EXPERIMENTAL INVESTIGATION ON POLYURETHANE FOAM BY USING RESPONSE SURFACE METHODOLOGY

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***Abstract*- This research aims in the study of natural fibres of different weight percentages and its influence on mechanical properties of polyurethane foam. Hence, natural fibres obtained from the wastes of groundnut shell, ash powder and banana fiber is combined with normal polyurethane foam to increase its strength. Seventeen different hybrid composites are prepared with different weight percentages of groundnut shell powder, Ash powder and Banana fiber. Mechanical properties is performed for the hybrid composites. The hybrid composites are tested for a total of 17 specimens are prepared as per ASTM standards. Results obtained are verified using the response surface methodology. The graph has been plotted and the results are in significant according to the given values. The optimum weight percentage of Tensile and Compressive strength are 2 and 5 with 15.71456 and 13.69953 Mpa of Strengths. From the experiment it was found that the adding ash powder, groundnut shell powder and banana fiber increases the strength of polyurethane foam.**

I.INTRODUCTION

The products based on ecological balance paved way from researchers as they connected global ecological protection of natural resources with worldwide problem. Nowadays, the use of polyurethane foam combined with natural fibers has drawn mind of researchers. The advantage of using natural fibers are their low cost, flexibility, stiffness, less weight [1]. Natural fibers can be found in myriad places. They requires less processing [2]. Hybrid composites formed from the natural fibers show comparable or more properties than that of the synthetic fiber composites.

Many different types of natural fibers can be found in environment, which are been explored for using them as fillers for polyurethane foam composites [3]. Ash powder, Banana fiber and groundnut shell have been identified as the ones which serve the purpose. They show good tensile and durability [4]. Banana fiber (PALF) is abundantly available and cultivated in coastal and tropical regions [5]. India stands at 7th place in production of banana [6].

Polyurethane foam is a preferred choice of polymer because of its low cost, and relatively low heat conduction coefficient, with low density has very less weight, with low water absorption property makes it preferable in water travel, relatively better mechanical properties with excellent an insulation property and good adherence with other types of materials [9]. Previous studies were made on polyurethane foam with kenaf [10]. It is clear that no study has been carried out on Banana fiber, ash powder and groundnut individual, and hybrid polyurethane foam composites. This paper aims at studying the properties of prepared hybrid polyurethane foam composites with Ash powder, groundnut, and banana fiber. Tensile modulus and compression properties of composites were examined.

II.ASH POWDER

Fly ash is a fine, glass-like powder recovered from gases created by coal-fired electric power generation. Fly ash material is solidified while suspended in the exhaust gases and is collected by electrostatic precipitates or filter bags. Since the particles solidify while suspended in the exhaust gases.

Fly ash is sourced from state of the art government-run coal-fired thermal power plants in the State of Gujarat in India, which have one-source long-term contracts for quality coal fly ash procurement. Moreover, the in-built classification system in the power plant enables extraction of a specific fineness consistently.

III.BANANA FIBER

In Nepal, the trunk of the banana plant is harvested instead of the shoots. Small pieces of these trunks are put through a softening process for mechanical extraction of the fibers, and then bleaching, and drying. The fiber obtained thus has appearance similar to silk which has become popular as banana silk fiber yarn. This fiber is refined, processed and skeined mostly by the Nepalese women. Only the aged bark or the decaying outer layers of the banana plant are harvested and soaked in water to quicken the natural process. When all the chlorophyll is dissolved, only the cellulose fibers remain. They are extruded into pulp so that they may become suitable for spinning into yarn. The yarn is then hand- dyed. They have high textural quality similar to silk and as such employed in making high end rugs. These traditional rugs are woven by hand-knotted methods again by the women of Nepal.

IV. GROUNDNUT SHELL POWDER

Preparing Groundnut Shell Powder (GSP) is one of the easiest processes, Groundnuts are removed from the shells and empty shells are collected. The reason to use groundnut shell powder is, it is easily available and very low cost just (INR 15 per kilogram), and also it promotes the waste management at very low cost and reduce pollution by these wastes and for the farmers

it will increase their economic base by selling the waste and there by promoting more production

V. POLYOL

Polyols are compounds with multiple hydroxyl functional groups available for organic reactions. Polymeric polyols are the second component for polyurethanes and are reacted with isocyanates.

VI. ISOCYNATE

Isocyanates are compounds containing the isocyanate group (-NCO). They react with compounds containing alcohol (hydroxyl) groups to produce polyurethane polymers, which are components of polyurethane foams, thermoplastic elastomers, spandex fibers, and polyurethane paints. Isocyanates are the raw materials that make up all polyurethane products. Jobs that may involve exposure to isocyanates include painting, foam-blowing, and the manufacture of many Polyurethane products, such as chemicals, polyurethane foam, insulation materials, surface coatings, car seats, furniture, foam mattresses, under-carpet padding, packaging materials, shoes, laminated fabrics, polyurethane rubber, and adhesives, and during the thermal degradation of polyurethane products.

VII. THERMOPLASTIC POLYURETHANE

With good physical and preferable chemical properties, Thermoplastic polyurethane has become a likeable choice of polymer to produce many engineering products, with an exceptional resistance to abrasion, oil and grease .TPU's can be processed in many ways such as compression and blow moulding, injection and extrusion. And also suited for varieties of manufacturing processes. Properties of commercial TPU include high resistance towards oil and grease. And also has high elasticity with good transparency. With its moderately high shear strength mixed with great abrasion resistance makes thermoplastic polyurethane preferred choice for industrial applications .

VIII.MATERIAL PREPARATION

Polyurethane foam is prepared by mixing polyol and isocyanate in equal amounts. After the polyol is taken powdered mixture of Ash powder, Banana fiber and groundnut shell powder are taken and mixed with polyol. Later equal amount of isocynate is mixed withpolyol and is left to form the reaction. Now the hybrid polyurethane foam is prepared and tests are being conducted.

IX MATERIALS

Polyurethane foam produced using Polyol and Isocyanate with a ratio of 1:1 at room temperature are supplied by GSRR Resins and Polymers, Madurai. Banana fiber were supplied by the Counts, Coimbatore and Ash powder and Groundnut shell powder were supplied by Astra chemicals, Chennai. The levels and weight percentages are shown in below table

Table 2.1: Levels of Produced for Hybrid Polyurethane foam composites

Natural Fibers	Low	High
A Ash powder (Wt%)	1	4
B Banana fiber (Wt%)	1	5
G Groundnut shell (Wt%)	2	6

X. 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 to make sure they are properly mixed along with Banana fibre (1, 3, 5) wt%, Ash powder (1.0, 2.5, 4.0) wt% and groundnut powder (2, 4, 6) wt% to prepare seventeen different hybrid composites with different composition, now slowly the foam rises. To 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 the reaction stabilizes and the weights and after 10 min when it completely solidifies it is properly released out and cut according to the required ASTM dimensions for testing.

XI. CODES AND STANDARDS

Table 2.3 below shows tests that are conducted for reinforced composites and their respective ASTM standards followed.

Table 2.3: Codes and standards

S. No	TESTS CONDUCTED	ASTM STANDARDS FOLLOWED
1	Tensile Test	ASTM D638
2	Compression Test	ASTM D 1621-16

XII. RESULTS

Table 3.1: Experimental Values of mechanical tests

Specimen	Ground nut shell (Wt%)	Ash powder (Wt%)	Banana Fiber (Wt%)	Tensile (Mpa)	Compression (Mpa)
1	1	4	5	12.68	10.34
2	2.5	4	3	13.82	11.97
3	1	4	1	16.74	14.87
4	4	4	1	11.86	10.17
5	4	2	3	12.44	10.86
6	4	4	5	15.02	13.52
7	2.5	4	3	15.97	13.83
8	1	6	3	14.05	11.76
9	4	6	3	12.87	10.95
10	2.5	6	5	16.33	14.32
11	2.5	4	3	15.63	13.24
12	2.5	6	1	15.92	13.69
13	2.5	4	3	16.97	14.58
14	2.5	2	1	17.42	15.34
15	1	2	3	14.68	12.74
16	2.5	4	3	13.8	11.8
17	2.5	2	5	16.66	14.56

XIII.TENSILE TEST RESULTS:

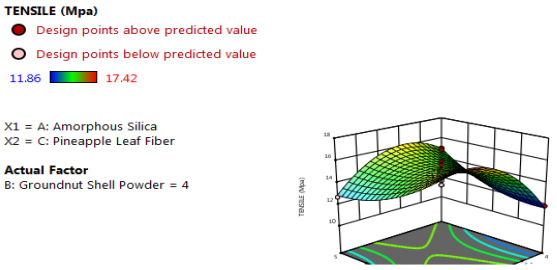

Figure 3.1: Effect of Banana Fiber and Ash powder on Tensile Strength

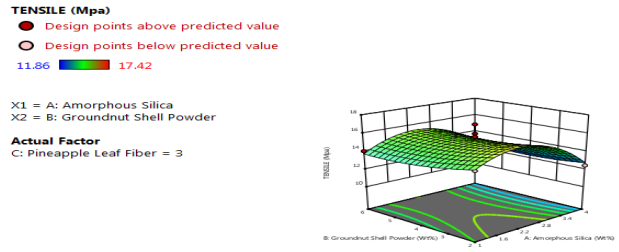

Figure 3.2: Effect of Groundnut shell Powder and Ash powder on Tensile Strength

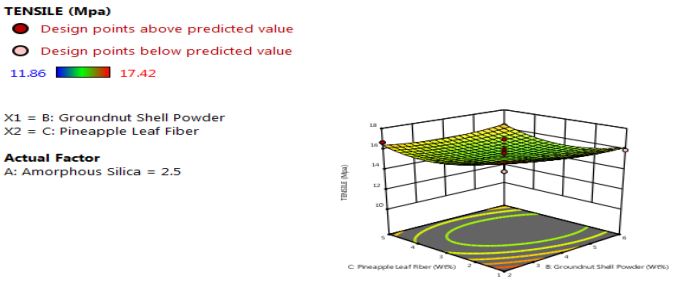

Figure 3.3: Effect of Groundnut shell Powder and Banana fiber on Tensile Strength

The main effects of Ash powder, Banana Fiber and Groundnut shell powder on Tensile Strength of polyurethane foam are shown in the above figures (3.1, 3.2, and 3.3). Fig 3.1 shows the effect of Banana fiber and Ash powder on the tensile strength. From the Fig 3.1 it can be noted that for weight percentage of Banana fiber up to 3 Wt% the tensile strength of composite increased slightly. Further increasing the weight percentage of Banana fiber the weight percentage was increased simultaneously. In case of addition of Ash powder to the composite the tensile strength value increased to a maximum of 17.42 at 1.5 weight percentage. Further increase in weight percentage of Ash powder decreased the tensile strength of the composite. A similar trend can also be seen in Fig (3.2 and 3.3). In fig 3.2 the tensile strength value decreased up to 11.86Mpa for 4 weight percentage of Groundnut shell powder and further increase in the weight percentage of groundnut shell helped the composite to increase the tensile strength. The maximum tensile

strength value observed was 17.42Mpa and the lowest being 11.49 Mpa.

TENSILE

= 21.3194 + 2.05111 * AS -1.34658 * G -3.30692 * PLF+ 0.0883333 * AS * G+ 0.601667 * AS * PLF+ 0.073125 * G* PLF -0.941222 * AS^2 + 0.0974375 * G^2 + 0.238688 * PLF^2

Equation (1)

Where G- Groundnut shell Powder, AS- Ash powder and PLF- Banana fiber

Using Design Expert the main effects of Ash powder, Banana fiber and Groundnut shell fiber on tensile strength was analysed. Equation -1 represents the quadratic model for Central Composite design of reinforced polyurethane foam composites.

XIV.COMPRESSION TEST RESULTS

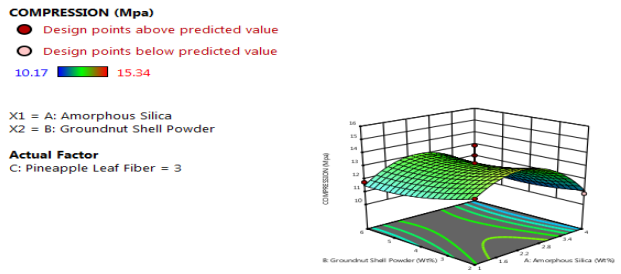

Figure 3.7 Effect of Groundnut shell Powder and Ash powder on Compressive Strength

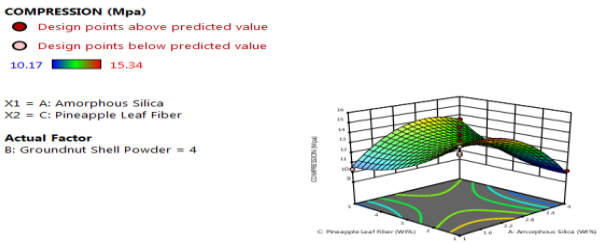

Figure 3.8 Effect of Ash powder and Banana fiber on Compressive Strength

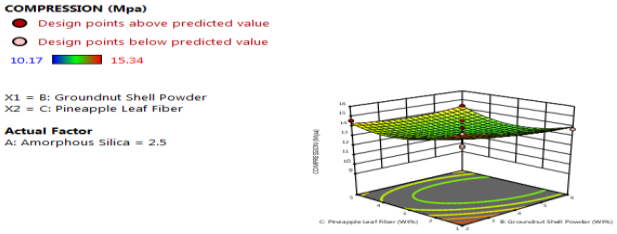

Figure 3.9 Effect of Groundnut shell Powder and Banana fiber on Compressive Strength

Effects of Ash powder, Banana fiber and groundnut shell powder on compressive Strength of Polyurethane foam are shown in Fig (3.7, 3.8, and 3.9). Fig 3.7 shows the effect of weight percentage of Groundnut shell powder and Ash powder on the reinforced composites. It can be seen that the Compressive strength decreased up to 10.17 weight percent of 4 for groundnut shell powder and increasing from then, increased the Compressive strength of the compositeupto 15.34. Whereas for Ash powder the compressive strength increased with increase in the weight percentage of the Ash powder in the composite preparation. Same generalizations can be deduced from Fig 3.8 and Fig 3.9.

COMPRESSION

= 20.3469 + 1.49917 * AS -1.40704 * G -3.60804 * PLF+ 0.0891667 * AS* G+ 0.656667 * AS* PLF+ 0.088125 * G* PLF -0.835333 * AS^2 + 0.09325 * G^2 + 0.255125 * PLF^2

Equation (2)

Where G- Groundnut shell Powder, AS- Ash powder and PLF- Banana fiber.

Using Design Expert the main effects of Ash powder, Banana fiber and Groundnut shell fiber on Compressive strength was analysed. Equation -2 represents the quadratic model for central composite design.

The suggested model's trustworthiness was evaluated using Analysis of Variance (ANOVA). The mathematical models establish to be significant with P-values of 0.0436, 0.0180 and 0.0240 for tensile and compression strength respectively. This shows that the model is significant fit to the experimental value and the lack of fit is not significant. From the variance analysis, F-value for tensile and compression was found out to be 3.89 and 4.89 respectively. Results showed that the quadratic models can be used to predict the results with 95% confidence level. The optimum weight percentage values of first five rank of tensile and Compressive strength are shown in Table 3.5.

Table 3.5: Optimum weight percentage of Banana fiber, Ash powder and Groundnut shell powder.

Number	Ash powder (wt%)	Groundnut shell powder(wt%)	Banana fiber (wt%)	Tensile (Mpa)	Compression (Mpa)	Desirability
1	2	2	5	15.75	13.55	0.590
2	2.5	2	5	16.32	14.21	0.567
3	1.5	2	5	14.73	12.50	0.546
4	3	2	1	15.58	13.71	0.537
5	3	2	5	15.23	13.72	0.534

XV.CONCLUSION

The hybrid polyurethane foam composites prepared from the reinforcements of Banana fiber, Ash powder and Groundnut shell powder will act as a good substitute and are manufactured at low cost and biodegradable in nature. On the other hand the hybrid foam composites prepared have significant differences in physical and mechanical properties when compared to neat PU foams.

This research proved that addition of natural fibers to the polyurethane foam to prepare hybrid composites enhances the mechanical properties due to good adherence between natural fibers and PU foam. After reaching to a certain extent further increase in fiber content in the PU matrix reduced the mechanical properties considerably due to formation of porosity and agglomerations. The optimum weight percentage to prepare a hybrid composite to achieve maximum desirability are Ash powder, Banana fiber and Ground nutshell powder are 2%, 5% and 2% respectively. These results are thus verified through mechanical characterization and statistical comparison using RSM.

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