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INVESTIGATION OF STRENGTH CHARACTERISTICS OF STYROFOAM AND GUM ARABIC IN BIODEGRADABLE MATERIALS FOR LAGGING PURPOSES

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Abstract

This work reports on the strength characteristics of Styrofoam and Gum Arabic in biodegradable materials for lagging purposes. The materials studied were sugarcane bagasse, coir, and kapok mixed with clay in different size grading of constituents. The sugarcane bagasse and coir were sun dried for 7 days, grinded using a blender and sieved to obtain 0.25, 0.375, 0.5, 0.75 and 1.0 mm sieve sizes. The clay was sun dried for 24 hours, grinded using laboratory pestle and mortar, and also sieved to obtain sieve size of 0.25, 0.375, 0.5, 0.75 and 1.0 mm. The kapok was obtained from kapok tree, separated from it pod by hand picking. The tensile strength of the samples were investigated using universal testing machine (Testometric FS 50AT). The results show that, the biodegradable composite with 0.25 mm size prepared with Styrofoam had UTS and MOE of 8.2% and 68% respectively higher than that prepared with gum Arabic.

1.0 Introduction

Lagging (thermal insulation) is carried out generally to conserve energy, control surface temperatures for personal protection and comfort, prevent vapor flow and water condensation on cold surfaces and increase operating efficiency of heating/cooling/ventilating and or plumbing in commercial and industrial installations [1]. According to [1, 2 and 3] the temperature ranges within which lagging applies is from -75°C to 815°C, applications below -75°C are cryogenics and above 815°C are refractories. Low temperature lagging materials include: polyurethane foam, polystyrene (expanded or extruded), fiber glass, mineral wool and cellular glass [4]. These are synthetic lagging materials which are presently in high demand due to their good mechanical and thermal properties coupled with their high production rate as a result technological advancement [5]. However, their adverse negative health effect on humans and the environment has become noticeable in recent years. [6 and 7] found that fiberglass is carcinogenic and while installing this lagging material one might feel itching, redness of skin and breathing issues.

Polyurethane foam is highly flammable whose smoke contains carbon monoxide, benzene etc. which is not good for environment as well as humans. Due to these disadvantages there is need to develop bio-degradable materials that can provide the strength characteristics of the synthetic lagging materials presently being used.

Composite materials are materials from two or more constituent materials with significantly different physical or chemical properties that, when combined with the aid of a binder, produce a material with characteristics different from individual components [8]. They are cohesive structures made by physically combining two or more compatible materials, different in composition and characteristics and sometimes in form [9]. Bio-Composite insulating materials are renewable, cheap, completely or partially recyclable, and biodegradable. Plants, such as flax, cotton, hemp, jute, sisal, kenaf, pineapple, ramie, bamboo, banana, coconut fiber, sugarcane bagasse, kapok, etc., as well as wood, used from time immemorial as sources of lignocellulose fibers, are more often applied as the reinforcement of composites. Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, polystyrene, polyurethane, carbon and man-made fibers used for low temperature thermal insulation. Renewable fibrous thermal insulation materials from trees, plant or animals has the ability to regenerate itself, it requires less energy for production and biodegrade easily when disposed as waste hence have low environmental impact [10]. Using agricultural by products as lagging material also generates economic development for farmers in rural areas. A cheap reliable and abundant supply of biodegradable fibrous materials can be obtained as waste by-products from many commercial agricultural processing industries [11]. Materials such as kapok, coconut and sugarcane fiber, cotton, wheat straw, palm leaves, oil palm fiber and others consist of lignocelluloses fibers which can be used as alternative lagging materials. Agricultural wastes such as, sugarcane bagasse, coconut husk, corn cob or stalk oil palm shell and leaves or straw from cereal crops have high degree of fibrous content (lingo-cellulosic compound) and can serve as the main ingredient for composite materials making them suitable for manufacturing of lagging materials. A composite material requires a binder to hold the different constituents together since the constituents cannot chemically react. [12 and 13].
Among the binders is Gum Acacia or Arabic (GA) which is an edible natural gum, obtained from the mature stems and branches of Acacia Senegal [14]. A non-viscous liquid with rich soluble fibers. The properties observed in GA have wide range of applications in industry, it is used as a stabilizer, a thickener, emulsifier in food industries as well as packaging material in pharmaceuticals. [15]. This makes GA a biodegradable binder suitable for production of biodegradable lagging materials. This study investigates the strength characteristics of Styrofoam and Gum Arabic as binders for lagging purposes.

2.0 Materials and Materials Preparations

2.1 Materials

The binding materials used for this work were Styrofoam (STYF), waste from packaging industry and Gum Arabic (GA) powder manufactured by Nike Chemicals India. The Agricultural bi-products used to test the efficacy of the two binders were sugarcane bagasse and coconut fiber (coir) while the biodegradable ones were kapok from kapok tree and clay.

2.2 Materials Preparations

2.1.1 Sugarcane Bagasse: Sugar cane Bagasse was obtained as waste material from a dump site, the obtained bagasse (Fig 1) was washed and sun dried for 3 days. The dried bagasse was then blended using a blender The blended bagasse was sieved (Fig 2) using mechanical shaker to

obtain 0.25 mm,0.375 mm,0.5 mm, 0.75 mm and 1.0 mm sieve sizes respectively which are the available sieves parameters.



Fig: 1 Dried Bagasse (before preparation)



Fig: 2 Bagasse sieved into different size

2.1.2 Coir: Coir was obtained from the left over of the coconut Endocarp. The coir (Fig 3) was removed from the outer shell using knife and plier. Further processing of the coir follows the same procedure for that of sugarcane bagasse to obtain different sizes (Fig. 4).



Fig: 3 Dried Coir (before preparation)



Fig: 4 Coir sieved into different sizes

2.1.3 Clay: The clay was locally sourced at a clay site in Share, kwara state, Nigeria. The clay (Fig 5) was sun dried for 3 days. Laboratory mortar and pestle was used to reduce the clay to granules for sieve analysis. The clay was then sieved (Fig 6) using a mechanical shaker into 0.25mm,0.375mm,0.5mm,0.75mm and 1.0mm sieve sizes respectively



Fig: 5 Raw Clay (before preparation)



Fig: 6 Clay sieved into different sizes

2.1.4 Kapok: Kapok pods (Fig 7) were obtained from kapok tree; the wool (Fig 8) was then carefully removed from the pod. The kapok wool obtained was then brushed to remove unwanted black particles.



Fig:7 Kapok pod



Fig: 8 Kapok wool

2.2 Sample Formulations

Samples were weighed using an electronic weigh balance (Model HX-T-1037) with 300 g maximum capacity and sensitivity of 0.01 g. 0.5 g of kapok was mixed with 3.5 g of bagasse and

3 g each of coir and clay to give a total of 10 g for each sieve size sample (Table 1). 50% of the total sample (i.e. 5 g) of GA was dissolved in 50 g of water and mixed thoroughly before pouring into the mold to make three samples each per sieve size. (totaling 15 samples). The same procedure was followed for the Styrofoam, however, a solvent was used to dissolve 5 g of Styrofoam making a total of 30 samples for all the five sieve sizes. The mold was set on a Testometric universal testing machine (Model: FS 50AT) (Fig 9) where a static load of 180 N (Abdulkareem *et al* 2016) was applied for five minutes, after which they were removed and weighed. The samples were thereafter put into an oven at 105 degrees Celsius for 9 hours, [16] the samples (Fig 10) were then weighed to determine their dry weight.

Table: 1 Sample formulation

Sieve size (mm)	Kapok (%)	Bagasse (%)	Coir (%)	Clay (%)	Binder (%)
0.25	5	35	30	30	50
0.375	5	35	30	30	50
0.5	5	35	30	30	50
0.75	5	35	30	30	50
1.0	5	35	30	30	50

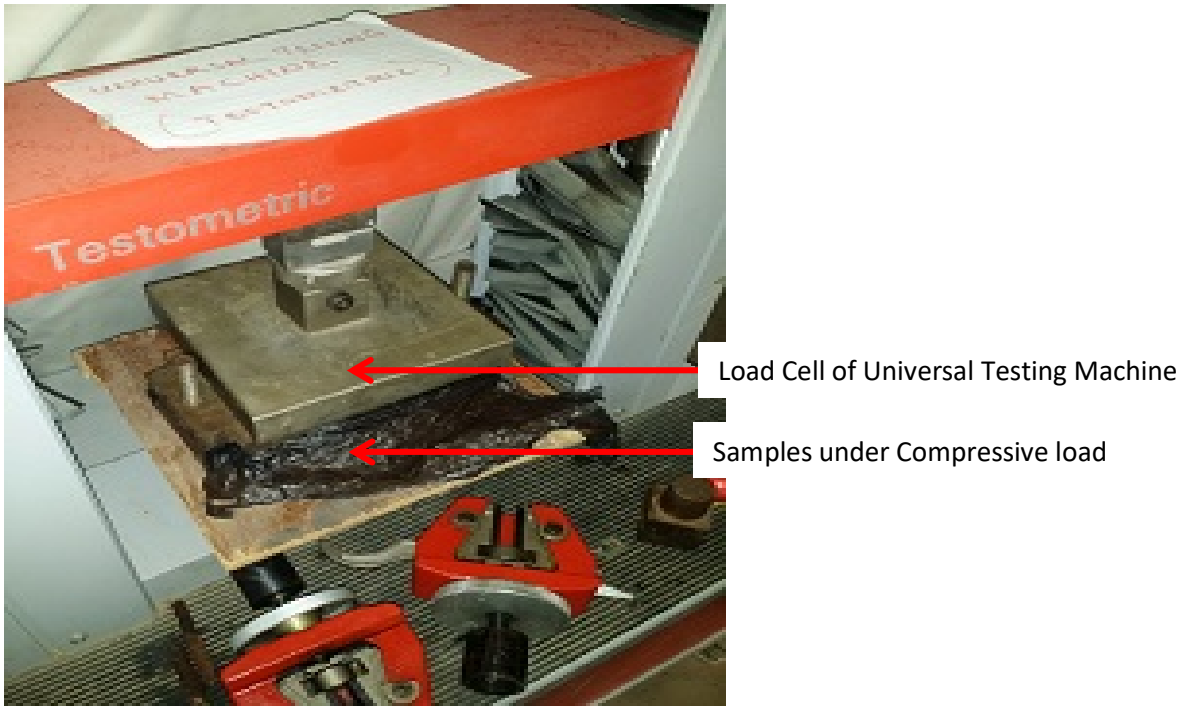


Fig: 9 Samples under load



Fig: 10 Dried samples

2.3 Tensile Test

The tensile test of the samples was determined in accordance with ASTM standard D- 3039 2014 using the 50 KN Testometric universal testing machine Model FS-50-AT. The samples were mounted one at time and test speed of 2 mm/minute was applied until samples failed (Fig 11). The test was repeated for the two binders (Styrofoam and Gum Arabic) in consideration. The ultimate tensile strength (UTS) and the modulus of elasticity (MOE) were then recorded for the two binders.

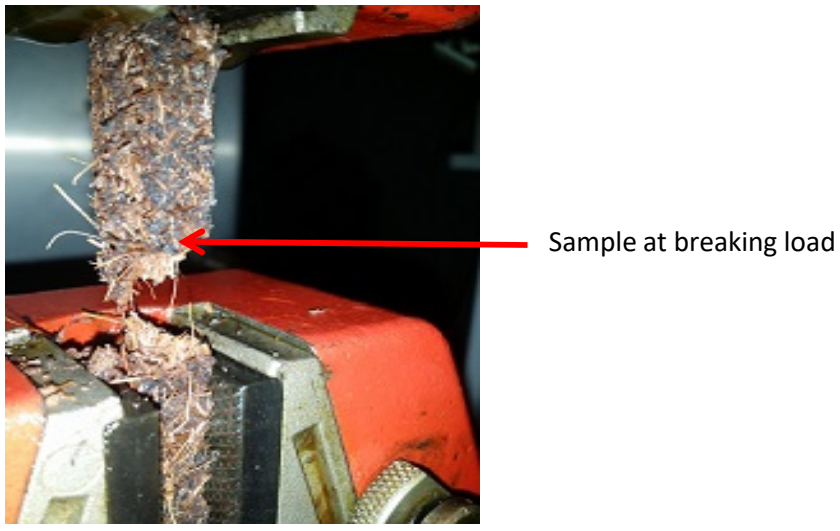


Fig: 11 Sample being tested on the UTM

3.0 Results and Discussions

3.1 Styrofoam

Figure 12 shows the result of UTS against sieve sizes. It can be observed that 0.5 mm sieve size sample mixed with Styrofoam has the highest UTS of 0.174 N/mm² with density (Table 2) of 0.805 g/cm³ and MOE of 31.698 N/mm² (Fig. 13). There is steady increase in tensile strength

with increase in the sieve size until after 0.5 mm particle size when the strength drop drastically at 1.0 mm sieve size as the size increases. This occurred to both sieve size, and density, at sieve size of 0.25 mm the particles are very small with high density which did not allow for proper homogeneous mixing with the binder since there was little space between particles for the Styrofoam binder to occupied. Furthermore, the difficulty of working with Styrofoam being dissolved in a solvent which tends to evaporate as soon as the solvent is added. But with higher sieve size of 0.5 mm there was just enough room for the binder to properly mix with the materials, and as the sieve sizes were increased to 0.75 mm and 1.0 mm the particles became too large and this reduced the cohesive force between the binder and materials.

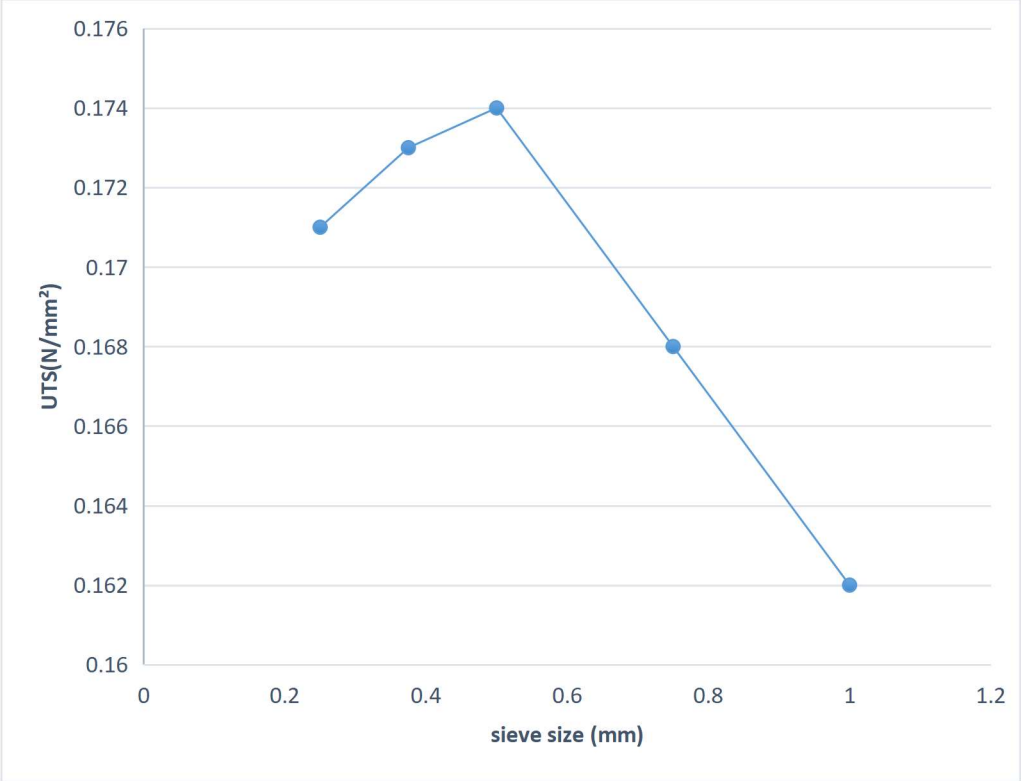


Fig: 12 UTS against Sieve Size (for Styrofoam)

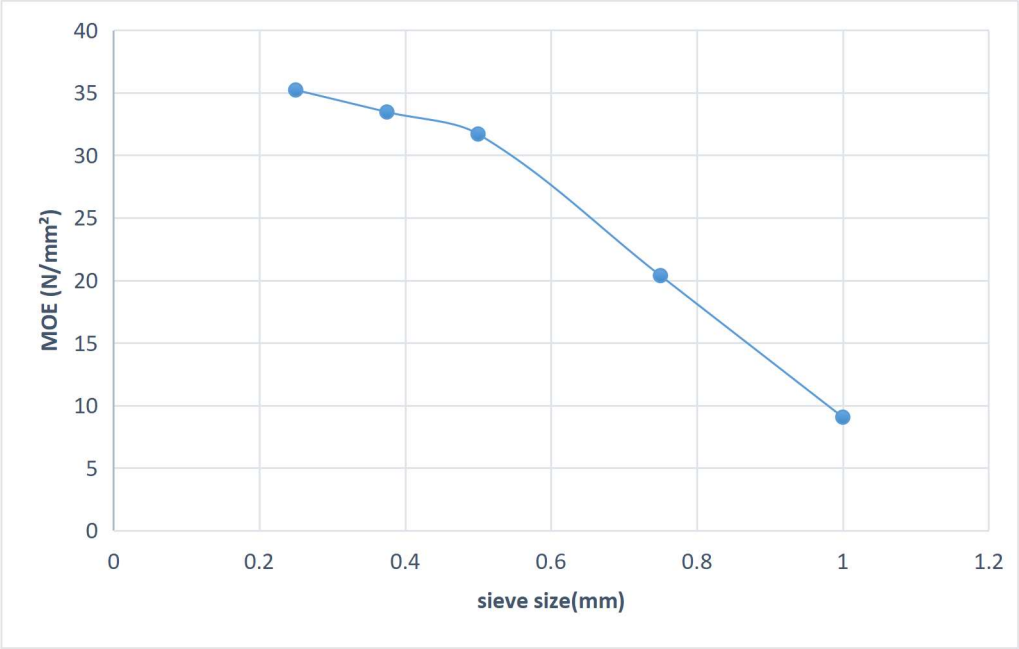


Fig 13: MOE against Size (for Styrofoam)

3.2 Gum Arabic

Unlike the Styrofoam binder, samples mixed with Gum Arabic shows a consistent declining in UTS as sieve size increases (Fig 14). Ultimately dropping to 0.103 N/mm². This observation is likely to be attributed to the better homogeneous mixing achieved with the Gum Arabic as it is water soluble and more stable to work with compared with the Styrofoam binder.

The 0.25 mm sieve size mixed with Gum Arabic has the highest tensile strength of 0.156 N/mm² with highest MOE (Fig. 15) value of 11.168 N/mm² and highest density of 0.852 g/cm³. This can be attributed to the small particle size and better homogeneous mixing which enabled the biodegradable Gum Arabic binder dissolved in water to mix thoroughly with the materials.

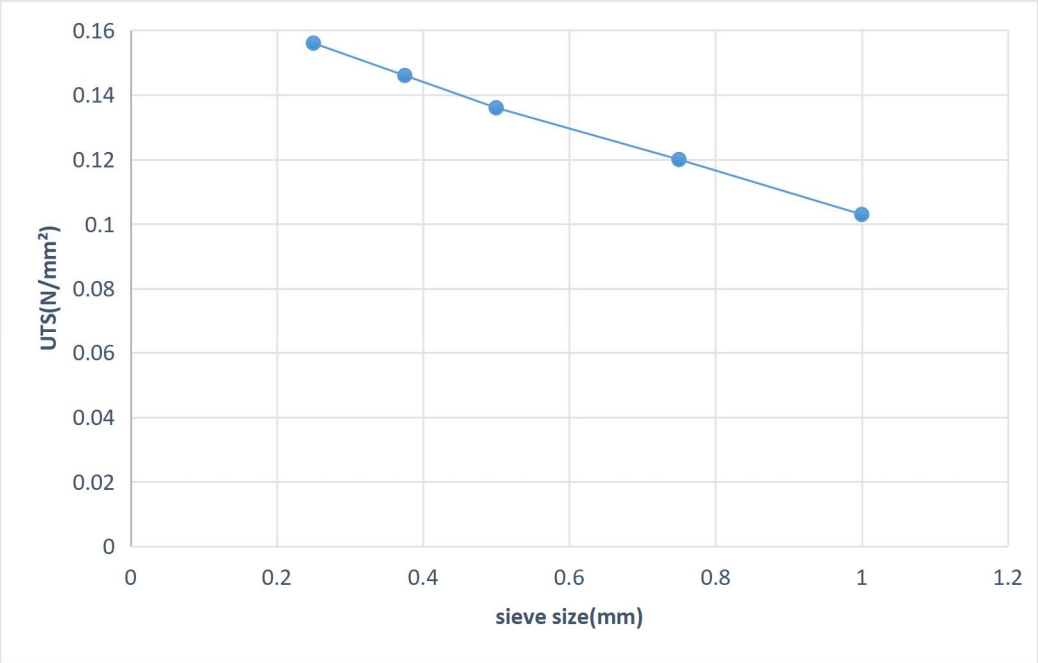


Fig 14: UTS against Sieve Size (for Gum Arabic)

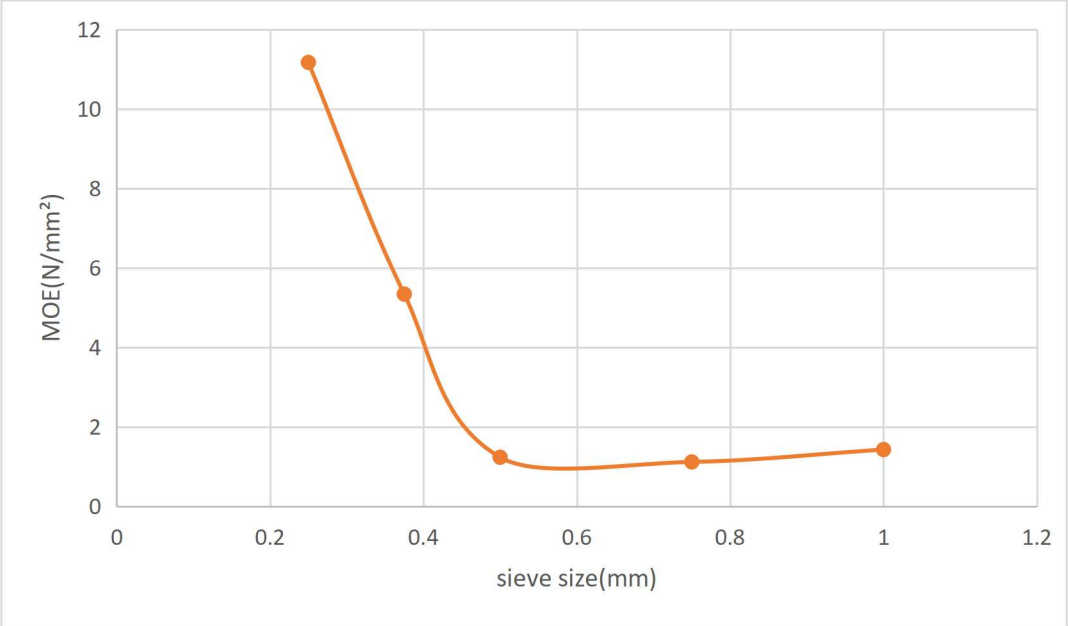


Fig: 15 MOE against Sieve Size (Gum Arabic)

Table: 2 density of samples mixed (Gum Arabic and Styrofoam)

Sieve Size (mm)	Gum Arabic					Styrofoam				
	0.25	0.375	0.5	0.75	1.0	0.25	0.35	0.5	0.75	1.0
Density (g/cm³)	0.852	0.753	0.683	0.661	0.643	0.783	0.794	0.805	0.814	0.823

Conclusions

The conclusions derived from the study can be summarized as thus: The observed strength characteristics of Gum Arabic and Styrofoam as potential binders for bio composite used for lagging has shown that the two binders can be applied though each with its peculiarity. Gum Arabic has a close tensile strength and dry density to that of Styrofoam, which makes it suitable as a binder for biodegradable lagging materials, however, it has lower modulus of elasticity compared with Styrofoam which makes it unsuitable for lagging in areas where stiffness is required. The MOE is quite different with samples mixed with Styrofoam having higher MOE values over samples mixed with gum Arabic, this might influence the decision to pick Styrofoam as a good binder if stiffness of the lagging material is of importance.

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