A REVIEW ON THE USE OF NATURAL FIBRES OF COGON GRASS MIXED WITH CONCRETE FOR RADIATION SHIELDING MATERIALS

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ABSTRACT

All living organisms and human beings on Earth continually exposed to harmful ionizing radiation from natural radionuclides and man-made radiological sources. As we cannot eliminate the risk of ionizing radiation from our daily life, protective actions needed to minimize the effects of radiation. Concrete is amongst the most common and inexpensive materials used for ionizing radiation shielding in radioactive source and radiation generation facilities other than lead. Concrete has a high shielding potential against radioactive radiation and good long-term longevity relative to other building materials. Specific natural fibers then incorporated into conventional concrete to improve the strength and shielding performance. Currently, the eco-friendlier material is demanded across the world, where therefore, this study uses a cogon grass fibre, which is in the class of natural fibre as reinforcement materials mix with concrete to enhance the performance of radiation shielding. The use of cogon grass as an alternative fiber will improve the use of unused resources and reduce global demand for deforestation. In fact, the insertion of fiber to the concrete matrix has long been accepted as a way of enhancing strength absorption. These fibers can even provide a tolerance to post splitting, high-energy absorption and an increased fatigue resistance of cement-based composites.

ABSTRAK

Semua organisma hidup dan manusia di Bumi terus terdedah kepada sinaran pengion berbahaya dari radionuklida semula jadi dan sumber radiologi buatan manusia. Oleh kerana kita tidak dapat menghilangkan risiko pengionan radiasi dari kehidupan seharian kita, tindakan perlindungan diperlukan untuk mengurangkan kesan radiasi. Beton adalah antara bahan yang paling biasa dan murah yang digunakan untuk pelindung sinaran pengionan di sumber radioaktif dan kemudahan penjanaan radiasi selain plumbum. Beton mempunyai potensi pelindung yang tinggi terhadap sinaran radioaktif dan jangka hayat jangka panjang yang baik berbanding dengan bahan binaan lain. Serat semula jadi tertentu kemudian dimasukkan ke dalam konkrit konvensional untuk meningkatkan kekuatan dan prestasi pelindung. Pada masa ini, bahan ramah lingkungan dituntut di seluruh dunia, di mana oleh itu, kajian ini menggunakan serat rumput cogon, yang berada di kelas serat semula jadi sebagai bahan penguat yang dicampur dengan konkrit untuk meningkatkan prestasi pelindung radiasi. Penggunaan rumput cogon sebagai serat alternatif akan meningkatkan penggunaan sumber daya yang tidak digunakan dan mengurangkan permintaan global untuk penebangan hutan. Sebenarnya, penyisipan serat ke matriks konkrit telah lama diterima sebagai kaedah meningkatkan penyerapan kekuatan. Serat ini bahkan dapat memberikan toleransi terhadap pemisahan pasca, penyerapan tenaga tinggi dan peningkatan daya tahan keletihan komposit berasaskan simen.

Keywords: concrete, cogon grass, ionising radiation shielding, building materials

INTRODUCTION

There are various uses of ionizing radiation that lead to maintaining high quality and protection of our everyday lives for instances where smoke sensors were used to alert people when the fire occurs, x-ray devices that were able to detect concealed weapons, as well as other kinds of imaging are all used by society to search diseases. However, lack in handling the radiation, or securely secured, a person who has exposed to its for more than a few minutes is likely to suffer permanent injury and cause deadly exposure within several minutes or one hour if not shielded. This is when the radiation shielding concrete come across to an act where it was built so that this harmful radiation can be shielded.

The ability of concrete to be used in many fields that required shielding of radiation sources is well recognized and acknowledged by most researchers. Furthermore, various reinforced concrete has been made to enhance the properties and performance of the concrete in construction and industry all around the world. It is well acknowledged that concrete is strong in compression but weak in tension, hence reinforcement also used to improve this matter. The adding of fibers as reinforced in concrete is one of the ways to enhance the performance of concrete especially in the aspect of energy absorption capacity. The purpose of adding natural fiber is to improve the strength and durability of the concrete. Hence, the performance of concrete as radiation shielding is also automatically improve and yet, natural fibers are suitable material as reinforcement in concrete. The use of natural fibers as reinforcement is the safest and environment friendly as it contributes no harm to the environment and it low in cost and ready availability to consume anytime [1].

In this study, natural fiber used as reinforcement in concrete to enhance the radiation shielding performance is "*Imperata Cylindrica*", usually known as Cogon grass or "*Lalang* Grass" in Malaysia. Among classification of natural fiber, cogon grass classified as a type of grass fiber together with bamboo, bagasse, Napier, corn and others [2]. Cogon grass is one of the ten worst weeds in the world because it is capable of quickly colonizing, spreading and displacing attractive species [3]. The growth of this exotic invasive species is still cannot be stoppable and might give major influence on either ecological or economic consequences at some area [3]. Therefore, the use cogon grass needs to be redefined whether in construction, manufacturing, or any other fields so that the creation of this tree is not just a waste. Moreover, the use of these natural fibres in the construction may replace lead in enhancing the shielding performance and at the same time, may leads to environmental protection purposes as lead exposure and its toxicity invite environmental disease and has devastating effects on the human body [16].

EXPERIMENTAL

Sample preparation

Cogon grass is an abundantly inexpensive weed growing in Malaysia, easily cultivated through seeds and large rhizome systems. It is a highly invasive exotic perennial grass that arrived in Alabama in 1911 as part of Japanese packing material. Production of these grass fibers can turn the wasted leaves into renewable and low-cost natural fibers that will be integrate in the concrete mixes. The *Imperata cylindrica* also known as cogon grass as seen in Figure 1 collected from the field area where it is also often visible as a luxurious yellowish-green grass on the roadside and usually in the full sun.

Later, a few steps procedure is performed to prepare the samples of the cogon grass fiber. Firstly, cogon grass was cleaned with water to eliminate dust, waste, and any harmful materials and was then left to dry under the sunlight for a week. Secondly, the dried grasses manually cut into fibers about 1 mm to 2 mm size for each fibres using knife or scissors as shown in Figure 2. Eventually, it was place in the airtight glass container after the cutting of the fiber was done and labelled as cogon grass (CGF).

Figure 1. Cogon grass fibre [6]

Figure 2. Manually cut of cogon grass [17]

Cogon grass characterization

Known that natural fibres consist of some basic chemical compositions, which are cellulose, hemicellulose, pectin, lignin, and others. The cogon grass could be used as a reinforcement which as complement for the natural fibre including jute, kenaf, sisal, bamboo and other natural fibres, as it is highly available, rarely used in manufacturing and has high cellulose content, approximately 40 percent [4]. The sample was brought to analyse for its chemical characteristic. To determine the chemical compositions of sample, it can be accomplish by conducting a hydrolysis test also known as Chesson Method [5].

To begin, firstly, 1 gram of dry cogon grass fibre (W1) mixed with 150 millilitres of distilled water in a glass tube with temperature 90° to 100°C for an hour. Then, the filter was used to filter the residue fibre and clean with 300 milliliter of hot water. After that, the residual fibre has been dried in an oven until the constantly weight is observe (W2). The process continued with a mixture of dry residue (W2) with 150 milliliters of $1\ \mathrm{N}\ H_2SO_4$ which after that being heated in glass tube as previous done with the same temperature and period of time. Then, the residue was filtered and washed again with 300 milliliters of distilled water which then it was dried and the weight taken (W3). Next, soaking of the dry residue with 10 milliliters of $72\%\ H_2SO_4$ done at a room temperature for about four hours. Later on, adding on 150 milliliters of $1\ \mathrm{N}\ H_2SO_4$ to the mixture and refluxed in glass tube with the same temperature of 90° to 100°C for an hour. Again, the fibre then washed with 400 milliliters of distilled water and being heat in an oven at the temperature of 105°C and the weight is taken (W4). As for final step, the fibre (W4) is heated until ashes are formed and the weight ashes is recorded (W5). The amount of cogon grass fibre's chemical compositions (hemicellulose, cellulose and lignin) can be calculate using the equations below [5].

$$\text{Hemicellulose, } \mathrm{He} = \frac{\mathrm{W2} - \mathrm{W3}}{\mathrm{W1}} \times 100\ \% \qquad (1)$$

$$\text{Cellulose, } \mathrm{Ce} = \frac{\mathrm{W3} - \mathrm{W4}}{\mathrm{W1}} \times 100\ \% \qquad (2)$$

$$\text{Lignin, } \mathrm{Li} = \frac{\mathrm{W4} - \mathrm{W5}}{\mathrm{W1}} \times 100\ \% \qquad (3)$$

Hence, using all the weights taken and the equations above, the percentage of hemicellulose (He), cellulose (Ce) and lignin (Li) in the cogon grass fibre can be obtain.

Furthermore, the cogon grass specimens have been study with field emission scanning electron microscopy (FE-SEM) as shown in Figure 3 and atomic force microscopy (AFM) in Figure 4 for their microstructural and surface characteristics. A small piece of specimen was placed onto a double-sided tape of the specimen stub. Before the specimen were submitted to SEM for visualization of the fibre surface morphological characteristics, the release paper was lightly pressed and covered with a thin layer of gold-palladium film [12].

Figure 3. Field Emission Scanning Electron Microscopy (FESEM)

Figure 4. Atomic Force Microscopy (AFM)

Chemical Treatment on Natural Fibre

To removes moisture content and increasing the strength of the fibers, chemical treatment on the fibers were done. In addition, the aim of chemical treatment is to eliminate the fragile boundary layers of natural fibers, which intended to protect the fiber but which do not resist the cement alkaline environments, and to create thin layers that can withstand the impact of alkaline attack [6]. For that, alkali treatment was utilized at which cogon grass fibers were soaked in sodium hydroxide (NaOH) solution for a certain period, at room temperature. Chemical treatment with NaOH removes moisture content from the fibers while increasing its strength [7]. Therefore, the fibers then immersed in 4% of NaOH concentration with the soaking duration of these fibers was 24 hours as shown in Figure 5.

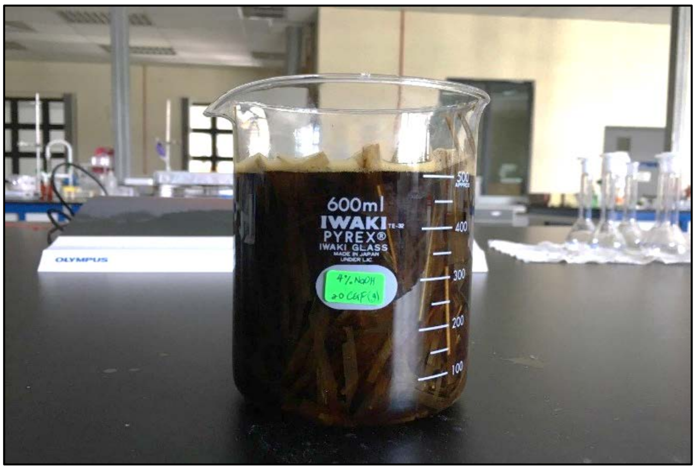

Figure 5. Cogon grass fibres immersed in NaOH solution

Cogon Grass Concrete Preparation

Ordinary Portland Cement (OPC) grade 53 used to prepare the samples tested. Fine sand, which passes by 4.75 mm to 63μm sieve size, while gravel (coarse aggregate) of 20 mm to 6.3 mm thickness has been used. Four concrete sample sets were produced utilizing different quantities of cogon grass fiber. Concrete mixtures of ratio 1:2:3.5 with a water-cement (w/c) ratio of 0.55 [8], and fiber content of 0 percent, 0.5 percent, 1 percent and 1.5 percent dosage by total dry volume added to the concrete mixture. Later on, the freshly mixed concrete was poured and spread out in a mold frame and the specimens were casting for 24 hours. After 24 hours, the concrete slab were de-molded from the molds and then completely immersed and cured in pool of water for 28 days in which, proper curing of concrete is very necessary not only in order to obtain the required compressive strength, but also in needed to design strong concrete [9].

Gamma-Ray Linear Attenuation Coefficient Measurement

The linear attenuation coefficients were measured as it was often being used to analyze the performance of radiation shielding of any types of materials. The linear attenuation coefficient (µ), described as the probability of radiation interacting with a material per unit length of path, where it is the most important quantity that characterizes the penetration and diffusion of gamma radiation in the medium [10]. Additionally, the linear coefficient of attenuation (µ) is the fraction of the attenuated incident photons per unit thickness of a substance [11]. This reflects the fraction of photons per unit thickness of the material separated from a monoenergetic beam [11].

The developed radiation concrete mix slabs brought to test in which to determine the measurement of linear attenuation coefficient of concrete, which contain different amount of natural fiber as an additive in the concrete. Linear attenuation coefficients of concrete were measured using the gamma spectrometer system containing the NaI (Tl) scintillation detector. It also recorded using the MAESTRO-32 gamma spectroscopy software (Figure 6). Measurements performed of gamma rays emitted from Cobalt-60, ^{60}Co radioactive source at different gamma photon energies.

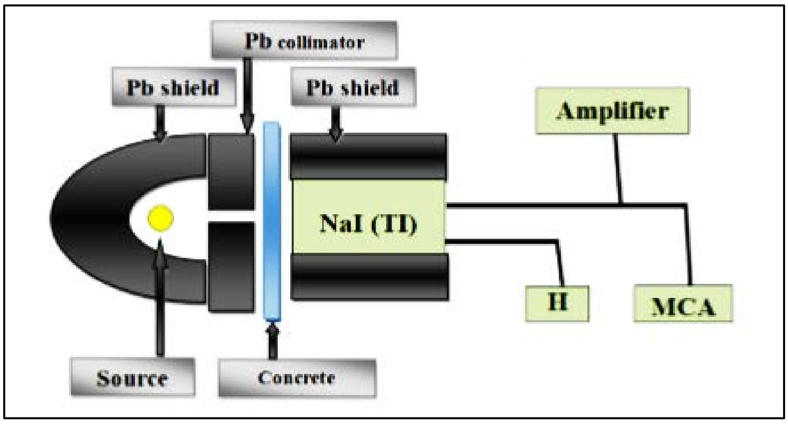

Figure 6. Schematic view of the experimental setup [21]

Next, the attenuation coefficients were determined by a calculation using the application of Beer-Lambert's law [11]. Attenuation due to absorption follows the Beer-Lambert's rule, $I = I_0 e^{-\mu x}$ where x is the thickness of the sample under study, I_o is the number of counts represent the intensity of gamma-ray photons, at a specific energy, without attenuation, whilst I is the gamma ray counts that penetrated the absorber with attenuation in the sample and µ is linear attenuation coefficient (cm^{-1}) [10]. Rearrange and take the log of both sides gives the equation of $\mu = -[\frac{\ln(I/I_0)}{x}]$ for linear attenuation coefficient [11].

RESULTS AND DISCUSSIONS

Chemical properties of cogon grass fibre

Table 1 below shows the chemical properties of cogon grass fibre which consist of cellulose, hemicellulose and lignin. For cellulose, cogon grass contains of 37.1% of cellulose [12], where it also shares the same result reported by Mohd Kassim et al. (2016) [13]. Cellulose is an important component because higher cellulose concentration results in higher-quality and stronger materials. As for hemicellulose, cogon grass characterized by a relatively low content of hemicellulose that is 27.13 percent where this amount could make a significant contribution to the products. Lastly, for lignin, the lignin content in cogon grass is 5.67 % were considered as low. These compositions are very important to know because it will affect the performance of the concrete.

Table 1. Chemical compositions of cogon grass fibre [12] [13]

Chemical composition of cogon grass fibre	Percentage of chemical composition (% w/w)
Cellulose	37.1
Hemicellulose	27.13
Lignin	5.67

PHYSICAL PROPERTIES OF COGON GRASS FIBRE

FE-SEM Analysis.

According to scanning electron microscopy images of cogon grass fibre, it shows that these fibres have a physical surface characteristic of jagged, rough surface, continuous and a non-uniform structure, as shown in Figure 7. This might be attributed to the raw condition of the fibre that have not undergone any chemical treatment [18]. At a magnification of 1000× that reported by Ibrahim et al. (2018), it indicates that the surface of the untreated cogon grass fibre was flat, rough and continuous as shown in Figure 8.

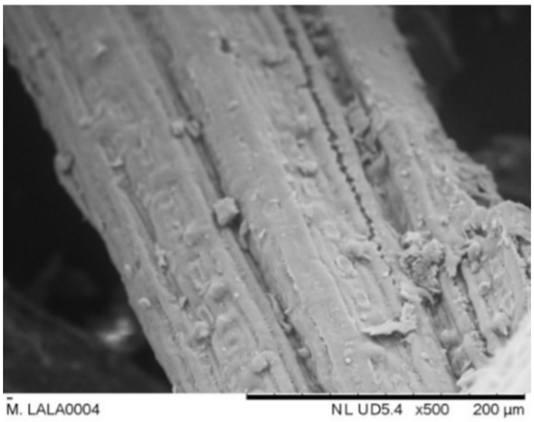

Figure 7. SEM images of cogon grass fibre [19]

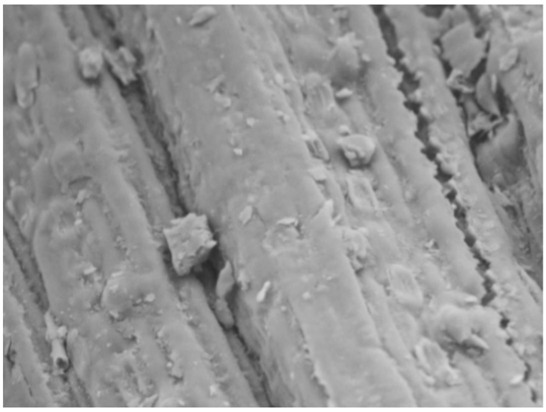

Figure 8. SEM images of cogon grass fibre at 1000× magnification [19]

AFM Analysis.

After that, the AFM image of raw cogon grass fiber, as shown in Figure 9 illustrates that the cogon grass fiber appears to have a blocky and rough surface due to the cuticular waxy layer, which contain a long chain of fatty acids, lipids and phenolic compounds.

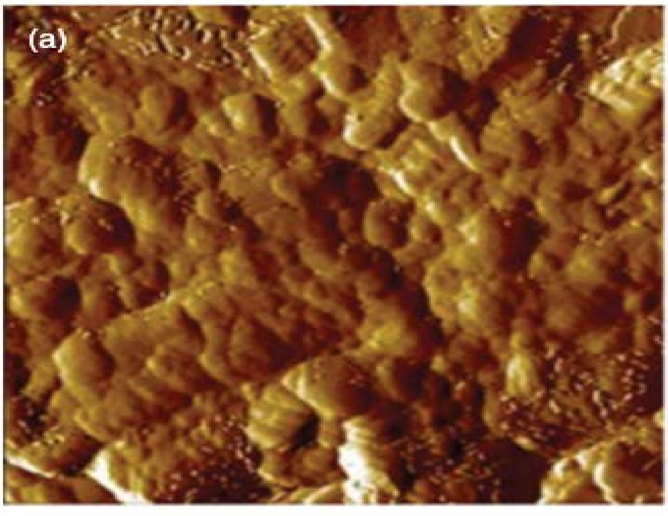

Figure 9. AFM image of cogon grass fibre [20]

Gamma Linear Attenuation Coefficient Analysis

The linear attenuation coefficient can be used to assess a material's radiation shielding performance. The effect of fibre reinforced in concrete on radiation shielding performance as the amount of fibre rises was studied using linear attenuation coefficient measurements. The linear attenuation coefficients of different amounts of fibre, for different gamma photon energy, reveal that for all investigated gamma energies, the linear attenuation coefficient significantly increases as the percentage of fibre in concrete increases. However, when the energy of the gamma photon increases, the linear attenuation reduces. [14]. The fraction of photons that pass through an absorber without reacting is known as gamma beam attenuation. When a high number of gamma beams collide, a number of gamma beams survive. The beam has been weakened. The faster the attenuation, the higher the 'chance of interaction.'

Ikraiam et al. (2009) investigated the gamma ray linear attenuation coefficient of concrete with different percentages of fibre where the fibre used was steel fibre. In his study, steel fibres added in concrete mixture with four different percentages of fibre content (1%, 2%, 3% and 4%). In his study, the result of linear attenuation coefficients of different amount of fibre, with different gamma photon energies (in MeV) as shown in Figure 10.

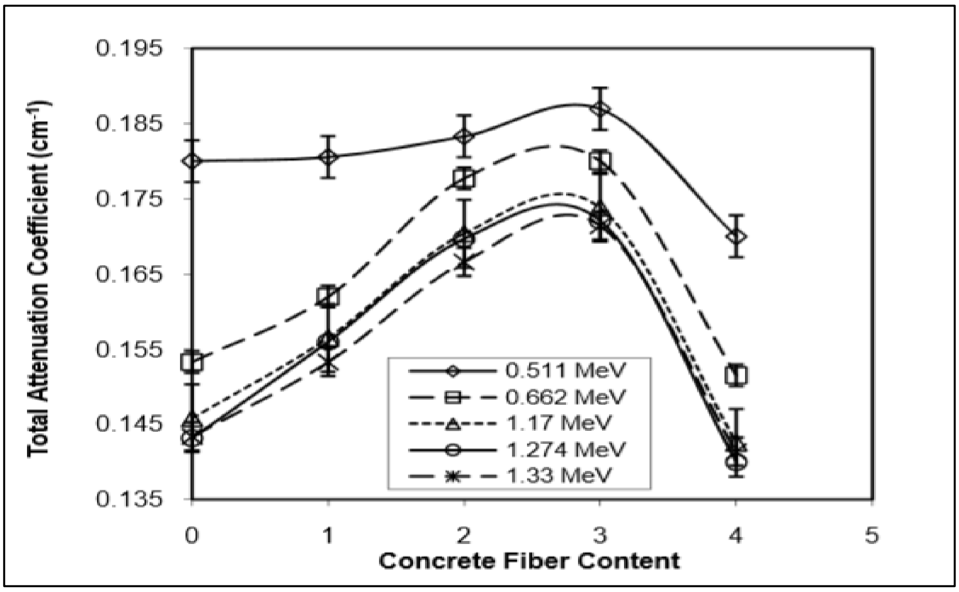

Figure 10. Effect of concrete fiber content on gamma ray total attenuation coefficient [15]

As a result, it found that that the linear attenuation coefficient measured increases with the increasing of fiber content up to 3% [15]. However, the total linear attenuation decreased at 4% fiber content due to decreasing density. They also show that the total gamma-ray linear attenuation coefficient decreases with the increasing of gamma-ray energies [15].

CONCLUSIONS

This paper aimed at discussing the possibility of using cogon grass natural fibre in enhancing radiation-shielding performance and identifying the characteristics of cogon grass fibre. This study revealed that chemical properties of cogon grass fibre contain of 37.1% cellulose, 27.13% hemicellulose and 5.67 % lignin content. After that, for physical properties, Scanning Electron Microscopy (SEM) images of cogon grass fibre indicate that it has jagged, rough surface, continuous and a non-uniform structure. Whilst, through Atomic Force Microscope (AFM), it shows that the cogon grass fibre appears to have a blocky and rough surface due to the cuticular waxy layer, which contain a long chain of fatty acids, lipids and phenolic compounds.

Through previous studies in this review, it indicates that adding fibre in the concrete can increase the gamma-ray linear attenuation coefficient in which at the same time, improves the performance of radiation shielding. Furthermore, it assumed that natural fibre has potential for use as reinforcement in concrete in enhancing the radiation shielding. Moreover, the use of these natural fibres in the construction may replace lead in enhancing the shielding performance and at the same time, reduce the environment pollution as lead exposure may invite environmental disease and has devastating effects on the human body. Furthermore, for future use, the radioactive materials can be used safely and less worries, as there is an improvement in radiation shielding.

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