EFFECTS OF JUTE YARN ON MECHANICAL PROPERTIES OF CONCRETE

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Received: December 12, 2017 **Accepted:** June 25, 2018

Abstract: Concrete is poor in tension and it is usually reinforced with reinforcing bars within tensile zone to prevent collapse and cracking. These reinforcing steels are very expensive and are susceptible to corrosion when exposed to adverse environment. Hence, effort to reduce dependency on steel reinforcing bars in concrete is a welcoming development. In this study, jute yarn, that is an agricultural by-product and abundantly available is investigated in order to determine its impact on the mechanical strength characteristics of concrete. Compressive, split tensile and flexural strength of concrete were investigated at 0.1, 0.25 and 0.50% percentage content of jute yawn addition at varying lengths of 12, 14 and 16 mm. The optimum compressive strength was attained at 0.1% jute yawn of 14 mm length, while the optimum split tensile and flexural strength were obtained at 12 mm jute length and at 0.1% content. The optimum strengths for compressive, split tensile and flexural are 35.49, 3.14 and 4.06 N/mm^2, respectively.

Keywords: Jute Yawn concrete, reinforcing bar, British Standard

Introduction

The importance of sustainable, non-hazardous and cost effective materials in the construction industry cannot be overemphasized. In many developing countries like Nigeria, concrete has been one of the main construction materials despite its poor tensile capacity. Generally, the major means of improving the tensile capacity of concrete is to provide tensile and sometimes compressive reinforcements within the tension and compression zones of the section. The provision of this reinforcement drives the cost of concrete up significantly. Any attempt to improve the tensile capacity of concrete will reduce the dependency on reinforcing steel. Many researchers have been preoccupied with this over the decades and there has never been a better time for such work than now when many developing economies are going through recession. To this end, the use of alternative reinforcing materials that are cheap and readily available would be a welcoming development. This work thus investigates the effect of the addition of jute yarns on mechanical properties of concrete. The work will be limited to the static and further effort will be required for dynamic characterization.

The problems associated with artificial fibres are usually nonexistent in natural fibres such jute yarns and the cost effectiveness of natural fibres endears them to consideration in the concrete strength properties improvement program. Hence, natural fibres are used for making good quality and low-cost fibre reinforced concrete for low cost housing development. Despite this, limited studies could be attributed to the effect of jute yarn on the mechanical characteristics of concrete.

Attempts to overcome the shortcoming of plain concrete in tension have many researchers to investigate the addition of both natural and artificial fibres to concrete. Using natural fibre to enhance the strength characteristics of concrete becomes attractive because of its eco friendliness and lower cost of achieving strength improvement. Savastano *et al.* (2009) noted the improvement in post cracking resistance, high-energy absorption, and fatigue resistance of cement-based composites using natural fibres. Ramakrishna and Sundararajan (2005) noted that natural fibres are preferred reinforcement in-order to overcome the inherent deficiencies in FRCC reinforced with polymer-based. Artificial fibres are known for some deficiencies such as high cost, health and environmental hazards. These could not be attributed to natural fibres because they are biodegradable, inexpensive, environmental friendly, and easily avaiable as reported by Xie *et al.* (2010). In addition, the other potential application of natural fibre-reinforced cement composites is for the absorption of energy from impact loading. Acordingly, natural fiber-reinforced cement composites are most suitable for earthquake-resistant construction, foundation floor for machinery in factories and low-cost housing. Aziz *et al.* (1981) established that variety of factors influence mechanical properties of concrete reinforced with natural fiber. The factors are characteristics of fibers, nature of the cementbased matrix, and the way of mixing, casting, and curing of the composite concrete. Jarabo *et al*. (2012) stated thatamong these parameters, the type of fiber and their characteristics have a significant influence on the mechanical properties of these composites. Mixing of fibre reinforced concrete to consistent constituent can be a challenge. As noticed by Meddaha and Bencheikh (2009), inhomogeneous distribution of fibers yields bulk and surface flaws. Bezera *et al*. (2004) established that the stress concentration at these flaws would accelerate crack propagation which results to lower fracture strength of the mortar specimens. Chakraborty (2013) also reported the same phenomenon and established that agglomeration could not be avoided. Mansur and Aziz (1982) also noted that fibre intermeshing could limit amount of fibre that could be added to concrete. Bailing results in an ineffectual and segregated mix which produces a highly porous and honeycombed concrete. As a result, a remarkable strength decrease would be experienced. Obtaining a consistent mix of fibre reinforced concrete is key to the attainment of optimum strength. Despite the potential of jute fibre reinforced concrete, much work is done to fully establish its characteristic strengths. Additionally, natural fibers like cotton, sisal, jute, abaca, pineapple and coir have already been studied like as reinforcement and filler in composites.

Investigative studies have not yet been conducted to evaluate the effect of jute fiber on the mechanical properties of concrete. To this end, it is very much rationale to determine the effect for exploring potential use of jute for obtaining enhanced concrete with low cost, without affecting the environment and minimum health hazard. With this background, the main objective of the study is to develop jute fiber to reinforce concrete composites and to investigate the effect of fiber length and content (volume fraction) on its mechanical behavior.

Jute fibres are extracted from the ribbon of the stem after being harvested. The wood stems are then cut to 5 mm long being successively subjected to retting in water, stripping, beating and then dried. The fibre from the core of the stems are extracted and processed to the final yarns. A single jute fibre is a three dimensional composite material composing mainly of lignin, cellulose, hemicelluloses with minor amounts of protein, extractives and inorganic compounds. An example of final product is shown in Fig. 1 and its basic properties are shown Table 1.

Fig. 1: An example of jute yarns

Table 1: Properties of fibre

Specific gravity	1460 kg/m^3
Water absorption	13 %
Tensile strength	400-800 MPa
Stiffness	10-30 kN/mm^2

There are various natural fibres but jute fibre is considered a very high strength and stiffness material.

Zakaria *et al.* (2015) studied the effects of jute yarn on mechanical properties of concrete. They investigated a range of jute yarn lengths of 10, 15, 20 and 25 mm. Also, a range of proportion of addition of 0.1, 0.25, 0.5 and 0.75% of jute yarns were investigated for the range of the length considered, and observed the mechanical properties of JYRCC to be enhanced for a particular range of lengths of cut (10, 15, 20 and 25 mm) and volume content of jute yarn (0.1, 0.25, 0.5 and 0.75 %). They found that generally jute yarns addition improved the compressive, tensile and flexural strength of concrete by 33, 23 and 38%, respectively. Pooja and Shrinkhala (2016) investigated the properties of concrete by using jute fibre of different percentage in concrete (0.2%, 0.3%, 0.4%) and found that at 0.2% the maximum compressive strength was recorded. The current work investigated the compressive, split tensile and flexural strengths of concrete with jute yarn additions were experimentally investigated at 0.1, 0.25 and 0.50% percentage content with jute yarn length of 12, 14 and 16 mm.

Materials and Methods

In other to achieve the objectives for this study, tests on concrete behavior with different jute yarn contents (0.1, 0.25 and 0.50%) and length of 12, 14 and 16 mm characteristics will be carried out. Among the tests carried out were the sieve analysis of fine and coarse aggregates, compressive, split tensile and flexural strength tests of concrete for the range of jute yarn considered.

Materials

Jute Yarns

The locally available raw jute fiber shown in Fig. 1 was used without any treatment. This jute fiber with three different cut lengths (12, 14 and 16 mm) at 0.1, 0.25 and 0.5% of jute addition for each length.

Cement

The cement used was Portland cement (Dangote brand) which is in accordance with BS EN 197-1 (2011).

Aggregates

The fine aggregates were river washed sand while the coarse aggregates are the granites obtained from the quarry site. They were air dried before the particle size distribution analysis carried out in accordance with BS 410 (1986).

Water

Water which is equally suitable for human consumption obtained from the Departmental laboratory was used for mixing and curing of specimens.

Testing methods and results

The methods of testing include the determination of the gradation of both fine and coarse aggregates, compressive, tensile and flexural strengths for all the ranges of jute yarn considered. M30 grade of concrete of mix ratio of 1:1.5:3 and water cement ratio of 0.45.

Sieve analysis

The results of fine aggregates sieve analysis are presented in Tables 2 and the plot of the same is Fig. 2. It can be seen that the fine aggregates are uniformly graded and that they conform to near single sized particles. The results of coarse aggregate sieve analysis are also presented in Table 3 and Fig. 3. It can be seen that the coarse aggregates are also uniformly graded and that they conform to near single sized particles. Both the fine and coarse aggregates on site satisfy the requirements of BS EN 12620 (2008).

Table 2: Sieve analysis of fine aggregate

Sieve sizes (mm)	Total mass (Kg)	% Retain	%Passing
2.36	580.75	38.72	61.28
1.18	320	21.33	39.95
0.6000	250	16.67	23.28
0.3000	198	13.2	10.08
0.150	65	4.33`	5.75
0.075	75	5	0.75
Pan	11.25	0.75	0.00
Total	**1500**		

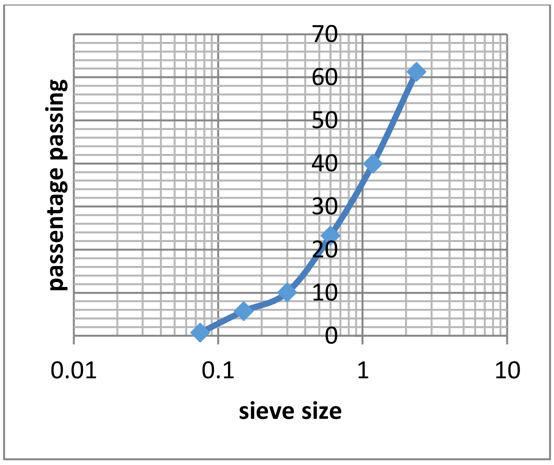

Fig. 2: Curve of sieve analysis of fine aggregate

Table 3: Sieve analysis of coarse aggregate

Sieve sizes (mm)	Total mass (Kg)	% Retain	%Passing
37.5	-	-	100
20	99	19.8	80.2
14	151	30.2	50
10	110.4	22.08	27.92
4.5	72	14.4	13.52
Pan	67.6	13.52	0.00
Total	**500**		

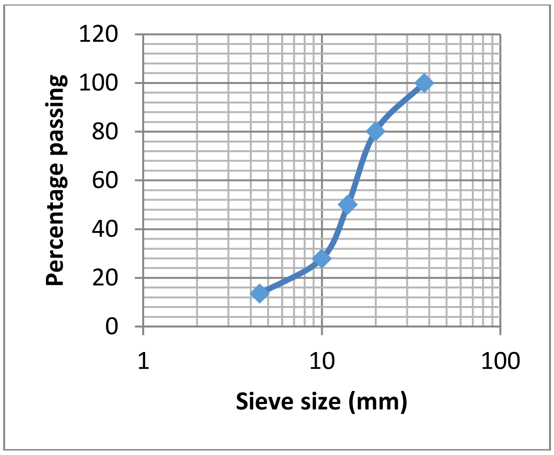

Fig. 3: Curve of sieve analysis for coarse aggregate

Compressive strength testing

Compressive strength of a concrete is a measure of its ability to resist static compressive load. The cube size of 150 x 150 x 150 mm was used for all the compressive strength tests. The concrete cubes were cast and cured for various ages of 7, 14, 21 and 28 days before being tested in accordance with AS 10129. The Fig. 4 shows the compressive strength machine.

Fig. 4: Test setup for compressive strength test

The failure load is used to calculate the compressive strength given as:

$$\textit{Compressive Stress} = F_u/A$$

Where F_u is the failure load *(N)* and A is the cross section area *(mm²)*

The results of the compressive tests are presented in Table 4 and Figs. 5 to 8. It is evident that the optimum compressive stress is obtained at 0.1% of jute yarn content and 14 mm cut length. The increase is in excess of 20% over the control concrete.

Table 4: Compressive strength

Yarn Content	Yarn Length	Compressive Strength 7 Days	14 Days	21 Days	28 Days
0%		22.86	24.33	29.12	30.38
	12	25.42	27.91	29.63	32.8
	14	27.18	29.24	32.36	35.49
0.10%	16	23.51	26.02	28.02	31.86
	12	19.19	21.87	24.08	26.29
	14	22.3	24.28	27.07	29.02
0.25%	16	18.95	21.24	23.18	24.45
	12	18.79	20.73	22.21	23.81
	14	20.74	22.8	24.57	26.28
0.50%	16	17.63	20.39	21.09	23.42

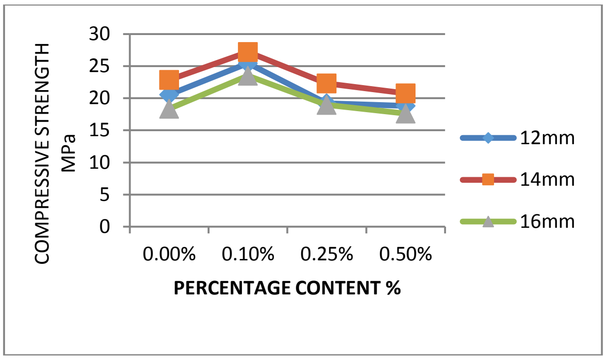

Fig. 5: 7 day compressive strength

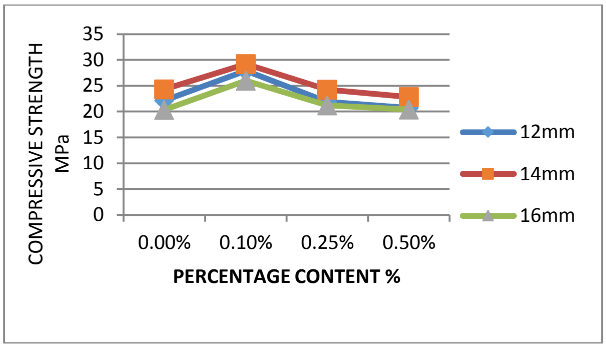

Fig. 6: 14 day compressive strength

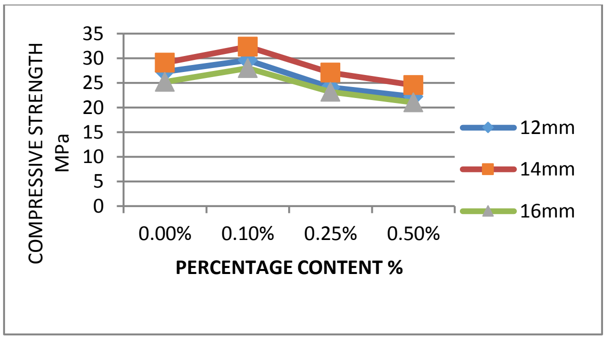

Fig. 7: 21 day compressive strength

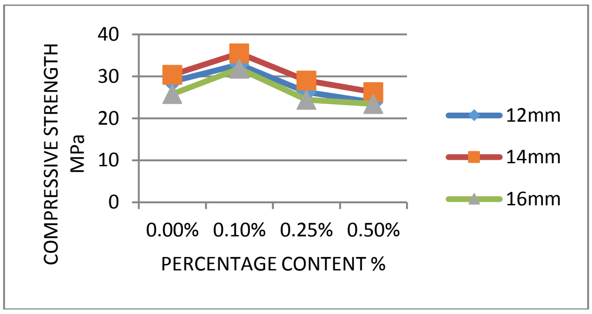

Fig. 8: 28 day compressive strength

Split tensile strength

Investigation of concrete's mechanical properties can be presented reasonably through the analysis of tensile strength. The brittleness and low tensile strength of concrete make it abortive to struggle with the direct tension. Hence the measurement of tensile strength is obligatory to determine the load at which the concrete members may crack therefore the cracking is due to the tension failure. The splitting tests (sometimes referred to as split tensile strength tests) are well known indirect tests used for determining the tensile strength of concrete. The test procedure consists of applying a compressive line load along the opposite generators of a concrete cylinder placed with its axis horizontal between the compressive planes. The splitting tensile strength test was conducted in accordance with ASTM C 496/M496 using a cylindrical specimen of 150 mm diameter and 300 mm cylindrical length. The tests were carried out at 7, 14, 21 and 28 day curing ages for all the percentage contents and the cut lengths.

Split tensile strength (N/mm^2) = (2P) / (π x d x l)

Where ***P*** is maximum failure load, ***l*** is length of cylindrical specimen and ***d*** is diameter of cylindrical specimen.

The test arrangement is shown in Fig. 9 and the results are presented in Table 5 and Figs. 10 to 13.

It is evident that the optimum tensile strength was observed for 0.1% jute yarn content at 12 mm cut length. It is in excess of 60% of the control value.

Fig. 9: Test arrangement for tensile strength

Table 5: Split tensile strength

		Split Tensile Strength			
Yarn Content	**Yarn Length**	**7 Days**	**14 Days**	**21 Days**	**28 Days**
0%		1.35	1.6	2.41	2.78
	12	1.69	2.28	2.72	3.14
	14	1.56	1.92	2.52	2.72
0.10%	16	1.43	1.51	1.78	2.25
	12	1.23	1.69	2.23	2.59
	14	1.14	1.51	1.79	1.81
0.25%	16	1.07	1.19	1.31	1.5
	12	1.13	1.28	1.64	1.76
	14	1.03	1.15	1.25	1.41
0.50%	16	1.04	1.09	1.22	1.31

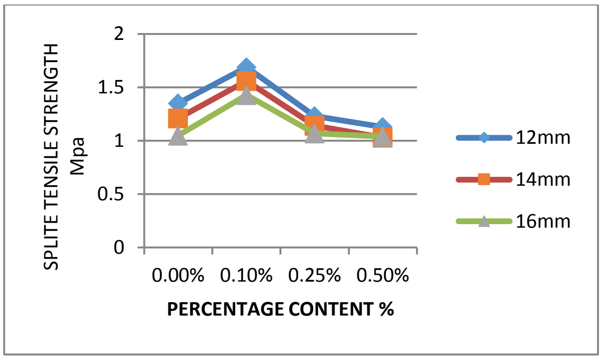

Fig. 10: 7 day split tensile strength

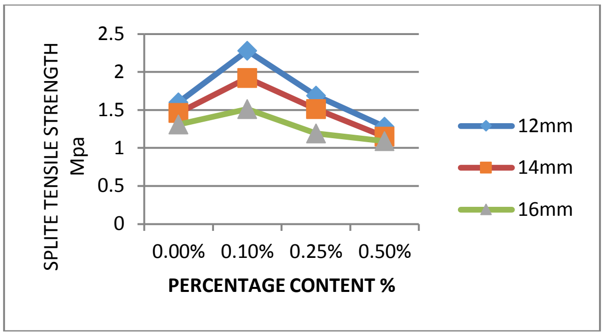

Fig. 11: 14 day split tensile strength

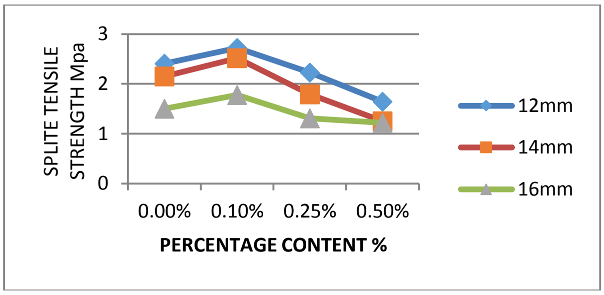

Fig. 12: 21 day split tensile strength

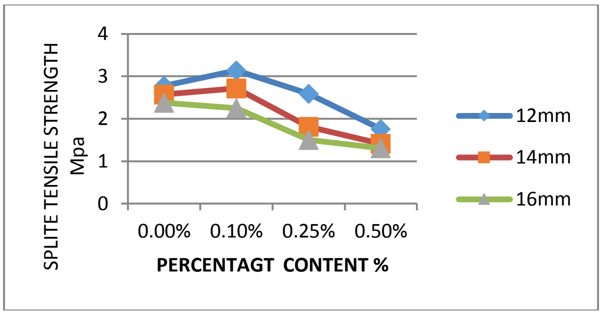

Fig. 13: 28 day split tensile strength

Flexural strength testing

Flexural strength of a concrete is a measure of its ability to resist bending and it can be expressed in terms of modulus of rupture. Therefore, the two point loading method was used in making flexural strength tests of concrete employing bearing blocks which ensured that forces applied to the beam was perpendicular to the face of the specimen and was applied without eccentricity. During test the reaction was always parallel to the direction of applied force. The test procedure was carried out following the test method ASTM C 78-00. The load will be applied continuously and without any shock at a constant rate to the breaking point. Finally, total load at which the beam fails is the ultimate load. The test arrangement is shown in Fig. 14. The mold size for the flexural cast is 100 x 100 x 500 mm length. The flexural tests were conducted t 28 day curing age for all jute yarn contents and cut lengths. The results are presented in Table 6 and Figs. 15 to 18. It is evident that the optimum flexural strength was recorded at 0.1% jute yarn content and for the cut lengths of 12 and 14 mm, respectively.

Fig. 14: Flexural test arrangement

Table 6: Flexural strength

Yarn Content	Yarn Length	Flexural Strength 7 Days	14 Days	21 Days	28 Days
0%		3.05	3.28	3.5	3.83
	12	3.14	3.43	3.68	4.06
	14	3.14	3.43	3.63	4.06
0.10%	16	3.01	3.08	3.29	3.41
	12	3.04	3.3	3.46	3.8
	14	2.98	3.08	3.29	3.64
0.25%	16	2.35	2.57	2.71	2.81
	12	2.7	3.08	3.29	3.64
	14	2.35	2.96	3.18	3.36
0.50%	16	1.98	2.04	2.23	2.36

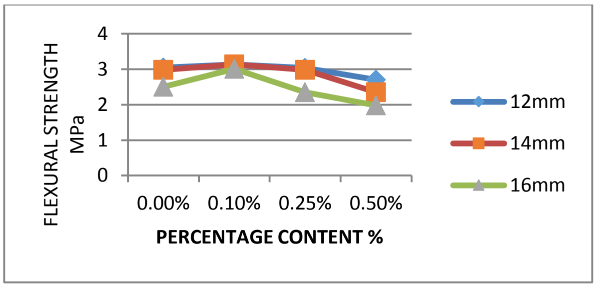

Fig. 15: 7 day flexural strength

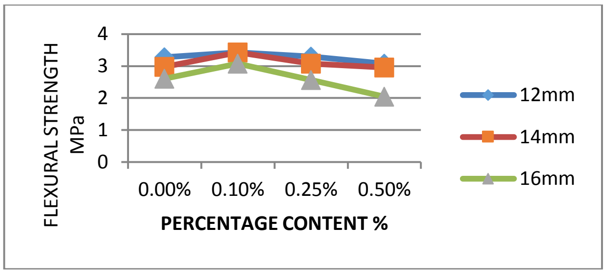

Fig. 16: 14 day flexural strength

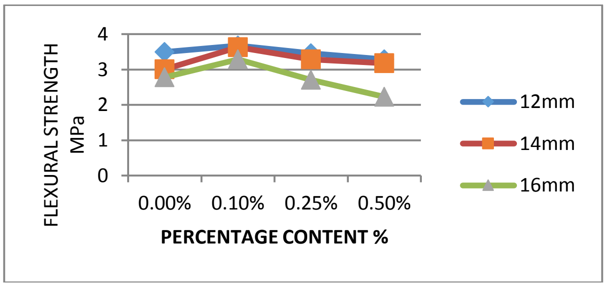

Fig. 17: 21 day flexural strength

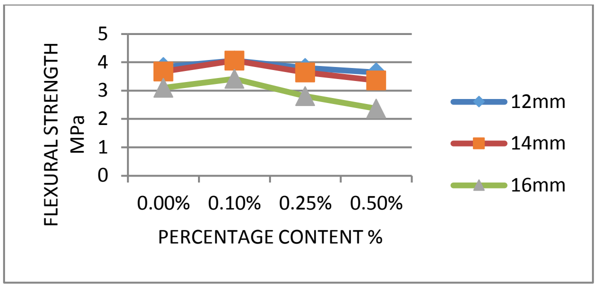

Fig. 18: 28 day flexural strength

Conclusion

From the above results it can be concluded that the addition of jute yarn of 0.1% improves the static mechanical strengths of concrete for cut length between 12 and 14 mm. The compressive strength is about 36MPa at cut length of 14 mm while split tensile strength of 3.2MPa at the cut length of 12 mm. The flexural strength is also optimum at 0.1% content with about 4.1MPa at cut length of 12 and 14 mm, respectively. The improvement is most significant for the tensile strength of the concrete.

References

AS 1012 2002. Compressive test of concrete specimen, Methods of testing concrete, Standards Australia.

Aziz MA, Paramasivam P & Lee SL 1981. Prospects for natural fibre reinforced. *Int. J. Cem. Comp. Lightweight Concrete*, 3(2): 123–132.

Bezerra E, Joaquim A & Savastano H Jr 2004. Some Properties of Fibre–Cement. In: NOCMAT conference 2004. Pirassununga, Brasil, pp. 1–11.

Chakraborty S, Kundu SP, Roy A, Basak RK, Adhikari B & Majumder SB 2013. Improvement of the mechanical properties of jute fibre reinforced cement mortar: A statistical approach. *Constr. Build Mat.*, 38: 776–784.

Jarabo R, Fuente E, Monte MC, Savastano H, Mutjé P & Negro C 2012. Use of cellulose fibers from hemp core in fiber-cement production. Effect on flocculation, retention, drainage and product properties. *Ind. Crops Prod.*, 39(1): 89–96.

Mansur M & Aziz M 1982. A study of jute fibre reinforced cement composites. Int. *J. Cem. Comp. Lightweight Concr.*, 4(2): 75–82.

Meddaha MS & Bencheikh M 2009. Properties of concrete reinforced with different kinds of industrial waste fibre materials. *Constr Build Mat.*, 23: 3196–3205.

Pooja Warke & Shrinkhala Dewangan 2016. Evaluating the performance of jute fiber in concrete. *J. Trend in Res. & Devt.* (IJTRD), 3(3).

Ramakrishna G & Sundararajan T 2005. Impact strength of a few natural fibre reinforced cement mortar. *Cem. Concr. Comp.*, 27(5): 547–553.

Savastano H, Santos S, Radonjic M & Soboyejo W 2009. Fracture and fatigue of natural fiber-reinforced cementitious composites. *Cem. Concr. Comp.* 31(4): 232–243.

Xie YJ, Hill CA, Xiao Z, Militz H & Mai C 2010. Silane coupling agents used for natural fiber polymer composites: a review. *Comp. Part A Appl. Sci. Manuf.*, 41: 806 – 819.

Zakaria Mohammad, Mozammel Hoque, Md. Abdul Hannan & Abdul Hannan 2015. Effect of jute yarn on the mechanical behaviour of concrete composites. *SpringerPlus*, 4: 731, DOI 10.1186/s40064-015-1504-7.