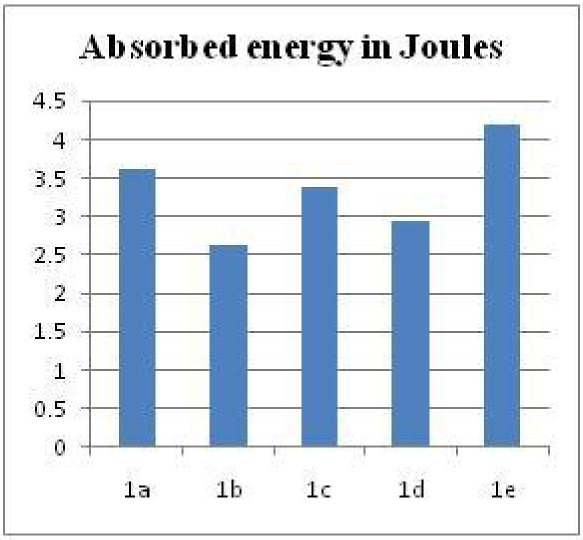

Fig-13 the amount of energy absorbed in joules

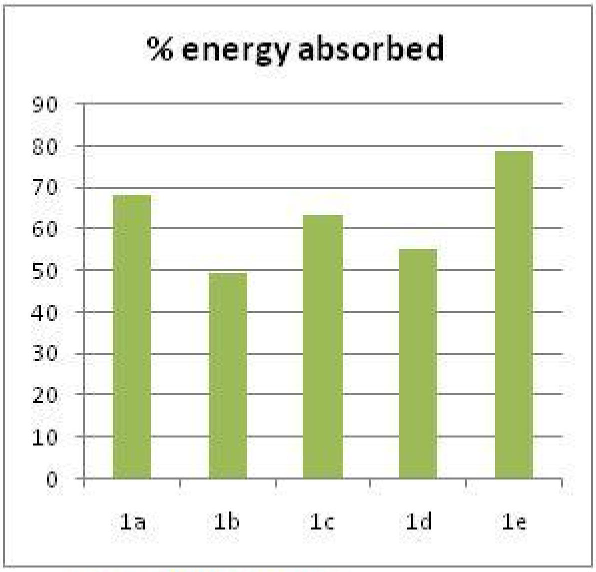

Fig-14 % Energy Absorbed

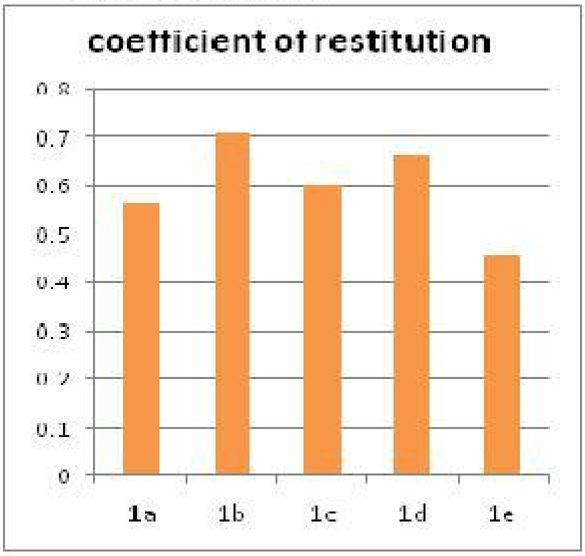

Fig- 15 Coefficient of Restitution

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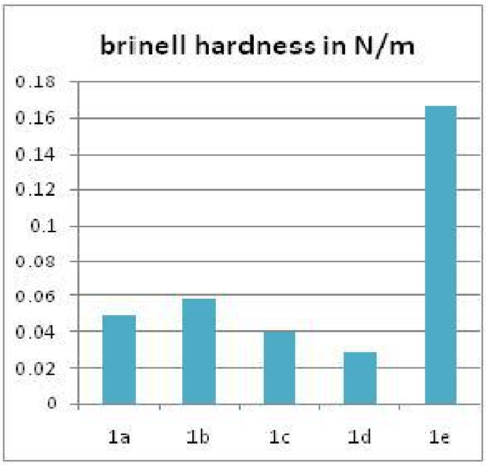

Fig- 16 Brinell Hardness in N/m

TABLE-III
HARDNESS AND ABSORBED ENERGY FOR SPECIMENS

S.No	Composite Sample	Fiber Orientation	A.E. in (kgm^2/s^2)	% A.E	COR	Brinell Hardness in N/m
1	1a	0, -45	3.616	68.149	0.565	0.049
2	1b	0, +45	2.637	49.69	0.709	0.058
3	1c	+45, +45	3.379	63.68	0.602	0.039
4	1d	0, 0	2.949	55.57	0.666	0.029
5	1e	+45, -45	4.181	78.79	0.46	0.167

IV. CONCLUSIONS

The GFRP composite corrugated beams fabricated using hand lay-up and compression moulding technique using different orientation of glass fabric. Later all the fabricated specimens are tested for 3 point bending test and impact test for finding the load resistance capacity of different orientations .The (0,-45) orientation has the best bending strength obtained during three point bending test The (+45,-45) oriented specimen has highest energy absorption capacity which is obtained during impact test. The specimen of orientation (0,+45) has highest coefficient of restitution and specimen of orientation (+45,-45) high brinell hardness value. The Results showed that fabric orientations can affect the performance of composite corrugated structures.

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