International Journal of Scientific & Engineering Research Volume 12, Issue 2, February-2021
ISSN 2229-5518

Design and Analysis of Solid Waste Reinforced Material for Engineering Applications

Sharath Raj T, Sanchet Deshpande, Satvik Nath, Mantesh B Khot*

*Corresponding Author, Assistant Professor, PES University, Bangalore, India. *E-mail: manteshkhot36@yahoo.com*

Abstract— There is an increasing amount of post-consumer textile waste that is generated in India with an estimated population of above 1.33 billion, but limited studies have been carried out on the channels of recycling of postconsumer apparel waste in India. In India textiles being 4 per cent of India's GDP, the annual consumer expenditure on clothing and footwear is almost 68 billion dollars. Hence recycling of textile waste is of prime concern which is not being addressed adequately. The present work is to utilize this end-of-life textile materials as reinforcement for composite material. The textile reinforced composite material is fabricated using the hand layup technique with epoxy resin as the matrix material and fly ash as a filler material. The material is fabricated for different ratios of textile waste to epoxy resin. The fabricated material is subjected to series of mechanical tests including tensile test, bending test, water absorption test and Poisson's ratio test. The properties (density, Poisson's ratio, Young's modulus) thus obtained are used for analysis and for comparing load bearing capabilities with commercially used balsa wood. The material is also analyzed for its response as a safety helmet. The simulation of the crush test in downward direction, longitudinal direction and transverse direction is simulated using ANSYS software. The results obtained are validated with the BIS protocols and conclusions are derived.

Key Words: Recycling, Textile waste, Mechanical Properties, Crush test

———————————— ◆ ————————————

1 INTRODUCTION

THE composites are multifunctional material systems that provide characteristics not obtainable from any discrete material. They are cohesive structures made by physically combining two or more compatible materials, different in composition and characteristics [1, 2]. Over the past few decades the volume and number of applications of composite materials have grown steadily, penetrating and conquering new markets. Most commonly, composite material consists of a bulk phase, which is continuous, called the matrix and one dispersed, non-continuous phase called the reinforcement which is usually harder and stronger[3, 4]. Polymers make ideal matrix material as they can be processed easily, possess light weight and desirable properties. Two main kinds of polymers are thermoplastic and thermoset polymers. Some of the commercially used resins include polyethylene, polystyrene, polypropylene, epoxy, silicone resin etc., The reinforcements used commercially include glass fibers, aramid fibers, carbon fibers etc., In recent times emphasis has been laid on use of new reinforcement materials which are light weight, cost effective, and possess better mechanical properties than the existing materials[5].Extensive research is being conducted on use of naturally derived fibers like bamboo, sisal, hemp as substitutes for conventional reinforcing material. Another such material happens to be textile waste, which are otherwise discarded in landfills causing environmental issues[6]. This paper aims to use such end-of-life textile material as reinforcement for composite materials. The material once fabricated is subjected to series of mechanical testing – tensile test, bending test, water absorption test. The properties (density, Poisson's ratio, Young's modulus) thus obtained are used for analysis and to compare with other material.

2. FABRICATION PROCESS

2.1 Hand Lay Up Process

A wooden mould of dimensions 250mm x 150mm x 50mm is created. The mould is made by joining the walls of the mould by screws as the screws can be removed easily later which helps in removing the manufactured composite from the mould without damaging the mould. Once the mould is ready, it is covered with a plastic non sticky sheet so that the resin used does not stick to the mould and can be removed off easily once the composite is manufactured. Denim fabric is cut suitable to the dimensions of the mould box.

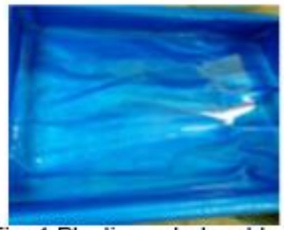
Fig. 1 Plastic coated mold


Fig. 2 Waste Denim material

In a separate container, the resin is mixed with the catalyst and the hardener to prepare the matrix. The epoxy resin, denim fabric, and fly ash are mixed in the ratio 60:30:10 by weight with respect to the matrix.


Fig. 3 Epoxy resin


Fig. 4 Hand lay-up process


Fig. 5 Final product

3. MECHANICAL TESTING

The following mechanical test were performed according to ASTM standards as it is one of the most widely accepted standard around the globe.

1. Tensile test
2. Three point bending test
3. Water absorption test

3.1 Tensile Test

It is one of the fundamental tests and forms the basis of material science and mechanical engineering. It is used to calculate various mechanical properties. The experiments were carried out as per ASTM D3039 standards. The compositions for specimen 1 and 2 are Resin (60%): fabric waste (30%): fly ash (10%) and resin (55%):fabric waste (35%): fly ash (10%) respectively. The test results are shown in below tables.

TABLE 1
Results of tensile test for specimen 1

Input data	Tensile test results
Specimen shape: Flat	Load at peak: 6.414 KN
Specimen width: 24.6 mm	Elongation at peak: 8.58 mm
Specimen thickness: 3 mm	Tensile strength: 85.745 MPa
Gauge length: 50 mm	Load at break: 6.414 KN
Max. Load: 600 KN	Young's modulus: 588.23 MPa

Fig. 6 Specimens 1 before and after tensile test

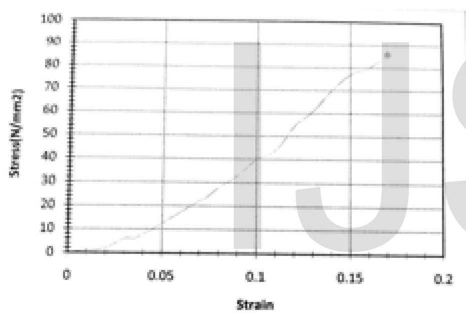

Fig.7. Stress v/s Strain graph for specimen 1

TABLE 2
Results of tensile test for specimen 2

Input data	Tensile test results
Specimen shape: Flat	Load at peak: 5.426 KN
Specimen width: 24.8 mm	Elongation at peak: 7.436 mm
Specimen thickness: 3 mm	Tensile strength: 63.854 MPa
Gauge length: 50 mm	Load at break: 5.426 KN
Max. Load: 600 KN	Young's modulus: 475 MPa

Fig. 8. Specimens 2 before and after tensile test

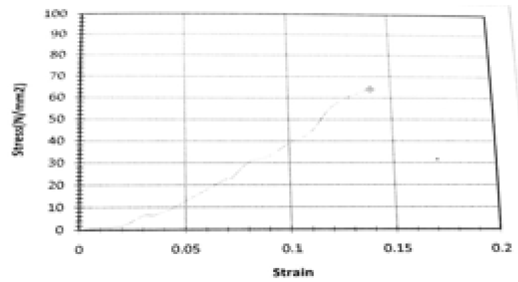

Fig. 9 Stress v/s Strain graph for specimen 2

3.2 Three Point Bending Test

The three point bending test is of prime importance in engineering applications especially in infrastructure and construction field where ductile materials need to be tested for their bending test as they would undergo lot of bending stresses. The process of 3 point bending test involves a work piece being stationed in a fixture at ends and a downward point force is applied, and the work piece is deformed into a concave shape. The bending test conducted was according to ASTM D760**,** 100 mm×25 mm× 3 mm.

TABLE 3
Results of bending test for specimen 1

Input data	Three Point Bending test results
Specimen shape: Flat	Load at peak: 470.7192 N
Specimen width: 24.6 mm	Load at break: 215.7463 N
Specimen thickness: 3 mm	
Max. Load: 600 KN	

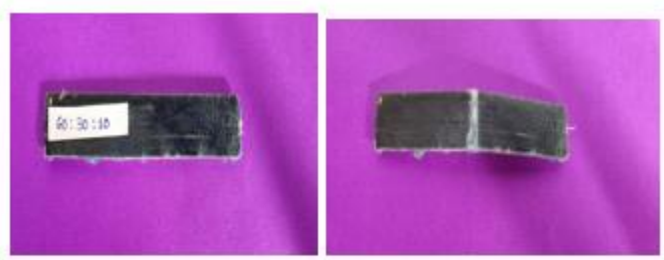

Fig. 10. Specimen 1 before and after bending test

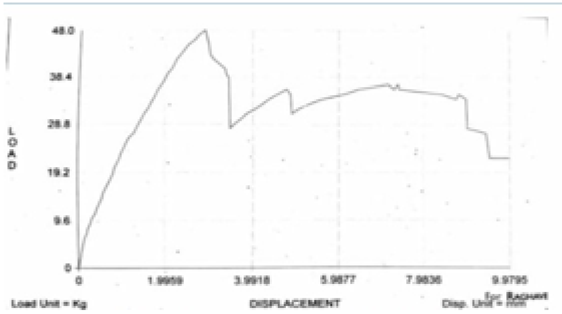

Fig. 11. Bending test graph for specimen 1

TABLE 4
Results of bending test for specimen 2

Input data	Three Point Bending test resul
Specimen shape: Flat	Load at peak: 284.3928 N
Specimen width: 25 mm	Load at break: 196.1330 N
Specimen thickness: 3 mm	
Max. Load: 600 KN	

Fig. 12. Specimen 2 before and after bending test

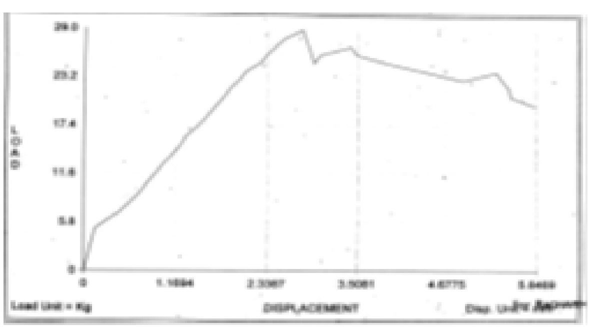

Fig. 13. Bending test graph for specimen 2

3.3 Water Absorption Test

Water absorption test is an essential test in determining the water absorptivity properties of the material. The test was conducted according to ASTM D570 standards, 10mm x 10mm x 3mm. The specimen was dried in sunlight for 6 hours to remove as much moisture as possible.

Water absorptivity % = (wet wt. – dry wt.)/ dry wt. x 100. Water absorptivity for specimen 1 0.28 % and for specimen 2 is 0.30%.

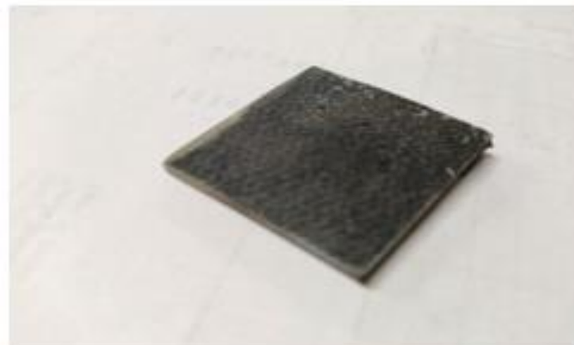

Fig. 14. Specimen after immersion and drying

4. COMPARISON AND APPLICATIONS

4.1 Comparison with Balsa Wood

The fabricated material is compared with widely used Balsa wood for its strength. The loading conditions and the dimensions used are as follows:

Deformation Analysis

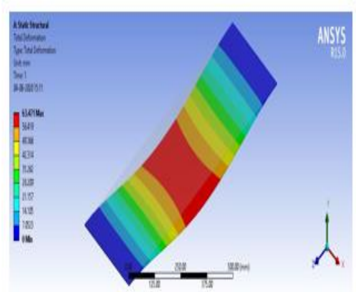

Fig. 15. Deformation analysis of fabricated material

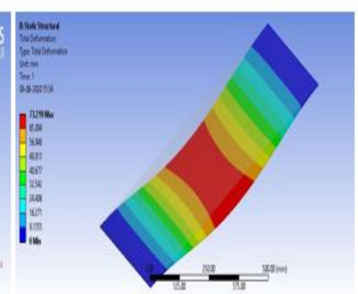

Fig. 16. Deformation analysis of Balsa wood

Stress Analysis

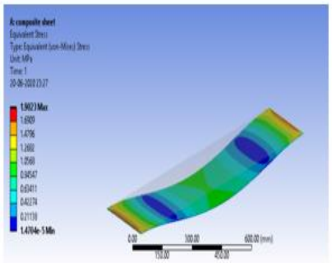
Fig. 17. Stress analysis of fabricated material

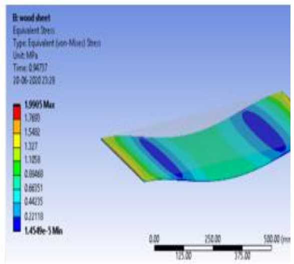
Fig. 18. Stress analysis of Balsa wood

For a uniformly distributed load of 10 N and both the ends fixed the comparative analysis shows that the balsa wood deforms more than the fabricated material. In terms of the equivalent Von- Misses stress developed inside the material, both the materials show similar values.

4.2 Applications: Safety Helmet

A safety helmet is designed according to BIS standards and tests are performed according to standard protocols. The tests conducted are:

1. Crush test in downward direction
2. Crush test in longitudinal direction
3. Crush test in transverse direction

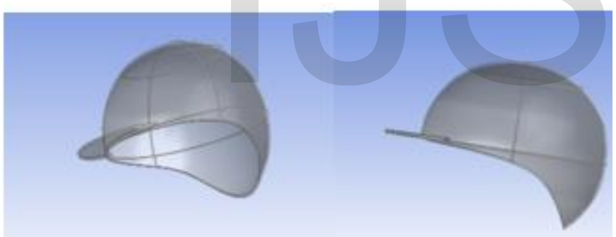
Fig. 19. Safety helmet design isometric and side views

4.2.1 Crush Test in Downward Direction

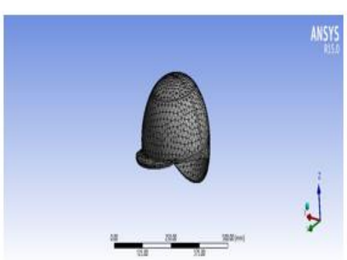
Fig. 20. Edge meshing of helmet

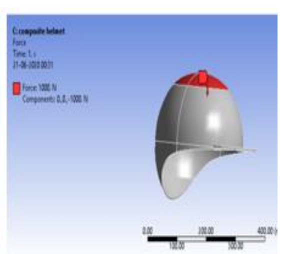
Fig. 21. Downward force of safety

A downward crushing force is applied on top of the helmet. The magnitudes of the force applied are as follows: 1000 N, 2000 N, 3000 N and 4000 N

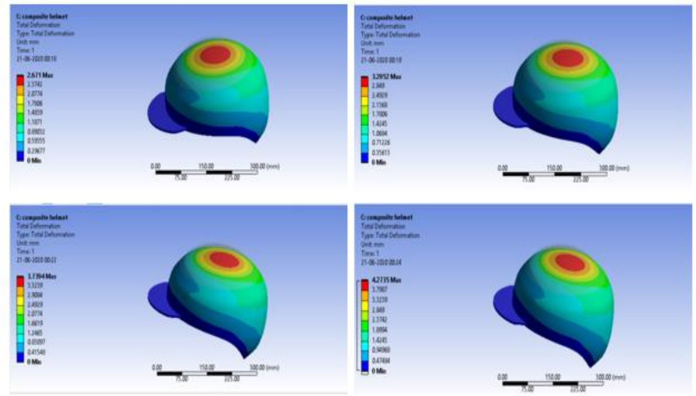
Fig. 22. Downward crushing forces of 1000 N, 2000 N, 3000 N and 4000 N

TABLE 5
Force applied and corresponding deformation

Force	Maximum deformation
1000 N	2.671 mm
2000 N	3.2052 mm
3000 N	3.7394 mm
4000 N	4.2735 mm

4.2.2 Crush Test in Transverse Direction

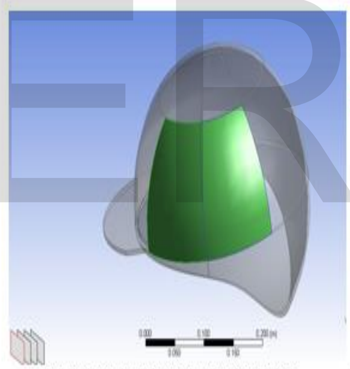
Fig. 23. Face split of safety helmet 30 N

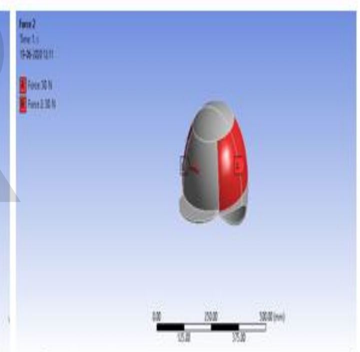
Fig. 24. 30 N load in transverse direction

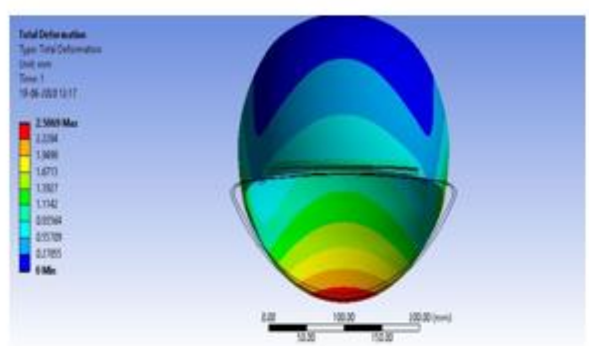
Fig. 25. View for deformation for 30 N transverse load

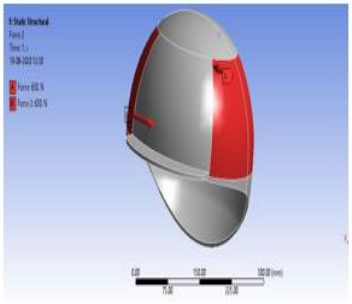

Fig. 26. 630 N load in transverse direction

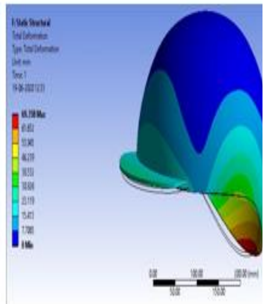

Fig. 27. View for Deformation for 63

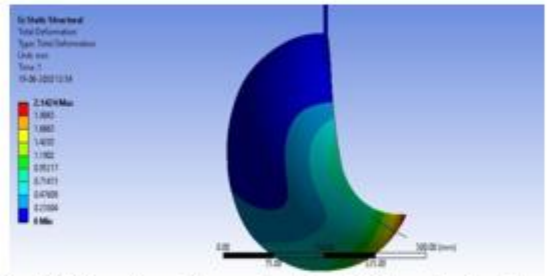

Fig. 30. View for deformation for 30 N longitudinal load

TABLE 6
Force and corresponding deformation of transverse crush test

Force	Maximum Deformation
30 N	2.5069 mm
630 N	69.358 mm

The difference between the maximum deformation for 630 N and 30 N load is given by: 69.358 - 2.5069 = 66. 8511 mm. According to BIS standards the maximum allowed difference between deformation for 630 N and 30 N load is 40 mm. Hence the safety helmet fails to comply with BIS standard testing protocols that are followed in India.

4.2.3 Crush Test in Longitudinal Direction

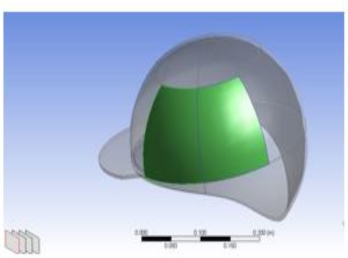

Fig. 28. Face split of safety helmet

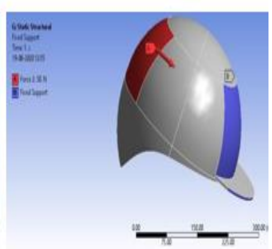

Fig. 29. 30 N load in longitudinal direction

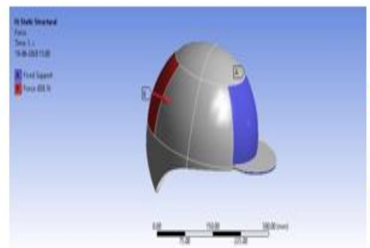

Fig. 31. 630 N load in longitudinal direction

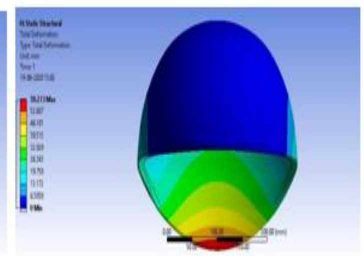

Fig. 32. View for deformation for 630 N

Table 7
Force and corresponding deformation of Longitudinal crush test

Force	Maximum Deformation
30 N	2.142 mm
630 N	59.273 mm

The difference between the maximum deformation for 630 N and 30 N load is given by: 59.273 - 2.142 = 57.131 mm. According to BIS standards the maximum allowed difference between deformation for 630 N and 30 N load is 40 mm. Hence the safety helmet fails to comply with BIS standard testing protocols that are followed in India.

5. CONCLUSIONS

- The composite materials shows better water absorption properties than commercially used balsa wood.
- It shows better tensile and bending properties than balsa wood.
- The safety helmet designed and tested fails to comply with ISI standards.
- The properties of the material can be enhanced by using other reinforcement materials with filler material.

REFERENCES

[1] Harshit Khandelwal, Arun Kumar Thalla, Sunil Kumar and Rakesh Kumar, "Life cycle assessment of municipal solid waste management options for India", *Bioresource Technology* 288 (2019) 121515.

[2] Yash Pujara, Pankaj Pathak, Archana Sharma and Janki Govani, "Review on Indian Municipal Solid Waste Management practices for reduction of environmental impacts to achieve sustainable development goals", *Journal of Environmental Management* 248 (2019) 109238.

[3] Patricia Pena-Pichardo, Gonzalo Martínez-Barrera, Miguel Martínez-Lopez, Fernando Urena-Nunez and Joao Marciano Laredo dos Reis, "Recovery of cotton fibers from waste Blue-Jeans and its use in polyester concrete", *Construction and Building Materials* 177 (2018) 409–416.

[4] M. Jawaid, H.P.S. Abdul Khalil and A. Abu Bakar, "Woven hybrid composites: Tensile and flexural properties of oil palm-woven jute fibers based epoxy composites", *Materials Science and Engineering A* 528 (2011) 5190–5195.

[5] Mohd Iqbal Misnon, Md Mainul Islam, Jayantha Ananda Epaarachchi and Kin-tak Lau, "Potentiality of utilizing natural textile materials for engineering composites applications", *Materials and Design* 59 (2014) 359–368.

[6] Muhammad Umar, Khubab Shaker, Sheraz Ahmad, Yasir Nawab, Muhammad Umair and Muhammad Maqsood "Investigating the mechanical behaviour of composites made from textile industry waste", *The Journal of The Textile Institute*, DOI: 10.1080/00405000.2016.1193982, 2016.

[7] C.A Echeverria, W. Handoko, F. Pahlevani and V. Sahajwalla, "Cascading use of textile waste for the advancement of fiber reinforced composites for building applications", *Journal of Cleaner Production*, doi: https://doi.org/10.1016/j.jclepro.2018.10.227, 2018.

[8] Ayhan Demirbas, "Waste management, waste resource facilities and waste conversion processes", *Energy Conversion and Management* 52 (2011) 1280–1287.

[9] Samy Yousefa, Maksym Tatariants, Martynas Tichonovas, Zahid Sarwar, Ilona Jonuškiene and Linas Kliucininkas, "A new strategy for using textile waste as a sustainable source of recovered cotton, Resources", *Conservation & Recycling* 145 (2019) 359–369.

[10] Shafiqul Islam and Gajanan Bhat, "Environmentally-friendly thermal and acoustic insulation materials from recycled textiles", *Journal of Environmental Management* 251, 109536, 2019.