

Article

Comparison of Thermomechanical Properties of Cement Mortar with Kenaf And Polypropylene Fibers

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Abstract: In the past decades, Fiber Reinforced Concrete has been gaining more attention in the concrete research development. There are many advantages of the inclusion of fiber into reinforced concrete structures. It was found that the inclusion of fibers in concrete, be it synthetic or natural, resulted in the improvement of the thermal properties of concrete, as well as its strength to some extent. However, the inclusion of fibers in concrete does affects its thermo-mechanical properties. The objective of this study is to identify the potential of the addition Polypropylene and Kenaf fibers in cement mortar at different compositions (0.1%, 0.2%, and 0.3%). Eight mixes were analyzed for this purpose. Upon investigating the flow ability, compressive strength, tensile strength, and thermal conductivity of the mortar samples, it was found that the incorporation of PP and Kenaf fibers reduced the flow ability. Cement mortar samples containing 0.1% addition of PP and Kenaf fibers show the highest compressive strength compared to other percentages, while samples containing 0.3% addition of PP and Kenaf fibers show the highest tensile strength compared to other percentages. The thermal conductivity of mortar samples shows reduction when high percentages of both fibers were used.

Keywords: Mono fiber; concrete strength; tensile strength; kenaf; Polypropylene.

1. Introduction

Concrete has become one of the most important construction materials commonly used in many types of engineering structures. Concrete is a material which is very strong in compression and weak in tension, thus causes cracking in the tension zone. This causes numerous long term concrete failures such as fatigue and deterioration which may happen slowly over time, as well as short term concrete failure such as alkali-silica reaction, which could induce rapid deformation well before a structure's serviceability limit is reached [1]. Many studies have been conducted in order to overcome these problems, among which include the usage of Fiber Reinforced Concrete (FRC) with the objective to increase the tensile bearing capacity of a concrete structure.

In the past decades, FRC has been gaining more attention in the concrete research development and were used in numerous types of civil engineering application such as architectural precast concrete, pavement slabs, precast products, shotcrete, tunnel linings, seismic structures, marine, and refractory applications [2]. There are many advantages of the inclusion of fiber into reinforced concrete structures, such as the increment of the tensile strength, cracking avoidance, and reduction in creep and shrinkage problems [3]. Based on previous researches, typical fiber materials that have been used in concrete are glass fibers [4], steel fibers [5], polypropylene [6], graphite or polyester fibers [7]. In recent years, chopped synthetic fibers, such as polyethylene (PE), polyvinyl alcohol

(PVA), polyethylene terephthalate (PET) and polypropylene (PP) have been added to concrete as reinforcement to enhance the mechanical and engineering properties of concrete.

Polypropylene (PP) is a thermoplastic polymer utilized as a part of wide assortment of uses including bundling, materials (e.g., ropes, warm clothing and covers) stationery, plastic parts and reusable compartments of different sorts, research facility gear, amplifiers, car segments, and polymer banknotes. According to Sohaib (2018), the addition of PP fibers to concrete improve its mechanical properties by increasing tensile, flexural and compressive strength [8]. However, the inclusion of Polypropylene causes the reduction of the thermal conductivity of concrete. And not only was fiber capable of increasing concrete strength, studies by Afiqah Nadhirah et al. (2017) also found that the inclusion of glass fibers in composite materials such as crossarms could also increase the material's strength [9].

In recent years, due to socioeconomic and environmental sustainability concerns, agricultural waste has been gaining recognition for its contributions in the construction industry. Studies have found that agricultural wastes such as palm kernel shell and coconut shell can be used as aggregate replacement to produce lightweight concrete [10,11]. Agricultural ash has also been used as a partial cement replacement with good results in strength and behavior. Such agricultural ash include rice husk ash [12], bamboo ash [13], corn cob ash [14], and many more. Studies on the usage of natural fibers such as rubber fibers [15], bamboo [16], and rice straws [17] in concrete have also been vastly conducted. It was found that the inclusion of fibers in concrete, be it synthetic or natural, resulted in the improvement of the thermal properties of concrete, as well as its strength to some extent [18]. This gives way to the opportunity of reutilizing natural agricultural waste as natural fibers.

Kenaf (*Hibiscus Cannabinus* L.) is a species of *Hibiscus* that can be found in Southern Asia. Kenaf is a warm season annual fiber crop closely related to cotton and jute. It is also known as Ambary, Bimli, Deccan Hemp, Ambari Hemp, and Bimlipatum Jute. Recently, Kenaf fiber has been seen to be a promising green material to be reutilized as a natural resource in the concrete production. According to I.S.Aji et al. (2010), kenaf is believed to be able to absorb three to eight times more Carbon Dioxide than other trees, which would benefit the environment [19]. What is even more significant is that researches by Lam et al. (2015) as well as M. Z. Abdul Mulok et al. (2018) found that the inclusion of kenaf fiber in concrete resulted in better flexural and shear strength, ductility but reducing the compressive strength of concrete [20,12].

Hence, for both synthetic and natural fibers usage in concrete, it shows that the mechanical properties of concrete, such as residual strength, tensile splitting strength, and flexural strength after heating may also change by including fibers, making the understanding of its process crucial. This study focuses on the comparison of the thermomechanical properties of mortar containing (1) Natural Kenaf fibers, and (2) Synthetic Polypropylene fibers at 0%, 0.1%, 0.2%, and 0.3%.

2. Materials and Methods

In order to achieve more reliable results, practicing of strict measures of quality control is one of most important criteria for experimental investigation as part of any research program. Therefore, the spurious results and false trend can be avoided by applying the prevailing code of standards and specifications for the selection of concrete making materials and mix proportions. Eight mixes were prepared with three different composition of mono fibers at 0.1%, 0.2%, and 0.3%. Water and admixture were measured in percentage by weight proportion of cement used.

2.1. Super Plasticizer

Super plasticizer is a synthetic organic water soluble substance that will reduce the amount of water required up to 30%. Hence, this will improve the cement mix workability, strength, and eventually reduce the potential of thermal cracking and shrinkage.

2.2. Ordinary Portland Cement (OPC)

Ordinary Portland cement (OPC) from Tasek Corporation Berhad was used in this research. The selection was based on the fact that with this specific gravity, the concrete properties of the mix could be observed under normal hydration process.



Figure 1. Ordinary Portland Cement (OPC).

2.3. Polypropylene Fibers

Polypropylene (PP) is a high performance fiber that is 100% synthetic, cut into 19 mm length, and brought directly from Oriental Housetop Company. In this study, PP was added in cement mortar mixtures as a means to control plastic shrinkage, and to deliver high compression and high tensile strength.



Figure 2. Polypropylene Fibers.

2.4. Kenaf Fibers

Kenaf is a natural fiber that is believed to be able to improve the tensile and flexural strength of concrete. The powder core (40 mesh) type of Kenaf fiber was purchased from National Kenaf and Tobacco Board, Malaysia. The Kenaf powder was then soaked in water for 15 minutes in order to avoid it from absorbing moisture during mixing.



Figure 3. Kenaf Fibers.

2.5. Mortar Design Mix

The mortar mix design was carried out using the 1:3 mix according to the standard specifications given by ASTM C91. This was based on the fact that mortar of type M is the most suitable mortar type for plastering works. In order to find the perfect mix design, several trials were conducted. Then, it was concluded that the most suitable water/cement ratio was 0.5% with 2% of super plasticizer as the water reducer. At the same time, the fiber volume fractions were added individually as listed in Table 1:

Table 1. Fiber Volume Fractions.

Fiber		Volume fraction (%)	
Polypropylene	0.1	0.2	0.3
Kenaf	0.1	0.2	0.3

2.6. Experimental Method

The flow table test is a method to determine the consistency of concrete mortar. The flow table test was conducted immediately after mixing the cement mortar batch in the laboratory by following the ASTM C1437 standard. Eight fresh cement mortar samples were tested to evaluate all the fresh properties. The density of each sample is either Oven Dried Density or Super Saturated Density, and was taken after 24 hours of curing by measuring weight samples and divided by its volume. The compressive tests were done to determine the ability of the cement mortars to carry loads before failure by following the ASTM C109 standard. Referring to ASTM C496 standard, the tensile strength of the cement mortars were deduced from the splitting tensile test. Both the compressive and splitting tensile strength were measured by using the Universal Testing Machine. The thermal conductivity was measured by using FOX 50 Heat Flow Meter as per the ASTM C1783 standard.

3. Results and Discussion

3.1. Flow Ability

The flow table test was studied to determine the consistency of the concrete mortar. The variation of mortar flow of all concrete mixes is reported in Figure 4. It can be seen that the flow ability is reduced for both cases of PP and Kenaf fibers addition. For instance, the flow ability was noticed to reduce by 34% when 0.1% of PP fibers are added, and 29% reduction was noticed for the addition of 0.1% of Kenaf fiber compared to the 0% addition (Control Mix). This could be due to the

fact that fiber has ability to absorb water in the fresh mixes, hence the incorporation of fiber in the cement mix will reduce the mortar flow ability.

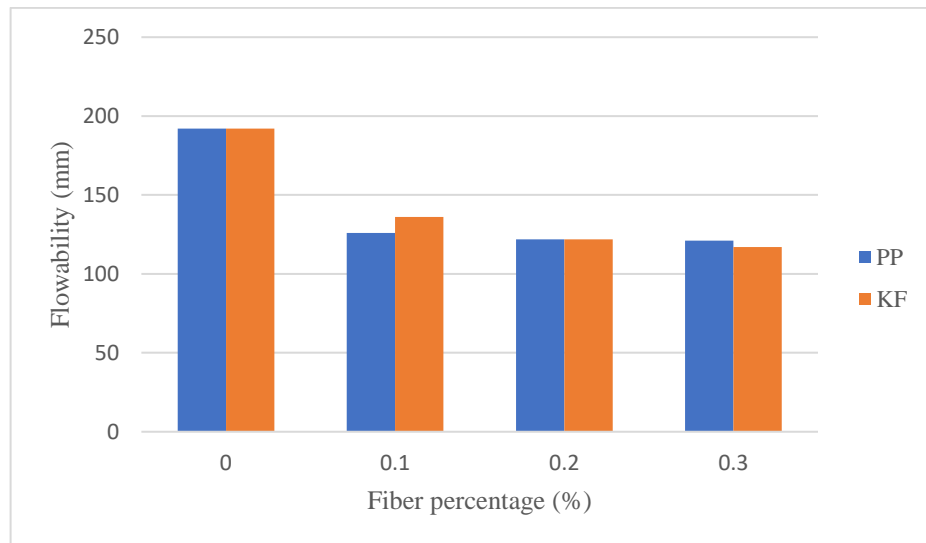


Figure 4. Variation of mortar flow of all cement mixes.

3.2. Compressive Strength

To determine the compressive strength of cube specimen, a load was applied until failure by using compression testing machine. It was observed in Figure 5 that the inclusion of a higher percentage of fibers reduced the compressive strength compared to Control Mix. The inclusion of 0.1% Kenaf fiber increased the compressive strength by 33%. However, the numbers reduced to 15% and 8% when 0.2% and 0.3% respectively when Kenaf fiber was added. The compressive strength of concrete mortar with the addition of 0.1% PP fibers was observed to decrease by 10% compared to the Control Mix. However, the inclusion of 0.2% and 0.3% of PP fibers caused more strength reduction, which are 13% and 29% respectively.

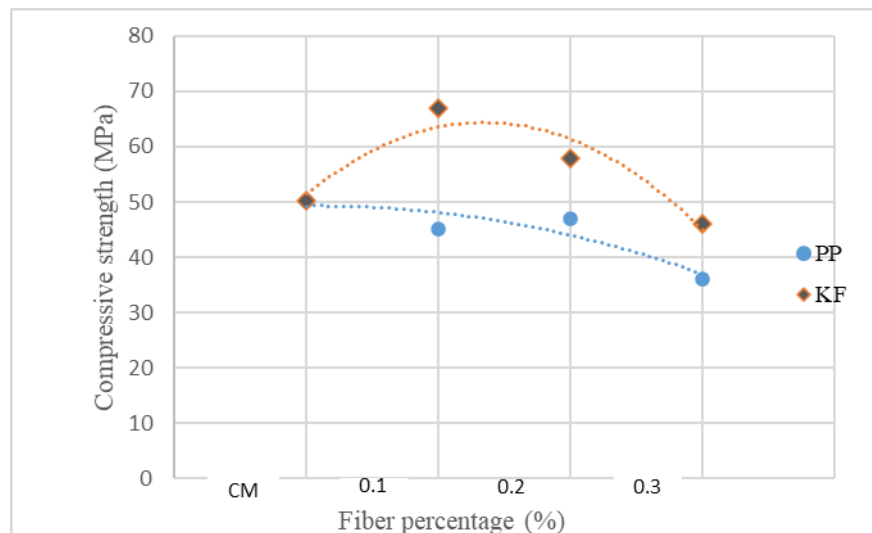


Figure 5. Compressive Strength.

The relationship between the Kenaf fiber percentage and compressive strength was obtained and given as below:

$$f_c = -7.125 F_k^2 + 33.455 F_k + 25.125, \quad (1)$$

$$R^2 = 0.8947$$

where f_c = Compressive strength (MPa), and F_k = Dosage of Kenaf fibers (%)

An identical trend also observed for Polypropylene fiber as follow:

$$f_c = -1.45 F_{pp}^2 + 3.15 F_{pp} + 47.6, \quad (2)$$

$$R^2 = 0.8222$$

where f_c = Compressive strength (MPa), and F_{pp} = Dosage of Polypropylene fibers (%)

3.3. Tensile Strength

The tensile strength of the cement mortar was performed after 28 days of curing to determine the strength between mortar and fibers. Figure 6 shows the trend for Control Mix, and mixes with PP and Kenaf fibers. The trend shows a linear increment in the tensile strength with the increment of PP and Kenaf fibers. The tensile strength of the concrete mortar from control mix to 0.1% of PP and Kenaf fibers contents have increase greatly by 50% and 82% respectively. However, the tensile strength for the concrete mortar with the inclusion of Kenaf fiber was slightly lower compared to the concrete mortar made with PP fibers.

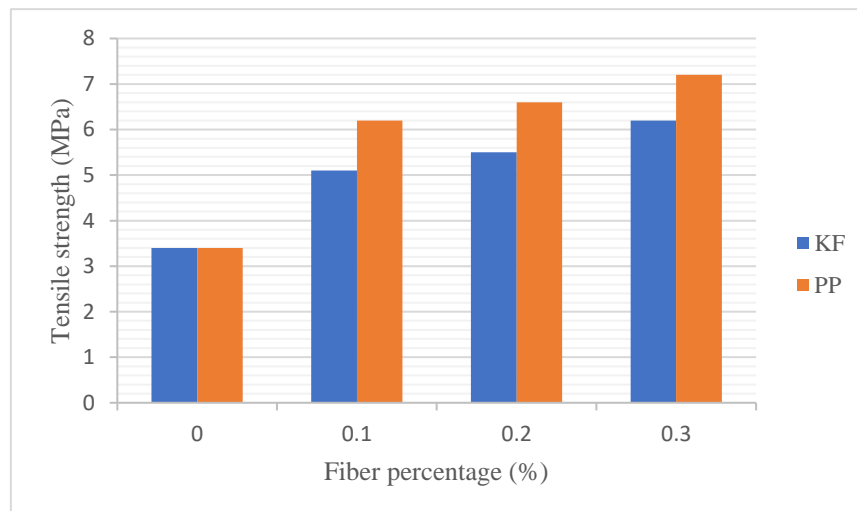


Figure 6. Tensile Strength.

3.4. Thermal Conductivity

The purpose of the thermal conductivity test is to determine the ability of material to transfer heat. The test was performed using the FOX 50 Heat Flow Meter. The K values are shown in Figure 7 below. It can be observed that with the inclusion of 0.1%, 0.2%, and 0.3% of Kenaf fiber, the K values was reduced to 4%, 4%, and 8% respectively as compared to the Control Mix. As for the PP fibers, for the inclusion of 0.1%, 0.2% and 0.3% fiber, the K values were reduced to 8%, 12%, and 12% respectively as compared to the Control Mix.

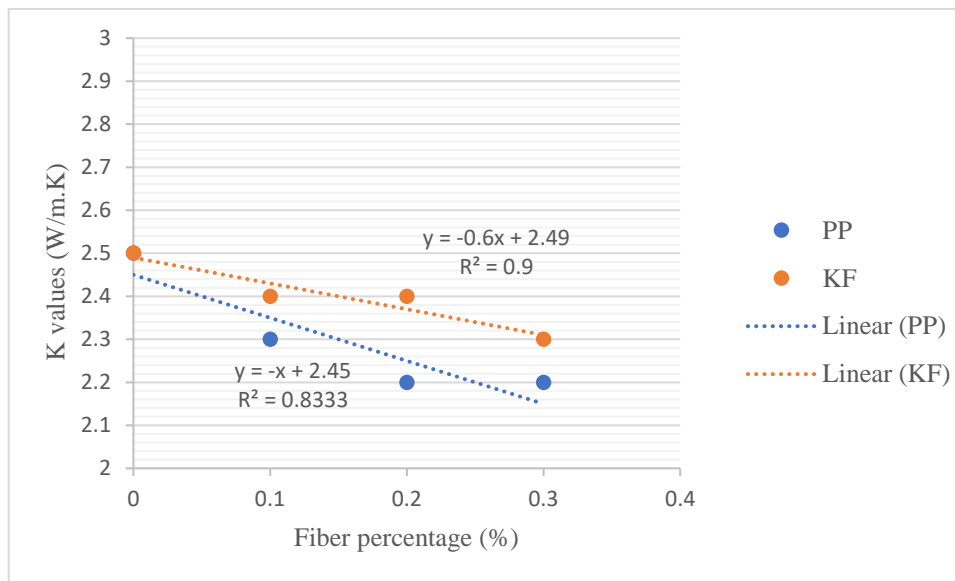


Figure 7. Thermal Conductivity, K for cement mortar with PP and Kenaf fibers.

4. Conclusions

Based on the result obtained, it can be concluded that:

- The ability of fiber to absorb water in fresh mortar mixes causes the decrement of flow ability for 0.1% PP fiber addition as much as 34%, and 29% for Kenaf fibers at 0.1% addition compared to the Control Mix.
- The addition of 0.1% Kenaf fiber in the cement mix resulted in the highest compressive strength values compared to the other mortar samples. Mixes with Kenaf fiber have higher strength than that with PP fibers. .
- The tensile strength of the concrete mortar increases with the addition of PP and Kenaf fibers 50% and 82% respectively, with 0.3% addition having the highest strength. The tensile strength for the concrete mortar with Kenaf fiber was higher compared to the concrete mortar made with PP fibers.
- In terms of thermal conductivity (K), it was found that the inclusion of fibers causes the reduction of the K values until up to 12% of reduction.

5. Patents

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