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The influence of addition of treated kenaf fibre in the production and properties of fibre reinforced foamed composite

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HIGHLIGHTS

- Treatment of fibre on the durability properties.
- Durability properties of kenaf fibre reinforced lightweight foamed concrete.
- Better adhesion of treated kenaf fibre with matrix and lower ductility.

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ABSTRACT

This paper describes the investigation of the influence of treatment of fibre on the durability properties includes drying shrinkage test, water absorption test, initial surface absorption test (ISAT), and accelerated weathering test (wet/dry cycling). Additionally, scanning electron microscopy with energy dispersive X-ray (SEM/EDX) analysis was carried out to study the surface morphology under magnified graphics of lightweight foamed concrete with the inclusion of both treated and untreated kenaf fibres. The foamed concrete mixture was set to a target density of 1250 kg/m^3 with a tolerance of 75 kg/m^3. The cement, sand and water ratio used was 1:1.5:0.45 with 0.45% volume fraction of kenaf fibre inclusion. Correspondingly, the most optimal condition to perform such treatment was studied based on previous researchers, in which the alkaline medium used was 6% sodium hydroxide (NaOH), followed by 12 h immersion period. The study on durability properties of kenaf fibre reinforced lightweight foamed concrete (KFLFC) helps to determine the suitable application for various industrial products in term of lifespan and functionality. The advantageous properties such as low in density and light in weight can reduce the self-weight of structure, by all means, lowering the project cost and time. In this project, the durability tests of the kenaf fibre reinforced lightweight foamed concrete (KFLFC) were conducted according to American Standard Testing Method (ASTM), British Standards (BS EN), and Eurocodes (EC EN). The results showed that alkaline treatment could clean and chemically modify the kenaf fibres surface morphology, rendering to increase in surface roughness which gives better surface adhesion between fibre and cement matrix in terms of adhesion, hydration process, and internal curing process. Similarly, SEM analysis indicating better adhesion of treated kenaf fibre with matrix and lower ductility.

1. Introduction

Construction was known to consume significant global resources causing severe impacts to the surrounding environment since the era of industrial revolution to date. Various actions such as the sustainable design of project development, green building design and well-planned site management were conducted to minimise the negative impacts of construction.

Natural fibres are renewable and readily available in Asia and Europe countries. It offers low density, lower cost, recyclable and less abrasiveness when compared to inorganic reinforcement fibres. The mechanical properties of natural fibre are highly dependent on shape, strength and size affected by cultivation environment. They have a high variation in properties which lead to unpredictable fibre-cement composite properties. The purpose of fibre reinforcement is to enhance the properties of construction material, but the main drawback of application is the durability

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concern of the fibres in the cementitious matrix. The main drawbacks of natural fibres are poor wettability, mechanical and thermal degradation during processing and high moisture absorption. These features cause inability to transfer stress from matrix to fibre in additional to dimensional changes of fibres which may lead to microcracking of composites, hence reducing its mechanical properties. Besides, natural fibres contain a significant amount of hydroxyl groups (OH) which causes hydrophilic behaviour, leading to poor adhesion with the matrix. Surface treatments are often used to improve performances of the composites by closing the gap incompatibility between hydrophilic fibres and hydrophobic matrices [1]. Thus, natural fibres can be either treated or untreated depending on its application. The methods used are alkali treatment, saline treatment and graft copolymerization of monomers [2]. Results showed that the treatment has removed the hydroxyl group in cellulose and increased the performance of tensile properties due to the improved surface roughness [3]. Eventually, the procedures involving natural fibre as reinforcement are different from synthetic fibre product such as carbon fibre and glass fibre.

Kenaf fibre belongs to species of Hibiscus Cannabinus, existed 4000 years old crop originates from ancient Africa, and it is regarded as one of the common industrial crop in Malaysia to date. Kenaf fibres are produced all around the world including Malaysia, where it contributes toward the development of environmental friendly assets for the sports industries, automotive, food packaging, furniture, textiles, paper pulp and fibreboards based industries [4,5]. Kenaf has a great potential to be used as alternative raw material to replace synthetic fibre in MDF and particle board manufacturing industry [6].

The height of a kenaf plant can grow up to 4.5 m within 4–5 months [7] with approximate 6–10 tons of dry fibre/acre annual fibre yield, producing four times the yield of southern pine trees in comparison [8]. Also, it absorbed 21–89 tonnes CO_2/ha/year depending on the agronomic management, showing the ability to mitigate the greenhouse gases effectively [9]. The recent study shows that the high photosynthetic rate of the kenaf plants can absorb up to 1.5 times its weight in carbon dioxide, showing highest absorption level among another type of plants studied [10]. Moreover, kenaf requires short plantation cycle, low quantity of pesticide and flexible toward various environmental conditions [11]. The mechanical properties of kenaf fibre are highly dependent on the specimen location, where the fibre obtained from the middle of the stalk gives stronger characteristics as compared to the end of the stalk [12]. Based on various studies, the average tensile strength of kenaf fibres fall between 157 MPa and 600 MPa, average ultimate tensile strain ranging 0.015 to 0.019 and elastic modulus ranging 12,800 MPa to 34,200 MPa ([12–14]). It is clearly shown that the mechanical properties of kenaf fibres are comparable to existing synthetic fibres in the cement composition.

This research mainly focused on the durability of both untreated and NaOH treated kenaf fibre reinforced lightweight foamed concrete (KFLFC). Durability properties of kenaf fibre reinforced light-weight foamed concrete (KFLFC). Here investigated the compressive strength of both untreated and 6% NaOH treated kenaf fibre reinforced light-weight foamed concrete (KFLFC) when subjected to simulated heat/rain test (i.e., wet/dry cycling). Along with the water absorption, initial water surface absorption, and drying shrinkage of both untreated and 6% NaOH treated kenaf fibre reinforced light-weight foamed concrete (KFLFC) up to 28 days of air curing. Also, analysing the interfacial zone between fibre and matrix at a magnification level of 500, 1000, 5000, for both untreated and 6% NaOH treated kenaf fibre reinforced lightweight foamed concrete (KFLFC) via scanning electron microscopy with energy dispersive X-ray (SEM/EDX) analysis. To study the physical properties (such as- microcracking, fracture, and fibre pull out length on the surface of the composite), a different durability test was performed.

2. Materials and methods of testing

The type of test samples used in this project is both treated and untreated kenaf fibre reinforced lightweight foamed concrete (KFLFC). The mix proportion of the cement, sand and water was set to the ratio of 1:1.5:0.45 with 1% of superplasticiser along with the inclusion of both treated and untreated kenaf fibres at 0.45%. Petroleum-based foam with mixing ratio of foaming agent to water at 1:30 will be used to control the fresh density to 1300 kg/m^3 ± 50 kg/m^3.

Raw kenaf fibre was used, supplied by a local Malaysian company. The optimal length of kenaf fibre was controlled and cut into 5 mm ± 1 mm, as shown in Fig. 1. Sodium hydroxide, NaOH was used in the alkaline treatment for the kenaf fibres. It comes in solid pellet form instead of liquid form. The concentration directly correlates with the weight of the solid pellet, where it can be adjusted to 6% concentration via immersion in water.

Type I Portland cement in accordance with ASTM C150-07 [15] was used throughout the research program. Others materials such as water, fine sand and petroleum-based foaming agent were used throughout the research.

2.1. Preparation of kenaf fibre reinforced lightweight foamed concrete (KFLFC)

As for the test samples, total mix volume of 0.45% of untreated and treated kenaf fibre was used. The kenaf fibre bundles were separated into fine fibres, allowing high intertwining with a matrix to ensure optimal interfacial adhesion. Then, the mix was dry mixed for about 10 min to prevent homogenous state. After adding the required amount of water and kenaf fibre for a certain period, the slurry mortar was then mixed with the prepped foam with weight variation of 60–80 g/l. The quantity of foam was added in accordance to target wet densities of 1250 kg/m^3 In 75 kg/m^3. Inverted slump test was conducted for lightweight foamed concrete in accordance to ASTM C1611/C1611M-14 [16]. The fresh concrete was then poured into various sizes of a mould according to the specifications required by each type of test as shown in Table 1. Upon the mixes being extracted out from its mould carefully, it is then placed into a water tank for curing process according to test requirements.

2.2. Inverted slump test

The inverted slump test was performed to test the workability and consistency of foamed concrete in accordance with ASTM C1611/C1611M-14 [16]. Based on this method, it is suitable for self-consolidating concrete with aggregates size up to 25 mm, which means it is applicable in our case. The foamed concrete was allowed to spread freely as shown in Fig. 2. When the spreading ceased, two diameters of spread was measured in approximately two orthogonal directions. An average value was taken to control the fluidity consistency of fresh foamed concrete.

Fig. 1. Raw bundled kenaf fibres at 5 mm ± 1 mm length.