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Effect of the Variation of Fiber Percentage in the Gradients of Composite Materials on the Breaking Strength of Concrete Beams

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ABSTRACT

The use of bio-composites to reinforce concrete beams and improve their properties of bearing strength and strain reduces errors of buildings. The aim of this study was to avoid buildings` errors that result from using traditional building materials. Wood, as a building material suffers from strength shortage and fungi attack, whereas steel suffers from corrosion. Composite materials were used to reinforce concrete beams. Three different samples were made by reinforcing epoxy with kenaf and steel fibres. Samples (A, B, and C) were composed of 70%:30%, 50%:50%, and 30%:70% of kenaf to steel respectively. Each sample replaced the cement ingredient in the concrete mixture by 20% weight. The samples were thus: a standard sample which was composed of cement, sand, and concrete together with the other three samples. The procedure of making the concrete beams was implemented by well mixing the components, putting the mixture in the mold for 24 hours, and immersing it in water for 7 and 28 days. The bearing strength test was carried according to the ASTM E4 OR ISO 7500-1. The results taken in the 7 days' period have shown an average of 12.68 KN, 10.79 KN, and 9.73 KN for samples A, B, and C respectively compared to 15.32 KN for the standard sample. However, the results for the 28 days for the samples A, B, and C were 17.86 KN, 15.41 KN, 14.1 KN respectively, compared to 21.38 KN for the standard sample. Thus, sample A (kenaf to steel ratio of 70%: 30%) has had the best breaking strength compared to the other two samples taking the standard sample as the reference sample.

Key words: *concrete, kenaf fibre, steel fibre, breaking strength, and composite materials*.

1. Introduction:

Kenaf is a warm-season, annual, herbaceous plant that is grown commercially in the United States and it was formerly used for rope and canvas. Kenaf fiber reinforced composites have gained wide use in diverse of applications. It could be utilized as reinforcement material for polymeric composites as a substitute for glass fiber. It provides high inflexibility and strength values. it also has high aspect ratios, which renders it suitable for use as reinforcement in polymer composites. Kenaf fiber possesses several desirable characteristics: it has low cost, light weight, renewability, biodegradability, good mechanical properties, and a neutral color and smell. Additionally, it is easy to extract and process. It also has a superior flexural strength and a brilliant tensile strength, which makes it a good candidate for many applications such as automotive products. It is also chosen for a wide range of extruded, molded and non-woven products. (Arjmandi, Yıldırım et al. 2021) .

Kenaf fiber-reinforced composites have gained wide use in a variety of applications. Kenaf fiber could be utilized as reinforcing material for polymeric composites as a substitute for glass fiber. It exhibits high stiffness and strength values. It also has high aspect ratios, making it suitable for use as reinforcing material in polymer composites. The attractive features of kenaf fibers are the low cost, light weight, renewability, biodegradability, highly specific mechanical properties, and its neutral color and smell. Kenaf fiber is also easy to extract and process, and it has superior flexural strength and excellent tensile strength, which makes it a good candidate for many applications, such as automotive products. It is also the material chosen for a wide range of extruded, molded, and non-woven products.

There are numerous advantages of using natural lignocellulose fibers as reinforcing material in matrix. Kenaf, in particular, is well known as a cellulosic source with chemical and biological advantages. Kenaf exhibits low density, non-abrasiveness during processing, highly specific mechanical properties, and biodegradability. Lately, kenaf has been used as a raw material alternative to wood in pulp and paper industries for avoiding the devastation of forests. It has also been used as non-woven mats in automotive industries. (Keya, Kona et al. 2019) .

2. Materials and methods:

2.1. Materials:

Kenaf fibers were used as a source of fiber reinforcements in this research work. The fibers were cut with scissors and prepared to fit the fabrication technique of the composite as shown in Figure 1. A mold was used for preparing the composite materials that contained kenaf fibers, epoxy adhesive and metallic particles. Parallel rectangular molds employed to fabricate the composite materials.

Figure 1: Preparation of fibers

The physical properties of kenaf fibers are shown in Table 1 below.

Table 1: Physical properties of kenaf fibers

No.	Properties	Typical Values
1	Length	1.5-2.6 cm
2	Diameter	25-75 micron
3	Color	white inclined to yellow
4	Cellulose %	44 – 57
5	Hemi cellulose %	21 – 23
6	Lignin %	8-13
7	Density	1.2 – 1.5 g / cm3
8	Water absorption %	8 – 18
9	Tensile strength	223 – 930 MPa
10	Young s modulus	14 – 73 GPa
11	Elongation %	12 – 15
12	Flexural strength	50 – 120 MPa
13	Flexural modulus	1.5 – 6.5 GPa

The physical properties of metallic particles vary depending on the type of metal and its form (e.g., nano, micro, or bulk particles), but generally the followings are the key characteristics:

Table 2: Physical properties of metallic particles

No.	Property	Description
1	Density	high density (7.87 g/cm3)
2	Particle size & shape	ranges from nanometers to micrometers; shape affects surface area and reactivity
3	Color	reddish brown
4	Melting point	high melting point
5	Thermal conductivity	excellent conductors of heat
6	Electrical conductivity	excellent conductors of electricity
7	Magnetic properties	ferromagnetic
8	Surface Area	inversely proportional to particle size; nano particles have high surface area
9	Hardness	varies; often harder at smaller scales due to grain size effects.
10	Luster	metallic shine due to free electrons

2.2 Methods

2.2.1 Composite fabrication:

2.2.1.1 Improving the absorbency of kenaf fibers

Kenaf fibers were immersed in caustic soda concentrically 2% for 45 minutes at 70c. The fibers were washed with hot water for 5 minutes and then they were washed with water and soap at 80c for 5 minutes. Finally, the fibers were washed with water and soap at room temperature.

2.2.1.2 The process of manufacturing composite materials

The fiber, epoxy resin and metallic particles were weighed and mixed together in different ratios to prepare the composite laminates.

The molds were prepared by using film to prevent the adhesion of the composites to them. The dimensions of each mold were 30cmx10cmx2cm.

Figure 2: Preparation of the composite laminates

The fiber, epoxy resin and metallic particles were mixed together in different ratios by using a metallic tool for preparing the composite laminates. These laminates were left to dry at room temperature for 10 hours.

Figure 3: Epoxy resin and hardener epoxy

2.3 Manufacture of concrete beams

2.3.1 Standard sample

Concrete was prepared with a weight of 21164g, washed well, and then poured into the mixing bowl. The sand was prepared with a weight of 9336g, cleaned well, and then poured into the mixing bowl. The cement was prepared with a weight of 3300g, then it was poured into the mixing bowl. The ingredients were mixed well and water was added to them until they became well mixed by hand. The molds were equipped with dimensions of 15cm x 15cm x 52.5cm. The molds were wiped with hydraulic oil to facilitate the extraction of concrete beams from them after they dried. The weights of the ingredients are shown in table 1 below.

Table 3: Composition of the standard sample

Ingredients	Concrete	Sand	Cement
Weight (gm)	21164	9336	3300

Figures 1 and 2 show the preparation of the standard sample. The components of the concrete mixture were poured into the mold in three stages, with pressure being applied with a metal tool after each stage. The concrete was left in the molds to dry for 24 hours, and then the concrete was extracted from the molds and immersed in plastic basins containing water. After 7 days of immersion, preliminary tests were conducted, and after 28 days of immersion, final tests were conducted.

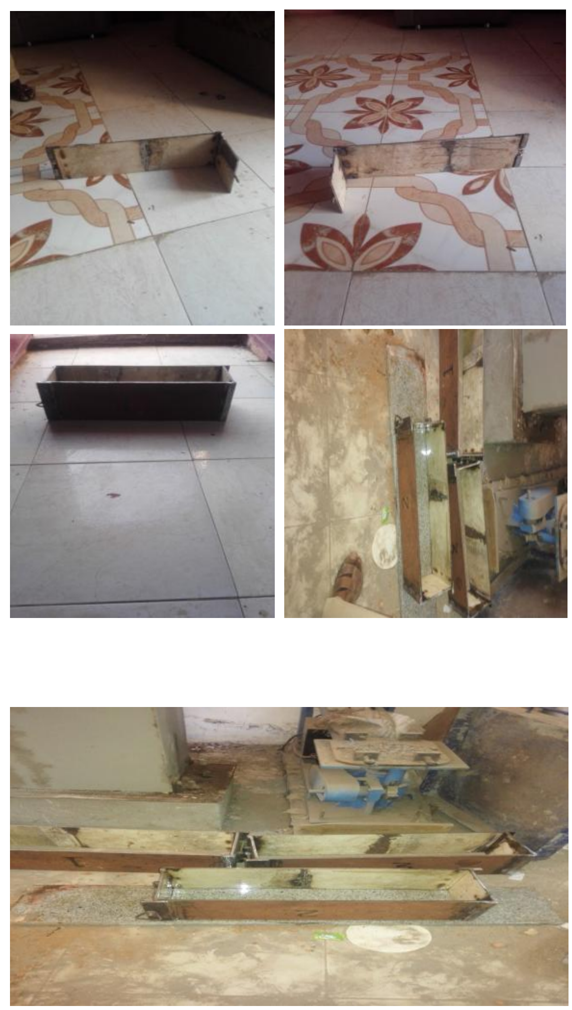


Figure 4: Mold parts

Figure 5: Preparing and mixing the concrete components

Figure 6: Manufacturing concrete beams

2.3.2. Samples:

The fiber, epoxy resin and metallic particles were mixed together in different ratios by using metallic tools for preparing the composite laminates. These laminates were left to dry at room temperature for 10 hours. The samples are shown in table 3.

Table 4: Samples and weight characteristics

Samples	Weight (gm)			
	Kenaf fibers	Metallic particles	Epoxy + hardener	Laminate
A (70%&30%)	21	9	630	660
B (50%&50%)	15	15	630	660
C (30%&70%)	9	21	630	660

For samples, A, B, and C, concrete was prepared with a weight of 21164g, washed well, and then poured into the mixing bowl. The sand was prepared with a weight of 9336g, cleaned well, and then poured into the mixing bowl. The cement was prepared with a weight of 2640g. Then these components were poured into the mixing bowl, mixed well and water was added to ensure a well-mixed material. The mixture was poured in the mold in three equal amounts. The composite material (laminate) was placed after the first amount and then completed by the second and third amounts, being well mixed after adding each amount. Pressure was applied with a metal tool after adding each amount. The mixture was left in the molds to dry for 24 hours, then extracted and immersed in plastic basins containing water. After 7 days of immersion, preliminary tests were conducted, and after 28 days of immersion, final tests were conducted. The ingredients are shown in table 4 below.

Table 5: The components of the composite materials

Ingredients	Concrete	Sand	Cement	Laminate
Weight / g	21164	9336	2640	660

2.4 Compression testing machine controller:

A Concrete compression testing machine controller is a specialized device used for operating and monitoring the compression testing machine during the testing of concrete specimens such as cubes, cylinders, or blocks. The controller ensures the accurate application of load and the precise measurement of the compressive strength of concrete.

2.4.1 Calibrating the concrete compression testing machine:

Calibration of concrete compression machine is essential to ensure accurate and reliable test results. The procedure must follow international standards ASTM E4 OR ISO 7500-1, as follows:

- Calibrated load cell with valid certification
- Digital indicator or readout device
- Calibration certificate form
- Trained technician of certified calibration agency

2.4.2 Calibration procedure:

1. Preparation:
   - Ensuring the machine was cleaned, powered on, and in good working condition.
   - The loading surfaces were cleaned to remove debris or dust.
   - The system was allowed to reach room temperature (typically 20-25c).

2. Setting up the calibration equipment:
   The calibration load cell was placed at the center of the machine loading platen, where a concrete specimen would normally be placed.

   The load cell was connected to the digital indicator or calibration readout device.

3. Applying load gradually:
   The machine was started and applied load incrementally (e.g. 10%, 25%, 50%, 75% and 100%) of full capacity).

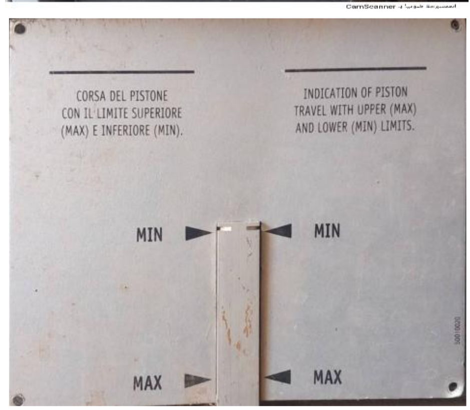
At each step, the machine's reading and the reference reading from the load cell were both recorded

4. Comparing and analyzing:

The difference between the machine's reading and the standard load cell was calculated

5. Adjusting if necessary:

If discrepancies exceed the allowed tolerance, the machine should be adjusted or serviced, but if results are within tolerances the machine is considered properly calibrated.



6. Completing the calibration certificate including:
   - Date of calibration
   - Equipment used
   - Readings and deviations
   - Name and signature of technician

7. Calibration frequency:

Recommended once per year or as specified by your internal quality system or accrediting body.

Figure 7: Parts and adjustment of testing machine controller

3.Results and discussions:

3.1 Breaking strength of the standard beam

Table 6: The breaking strength of the standard beam

Beam	7days	28 days
1	17.11KN	24.32KN
2	15.32 KN	20.68 KN
3	14.91 KN	20.54 KN
4	16.39 KN	22.98 KN
5	12.86 KN	18.37 KN
The average	15.32 KN	21.38 KN

3.2 Breaking strength of the standard beam of 70% kenaf fibers + 30% metallic particles

(Sample A)

Time	7 days	28 days
Composite	20%	20%
Concrete beam	**A**	**A**
1	14.52	20.05
2	14.11	19.97
3	14.39	19.13
4	13.41	19.44
5	14.22	19.56
The average	14.13	19.63

It was found that the best results of breaking strength of beams were those seen after 28 days. The best result of the breaking strength of beams was the result of the sample which contained 20% laminate and recorded 19.63KN, compared with the breaking strength of the standard beam which recorded 21.38KN breaking strength. This result was considered excellent.

3.3 Breaking strength of the standard beam of 50% kenaf fibers+ 50% metallic particles

(Sample B)

Time	7 days	28 days
Composite	20%	20%
Concrete beam	B	B
1	13.51	18.77
2	13.09	18.53
3	13.52	18.70
4	14.08	18.91
5	13.79	18.59
The average	13.59	18.70

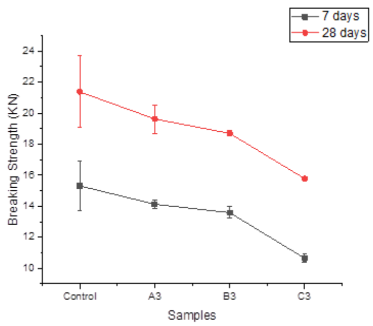
We found that the best results of the breaking strength of beams were the ones exhibited after 28 days. The best result of breaking strength of beams was exhibited by the sample which contained 20% laminate and recorded 18.7 KN, compared with the breaking strength of the standard beam which recorded 21.38KN breaking strength. This result was very good.

3.4 Breaking strength of the standard beam of 30% kenaf fibers+ 70% metallic particles:

(Sample C)

Time	7 days	28 days
Composite	20%	20%
Concrete beam	C	C
1	10.71	15.81
2	10.72	15.89
3	10.33	15.75
4	10.50	15.66
5	10.99	15.79
The average	10.65	15.78

We found that the best results of the breaking strength of beams were exhibited after 28 days. The best results of the breaking strength of beams were shown in the sample which contained 20% laminate and recorded 15.78KN, compared with the breaking strength of the standard beam which recorded 21.38KN of breaking strength. This result was good.



4. Conclusion:

The study has concluded that using composite materials of kenaf fiber and metallic fibers in samples (A, B, C,) of the percentages (70%&30%), (50&,50%), and (30%&70%), respectively, along with proxy resin as adhesive with hardener materials, where the composite materials represent (20%) of the weight of the entire cement used in the ingredients of concrete beams – this process – improves the breaking strength of the concrete beams. The study has also concluded that samples (A, B, and C) represent the best samples sequentially.

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