The International Journal Of Engineering And Science (IJES)
|| Volume || 4 || Issue || 7 || Pages || PP -21-24|| 2015 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Development of Alternative Extenders for Flexible Polyurethane Foam Production Using Bambara Nut Shell and Corn Chaff

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ABSTRACT
The effects of bambara nut shell (Voandzeia Subterranean)and corn chaff (ZeaMays) as fillers for the production of flexible polyurethane foam were studied and compared with calcium carbonate filled sample. The fillers were reduced to 60µm, and 20g (20% parts per hundred polyol) of the fillers were introduced into the foam mixture. The density and mechanical properties tests were carried out on the samples. The results showed increase in densities of the Bambara nut and corn chaff filled samples as compared with calcium carbonate filled sample. In addition, the bambara nut filled sample gave the highest tensile strength property of 0.1720N/mm^2, it also showed 41.282mm for the elongation at break and 0.1934N/mm^2 for the elastic modulus. The corn chaff filled sample showed the greatest compressive strength of 20.025N force. The calcium carbonate filled sample offered the least compressive strength of 14.40N force.

KEYWORDS: *Bambara nut shell, corn chaff, calcium carbonate, density, tensile strength, compressive strength*

Date of Submission: 06 May 2015 Date of Accepted: 30 July 2015

I. INTRODUCTION

There has been a rapid increase in the production volume of flexible polyurethane foam, and this is as a result of new development areas such as packaging industry, furniture making, automotive industries and transportation. Foam can easily be cut or molded to almost any shape. At the same time, foam can be made to provide very supple or very firm cushioning for any given application. This remarkable versatility allows foam to provide the support needed for long-term medical confinement, or the comfort of furniture cushioning. Flexible polyurethane foam appears to be a simple product, but it is actually very complex. It can be produced to have an almost infinite variety of properties. Even though two foams may look exactly alike, they may feel and perform entirely differently (Intouch, 1991[1]).The polyol which is one of the main components of the foam is a product of petroleum and it is costly. Therefore, many researches to reduce the cost of foam production and also, the amount of polyol consumed in foam production have been in progress. One attempt to achieving this involved the chemical modification of its structure (Abdul-Rani et. al., 2004 [2]; Spitler et. al., 1981 [3]). Another modification involved the use of extenders commonly known as fillers (such as calcium carbonate, barium sulphate, clay, silicate, etc.) to achieve flexible polyurethane /filler composite formation.

Fillers are finely divided inorganic compounds which are purposefully added to foam formulations in order to increase their density, load-bearing ability, sound attenuation capacity, dimensional stability, and retraction from the mould (Saliba et. al.; 2005 [4] and Bartczak et. al.; 1999 [5]) at the expense of some undesired physical properties as well as some desired properties but to a safe degree. Also, depending on the nature of the filler used, significant cost reduction can be achieved. These fillers sometimes perform complicated roles during the chemical reactions of the polyurethane formation; this is because reactive filler groups on the surface can react with the diisocyanate and change the balance in the disocyanate–polyalcohol reaction. At higher concentrations, fillers have the tendency of increasing the viscosity of the reaction mixture which affects the cell growth process thus changing the cell geometry and consequently some physical properties of the foam (Erhievuyere-Dominic; 2008 [6]).

When adding a filler to a polymer to form a conjugated biphasic material, the tension applied to the polymeric matrix will be transferred in part to the disperse phase, the filler, since it presents properties superior to the pure polymer (Callister; 2000 [7]). Efficient reinforcement is achieved by interactions of the constituents of the biphasic material (Nunes et. al., 2000 [8] and Barma, 1978 [9]) via mechanisms of adhesion, which could be: adsorption, electrostatic attraction, chemical bonding and mechanical adhesion.

Chemical bonding is the most efficient form of adhesion and occurs with the application of coupling agents on the surface of the filler, which serves as a bridge between the polymer and the reinforcement. In mechanical adhesion, the polymer fills in the grooves of the filler; this adhesion tends to be low unless there are a large number of recesses on the surface of the filler (Rabello; 2000 [10]).

In principle any material can be used as filler. However, some aspects must be considered when selecting the material for this purpose. These include: size (Saint-Michel F. et. al.; 2006 [11]), in that the particles must be small and able to easily disperse in the polymer matrix; chemical purity, to avoid undesired reactions; and abrasiveness, which can cause excessive deterioration to the mixing equipment and increase costs (Rabello; 2000 [10]).

II. MATERIALS AND METHODS

2.1 Materials and Apparatus

The following materials were used; Polyol, Toluene diisocyanate (TDI), amine, silicone oil, stannous octate, methylene chloride, Bambara nut shell, corn chaff and calcium carbonate powder.The apparatus used include the following: The electrical grinder, triple beam balance, pH and conductivity meters, sieve and universal testing machine.

2.2 Preparation of the Filler

About 15kg of the bambara nut shell and corn chaff were collected and winnowed to remove extraneous materials, and then ground using the cassava crusher. The powdered materials were sun dried for two days. The size distribution of the filler was determined using U.S.A Standard Testing Sieve 60µm (ASTM E.11 Specification).

2.3 Preparation of the Flexible Polyurethane Foam

Polymeric polyol and toluenediisocyanate (TDI) were weighed out and poured into separate beakers. The raw materials required in small quantities were measured using triple beam balance. The 20g by weight of the fillers were also measured out, and other raw materials were measured based on 100g parts by weight of polyol. The mixture was poured into a mould. The mould was rubbed with mould release agent for easy removal of the foam block. The foam samples were kept at a room temperature of 25°C for 3 days before testing.

III. RESULTS AND DISCUSSIONS

The effect of the 20g by weight of the fillers on the density, tensile strength and compressive strength properties of the foam samples were studied and the results shown in Table 3.1.

3.1 Tensile Strength Analysis

Table 3.1: The effect of filler loadings on the tensile strength properties of flexible polyurethane foam

Fillers	**Density (g/cm^3)**	**Elongation at Break (mm)**	**Ultimate Tensile Strength (N/mm^2)**	**Young's Modulus (N/mm^2)**
Calcium Carbonate	1.1600	40.9990	0.1040	0.1138
Bambara nut shell	0.6700	41.2820	0.1720	0.1934
Corn Chaff	0.6900	24.5390	0.0790	0.1368

The Ultimate tensile strength is the maximum tensile stress the foam samples sustained without fracture, it determines the resistance of the foam to tearing and shredding during its end use application; the bambara nut shell filled sample gave the highest stress value of 0.1720N/mm^2 followed by the calcium carbonate filled sample with 0.1040N/mm^2 and the corn chaff filled sample with 0.0790N/mm^2.The elongation at break is the amount of permanent extension of the foam sample that has been fractured in a tensile test. Both calcium carbonate and bambara nut shell filled samples showed comparable elongation at 40.999mm and 41.282mm respectively, while corn chaff exhibits 24.539mm elongation at break. For the Young's modulus which is the ratio of stress (below the proportional limit) to strain, i.e., the slope of the stress-strain curve and also considered the measure of rigidity or stiffness of the sample ,the bambara nut filled sample showed a higher rigidity value of 0.1934N/mm^2, followed by calcium carbonate filled sample with 0.1138N/mm^2 and then corn chaff filled sample with 0.1368N/mm^2.

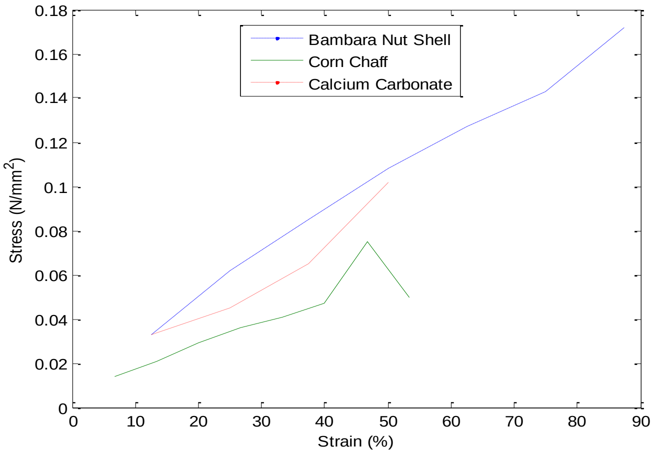

Figure 3.1: The effect of filler loadings on the tensile strength properties of flexible polyurethane foam

3.2 Compressive Strength Analysis

The ability of a foam board to resist deformation or maintain shape when a force or load is applied is due to the physical property known as compressive strength. It is defined as the force required to crush a material. Since foam samples do not fail on compressive strength test, the deflection of the foam at 30N compressive force was tested and recorded in Table 3.2.

Table 3.2: The effect of 20% filler loadings on the compressive strength properties of flexible polyurethane foam

Fillers	Deformation at Peak (mm)	Ultimate Tensile Strength (N/mm^2)	Energy to Break (N/mm^2)	Young's Modulus (N/mm^2)
Calcium Carbonate	19.9830	14.4000	0.1248	17.8110
Bambara nut shell	20.0550	16.1000	0.1150	21.9060
Corn Chaff	20.0250	20.3000	0.1888	20.4050

From Table 3.2 above, the calcium carbonate filled sample offered the least compressive strength because at 14.40N force it exhibited 19.983mm deformation; this is followed by bambara nut shell filled sample which exhibited 20.055mm deformation at 16.10N force. Corn chaff filled sample showed the greatest compressive strength because at 20.025N force it underwent 20.3mm deformation.

Also from the Table 3.2, the corn chaff filled sample required the highest energy to break which is $0.1888N/mm^2$ followed by calcium carbonate filled sample that required $0.1248N/mm^2$ and the Bambara nut shell filled sample which needs $0.12480N/mm^2$ energy to break.

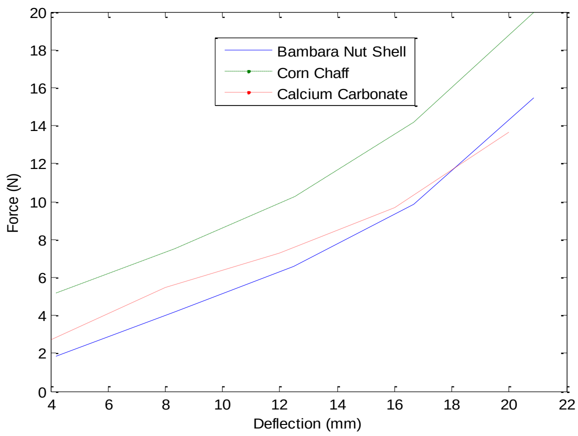

Figure 3.2: Effect of 20% Filler Loadings on the Compressive Strength of Flexible Polyurethane Foam

3.3 Porosity Index Analysis

Table 3.3: The effect of 20% filler loadings on the porosity index of flexible polyurethane foam

SAMPLE	WEIGTH BEFORE ABSORPTION (g)	WEIGHT AFTER ABSORPTION (g)	WATER ABSORBED (g)	POROSITY INDEX
20% $CaCO_3$	4.0810	10.7110	6.6300	1.6246
20% Bambara Nut Shell	1.8100	10.7540	8.9440	4.9414
20% Corn Chaff	1.7810	12.9410	11.1600	6.2661

Porosity index indicates the degree of the cell openness of a material; it is the ability to absorb moisture into void spaces. From Table 3.3, the corn chaff filled sample showed the highest porosity index of 6.2661 followed by the bambara nut filled sample with 4.9414 and then the calcium carbonate filled sample with 1.6246. Therefore, the corn chaff filled sample showed higher cell openings.

IV. CONCLUSION

From the above analysis, the results showed that the Bambara nut shell and corn chaff powder can compete favourably with calcium carbonate as fillers for flexible polyurethane foamproduction. The Bambara nut shell filled sample offered a better resistance to tearing and shredding and therefore can be use in upholstery. While corn chaff filled sample can be use in packaging applications since it showed a higher compressive strength.

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