Characterisation of Natural Fibres (Sugarcane Bagasse) in Cement Composites

M. J. Ghazali, C. H. Azhari, S. Abdullah & M. Z. Omar

Abstract— **In this work, Malaysia's natural sugarcane bagasse fibres and Portland cement were used as precursors for composites, with styrene butadiene (SBR) latex as a binding agent. The matrix was Portland cement whilst the filler and reinforcement was bagasse fillers. Various compositions of SBR ratio; ranging between 3 - 18 %wt were prepared for evaluation. These samples were then evaluated for mechanical property measurement as well as morphology. It was found that the composites with 6 % of SBR content showed the highest stiffness. Composites with the highest stiffness and elastic modulus value were then subjected to radiations between 10 - 70 kGy. The electron beam radiation technique at different doses was carried out in order to modify the microstructure of the bagasse/cement composites. It was noted that the elastic modulus was greatly improved by 26.5% with 30 kGy radiation dose. Analyses by the scanning electron microscopy on the microstructures of the irradiated composites indicated that the voids within the matrices were greatly reduced, which therefore increases the mechanical properties of the composites, as a whole, than those of unirradiated ones.**

***Index Terms*— sugarcane bagasse, mechanical properties, cement composites**

I. Introduction

Requirement for economical and environment-friendly materials has extended an interest in natural fibres. Most of the natural fibres, like softwood pulp [1] and banana [2] fibres have been used as reinforcement materials in cement composite products. In this work, natural sugar cane bagasse have been utilised for similar study. Bagasse is a fibrous residue obtained from sugar cane during extraction of sugar juice. Sera and co-workers [3] studied the effect of reinforcing concrete with bagasse fibres. The bagasse fibres were boiled in water for 30 minutes to remove the sugar prior to using it as reinforcement. In the vast majority of countries in South-East Asia, sugar cane is a commercially grown agricultural crop. Countries like Guadeloupe (The French West Indies) have been using the bagasse as a combustible material for energy supply in sugar cane factories as in thermal power station. But other countries such as Egypt, Cuba, etc. used it in pulp, paper industries and for board materials [4]. Thus, these natural residues are not just helping some nations in their economy, but also reducing or eliminating urban waste.

The aim of the present work is to study the influences of varying the binding agent; styrene butadiene latex dispersion (SBR latex) contents and the electron beam irradiation doses on mechanical properties of sugarcane bagasse fibres cement composites. It was found that in previous literatures, the latex content may increase some properties like flexural strength and impact resistance, but the works were focused only on other types of fibres; carbon [5], bamboo [6] and steel [7].

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II. Methods & materials

A. Starting Materials

The main precursor; sugarcane bagasse is obtained by crushing the cane stalks using the RLL-3 Portable Crusher before being washed under running water. The crushed bagasse was then dried at 105^{o}C for 24 hours and grind. After grinding, the fibres were sieved, yielding particles with < 5 mm in length and diameter that ranged between 300 – 500 μm.

Commercial Portland cement was used as one of the precursor. The chemical composition of this cement is given in Table I.

Table I. Chemical composition of Portland cement (%)

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO
20.32	4.20	5.56	63.96	1.13
SO_3	Ignition loss	Free CaO	Insoluble residue	
1.57	2.22	1.22	1.64	

To ensure good contact between the bagasse and cement, styrene butadiene latex dispersion (SBR latex) provided by Synthomer company was used as the binding agent. Table II shows the important properties of the polymer latex.

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Table II. Properties of styrene butadiene latex dispersion (SBR latex)

Total Solids (%)	47
pH	10
Viscosity (Brookfield LVF, 60rpm) mPa.sec	<500

B. Sample Preparation

Blended cement composites were prepared by mixing the Portland cement with bagasse fibres and water. The mixing process was carried out by using the Winkworth mixer machine with water to cement ratio (W/C) of 0.25. The water was added gradually to the fibre-cement mixture for 5 minutes. Polymer emulsions were added to the mixture of fibre-cement composites after a complete addition of water, for a period of 10 minutes, with different weight percentages of 3, 6, 9, 12, 15, 18 and 21% to the weight of the mixture, respectively.

The homogenous mixture was then hot-pressed into a mould of 10 mm diameter and 3.5 mm thick at 130^{o}C with 50 tons load for 30 minutes. The samples were finally cooled at room temperature and kept for mechanical testing.

C. Mechanical Tests & Electron Beam Irradiation

The mechanical test (tensile) of the composite samples was carried out according to the ASTM standards prior to the irradiation process in order to select samples with good mechanical properties.

Samples that exhibited the highest value of the mechanical properties were selected to be irradiated in air at ambient temperature for different doses; 10, 20, 30, 40, 50, 60 and 70 kGy. Most parameters of the accelerator were fixed; 3.0 MeV of energy, 20 mA of beam current, and scan width of 3.4 cm. Detailed investigations of the fracture surface morphology of bagasse fibre cement composites were carried out using a Philips XL30 scanning electron microscopy (SEM).

III. Results & Discussion

A. Mechanical Properties

Fig. 1 shows the tensile strength and Rockwell hardness of the bagasse fibre/polymer cement composite as a function of SBR percentages. It was found that the strength increases with the polymer latex ratio up to 6% and decreases gradually as the SBR percentages increased, whilst the hardness property decreased with increasing polymer latex ratio.

The observation is essentially depended upon adhesive forces between the composite components during the hot pressing process. When polymer emulsion is allowed to dry through water loss by evaporation or absorption into a substance, the suspended resin or polymer particles are crowded together. The capillary forces due to concave menisci at the water-air interface generate forces of sufficient magnitude to overcome the repulsive forces between polymer particles, which are then through into contact, at the same time causing an increase in concentration of the material soluble in water phase. Further evaporation of the retained water will exert considerable capillary pressure leading to closer contact between suspended polymer particles in the latex. So, the driving forces for the coalescence of the polymer particles arise from surface tension and capillary forces [8]. These forces increase with decreasing particle size resulting from water loss. The quantity of emulsion also exerts an influence on the development of the final mechanical properties.

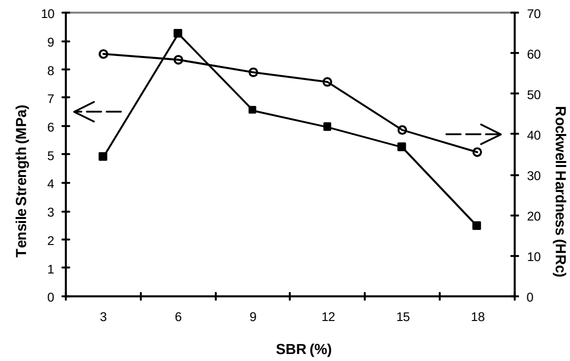

Fig. 1. Effect of polymer latex ratio on tensile strength and hardness of bagasse fibre-cement composites

In this work, the strength of the bagasse polymer cement composite increases with increasing emulsion percentage at a certain ratio as results of the diffusion of the emulsion latex into the hollows of the bagasse fibres. When the samples were hot pressed at 130^{o}C, the water evaporated and the latex particles reacted with the bagasse fibres, in which the latex particles reacted with the cement constituents to form a three dimensional structure, leading to a strong adhesion of composite components.

Addition of emulsion latex is associated with the improvement of the tensile strength of the composite up to 6 % of the emulsion latex. A gradual decrease in tensile strength, particularly in hardness value is noted with further addition of latex percentage. This was likely due to the water content in the mixture that increases as the percentage of polymer latex increased, leading to a higher porosity in final products (as shown by an arrow in Fig. 2(b)).

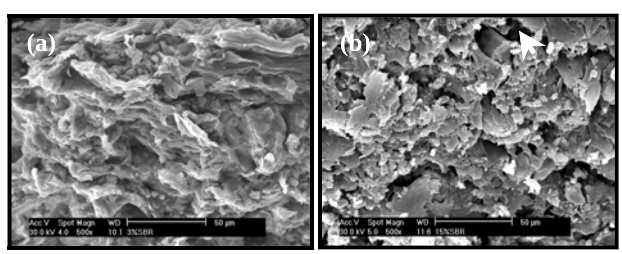

Fig. 2. Fracture surface of (a) 3% and (b) 15% of SBR content in bagasse fibre-cement composites

B. Electron Beam Irradiation Doses

Based on the mechanical tests, it was found that bagasse fibre-cement composites with 6 % of SBR exhibited the best hardness and tensile strength. Thus, the selected samples were subjected to irradiation doses ranges from 10 to 70 kGy.

Fig. 3 shows the tensile strength of the bagasse fibre/polymer cement composite as a function of electron beam irradiation dose.

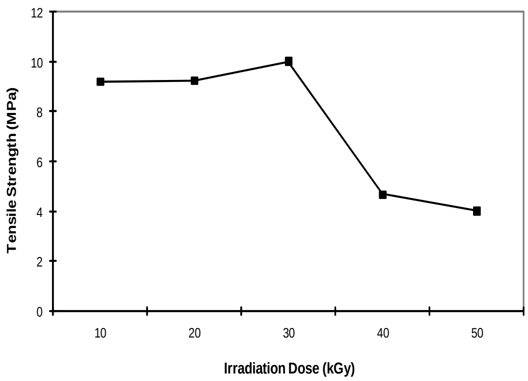

Fig. 3. Effect of electron beam irradiation dose on tensile strength of bagasse fibre cement composites.

The result indicated that the tensile strength of bagasse polymer cement composites increased with increased irradiation dose up to 30 kGy and decreased as the doses increased. For the first three doses (10, 20 & 30 kGy) radiated polymers will experience changes such as chain-scission, cross-link, recombination of broken chains [9] in their microstructures and also capable of dislocating or abstracting hydrogen atoms from the polymer chain [10]. The sites where hydrogen has been abstracted can instantly be joined with adjacent molecular chains to form strong bonds.

In this work, an increase of tensile strength in samples radiated at 10-30 kGy doses are mainly due to the formation of chemical bonds between ionic polymer with both fibres and hydrated cement. During mixing of the composite components, the latex polymer was distributed and filled into voids and porous areas within fibres and cement particles. Thus, interaction of both hydroxyl groups; ionic polymer with both fibres and hydrated cement, yields adhesion within the composite components [11]. However, with further irradiation doses, polymer scission and degradation may occur, which lead to reduction in tensile strengths.

C. Morphology Analyses

Fig. 4 shows the fracture surfaces of both irradiated and unirradiated cement fibre composites with different SBR contents. It was clearly noted that the presence of agglomerated SBR latex precipitated in the hollows and on the surface of the bagasse fibres (Fig. 4 (b)). Thus, when the fibre and matrix combined, organic composition and hydration products in the matrix diffuse each other, resulting denser materials.

Fracture surface of irradiated composite as shown in Fig. 4 (c) proves that the bagasse fibres and hydrated products of cement are diffused together and deposited on the interface layer between the bagasse and the matrix. The voids between the composite components were almost diminished, leading to an increase in the interface layer which consequently improved the mechanical properties of the material as a whole, compared to the unirradiated ones.

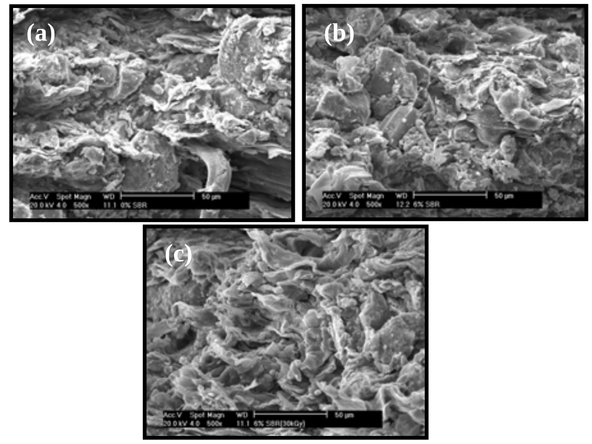

Fig. 4. Fracture surface of unirradiated cement fibre composite with (a) 0% (b) 6% and (c) irradiated cement composite with 6% of SBR content.

IV. Conclusion

The ratio and adhesion behaviour of bagasse-SBR-cement matrix played an important role in determining the mechanical propoerties of the composite product. It was found that composites with 6 % of SBR exhibited the greatest tensile strength with good hardness properties. Tensile strength of composites increased with increasing electron beam irradiation doses up to 30 kGy.

In general, mechanical properties of irradiated composites showed improved mechanical properties compared to both unirradiated composites and composites without any SBR latex.

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