A Study of the Tensile and Compressive Strengths of Jute Fiber Reinforced Concrete

Yusuf Dada Amartey, Bilkisu Hassan Sada and Eunice Folasade Adedibu
Department of Civil Engineering, Faculty of Engineering, Ahmadu Bello University, Zaria.
Corresponding Author's email: dadaamartey@yahoo.co.uk

Abstract

This research work was carried out to investigate the behaviour of concrete containing jute fiber of different weight fractions with different curing ages. Tests were carried out on both fresh concrete (slump and compaction factor test) and hardened concrete (compressive and split tensile tests) using different weight fractions of jute fiber at 0, 0.25, 0.5, 0.75, 1.00 and 1.5 %; with different curing ages of 3, 7, 14, 21 and 28 days strength. Using the 28 days curing age strength, the use of 0.5 % weight fraction of jute fiber increased slightly the compressive strength of concrete by 10.2 % while further increase in the fiber weight fraction reduced the compressive strength when compared with the control at 0 %. There was a progressive increase in tensile strength of concrete with an increase in percentage of jute fiber. An average optimum tensile strength value of 68.13 % was obtained with fiber content of 0.75 %.

Keywords: Jute fiber, reinforced concrete, compressive strength, tensile strength and workability

1. INTRODUCTION

The utilization of fiber has gained attention due to the increase of waste disposal problems; especially in industrial and agricultural fields. Fibers are thread like materials which are flexible, macroscopically homogenous, having a high ratio of length to width and a small cross-section [1]. Fiber reinforced composite materials are important class of engineering materials which offer outstanding mechanical properties, unique flexibility in design capabilities and ease of fabrication [2]. Fiber can be classified into natural and man-made. However, the development of natural fiber reinforced composites became an attractive research lines due to the non recyclability, high density and health hazards of composites reinforced with synthetic fibers such as glass, carbon and aramid fibers etc [3].

Many Research papers indicate various advantages in the use of natural fibers in cement composites [3, 4]. Such advantages include: increase in flexural strength, increased post-crack load bearing capacity, increased impact toughness and improved bending strength [4]. The major advantages of using natural fibers are that they offer significant cost reduction and benefits associated with processing when compared with synthetic fibers. Fiber content can be the part of total weight of composite, or the part of weight of any ingredient to be replaced. Researchers have emphasized the importance of selecting optimum fiber quantity together with the optimum fiber length (e.g. matrix/composite with 3 % volume fraction of fibers and 40 mm fiber length can achieve maximum strength; further increase/decrease in volume fraction and/or fiber length may decrease strength of matrix/composite) [5].

2. MATERIALS AND METHODS

The cement used in concrete mix for the research is Dangote cement (OPC) produced in Nigeria. The chemical composition was determined by using X-ray fluorescence (XRF) equipment and the results obtained are given in Table 1. The physical properties of Dangote Cement were determined in accordance with [6] and are shown in Table 2. The fine aggregate used is natural sand, whose specific gravity and bulk density are 2.63 and 1342.59 kg/m^3 respectively. The coarse aggregate used is also from crushed stone with nominal aggregate size of 20 mm. The aggregate crushing value, aggregate impact value, specific gravity and bulk density were determined as 20.55, 26.21, 2.86 and 1320 kg/m^3 respectively. The jute fiber was produced through the enzymatic process called retting. Retting is the process by which the bundles of cells in the outer layers of the stem are separated from the woody core and from non-fibrous matter by the removal of pectin and other gummy substances. The characteristics of the jute fiber are as shown in Table 3.

Table 1: Chemical Composition of Dangote cement

Chemical composition	% Concentration	Chemical composition	% Concentration composition
Al_2O_3	4.80	MgO	2.01
SiO_2	23.0	SO_3	2.75
CaO	65.12	TiO_2	0.16
Fe_2O_3	1.57	V_2O_5	0.06
K_2O	0.24	Cr_2O_3	0.038

Table 2: Physical Properties of Dangote Cement

S/No	Test carried out	Test result
1	Fineness	0.0152
2	Initial setting time (min)	159
3	Final setting time (min)	234
4	Soundness (mm)	1
5	Consistency (%)	27

Table 3: Characteristics of Jute Fiber

	Fiber properties
Average fiber length (mm)	130
Average diameter (mm)	0.60
Strain (%)	3.16
Stress (N/mm^2)	595

2.1 Mix Proportions

The desired concrete compressive strength is 40 N/mm^2, thus the mixed ratio used for this research work is 1:2:4. The water cement ratio used is 0.5 and this is due to the absorption capacity of the fiber. Approximate concrete composition is given in Table 4.

Table 4: Jute Fiber Reinforce Concrete Mixes

Ingredient	Weight of concrete ingredient per cubic meter (kg)					
	0 % JF	0.25 % JF	0.5 % JF	0.75 %JF	1 % JF	1.5 % JF
Cement	336.06	335.22	334.38	333.54	332.7	331.02
Fine aggregate	672.11	670.44	670.44	667.08	665.4	662.04
Coarse aggregate	1344.24	1340.87	1337.51	1334.15	1331	1324.1
Water	168.03	167.61	167.19	166.77	166.4	165.51
Fiber	0.00	6.3	12.06	18.9	25.2	37.81

JF = Jute fiber

2.2 Test method

Six mixes (0, 0.25, 0.5, 0.75, 1 and 1.5 % jute fibre content) were made using a mix of 1:2:4 and a water/cement radio of 0.5. The slump and compacting factor tests for all mixes were performed in accordance with [7] and [8] respectively. Three cube samples of 150 mm by 150 mm and three cylinder samples of 150 mm diameter and 300 mm height were used for each mix to test the compressive and split tensile strength respectively. The cube and cylinder specimens were left in the moulds for 24 hours at 20^0C before de-molding. After de-molding, the specimens were kept in water curing till the age of test was adopted and implemented according to [9]. The compressive and spilt tensile tests were achieved in accordance to [10] and [11].

3. DISCUSSION OF RESULTS

The inclusion of fiber reduces the workability of the concrete (see Table 5). Tables 6 and 7 show the comprehensive strength results of the hardened concrete, compressive strength and split tensile strength for different percentages of fiber at different curing ages. It can be noticed that the inclusion of jute fiber in the concrete mixes slightly reduces its density. It was observed that the inclusion of jute fiber increased the compressive strength of the concrete; the highest value of compressive strength was obtained by using 0.5 % of jute fiber as shown in Figure 1. The increase in percentage for compressive strength was 10.2 % using 28 days curing age, compared to the control mix (0 %). The relationship between the compressive strengths and curing ages is as shown in Figure 2. There is a progressive increase in tensile strength of concrete; the optimal value was obtained by using 0.75 % of jute fiber as shown in Figure 3. The increase in percentage for tensile strength is 68.13 %, using 28 days curing age compared to the control mix (0 %). The relationship between the tensile strengths and curing ages areas is as shown in Figure 4.

The workability of the concrete (see Table 5) reduced as the fiber content increased, which is likely to reduce the permeability of the concrete and thus bleeding of water. The results of this study indicate that the use of jute fiber with concrete can improve strength properties of concrete. The results of density of hardened concrete indicate that the inclusion of jute fiber reduces the density. This can be attributed to the light weight of the fiber used in the mix [2]. The compressive strength results show that there is increase in compressive strength as the fiber content is increased to 5 %.The increase in compressive strength may be due to the reduction of the porosity in the concrete mixes containing 0.5 % of weight fraction of jute fiber. According to [12], compressive strength improvement implies an increase in modulus of elasticity, strain at maximum stress and toughness of stress-strain curve.

Tensile strength of jute fiber concrete increased progressively as shown in Table 8. The optimum value was obtained with concrete mix containing 0.75 % of weight fraction of jute fiber. The use of the jute fibers in concrete mixes has beneficial effects with respect to increasing the tensile strength and providing a ductile post-cracking behavior of the Jute fiber reinforced concrete mix. According to [13], fibers are usually used in concrete to control plastic shrinkage cracking and drying shrinkage cracking.

Table 5: Workability of Mixes at Different Jute Fiber Content

Fibre percentage	Slump (mm)	Compacting factor
0.00	35	0.72
0.25	30	0.81
0.50	10	0.84
0.75	10	0.87
1.00	0	0.90
1.50	0	0.96

Table 6: Hardened Density, Compression and Tensile Strength Tests Results

	0 %			0.25 %			0.50 %		
Curing age (days)	Density kg/m^3	Compr. strength N/mm^2	Tensile strength N/mm^2	Density kg/m^3	Compr. strength N/mm^2	Tensile strength N/mm^2	Density kg/m^3	Compr. strength N/mm^2	Tensile strength N/mm^2
3	353.04	19.1	168	352	19.6	211	350.37	22.7	256
7	372	29.8	212	371.41	30.3	265	369.63	32.8	335
14	379.26	33.9	284	377.41	35	310	376.15	36.9	387
21	386.81	35	304	377.04	36.5	374	380.74	38	457
28	393.33	38	313	388.44	38.7	378	384.73	39.7	467

Table 7: Hardened Density, Compression and Tensile Strengths Result

	0.75 %			1.00 %			1.50 %		
Curing age (days)	Density kg/m^3	Compr. strength N/mm^2	Tensile strength N/mm^2	Density kg/m^3	Compr. strength N/mm^2	Tensile strength N/mm^2	Density kg/m^3	Compr. strength N/mm^2	Tensile strength N/mm^2
3	343.41	18.30	292.00	340.15	16.50	272.00	336.59	13.40	266.00
7	367.11	24.70	369.00	348.00	21.00	322.00	352.44	19.10	284.00
14	371.41	31.80	439.00	366.67	26.70	377.00	352.44	24.00	354.00
21	376.74	32.30	516.00	372.30	30.00	465.00	365.48	27.20	354.00
28	381.48	32.40	525.00	375.85	30.00	434.00	370.96	27.20	427.00

Table 8: 28days Tensile Strength of Jute Fibre Reinforced Concrete

Fibre (%)	Average load (kN)	Tensile strength (N/mm^2)	Variation of tensile strength of JFRC from control (%)
0	313	4.42	0
0.25	378	5.34	20.81
0.5	467	6.6	49.32
0.75	525	7.42	67.87
1	434	6.14	38.91
1.5	427	6.03	36.43

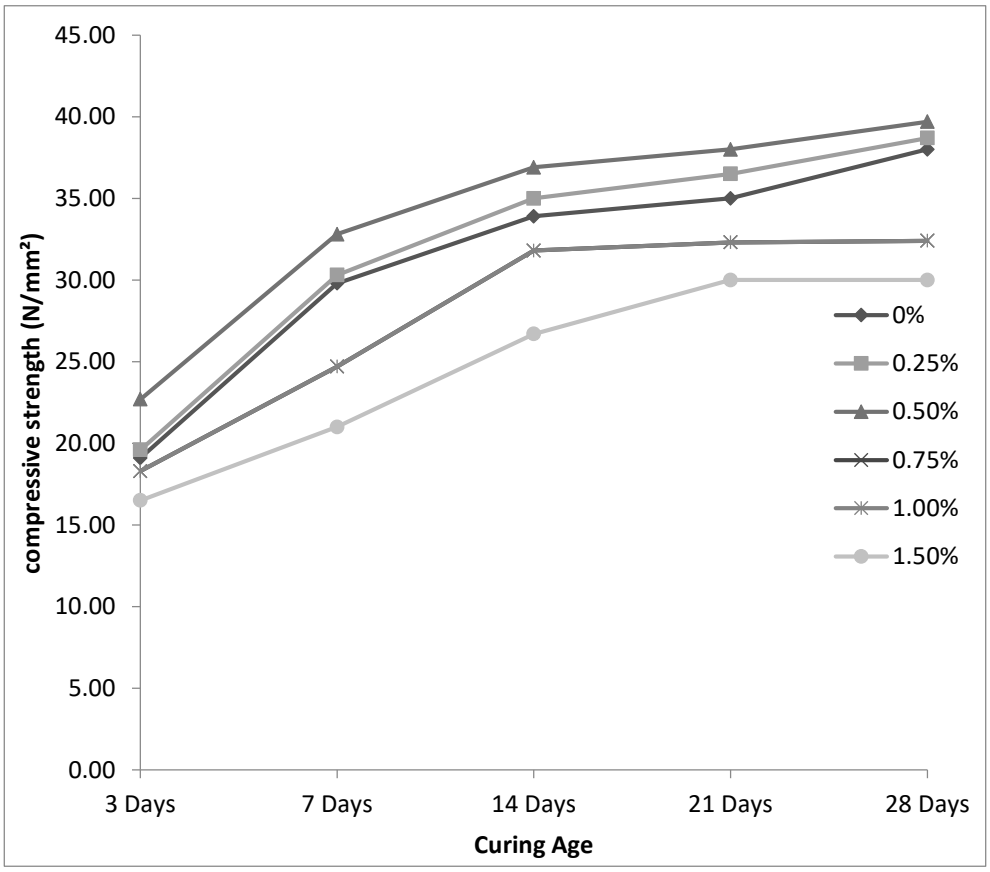

Figure 1: Compressive Strengths versus Curing Age for Different Fiber Percentages

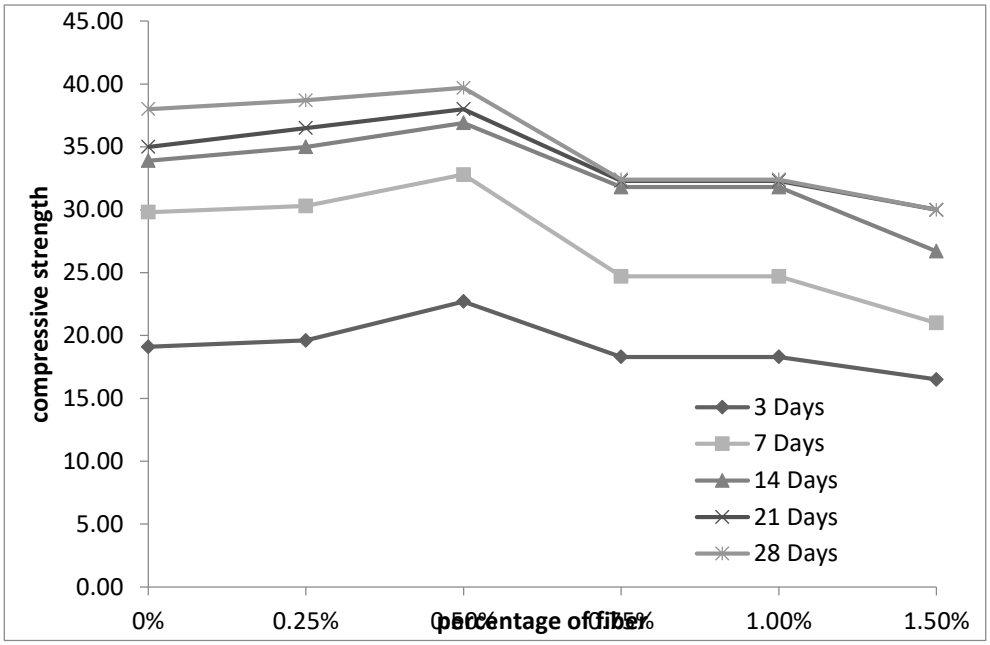

Figure 2: Compressive Strengths versus Fiber Percentages at Different Curing Ages

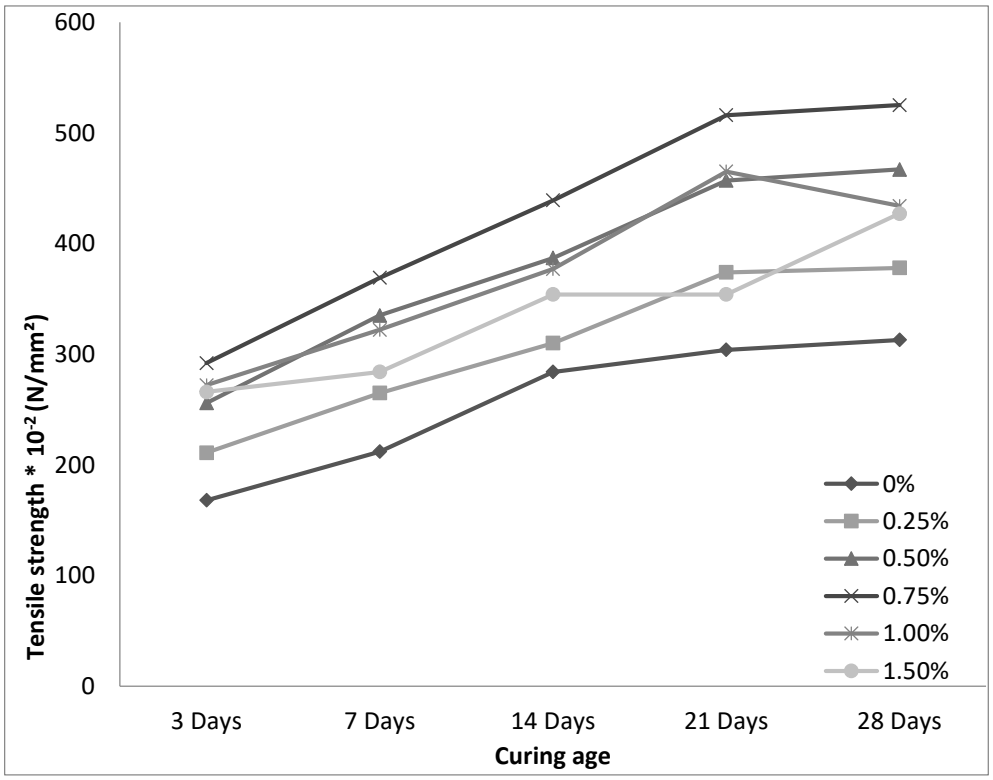

Figure 3: Tensile Strength versus Curing Age at Different Fiber Percentages

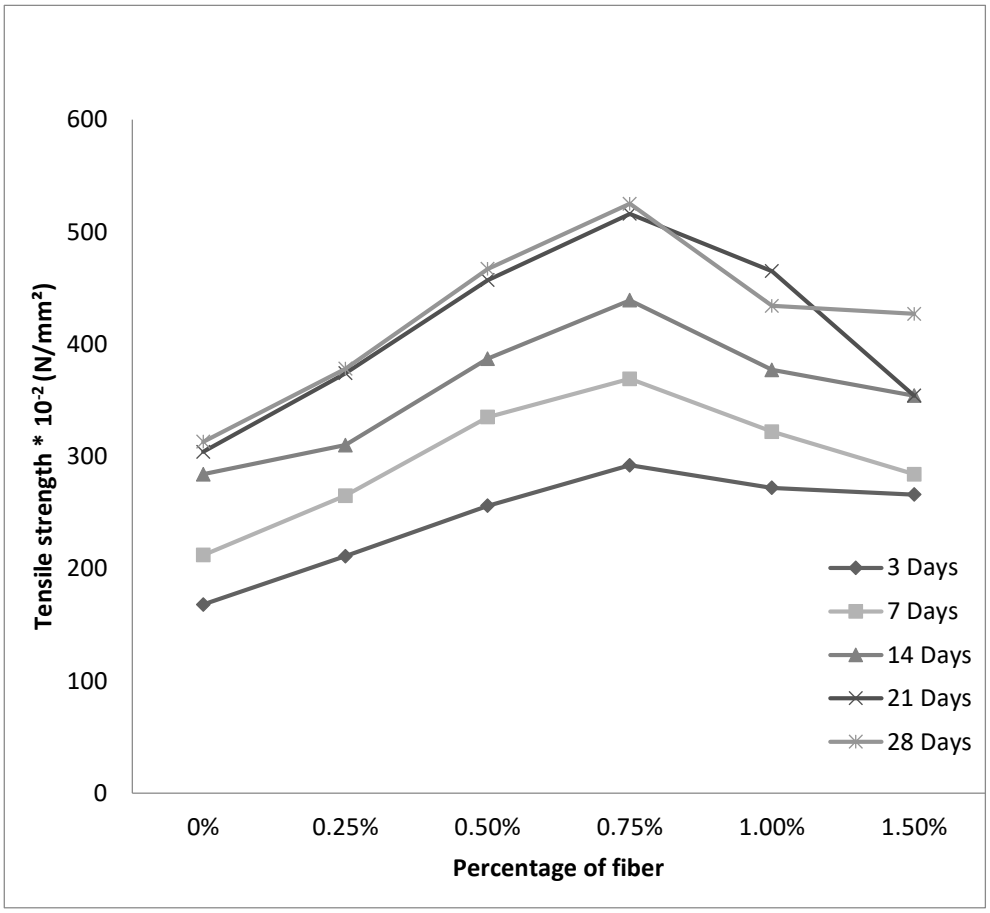

Figure 4: Tensile Strength versus Percentage of Fiber at Different Curing Ages

4. CONCLUSION

In conclusion, the research found the following:

a) The density of jute fiber reinforced concrete slightly reduces by the introduction of jute fiber in the mix.

b) The use of 0.5 % of weight fraction of jute fiber can be considered optimal percentage for this type of concrete, in view of highest compressive strength.

c) The increase in percentage of 28 days compressive strength using the optimal weight fraction of fiber is 10.2 %.

d) The use of 0.75 % of weight fraction of jute fiber can be considered optimal percentage for this type of concrete in view of highest tensile strength.

e) The increase in percentage of 28 days tensile strength using the optimal weight fraction of fiber is 68.13 %.

References

1. Mark, H. F., Bikales, N. M., Overberger, C.G. and Menges, G *et al*, (1986): "*Encyclopedia of Polymer Science and Engineering"*, 2nd ed., Vol. 6, New York: John Wiley and Sons
2. Mohammadi, Y., Singh, S.P and Kaushik, S.K, (2008), *Properties of steel fibrous concrete containing mixed fibers in fresh and hardened concrete*. Building Material, 22:956-965.
3. Saira, T, Munawar, A.M, and Shafi'ullah,K, (2007) "*Natural Fiber-Reinforced Polymer Composites* "Applied Chemistry Research Centre, PCSIR Labs Complex, Lahore-54600, Pakistan.
4. Do, L.H. and Lien, N.T., (1995) "*Natural Fiber Concrete Products*". J. Ferroce., 25: 17-24. http://cat.inist.fr/?aModele=afficheN&cpsidt=3546
5. Muhyuddin, R. and Eethar, T. D., (2010) "*Effect of Palm Fiber on the Mechanical properties" of Lightweight concrete crushed Brick*, American Journal of Engineering and Applied Sciences, 3(2)
6. BS-EN196-8 (2003)*"Methods of testing cement"* British Standard Institute, 389 Cheswick High Road, London, W4 4AL, www.bsi-global.com
7. BS 1881- Part 102, (1990) "*Method for determination of slump".* British Standard Institute, 389 Cheswick High Road, London, W4 4AL, www.bsi-global.com
8. BS 1881-103, (1993) "*Method for determination of compacting factor"*. British Standard Institute, 389 Cheswick High Road, London, W4 4AL, www.bsi-global.com
9. BS 1881: Part 114(1983), "*Methods for determination of density of hardened concrete"*British Standard Institute, 389 Cheswick High Road, London, W4 4AL, www.bsi-global.com
10. BS 1881, Part 116: (1990) "*Method for determination of compressive strength of concrete cubes"*. British Standard Institute, 389 Cheswick High Road, London, W4 4AL, www.bsi-global.com
11. BS 1881: Part 117, (1983). British Standard Institutions, *Method for Determination of Tensile Splitting Strength*, British Standard Institute, 389 Cheswick High Road, London, W4 4AL, www.bsi-global.com
12. Naaman, A. and Harajli, M. (1990). *A state-of-the-art report on mechanical properties of high Performance fiber concrete.*University of Michigan, USA
13. Rajeshkumar, K., Mahendran, N, and Gobinath, R, (2010), "*Experimental Studies on Viability of Using Geosynthetics as Fibers in Concrete"* International Journal of Applied Engineering research, Dindigul volume 1, no1, 2010