Experimental Investigation on Hybrid Bio-Polyurethane Foam Composites

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***Abstract*—The aim of this paper is to study the influence of different natural fibres (banana fibre, egg shell and combination of banana fibre egg shell) when reinforced with polyurethane foam. Four different hybrid composites samples are prepared using melt mixing method, followed by compression moulding process. Mechanical (Tensile, flexural and compression) and water absorption properties of the hybrid composites is performed according to ASTM standards. In this context, the use of plant fibres and polyurethane foam composites derived from banana fibres and Egg shell powder composites has been shown to be a good alternative. Natural fibres have been selected for the process because they demonstrate good performance in terms of Mechanical properties and physical properties such as flexibility, stiffness, renewability, light weight and biodegradability. In this Project egg shell powder, Banana fibre and combination of egg shell powder and banana fibre are used as fillers in formation of hybrid Polyurethane.**

Index Terms— Hybrid Bio-Polyurethane Foam Composites

I. INTRODUCTION

The developing worldwide problem in connection with the global environment and the protection of non-renewable natural resources has fascinated researchers from different fields to come up with products based on ecological balance. Nowadays, the use of polyurethane foam filled with natural fibres has increased attention of researchers. The advantage of using natural fibres are their low cost, flexibility, stiffness, less weight. Natural fibres can be found in myriad places. They are also non-abrasive to equipment and requires less processing. Hybrid composites formed from the natural fibres show comparable or more properties than that of the synthetic fibre composites. Demographic distribution of natural fibres such as egg shell, banana fibre can be found in India. Many different types of natural fibres can be found in nature, which has been analysed for the purpose of using them as reinforcements for polyurethane foam composites. Banana fibre, and Egg shell have been identified as the ones which serve the purpose. Egg shell and banana fibre has properties that are similar to jute fibres. Fibres of Egg shell are coarse. They show good tensile and durability. They increase mechanical properties of the reinforced composites. Banana leaf fibre [BALF] is abundantly available and cultivated in coastal and tropical regions. Annually tons of BALF is being produced and a very less portion of is used for feedstock. The usage of banana leaf fibre in composites has increased its importance and reduced the wastage of BALF. Banana fibre has a high amount of cellulose content. Due to which it is hydrophilic nature. It also has high strength and stiffness. India stands at 5th place in production of Banana.

Polyurethane foam is a preferred choice of polymer because it has low cost, low heat conduction coefficient, low density, low water absorption property, relatively good mechanical strength with excellent insulation property and good adherence with other types of materials. Previous studies were made on polyurethane foam with kenaf, Talc, zinc borate and aluminium hydroxide and sisal. It is clear from the literature that no study has been carried out on Banana, Egg shell, individual, and hybrid polyurethane foam composites. This paper aims at studying the properties of prepared hybrid polyurethane foam composites with Egg shell, and banana leaf fibre. Tensile modulus, flexural modulus, compression and water absorption properties of composites were examined.

1) TPU's (Thermoplastic Polyurethane):

Thermoplastic polyurethane (TPU) is a preferred choice of polymer to produce engineering products because it has good physical and chemical characteristics, such as good mechanical properties, and good resistance to oil, grease and abrasion. Technically, TPU is a polymer consisting of linear chains which are divided into hard and soft segments of the copolymer. These properties joined to each other between segments flexibility, rigidity aromatic unit, chain stuck, orientation segment, hydrogen bonds and other molecules. TPU can be processed with extrusion, injection, blow and compression moulding equipment. Besides that, TPU can be vacuum-formed or solution-coated and is well suited for a wide variety of fabrication processes.

2) Preparation of mould:

The mould is prepared using the Acryline fibre sheets. The sheets are cut according to the required dimensions and attached together using the araldite glue to form the required Mould. Mould is left around a day for drying. An adjustable cover is also prepared to the set the specimen.

3) Material Preparation:

Polyurethane foam is prepared by mixing polyol and isocyanate in equal amounts. Banana leaf fibres with lengths of 20 and 30 mm were treated for 1 h under ambient conditions with 10 wt.% NaOH aqueous solutions. The fibres were washed thoroughly with water to remove the excess of NaOH and washed again with distilled water. Same procedure is used for Egg shell fibre and made in to Powder for proper setting with Pu foam.

4) Polyurethane Foam:

Initially releasing agent is completely applied on the inner surface of the mould and after 2-4 min, polyol and isocyanate are taken in equal volumes and then mixed with the help of a mixer. Now slowly the foam rises and appropriate weights are placed on the top plate so that it is properly balances the pressure of the rising foam to settle evenly, after some time reaction stabilizes and we can take off the weights and after 10 min when it completely cured it is properly taken out and cut according to the required ASTM dimensions in which the tests should be performed.

5) Hybrid Polyurethane Foam:

Releasing agent is completely applied on the inner surface of the mould and polyol and isocyanate are taken in equal volumes and then mixed with the help of a mixer and make sure they are properly mixed along with banana/egg shell fibre where these fibres are taken 5%,10wt% to the polyurethane solution , now slowly the foam rises make sure that appropriate weights are placed on the top plate so that it is properly opposes the pressure of the rising foam, after some time reaction stabilizes and we can take off the weights and after 10 min when it completely solidifies it is properly taken out and cut according to the required ASTM dimensions in which the tests should be performed.

II. Experimental Results

1) Tensile Test:

Tensile test is conducted according to ASTM D-638 using INSTRON 8801 at the temperature 25 and relative humidity of 60. Four Dumbbell shaped samples were cut according to ASTM dimensions and were tested. Measurements were taken at crosshead speed of 1.3 mm/min.

TABLE I
Tensile Test

	Specimen label	Tensile strain at maximum load %	Load at break (standard) (KN)	Tensile stress at break(standard) (MPa)	comment
1	001	5.54779	0.00	0.01	BALF
2	001	4.67699	0.00	0.01	PU
3	001	6.02031	0.01	0.05	PBE
4	001	7.27825	0.00	0.01	EGG SHELL
Maximum		7.27825	0.01	0.05	
Mean		5.88084	0.00	0.01	
Minimum		4.67699	0.00	-0.01	

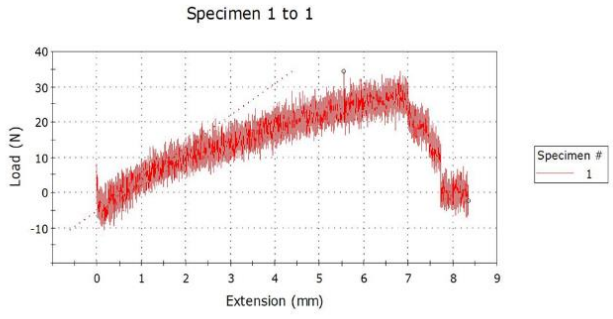


Fig. 1. Plot showing Extension vs. Load

2) Flexural Test:

Flexural or three point bending test was conducted according to ASTM D-790 using INSTRON 8801 at room temperature and relative humidity of 60. Four cuboid shaped samples were cut according to ASTM dimensions and were tested.

TABLE II
Flexural Test

S.No.	Specimen label	Comment	Max. load	Max. flexure stress(MPa)
1	001	Egg shell	18.36	0.24792
2	002	BALF	16.22	0.21895
3	003	PUF	13.63	0.18403
4	004	PBE	16.77	0.22643

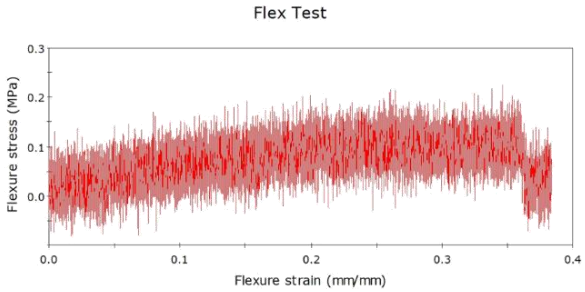


Fig. 2. Plot showing Flexure strain vs. Flexure stress

3) Compression Test:

Compression test is conducted according to ASTM D-1621-16 using INSTRON 8801 at the temperature 25 and relative humidity of 60. Four cuboid shaped samples were cut according to ASTM dimensions and were tested.

TABLE II
Compression Test

S.No.	Specimen label	comment	Max.comp. load (N)	Comp. strength (MPa)
1	001	Egg shell	222.2128	0.0669
2	002	BALF	167.81378	0.0888
3	003	PBE	168.2463	0.0673
4	004	PU	86.73663	0.0346

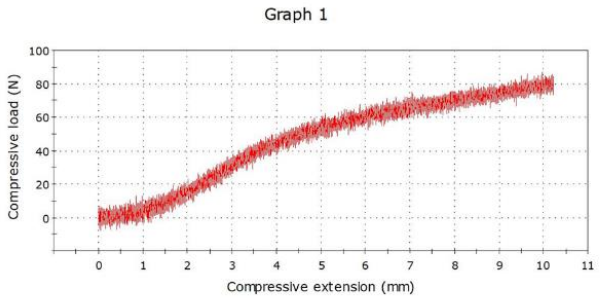


Fig. 3. Plot showing Compressive extension vs. Compressive load

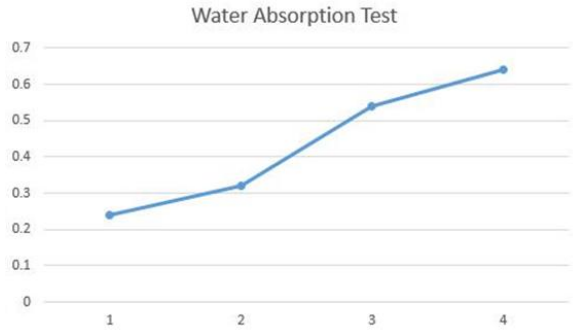
4) Water Absorption Property:

For the water absorption test, the specimens are dried in an oven for a specified time and temperature and then placed in a desiccator to cool. Immediately upon cooling the specimens are

weighed. The material is then emerged in water at agreed upon conditions, often 23°C for 24 hours or until equilibrium. Specimens are removed, patted dry with a lint free cloth, and weighed.

Water absorption is expressed as increase in weight percent.

Percent Water Absorption = [(Wet weight - Dry weight)/ Dry weight] x 100



1-POLYURETHANE PUF 2-POLYURETHANE BALF
3-POLYURETHANE EGG SHELL 4-POLYURETHANE PBE

Fig. 4. Water Absorption Test

III. Conclusion

Series of bio-PU composites containing dispersed diverse quantity of banana fibers and eggshell were successfully obtained and analyzed. Based on mechanical results, it was found that the banana fibers and eggshell can be added to the bio-based polyurethane matrix in the maximum quantity of 15 mass% and obtained materials characterize of good properties. Regardless of modified banana fibers and eggshell content, the composites are characterized by similar mechanical properties. On the whole, banana fibers and eggshell addition to the bio polyurethane matrix provided to increase in the composites mechanical properties compared to reference sample. It was found that with increasing banana fibers and eggshell in the bio-PU composites, the tensile strength and elongation at break increased. In the case of bio-PU composites containing banana fibers and eggshell, the tensile strength of these materials was similar although fibers content.

References

[1] A. M. Radzi, S. M. Sapuan, M. Jawaid, and MR. Mansor, "Influence of fibre contents on mechanical and thermal Properties of roselle fibre reinforced polyurethane composites," *Fibers and Polymers*, vol.18, no.7, pp. 1353-1358, 2017.

[2] A. Oushabi, S. Sair, Y. Abboud, O. Tanane, and A. El Bouari, "An experimental investigation on morphological, mechanical and thermal properties of date palm particles reinforced polyurethane composites as new ecological insulating materials in building," *Case Studies in Construction Materials*, vol. 7, pp. 128-137, 2017

[3] E. Baştürka, S. Madakbaşa, and M. V. Kahramana, "Improved thermal stability and wettability behavior of thermoplastic polyurethane / barium metaborate composites," *Material Research*, vol. 19, no. 2, pp. 434-439, April 2016.

[4] F. Pourjavaheri, O. Jones, F. Mohaddes, F. Sherkat, A. Gupta, and R. Shanks, "Green plastics: Utilizing chicken feather keratin in thermoplastic polyurethane composites to enhance thermo-mechanical properties',in *74th Annual Technical Conference of the Society of Plastics Engineers* 2016, Indianapolis, Indiana, 23-25 May 2016, pp. 1-8.

[5] G. Huang, and P. Wang, "Effects of preparation conditions on properties of rigid polyurethane foam composites based on liquefied bagasse and jute fibre," *Polymer Testing*, vol. 60, pp. 266-273, 2017.

[6] Y.A. El-Shekeil, S.M. Sapuan, K. Abdan, and E.S. Zainudin, "Influence of fiber content on the mechanical and thermal properties of Kenaf fiber reinforced thermoplastic polyurethane composites," *Materials & Design*, vol. 40, pp. 299-303, 2012.

[7] E. Głowińska, J. Datta, and P. Parcheta, "Effect of sisal fiber filler on thermal properties of bio-based polyurethane composites," *Journal of Thermal Analysis and Calorimetry*, vol. 30, no.1, pp. 113-122, March 2017.

[8] Maria Kuranska, Aleksander Prociak, Porous polyurethane composites with natural fibres, *Composites Science and Technology*, vol. 72, no. 2, pp. 299-304, 2012.

[9] A. Hejna, M. Kopczyńska, U. Kozłowska, M. Klein, P. Kosmela, and Ł. Piszczyk (2016), "Foamed polyurethane composites with different types of ash - morphological, mechanical and thermal behaviour Assessments," *Cellular Polymers*, vol. 35, no. 6, pp. 287-308, 2016.

[10] C. Merlini, V. Soldi, and G. M.O. Barra, "Influence of fiber surface treatment and length on physico-chemical properties of short random banana fiber-reinforced castor oil polyurethane composites," *Polymer Testing*, vol. 30, no. 8, pp. 833-840, 2011.

[11] S.M. Sapuan, F. Pua, Y.A. El-Shekeil, F. M. AL-Oqla, "Mechanical properties of soil buried kenaf fibre reinforced thermoplastic polyurethane composites," *Materials & Design*, vol. 50, pp. 467-470, 2013.