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PERFORMANCE OF KENAF FIBROUS PULVERISED FUEL ASH CONCRETE IN ACIDIC ENVIRONMENT

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Abstract

Kenaf Fibrous Pulverised Fuel Ash Concrete (KFPC) is a green concrete that using the plant fibre in order to enhance the strength and durability of composite material in an aggressive environment. Four mixes of concrete were prepared to compare the performance of concrete in an acidic environment which are Ordinary Portland Cement (OPC) samples, Kenaf Fibrous Concrete (KFC) using OPC, PFA concrete samples and KFPC. The 25mm length and 0.75% of kenaf fibre and 25% of Pulverised Fuel Ash of cement replacement were used for the study. The objective of the study is to investigate the compressive and flexural strength of KFPC in 365 days of sulfuric acid immersion. The mass loss result shows the degradation of concrete in acid was improved with the inclusion of pozzolana material. Kenaf Fibre has increased the tensile strength of concrete and the addition PFA enhances the durability. The microstructural analysis through SEM and EDX analysis has been carried out to examine the condition of fibre in concrete. The results showed that a significant loss of strength and mass due to the duration of immersion, however, KFPC has contributed the better performance in an aggressive environment.

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Keywords: Kenaf fibre, pulverised fuel ash concrete, acid, durability.

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1. Introduction

Natural fibre from Kenaf plan has proven its ability in engineering application. High tensile strength, lightweight and strong bending performance was its specialty that leads to many applications in the various industrial background (Saba et al., 2015). Many synthetic fibres show its ultimate strength however the emission of many CO_2 may harm the environment and change the ecosystem. Other than CO_2, nitrous oxide gas was released to the environment where its effects were 310 times more harmful than CO_2 (Hu, Lee, Chandran, Kim, & Khanal, 2012). The Kenaf fibre uses in automobile parts and wood industry to produce paper and pulps reduces forest destruction. The lightweight characteristics, hence strong specific mechanical properties make it receives attention from many industries. Because of this specialty, this natural fibre was used in biocomposite industries to apply in the structural component. Synthetic fibre like glass and polymer fibre has a higher density of fibre compared to kenaf fibre. Therefore, kenaf fibre is easier in handling and non-abrasive towards moulding and equipment. The production cost of using this material will be reduced. In the construction industry, cement and concrete were produced massively to fulfil the high demand of client needs. However, along the process, the Ordinand Portland cement production caused an effect on heat and gas release. Greenhouse effect, pollution and gas contamination were the main issues of selecting green material instead of synthetic (Uzal & Turanli, 2003). Natural plant is biodegradable, and the process of producing was less harmful hence offers a decrease in energy usage (Kim, Dale, Drzal, & Misra, 2008). In this study, waste material was used to replace cement and natural fibre from plant increase the properties of composite material. Pulverised Fuel Ash from Tanjung Bin Power Station and plant fiber from Kenaf were corporate to enlighten a competitive composite material from natural fiber and not from synthetic based. This composite concrete has many potentials on restraining from acid attack load and high tensile capability (Naik & Moriconi, 2005).

2. Problem Statement

The concrete composite performance depends on the properties of the types of fibres that used to reinforce the composite. However, using natural fibres distract the ability of composite as lower in elasticity, high absorption of moisture, disintegration in alkaline attack, and vulnerability in engineering properties (Swamy, 1990). Fibre from the Kenaf plant can be divided into different measure fibre by aspects ratio. Fibre behaviour in strengthening the composite, presently research by Elsaid, Dawood, Seracino, and Bobko, (2011) says that concrete beams from kenaf fibre was comparable to increase the properties of material strength. Babatunde, Yatim, Razavi, Yunus, and Azzmi, (2018) in his review said less of research about the fibre specification and fibrous concrete performance toward the environment in long term duration. The research that will be carried out will determine the 365 days durability of as an alternative composite of other natural fibres.

The intention of this research basically will emphasis on suitability KFPC in adaptation with environmental consideration in long-term performance. Many research and literature that have done already shown the strength and tensile properties of natural fibre to enhance the properties of concrete, but variability outcomes not stated of its performance in different environmental condition. Instead of performance of the composite itself, it is crucial part of new composite to restrain from the environmental specific condition and exposure to enhance the ability of KFPC through different parameters.

3. Research Questions

There are two main research questions in this study:

- What are the characteristics of KFPC that can be used as a building material in construction?
- Why the ordinary plain concrete and other composite material cannot perform in different kind of environment?

4. Purpose of the Study

Synthetic fibres were produced massively to fulfil high demand from the industries, however, increase the emission of CO_2 to the atmosphere hence, contaminated the environment through chemical process. Synthetic fibre tremendously shows high performance in mechanical properties, however, not friendly to the environment. Feasibility study of natural fibre material is hoped will contribute to the innovation of alternative material in civil engineering field. The strength and dynamic behaviour of composite concrete incorporating with natural fibre may determine to be used as an elemental data. The performance ability of KFPC that will be conducted are a useful reference to determine the properties of the material when exposed to the various environment through natural and selected condition. Limited data on the environmental performance of KFPC lead to this research. This study will establish the fundamental of future research related to the development of KFPC as a sustainable material.

5. Research Methods

5.1. Materials

5.1.1. Kenaf Fibre

The natural fibre was classified into three types, Vegetables, Animal and Mineral Fibre. Kenaf, Flax, Jute, Hemp, and Ramie were categorised under bast fibre that contains high cellulose and microfibrils. Kenaf fibre can be harvested within 3 to 4 months where the stalk provides higher mechanical strength (Pickering, Efendy, & Le, 2016). Besides the advantages, kenaf, however absorbs water as it a hydrophilic behaviour that restricts it from cooperate with concrete. Kenaf fibre needs to be treated by a chemical reaction in order to remove dirt and lignin. The 5% sodium Hydroxide (Na0H) was the appropriate concentration for kenaf fibre treatment plan (Babatunde et al., 2018). This treatment process was done to make the fibre free from any substances and impurities of hemicellulose and pectin (Mahjoub, Yatim, Mohd Sam, & Hashemi, 2014; Lam & Yatim, 2015). National Kenaf and Tobacco Board at Kelantan, Malaysia is the main contributor of kenaf fibre used in this research.

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5.1.2. Ordinary Portland Cement

The binder of concrete composition was used in the experiment is Portland Cement manufactured by Tasek Corporation Berhad. The major indication of chemical content of Calcium Oxide and Silicon Dioxide in the mix proportion of OPC were form a great adhesive of concrete composite.

5.1.3. Pulverised Fuel Ash Concrete

The replacement of 25% of cement in the mix proportion using the class F of Pulverised Fuel Ash was considered in this study. The pozzolanic material of Fuel Ash was selected based on durable characteristics in the acidic environment. Class F Pulverised Fly Ash Powder from Tanjung Bin Power Plant, Pontian, Johor has chemical content 70% of Silica, Alumina and Iron oxide 70% according to ASTM C618 (Abubakar & Baharudin, 2012). The cement was replaced by 25% of PFA that was defined by initial testing before from the previous study.

5.2. Specimen and concrete mix proportion

The KFPC performance in an aggressive solution was the main objective if this research paper. The 25% of cement replacement by using pozzolans material is the optimum value to observe the performance of this composite in acid environment. There were 72 samples of concrete by four mixes of normal concrete, OPC, PFAC (Portland cement and fly ash cement), KFC (Portland cement with fibre) and KFPC (Portland cement, Fly Ash and fibre). Table 1 shows the concrete mix proportions used in the study, Cubes of 100mm by 100mm by 100mm were prepared to indicate the compressive strength. The flexural strength was determined by using prisms size of 100×100×500mm. The addition of superplastisiser is to increase the workability of concrete and Rheobuild 1100 was selected in this study.

Table 01. Concrete Mix Proportions of KFPC

Constituent material	Proportions KFC (kg/m^3)	Proportions KFPC (kg/m^3)
Cement	463	347.3
Fly Ash	-	115.7
Fine aggregate	800	800
Coarse aggregate	867	867
Water	250	250
Kenaf Fibre 0.5%, 0.75%, 1%, 1.5%	6,9,12,15	6,9,12,15
Super plasticiser	4.63	4.63

5.3. Test for resistance to acid attack

The test was done in cube and prism samples after 28 days of water curing. The samples were wiped off to surface dry and weighed before immersion. The mass loss of samples was determined for 90,180 and 365 days of curing in 2% concentration of the acid sulphuric solution. The H_2SO_4 was used in this research to prepare an aggressive environment that contains sulphate impact to concrete samples as likely on natural ground conditions. After immersion, the samples were weight again and recorded. Visual observation on the physical appearance of concrete samples was investigated after the immersion to

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identify the changes towards samples. SEM and EDX analysis also have been carried out to validate the mechanical properties. The Compressive strength immersion samples were investigated in accordance to BSEN 12390-3:2009 and BSEN 12390-5:2009 standard for calculating the flexural strength

6. Findings

Compressive strength is one of the important properties that reflect the structure quality of composite concrete. The result in Figure 01 shows the compressive strength decreased in longer time of immersion of acidic for all types of mixes. The concrete mixes with no fibre, using OPC and PFAC mixes gradually loss strength in acidic immersion though they have good strength in water curing. The uniaxial stress has applied to the specimen, therefore more fracture on OPC and PFAC mixes. Compared to concrete mixes with fibre inside, KFC and KFPC the compressive strength decreased but not lower than OPC and PFAC. The fibre holds the brittleness of concrete when degradation occurred of concrete matrix and acid attack.

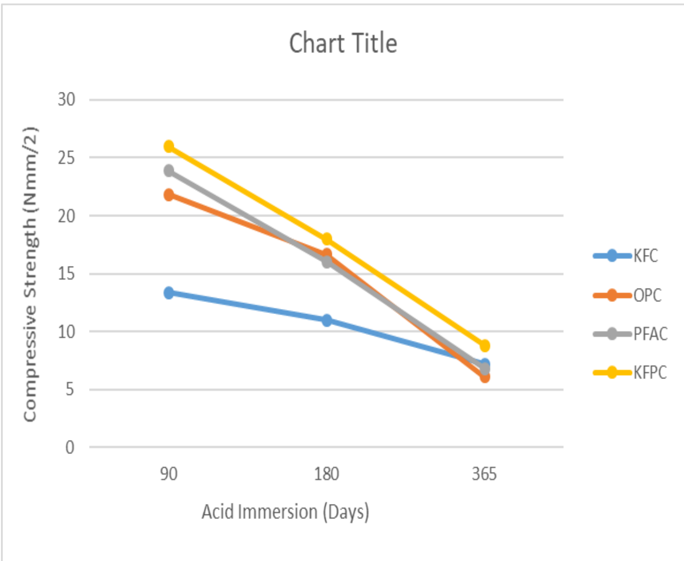

Figure 01. The compressive strength of KFC, OPC, PFAC and KFPC in acid immersion

The flexural strength of the concrete also shows a similar reaction of when immersion to acid in Figure 02. The KFPC shows the highest strength after immersion to 365 days of acid, explains the pozzolan action of Fly Ash in the concrete mixed. The presence of $Ca(OH)_2$ occupies pores in the concrete and reduce the process of degradation of acid attack. Great tensile strength of Kenaf fibre as likely in normal condition (Azzmi & Yatim, 2018; Azzmi, Yatim, Hamid, Aziz, & Adole, 2018) also contribute to the durability of KFPC in an acid attack (Reju & Jiji Jacob, 2012).

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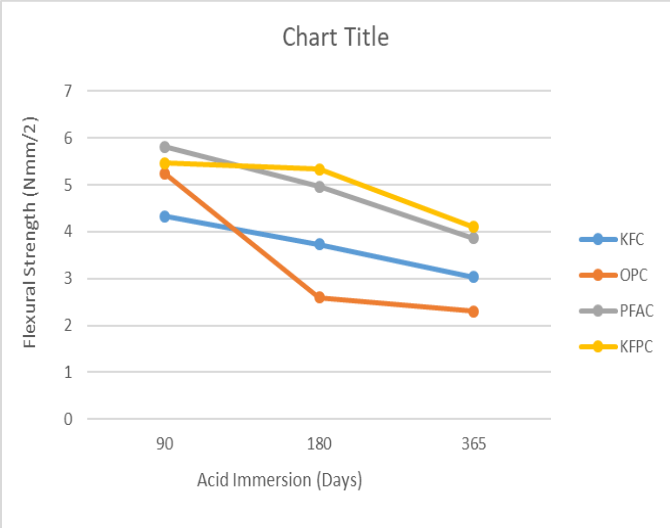

Figure 02. The flexural strength of KFC, OPC, PFAC and KFPC in acid immersion

The visual observation through the concrete samples of concrete OPC and KFC samples shows the physical appearance of samples were deteriorate when exposed to the acid solution. Figure 03 and Figure 04 shows that OPC samples almost strangled while the KFPC samples remain in shape even though the deterioration happened. The Kenaf fibre in KFC grasps the cement paste from spalling due to acid attack (Nosbi, Akil, Ishak, & Abu Bakar, 2011).

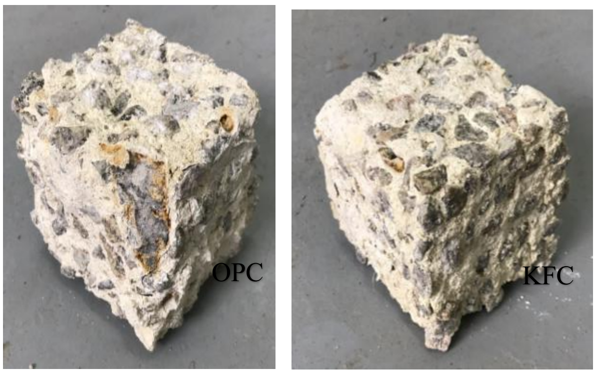

Figure 03. OPC and KFC samples after 365 days acid immersion

Figure 04. PFAC and KFPC samples after 365 days acid immersion

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Concrete samples of PFAC that using Fly Ash but no fibre inside happened to decrease in size but the concrete fragments not falling compared to OPC. The KFPC samples were observed an increase in size due to absorption and but remain in shape hence the outer layer of concrete was peeling off. Figure 05 displays the SEM and EDX spectrum KFPC in acid solution. The inclusion of fibre was to improve the bridging effect of fibre-matrix of KFPC. Nevertheless, the fibre happened to swell and degraded at a certain part of fibre after immersion in 365 days in acid solution. Despite that, the KFPC was considered as a durable material using natural fibre and waste composite compared to normal concrete. The capability of treated fibre in composite was in better condition as the flexural strength not decreasing much than normal concrete.

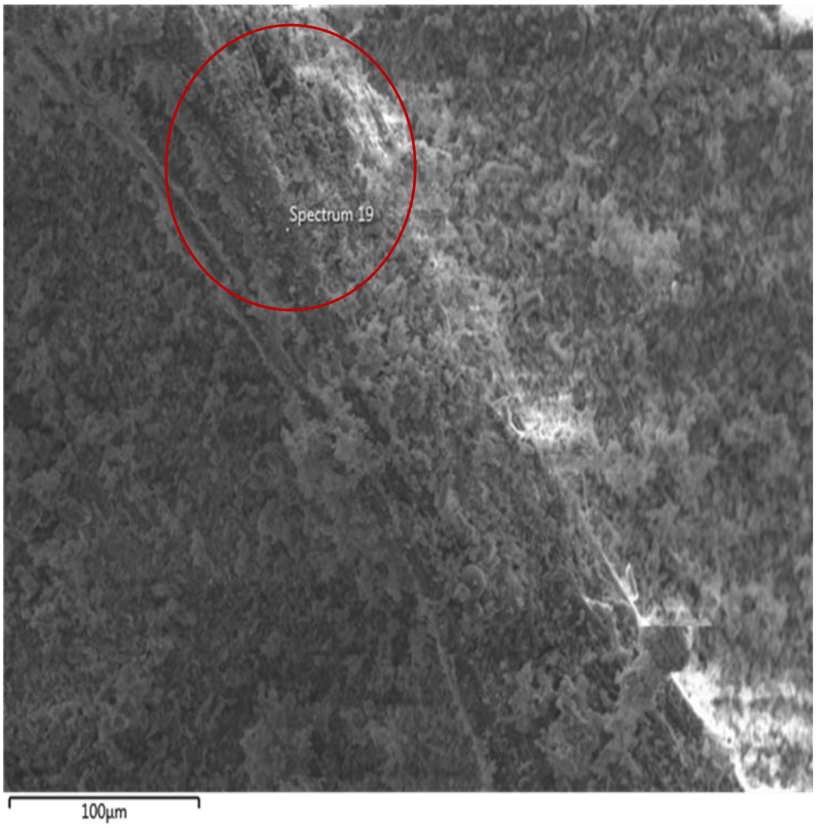

Figure 05. EDX spectrum of Kenaf Fibre in acid solution

EDX analysis in Figure 06 also displays the result of Oxygen, Carbon, Calcium and Sulfur in higher percentages. C-S-H gel was remarkably higher in OPC but leading to cracks formation. Ca(OH2) was formed by the hydration process of cement and the present of PFA and fibre in KFPC reduces the Ca(OH2). KFPC improves the solid density of concrete with FPA and fibre to resist the acid attack.

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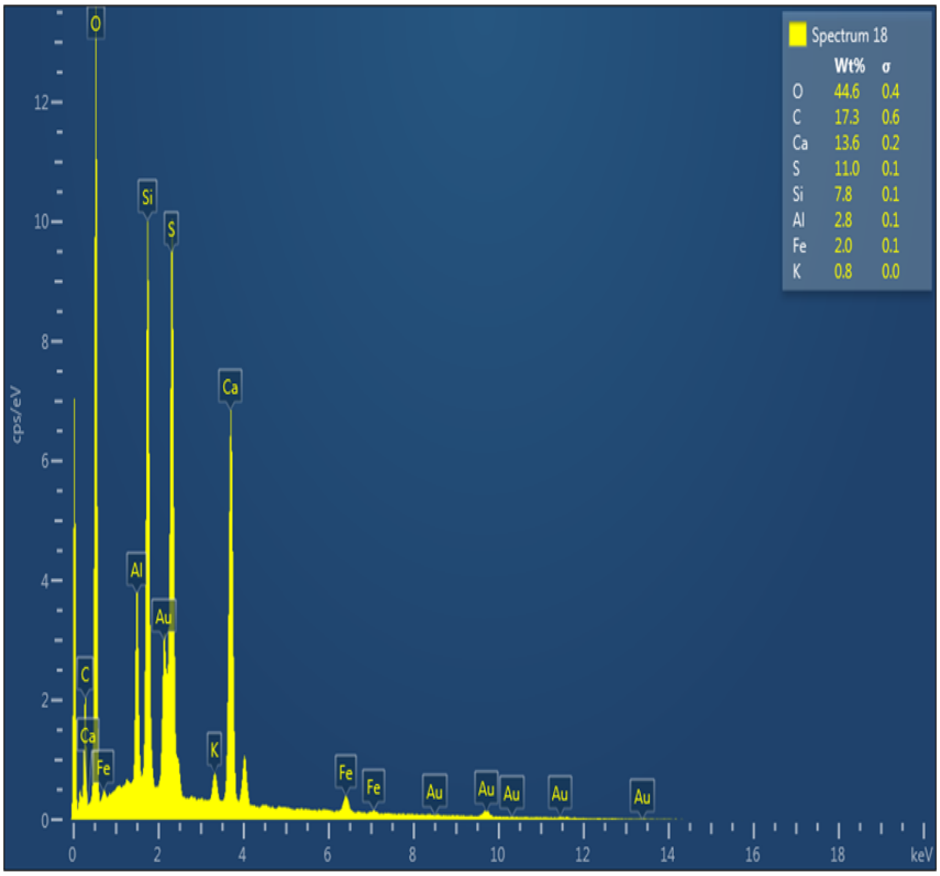

Figure 06. EDX analysis of KFPC in acid solution

7. Conclusion

From the results of experimentation investigation, there are few conclusions can be derived as

- The KFPC has good resistance to acid attack compared to normal and PFA concrete, however, the strength decreased as the duration of immersion increasing to 365 days.
- The strength loss of KFPC are lower, thus this composite was durable in an aggressive environment.
- SEM and EDX analysis was were verified the content of chemical attack on concrete after the immersion
- The capability of KFPC in flexural strength in normal and aggressive condition show this concrete composite has better mechanical performance.

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