Performance Evaluation Of Textile Fabric Fibre-Reinforced Concrete

N. M. Musa, M. M. Lawan, Z. B. Baba and U. Mukhtar

Abstract: the use of fibres as reinforcement in concrete were investigated and reported by many research works and proved to be satisfactory in improving some properties of the concrete in which they were incorporated. In this paper, the utilization of textile fabric as fibre reinforcement in concrete was investigated. Compressive, flexural and splitting tensile strengths tests were conducted using 0%, 1%, 2%, and 3% of textile fabric fibres as additive. The performance of the textile fabric fibres concrete in acidic medium was also investigated. Compressive strength test at 28 days before immersion in acid, Weight loss assessment after immersion in acid at an interval of 3 days and strength loss assessment after immersion in 2% hydrochloric acid (HCl) medium for 27 days were carried out. The results show that the textile fabric fibres were feasible for use as fibre reinforcement in concrete. Also, nominal improvement of compressive, flexural and splitting tensile strengths of concrete due to the addition of textile fabric fibre at the optimum value of 2% addition was manifested. In conclusion and in contrast, the addition of the textile fabric fibre does not improve the concrete resistance in the acidic medium.

Index Terms: Textile fabric fibre, concrete, compressive strength, flexural strength, splitting tensile strength, acid resistance, weight loss.

1. INTRODUCTION

Fibre Reinforced Concrete are composite materials comprising of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibre. Fibre reinforcement has been an effective means of improving the mechanical properties of concrete [1, 2]. Addition of small short fibres to the concrete assists in bridging the cracks in the concrete matrix and provides resistance to crack propagation. Various studies reported that fibre reinforcement significantly improves the tensile properties of concrete, and reduce shrinkage and shrinkage cracking and offers the possibility of more efficient structures [3-5]. Fibres suitable for use in concrete have been produced from various types of materials such as steel, glass, and organic polymers. Naturally occurring asbestos fibres and vegetable fibres, such as sisal and jute, are also used as reinforcement [6]. The use of fibres as a construction material for improving the properties of the concrete costs very little when compared to the total cost of the concrete [7]. Different types of fibres have different effect on concrete. It was ascertained [8] that the addition of up to 1.5% of steel fibre increases the compressive strength from 0 to 15%, and can improve the direct tensile strength of concrete up to 40%. Similarly, it was established that Nylon and Polypropylene fibres also improves both compressive and split tensile strength of concrete [9, 10]. Textiles fabrics are found mainly in municipal waste due to discarded clothing, although other sources include furniture, carpets, tires, footwear, and nondurable goods such as sheets and towels.

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Textile waste has been rated as the third in comparison to plastics and cardboards [11] and therefore their utilization will be an opportunity to mitigate today's waste management problems [12]. The aim of this research is to evaluate the mechanical properties of textile fabric fibre reinforced concrete. This will be achieved through assessing the effect of the fibre on the concrete compressive strength, tensile strength and its durability when exposed to acidic medium.

2 MATERIALS AND METHODS

2.1 Materials

The materials used in this study comprised of Portland cement, fine aggregate, coarse aggregate, water, textile fabric fibre and acid.

2.1.1 Cement

Dangote Portland limestone cement having grade 42.5 was used in this study. The cement specific gravity was tested to be 3.15 and its chemical composition is shown in Table 1. The cement has complied with CEM II of NIS-444 Part 1[13].

Table 1: *Chemical composition of the Portland cement*

Oxides	Conc. (%)
Fe_2O_3	1.51
Ni_2O	0.00013
CuO	0.00033
ZnO	0.0019
Na_2O	0.228
MgO	1.599
Al_2O_3	4.014
SiO_2	21.479
P_2O_5	0.1664
K_2O	0.666
CaO	66.454
MnO	0.01655
SrO	5.249

2.1.2 Fine Aggregates:

Naturally occurring clean river sand obtained locally in Wudil, Kano, Nigeria was used. The fine aggregate has a specific gravity of 2.13 and particle size distribution of the fine aggregate is shown in Figure 1, and the aggregate is within the stipulated limits of BS882 [14].

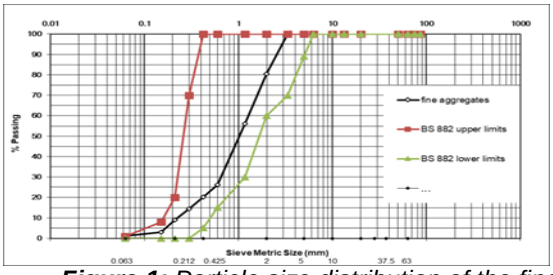

Figure 1: *Particle size distribution of the fine aggregate*

2.1.3 Coarse Aggregates:

Locally available crushed granite aggregate of nominal size 20 mm was used. The aggregate has a specific gravity of 2.6.

2.1.4 Water:

Portable water was used for both mixing and curing of the concrete specimens.

2.1.5 Fabric (Textile) fibre:

The fabric (textile) fibre used in this research was mainly cotton material obtained from the waste product of tailoring shops. The average length and diameter of the shredded fibre are 1.8 cm and 0.53cm respectively. The fibre has an average density of 1.53 g/cm^3.

Figure 2: *Textile fabric fibre of different sizes*

2.1.6 Acid:

Hydrochloric acid (HCl) used in this study was locally sourced and was not further synthesized.

2.2 Sample Preparation

The textile fabric fibres used in the study were shredded into the required size and added to the mixture of cement and sand, they were thoroughly mixed in dry form. The textile fabric fibre percentages used were 0%, 1%, 2% and 3% by weight of cement. In this study, concrete to achieve a target compressive strength of 25 N/mm^2 at 28 days was designed using the absolute volume mix design method. The mix ratio used was 1: 1.77: 4.13 for cement, fine and coarse aggregates respectively. The water-cement ratio used was 0.5.

2.3 Experimental Work

To ascertain the effects of the textile fabric fibres on the performance of concrete, the following tests were carried out.

2.3.1 Compressive Strength Test:

A compressive strength test was conducted on concrete containing 0%, 1%, 2%, and 3% of the textile fabric fibres additive. The test was performed on the cube specimens of sizes 150 x 150 x 150 mm. These cubes were prepared and cured in water in accordance with BS1881-111 [15] and tested at 7, 14 and 28 days per BS1881-116 [16]. A total of 108 cubes were tested. Furthermore, density tests were also conducted at the 7, 14 and 28 days by measuring the weight of the cubes before crushing.

2.3.2 Flexural Strength Test:

Flexural strength test of concrete with 0%, 1%, 2% and 3% textile fabric fibres additive was carried out on rectangular beams of 150 mm x 150mm x 450 mm length. The beams were cast and cured at 7, 14 and 28 days before tested using the three-point loading arrangement specified in BS1881-118 [17].

2.3.3 Splitting Tensile Strength Test:

Splitting tensile test of concrete with 0%, 1%, 2% and 3% textile fabric fibres additive was carried out at 7, 14 and 28 days in accordance with BS1881-117 [18], on cylinder of 150 mm x 300 mm length.

2.3.4 Durability test:

Weight loss assessment and compressive strength loss tests were conducted to ascertain durability on concrete containing 0%, 1%, 2% and 3% textile fabric fibres additive. The tests were performed on the concrete cube specimens. These cubes were prepared and cured in water for 28 days, after which three cubes from each mixture were immersed in 2% hydrochloric acid (HCl) medium and another three corresponding cubes were immersed in water. To minimize evaporation, these specimens were kept covered throughout the testing period. The weight of each specimen was taken at an interval of 3 days for 27 days duration. At the end of 27 days of acid immersion, the specimens were tested for compressive strength. Acid resistance was then evaluated by determining the weight loss (WL) of the specimens using this equation:

$$WL(\%) = \frac{w_1 - w_2}{w_1} \, x\, 100 \qquad -\, Equation\ (1)$$

Where w1 and w2 are the weights of the specimens (in kilograms) before and after immersion. The compressive strength of the specimen after exposure to 2% (by volume) hydrochloric acid (HCL) solution for 27 days was also compared with the one before the exposure.

3 RESULTS AND DISCUSSION

3.1 Influence of Textile fabric fibre on concrete Compressive strength:

The compressive strength results are presented in Figure 3. The Figure showed that at 7 days the strength of textile fabric fibre concrete increases from 0% to 2% with corresponding values of 15.67 N/mm^2 to 16.43 N/mm^2 and then slightly decreases to 16.29 N/mm^2 at 3% Textile fabric fibre content.

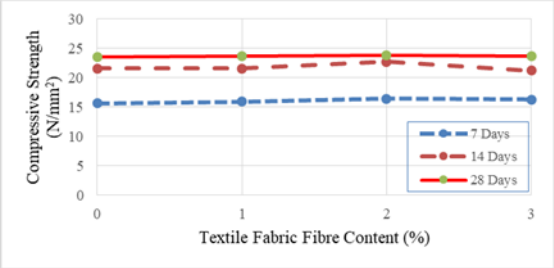

***Figure. 3**: Textile Fabric Fibre Concrete compressive strength at 7, 14 and 28 days*

3.2 Influence of Textile fabric fibre on concrete density:

Figure 4 illustrates the variation of concrete density with the Textile fabric fibre content at 7, 14 and 28 days. There is an increase in density with the curing age and also as the textile fabric fibre content increases. This can be attributed to the higher density of the textile fabric fibre.

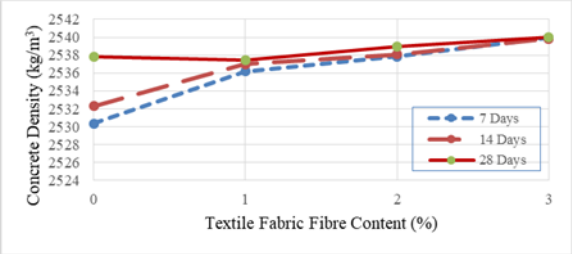

***Figure 4:** Textile Fabric Fibre Concrete cube density at 7, 14 and 28 days.*

Density is very important as a part of the design process of concrete because the unit weight of concrete will classify the categories of concrete, and also a denser concrete generally provides higher strength [20].

3.3 Influence of Textile fabric fibre on concrete flexural strength:

Flexural strength of a concrete is a measure of its ability to resist bending [21].The flexural strength results of concrete having addition of 0%, 1%, 2% and 3% textile fabric fibres are presented in Figure 4. The flexural strength generally increases with increase in curing age. At 7 days, increase in the fibre content increases the flexural strength from 3.57 N/mm^2 at 0% to 3.94 N/mm^2 at 1%; 4.12 N/mm^2 at 2% and to 4.5 N/mm^2 at 3% fibre content. At 14 days, there was an increase from 3.82 N/mm^2, 4.05 N/mm^2 and 5.58 N/mm^2 at 0%, 1% and 2% fibre contents respectively, and then there was a decrease to 4.61 N/mm^2 at 3% fibre content. The trend was similar at 28 days, with an increase from 5.18 N/mm^2, 5.37 N/mm^2 and 6.41 N/mm^2 at 0%, 1% and 2% fibre contents respectively, and decrease to 5.66 N/mm^2 at 3% fibre content. The increase in flexural strength indicates that the bonding within concrete increases by using textile fabric fibres. Thus helps in the reduction of cracks and enhances durability.

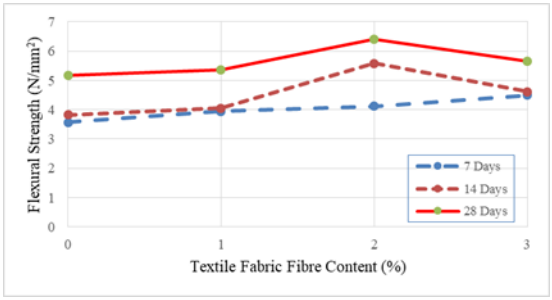

***Figure 5:** Textile Fabric Fibre Concrete flexural strength at 7, 14 and 28 days*

Figure 6 depicts the relationship between compressive strength and flexural strength at 28 days. There is a linear moderate correlation between the strengths. The relationship is in conformity with the trend obtained in other studies carried out on other types of fibres [8, 22].

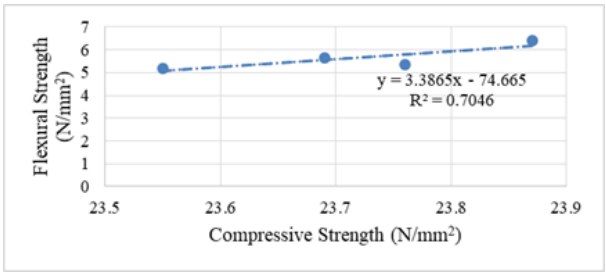

***Figure 6:** Relationship between compressive strength and flexural strength at 28 days.*

3.4 Influence of Textile fabric fibre on concrete splitting tensile strength:

The splitting tensile strength tests are well-known indirect tests used for determining the tensile strength of concrete. The influence of Textile fabric fibre on splitting tensile strength is described in Figure 7. The splitting tensile strength increases with an increase in curing period. It can also be observed that the splitting tensile strength increases with an increase in fibre content with 1% content having the optimum strength.

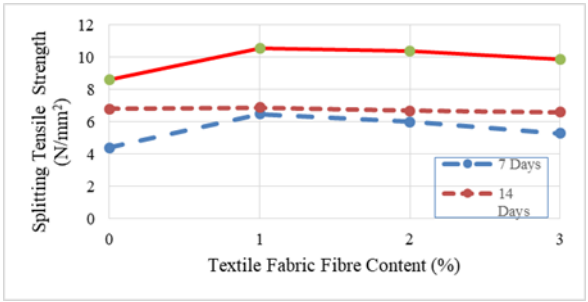

***Figure 7:** Textile Fabric Fibre Concrete splitting tensile strength at 7, 14 and 28 days.*

Table 2: *Results of Weights (kg) for Concrete cubes Immersed in HCl for 27 days*

		Average masses of concrete cubes (Kg)			
S/n	Days	0% Fibre Content	1% Fibre Content	2% Fibre Content	3% Fibre Content
1	0	2.371	2.376	2.381	2.383
2	3	2.364	2.371	2.373	2.374
3	6	2.356	2.368	2.365	2.366
4	9	2.351	2.364	2.359	2.359
5	12	2.345	2.361	2.351	2.35
6	15	2.339	2.356	2.344	2.343
7	18	2.333	2.352	2.339	2.336
8	21	2.328	2.347	2.335	2.33
9	24	2.323	2.341	2.327	2.326
10	27	2.319	2.337	2.322	2.32

The relationship between compressive strength and the splitting tensile strength is shown in Figure 8. There is a good correlation between the strengths. It can be observed that as the compressive strength increases the splitting tensile strength also increases.

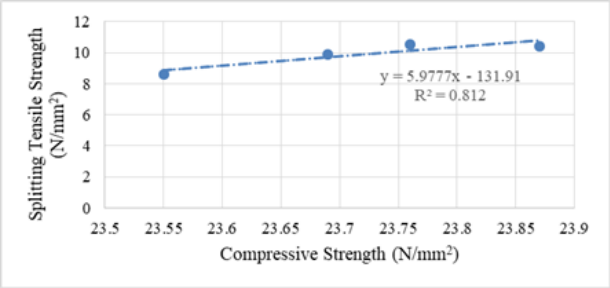

Figure 8: *Relationship between compressive strength and splitting tensile strength at 28 days.*

3.5 Influence of Textile fabric fibre on concrete when exposed to acid:

Durability of concrete is usually expressed as its resistance to deteriorating agencies to which the concrete may be exposed during its service life [23]. During that time, Concrete may be exposed to aggressive chemical environments by coming in contact with acidic effluents in industry and sewage in underground pipes [24]. Since cement concrete usually does not have good resistance to acid attack, it results in loss of weight, cracking of concrete and the consequent deterioration of concrete by loss of strength.

3.5.1 Weight loss:

The behavior of Textile Fabric Fibre in acids was investigated. The weight of the specimens when immersed in 2% HCl acid for 27 days were determined and the results are shown in Table 2. Deteriorations were observed due to leaching of both hydrated and anhydrate cement compounds as well as calcareous soluble calcium compounds. Based on the result in Table 1 the rate of weight loss due to the immersion in acid is calculated using equation (1) and the result in presented in Figure 9.

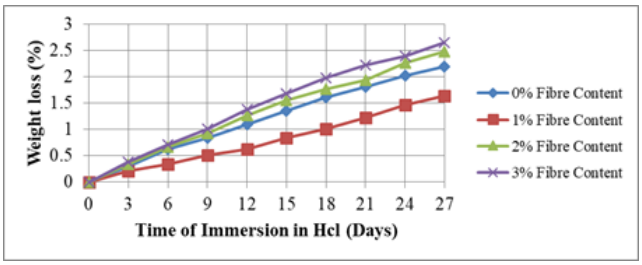

Figure 9: *Rate of weight loss of Textile Fabric Fibre Concrete immersed in HCl over time.*

It can be observed from Figure 9 that the higher the Textile Fabric Fibre content the higher the weight loss. The weight loss is an indication of resistance to acidic attack, the higher the percentage loss the lower the resistance. The deterioration of concrete due to hydrochloric acid can be characterized by the following reactions:

$2HCl + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O$ --Equation.(2) [25].

3.5.2Compressive strength after immersion in acids

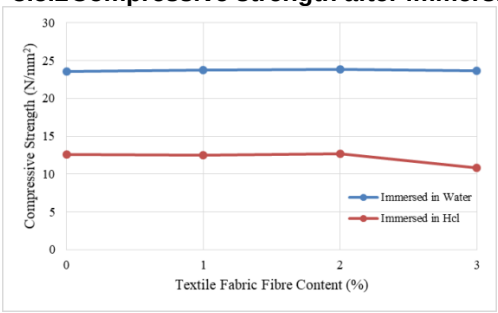

Figure 10: *Textile Fabric Fibre Concrete compressive strength after immersion in acids for 27 days.*

Figure 10 shows the result of the compressive strength of concrete containing Textile Fabric Fibre after immersion in 3% HCl for 27 days. It is evident that all specimens exposed to an acidic environment, exhibit a reduction in compressive strength having a lower ability to resist load in contrast to the specimens before immersion in acids. After 27 days, 0% fibre content loses 46.6%

strength in HCl and for 1%, 2% and 3% fibre contents the strength loss is 47.5%, 47% and 54.4% respectively. The reduction in compressive strength can be attributed to the deterioration of the concrete due to the acid attack on the matrix structure of the concrete. It can be deduced that 0% fabric content has the best resistance in acid followed by 2% fabric content.

4 CONCLUSIONS.

Based on the careful analysis of the test results, the following conclusions can be drawn:

1. There was a nominal improvement of the compressive strength of concrete due to the addition of textile fabric fibre at the optimum value of 2% fibre content. Furthermore, addition of textile fabric fibre increases the concrete density.
2. The flexural and splitting tensile strengths of concrete were observed to improve with the addition of textile fabric fibre.
3. Weight loss was observed in all the specimens when they were exposed to 2% HCl acid for 27 days. It can be concluded that the higher the textile fabric fibre content the higher the weight loss.

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REFERENCES

[1] Mohammadhosseini, H. and A. Awal, Physical and mechanical properties of concrete containing fibers from industrial carpet waste, 2014, Universiti Teknologi Malaysia.

[2] Wang, Y., H. Wu, and V.C. Li, Concrete reinforcement with recycled fibers. Journal of materials in civil engineering, 2000. 12(4): p. 314-319.

[3] Mohamed, M.A., et al., Experimental Study on Effects of Fiberglass and Fiber Waste in Concrete Mixes. International Journal of Engineering Sciences & Research Technology, 2016. 5(10): P. 485 - 493.

[4] Löfgren, I., Fibre-reinforced concrete for industrial construction. Göteborg: Chalmers, 2005.

[5] Jansson, A., Fibres in reinforced concrete structures-analysis, experiments and design. 2008.

[6] Daniel, J., et al., State-of-the-art report on fiber reinforced concrete reported by ACI Committee 544. ACI J, 2002. 96.

[7] Ali, M., et al., Mechanical and dynamic properties of coconut fibre reinforced concrete. Construction and Building Materials, 2012. 30: p. 814-825.

[8] Behbahani, H., B. Nematollahi, and M. Farasatpour, Steel fiber reinforced concrete: A review. 2011.

[9] Sohaib, N., et al. Using Polypropylene Fibers in Concrete to achieve maximum strength. In Proc. of the Eighth International Conference on Advances in Civil and Structural Engineering. 2018.

[10] 1Song, P., S. Hwang, and B. Sheu, Strength properties of nylon-and polypropylene-fiber-reinforced concretes. Cement and Concrete Research, 2005. 35(8): p. 1546-1550.

[11] Aghaee, K. and M. Foroughi, Mechanical properties of lightweight concrete partition with a core of textile waste. Advances in Civil Engineering, 2013. 2013.

[12] Alengaram, U.J., B.A. Al Muhit, and M.Z. bin Jumaat, Utilization of oil palm kernel shell as lightweight aggregate in concrete–a review. Construction and Building Materials, 2013. 38: p. 161-172.

[13] NIS-444, Quality standard for ordinary Portland cement. 2003, Standards Organisation of Nigeria, Lagos.

[14] BSI-882, Specification for aggregates from natural sources for concrete, 1983.

[15] BS1881-111:, Testing concrete. Method of normal curing of test specimens (20°C method) British Standards Institute, 389 Chiswick High Road, London, W4 4AL,http://www.bsi-global.com/. 1983.

[16] BS1881-116:, Testing Concrete: Method for determination of compressive strength of concrete cubes. British Standards Institute, 389 Chiswick High Road, London, W4 4AL, http://www.bsi-global.com/, 1983.

[17] BS1881-118, Testing Concrete: Part 118. Method for determination of flexural strength. British Standards Institute, 389 Chiswick High Road, London, W4 4AL, http://www.bsi-global.com/. , 1993.

[18] BS1881-117, Testing Concrete: Part 117. Method for determination of tensile splitting strength. British Standards Institute, 389 Chiswick High Road, London, W4 4AL, http://www.bsi-global.com/. , 1993.

[19] Abbas, A.-A., The effect of steel fiber on some mechanical properties of self-compacting concrete. American Journal of civil engineering, 2013. 1(3): p. 102-110.

[20] Iffat, S., Relation between density and compressive strength of hardened concrete. Concrete Research Letters, 2015. 6(4): p. 182-189.

[21] Zakaria, M., et al., Scope of using jute fiber for the reinforcement of concrete material. Textiles and Clothing Sustainability, 2017. 2(1): p. 11.

[22] Arunakanthi, E. and J.C. Kumar, Experimental studies on fiber reinforced concrete (FRC). International Journal of Civil Engineering and Technology, 2016. 7(5): p. 329-36.

[23] Murthi, P. and V. Sivakumar, Studies on Acid Resistance of Ternary Blended Concrete. Asian Journal of Civil Engineering (Building and Housing), 2008. VOL. 9(NO. 5): p. 473-486.

[24] 24. Verma, A., A.K. Sahu, and M. Shukla, Performance of fly ash and stone dust blended concrete in acidic environment. Concrete Research Letters, 2013. 4(1): p. 569-579.

[25] Sivakumar, N., et al., Experimental studies on high strength concrete by using recycled coarse aggregate. Int. J. Engg. Sci, 2014. 4(1): p. 27-36.