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# Effect of Sodium Hydroxide on Mechanical Characteristics of Kenaf Fibers Reinforced Concrete

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**Abstract.** This article shows the experimental analysis of sodium hydroxide (NaOH) effects on the mechanical properties upon the addition of kenaf fibres to the concrete mixture. The compression and flexural tests were carried out on seven different concrete mixtures for 28 days to evaluate the mechanical characteristics. Hence, the experimental trials comprise of seven different mixtures of concrete; the control (without the addition of kenaf fibre) was represented as the first mixture. The following six concrete mixtures contain different kenaf fibre volume fractions (1% and 2%); they were treated with 1%, 3% and 6% of sodium hydroxide concentrations in order to investigate their performances. The experimental results show that the compressive and flexural strengths of kenaf fibres reinforced concrete increase as sodium hydroxide concentration increases. Besides, it is worth noting that the addition of kenaf fibres has an insignificant effect on the compressive strength of the concrete owing to the reduction in concrete density. Therefore, the results of this study demonstrated that the concrete flexural strength increased to up to 12%) upon the addition of 1% kenaf fibre associated with 6% NaOH. Moreover, the failure state increasingly changed to ductile from brittle.

**Keywords:** kenaf fiber, compressive strength, flexural strength, sodium hydroxide, treatment

## 1. Introduction

Concrete is a common composite structural material valued for its resistance to aggressive environmental conditions, easy formability and high compressive strength. In the construction industry, reinforced concretes are mostly employed due to its durability, economical, robust, and strong characteristics. It has been reported in the literature that the addition of short discreet fiber to concrete; improve the flexural and shear strength, delay the cracking propagation, improve the ductility, impact the mode of concrete failure, and improve energy absorption [1-5]. There is an increasing interest in the fiber reinforced concrete as it is employed in different types of infrastructures and structures including pre-cast product, seismic building, pavement slab, shotcrete, and tunnel lining [6-9].



Kenaf fiber is a green material with great potentials, it can be reused as a natural resource in a concrete. Due to the importance in terms of tensile characteristics, the introduction of kenaf fibers in the concrete can improve the ductility, shear and flexural strengths of the structure of reinforced concrete [10-14]. Moreover, kenaf fiber needs to pass through a series of treatments to minimise higher water absorption property of fiber to ensure excellent outcomes like other kinds of natural fibers. The use of chemical like sodium hydroxide is one of the recommended treatments to minimise the hydrophobic property of the fibers; hence, it enhances the adhesion within the matrix and fiber surfaces. This was carried out through removal of a hydroxyl group in the cellulose and improving the roughness of surface; causing improved tensile characteristics of kenaf fiber in relative to untreated kenaf fibers [15-20].

It could be seen from the literature that kenaf fiber has demonstrated its ability to enhance the sustainability reinforced concrete structures. Nonetheless, it is worth mentioning that the effects of sodium hydroxide on the mechanical characteristics of kenaf fibers reinforced concrete has yet been investigated. Therefore, the present study aims at assessing the impact of sodium hydroxide on the mechanical characteristics of kenaf fibers added to concrete mixture and evaluate their performance.

## 2. Materials and Methods

In the present study, the control mixture was prepared based on British Standards (BS EN 206-1, 2000) [21] to achieve a minimum of concrete compressive strength (20 MPa) on the 28th day. There are three (3) different volume fractions ( $V_f$ ) considered (i.e., 0, 1 and 2%) to investigate the influence of kenaf fiber contents in the concretes. As presented in Table 1, seven concrete mixtures were prepared. The first mixture (Mix 1) serves as a control (C0) with 0% fiber content. Moreover, there are six concrete mixtures (Mix 2 through Mix 7) containing different kenaf fiber volumes fraction (1 and 2%) treated with 1%, 3%, and 6% of sodium hydroxide concentrations to investigate and compare their performances.

Figure 1 and Table 2 illustrate the pictorial image and the properties of kenaf fiber, respectively. The kenaf fibers were separated to a suitable diameter within the range of 0.5-1.0 mm, cut into a length of 30 mm. Kenaf fiber is one of the natural fibers from bast fiber of kenaf plant; it possesses significant water absorption feature that can result in reduced workability in the concrete mixture. Thus, superplasticizer (SP) was introduced to the concrete mixture to achieve the needed slump and retain 0.58 of the water-cement ratio. Sika ViscoCrete®-2199 was used as the superplasticizer in this study. In addition, the kenaf fibers were treated with 1%, 3%, and 6% of NaOH to evacuate and clean debris from the fiber surfaces and to investigate its effects on the mechanical characteristics of kenaf fibers adding to the concrete mixture.

**Table 1.** Design of concrete mix

Characteristics	Mix 1 C0	Mix 2 K1-T1	Mix 3 K1-T3	Mix 4 K1-T6	Mix 5 K2-T1	Mix 6 K2-T3	Mix 7 K2-T6
$V_f$ (%)	0	1	1	1	2	2	2
Cement (kg/m <sup>3</sup> )	280	280	280	280	280	280	280
Coarse Aggregate (kg/m <sup>3</sup> )	1292	1292	1292	1292	1292	1292	1292
Fine Aggregate (kg/m <sup>3</sup> )	556	556	556	556	556	556	556
Water (Liter/m <sup>3</sup> )	162	162	162	162	162	162	162
W/C ratio	0.58	0.58	0.58	0.58	0.58	0.58	0.58
SP (Liter/m <sup>3</sup> )	5.6	5.6	5.6	5.6	5.6	5.6	5.6
Kenaf fibre (kg/m <sup>3</sup> )	0	6.5	6.5	6.5	13	13	13
Treatment by NaOH (%)	0	1	3	6	1	3	6

Where, C0: Control mixture; K: Kenaf fibre; T: Treatment by sodium hydroxide

**Table 2.** Characteristics of kenaf fibre

Characteristics	Kenaf Fibre
Diameter, D (mm)	0.5-1.0
Length, L (mm)	30
Tensile Strength (MPa)	400-550
Unit Weight (kg/m <sup>3</sup> )	650



**Figure 1.** Kenaf fibre cut to a length of 30 mm

Moreover, the compression and flexural tests were carried out to estimate the compressive and flexural strength of the concrete mixtures by utilizing cube compression test machine and automatic flexural test machine under four-point bending test as shown in Figures 2 and 3, respectively. In each mixture, three cubes were prepared; also, three prisms were prepared for individual mixture. As recommended by (BS EN 12390-3, 2000) and (BS EN 12390-5, 2000) [22, 23], a sum of twenty-one cubes in a dimension of 150 x 150 x 150 mm and twenty-one prisms in a dimension of 100 x 100 x 500 mm were carried out on the 28th day, respectively.



**Figure 2.** Compression Test Machine



**Figure 3.** Automatic Flexural Test Machine

### 3. Results and Discussion

The effects of sodium hydroxide on the mechanical characteristics of concrete mixture added with kenaf fibers are discussed in this section, this includes the compressive and flexural strengths of the concrete.

#### 3.1. Compressive Strength Test

Figure 4 illustrates the obtained results of average compressive strength for the kenaf fiber reinforced concrete (KFRC) cubes added with the kenaf fibers. Most importantly, the compressive strength of kenaf fiber concrete mixtures treated with 6% of NaOH was higher compared to its target compressive strength (20MPa) at 28 days. The compressive strength was higher in control concrete mixture in relative to all the kenaf fiber mixtures. However, on the 28<sup>th</sup> day, it could be observed that there is a decline in the compressive strength of about 3% and 8% in K1-T6 and K2-T6, respectively, relative to the control concrete (C0). This behaviour may be due of a reduced concrete density added to the kenaf fibers; and because cubes were not completely dried and hardened. Moreover, the compressive strength of the concrete mixture declines as kenaf fiber volume fraction increases. This result agrees with the previous studies reported in [13-16]. This behaviour has been envisaged as the fibers possess a minimal impact on the concrete compressive strength. Mostly, the compressive strength of concrete with fibers is reduced as compared to concrete without fibers. On the other hand, there was a clear trend of increase in the compressive strength of the kenaf fiber specimens as the amount of NaOH increased, this is possibly due to a decrease in the hydrophobic characteristic of kenaf fiber, whereby high water absorption led to a delay in the internal hardening of KFRC cube specimens.

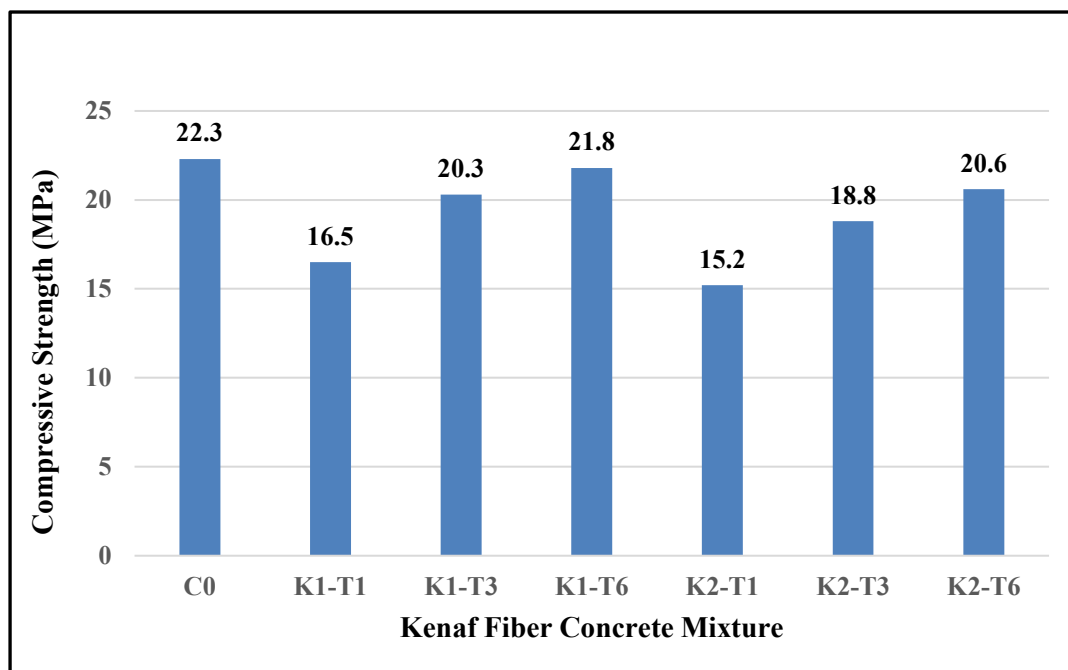


Figure 4. Compressive strength of concrete mixtures

#### 3.2. Flexural Strength Test

In the case of kenaf fiber concrete mixtures, the flexural strength of prism specimens tested on the 28th day is shown in Figure 5. The outcome reflected that the introduction of treated kenaf fiber to the concrete mixture had a significant impact on the flexural strength of kenaf fibers concrete mixture. The highest flexural strength of the specimens was seen in prism K1-T6 with 3.9 MPa (12%), higher

than control prism C0. However, the flexural strength of kenaf fiber prism specimen K2-6 and control prism specimen C0 have a similar flexural strength. The increasing volume fraction of kenaf fibers result in declined flexural strength of the concrete. This is because the prisms were not completely dried and hardened. The best amount of treatment through NaOH can be seen at 6%. As the amount of NaOH treatment in the kenaf fibers improves, the concrete flexural strength improves as shown in kenaf fiber prism specimens K1-T6 and K2-6.

Comparing the flexural and compressive strength at 28th day, the flexural strength of control concrete C0 is approximately 16% of the compressive strength; for kenaf fibers concrete K1-T6 and K2-T6, they are approximately 18% and 17%, respectively. Furthermore, the behaviour of treated kenaf fibers concrete and control concrete is almost similar.

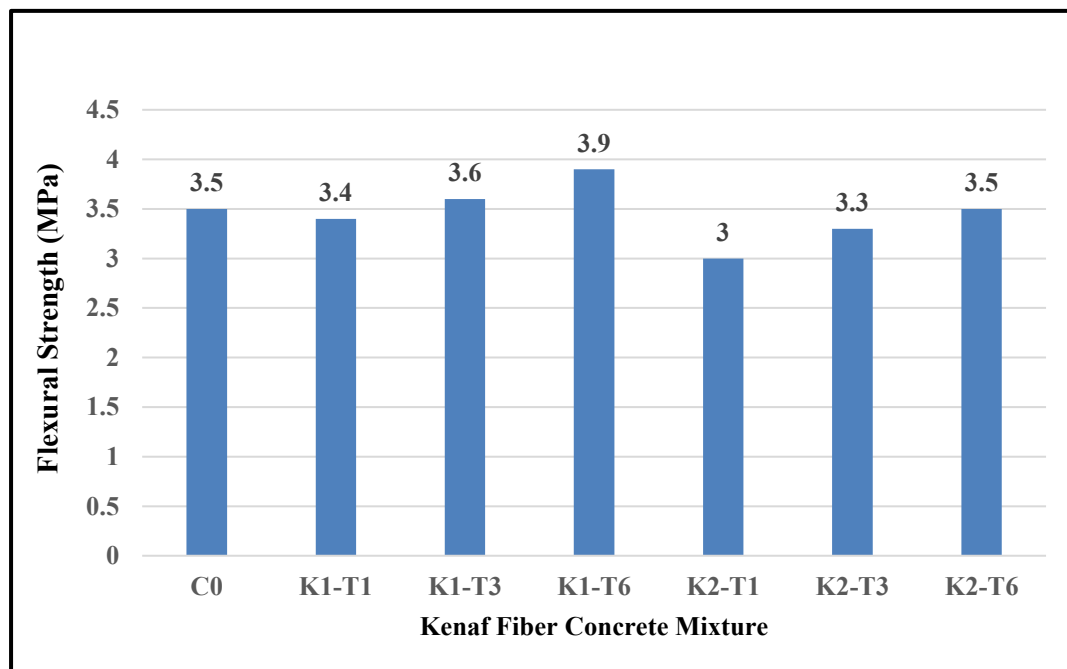


Figure 5. Flexural strength of concrete mixtures

During the testing, the control prism (C0) was seen to fail in a brittle fashion that occurred without any warning. Nevertheless, the prisms with kenaf fibers failed in a ductile manner with cracking being extended and propagated without breaking the prism into half. This suggests that the addition of fiber to concrete can potentially impact the cracking propagation and change the failure mode from brittle to ductile.

#### 4. Conclusion

This article experimentally studied the impacts of sodium hydroxide (NaOH) on the mechanical characteristics of kenaf fibers adding to concrete mixtures. Based on the results obtained, the addition of kenaf fibers has an inconsequential effect on the concrete compressive strength, primarily due to the reduction in the concrete density. As for the flexural strength, there was a significant improvement in the concrete prism added to treated kenaf fibers (up to 12%) at 1% of kenaf fiber and 6% of NaOH. Besides, there was a delay in the cracking propagation and failure mode of the prism was ductile.

Although, the kenaf fiber was treated using NaOH to minimise the hydrophobic feature of the fiber and improve the mechanical properties of the kenaf fiber concrete mixtures; however, the amount of NaOH was insufficient as seen in internal hardening for the specimens. Further studies are suggested to enhance the mechanical characteristics of the kenaf fiber concrete mixtures for better performance.



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