International Journal of Applied Environmental Sciences
ISSN 0973-6077 Volume 12, Number 10 (2017), pp. 1757-1767

http://www.ripublication.com

Investigating the impact of plant fibres in increasing the strength of concrete

G. Malarvizhi
Research scholar, Textile Technology, Bharathiar University,
Coimbatore, Tamil Nadu, India.

S. Karpagam Chinnammal
Head, Assistant Professor, Department of Costume Design and Fashion, Chikkanna Government Arts College, Tirupur, Tamil Nadu, India.

Abstract

The effect on utilization of thuthi and banana fibres to improve the strength of the fibre reinforced concrete was considered as the primary objective. Two fibres, thuthi and banana were selected to construct a hybrid composite fibre (HCF). Thuthi and HCF separately were reinforced with concrete matrix of standard M20 type. All the concrete after casting and curing for 28days, the three tests (Compressive strength test, split-tensile strength test and flexural strength test) emphasizing the strength of concretes were investigated as per BIS standards. During the analysis, compressive strength of M20 control concrete was found to be 19.5N.mm^2. Thuthi reinforced concrete showed 21.6N/mm^2 and hybrid composite fibre reinforced concrete showed 25.5N/mm^2. Increase in tensile and flexural strength for hybrid composite reinforced concrete was also observed. Thuthi reinforced concrete exhibited 3.6N/mm^2 and 4.2N/mm^2 of split-tensile and flexural strength. Hybrid composite fibre reinforced concrete showed 4.8N/mm^2 and 6.9N/mm^2 respectively. Test results reveals that the presence of fibre has direct influence in the increase of concrete strength. With Change in the length and percentage composition of fibres in the concrete mixture, the strength of the concrete along with the durability against deterioration will rapidly increase.

Keywords: Thuthi fibre, hybrid composite fibre, reinforced concrete, compressive strength, M20 concrete

INTRODUCTION

Natural fibres are of different types, used in different industries for the development of novel consumer products. In textile and allied industries, natural fibres have strong and potential applications [1]. In recent years, the fibres were experimented for their native strength and other physical properties [2]. The proven tensile strength of many fibres like sisal, banana and kenaf made the structural and civil engineers to include the fibres in concrete mix either as one of the major ingredient or as a partial replacement to fine aggregates [3]. A civil and structural engineers' fundamental requirement for making concrete structures is to fabricate strong balanced quality concrete with careful proportion of ingredients mix [4].

Many researchers have experimented the compressive strength, flexural strength, water absorption, porosity, resistance to cracking and thermal resistance of the concrete casted using the natural fibres. Very promising results like greater durability, improved impact strength and toughness in the fibre reinforced concrete were identified [5]. The contribution of fibre directly influences the composites behaviour to understand the properties of fibre reinforced concrete. The success of these concrete relies on the following properties like, length of the fibres used, type and orientation of fibres, percentage of the fibre, and ratio of fibre modulus to matrix modulus in the composite [6]. Even though fibre reinforced concrete was proved to be strong and tough, the durability of the fibre in the concrete was considered significantly. Durability was meant for its resistance to degradation or deterioration due to any external or internal causes [7]. Most of the research work performed till date was by using sisal reinforced concrete structures. Sisal fibre is a hard fibre extracted from the leaves of the sisal plant (*Agave sisalana*) [8].

In this study, two fibres thuthi and banana was selected and investigated for the compression strength and tensile strength of the fibre reinforced concrete. Thuthi and banana fibre was selected for the concrete studies since their properties were found similar to sisal fibre. Therefore, the effect on utilization of thuthi and banana fibres to improve the strength of the fibre reinforced concrete was considered as the primary objective.

MATERIALS AND METHODS

The present research work was carried out in Department of Costume and Fashion, Dr. N.G.P.Arts and Science College, Coimbatore, India. The entire research work was performed from March 2017 to June 2017.

A. Cement (BIS-8112, 1989)

Commercial cement with IS mark 43 grade was commercially procured from the cement suppliers, Coimbatore, Tamil Nadu, India. Cement was checked for its freshness and presence of any lumps on it. Cement was tested as per BIS-8112, 1989 [9] (Initial and final setting, specific gravity, and fineness).

B. Coarse and Fine Aggregates (BIS-383, 1970)

Coarse and fine aggregates were commercially procured from the building material suppliers. About 12mm size of coarse aggregates was selected for the study. Both the aggregates were tested as per BIS-383, 1970 [10] standards. Specific gravity, fineness modulus, and water absorption tests were performed prior to the study.

C. Water (BIS- 456, 2000)

Water is considered as a significant component and hence conformed to the requirements of BIS- 456, 2000 [11]. pH, dissolved solids, suspended solids, chloride and sulphate was tested.

D. Fibres: Collection and fibre extraction [12]

Thuthi (*Abutilon indicum*) and banana were procured commercially and the fibres were extracted using fibre extractor equipment by the method called scraping. Scraping was carried out in two stages called linear scrapping and rotational scrapping. Long fibre was extruded by the means of scrapping method (Fig. 1 and Fig. 2).

Fig. 1. Thuthi fibre

Fig. 2. Banana fibre

The fibre length ranging from 1m to 2 m was chopped in a developed machine to small lengths according to the requirements of the study (5mm to10mm). Thuthi and banana fibres were mixed in equal volumes to produce hybrid composite fibre (HCF). The quality and contamination free status of the selected fibre (Thuthi and HCF) was determined using standard protocols. The defined size and structure of the fibres were observed under hand microscope before pretreament. During the microscopic analysis, no other plant fibre was observed with either thuthi or banana fibers.

E. SEM analysis of extracted fibres

Thuthi fibres separately and HCF - hybrid composite fibre (thuthi + banana fibres) were observed using Scanning electron microscopy. SEM evaluation was performed to understand the uniformity of fibres in the sample size selected for the concrete preparations. All the test materials were prepared for SEM using a suitable accelerating voltage (10 KV), vacuum (below 5 Pa) and magnification (X 3500).

F. Concrete preparation using thuthi and HCF [13]

M20 concrete cubes of standard size (150 mm x 150 mm x 150 mm) were made in triplicates using thuthi fibre and HCF as partial replacement of fine aggregate. Along with these concretes, control concretes with regular ingredients of M20 concrete were also prepared (TABLE I and TABLE II).

Table I. Regular Mix Proportion Used For M20 Concrete Preparation

S. No.	Parameters	Cement	Fine aggregate	Coarse aggregate	Water
1	Ingredient ratio	1	1.5	3.0	0.5
2	Contents for cubes preparation (Units)	10 kg	15 kg	30 kg	5 lit

Table II. Distribution in concrete mix proportions with and without fibres

S. No.	Ingredients	Concrete casting using Thuthi fibre	Concrete casting using HCF[a]	Control concrete casting
1	Thuthi fibre	3%	-	-
2	HCF	-	3%	-
3	Cement (kg/m^3)	10	10	10
4	Fine aggregate (kg/m^3)	14.7	14.7	15
5	Coarse aggregate (kg/m^3)	30	30	30
6	Water (lit)	5	5	5

[a]HCF: Hybrid composite fibre (Banana + Thuthi fibre)

G. Casting of cubes

Cubes were made (Fig. 3 and Fig. 4) using concrete mixture with and without fibres separately based on the standard concrete casting conditions.

Fig. 3. Thuthi reinforced concrete

Difference in the presence of thuthi fibre randomly reinforced with the concrete mix is observed after comparing with the conventional concrete in the left (without thuthi fibre)

Fig. 4. Hybrid composite reinforced concrete

Difference in the presence of hybrid composite fibre randomly reinforced with the concrete mix is observed after comparing with the conventional concrete in the left (without fibre)

H. Study of concrete properties

All the concretes were subjected to analyze the properties like compressive strength, split-tensile strength and flexural strength as per BIS standards.

I. Testing of Compressive Strength [BIS: 516 (1959)]

Compressive Strength of concrete cubes prepared with thuthi fibre, hybrid composite fibre (banana and thuthi) and without fibre (Control) was determined by BIS: 516, 1959 [14] using a Digital Compression Testing Machine.

J. Flexural strength test [BIS: 516 (1959)]

Flexural Strength tests were carried out on prisms of size 100×100×500 mm on flexure testing machine of capacity 100 kN as per IS: 516, 1959. The tests were carried out for all the concretes after 28days of curing.

K. Split-tensile strength test (IS: 5816-1970)

Split- tensile strength is indirect way of finding the tensile strength of concrete by subjecting the concrete cylinders to a compressive force [15]. Cylinders of size 150mm diameter and 300mm long were casted. After 24 hours the specimen were demoulded and subjected to water curing. After 28 days of curing the cylinders were taken allowed to dry and tested in compression testing machine by placing the specimen horizontal. The tensile strength is calculated from the formula as given below

$$\sigma Max = 2P/\Pi DL$$

where, P- is the maximum applied load to the specimen, D- is the diameter of the specimen, L- is the length of the specimen.

RESULTS AND DISCUSSION

A. Microscopic observations of the enzyme treated plant fibres

Microscopic observations of thuthi and banana fibres were carried out two different magnifications under polarized light using a stereo-zoom microscope. The width of the fibres before and after enzyme wash was observed and measured. The differences in fibre surface observations between before and after wash enzyme treatment were observed for thuthi and banana fibre respectively. Difference in pretreated fibres of thuthi and banana were mainly due to the action of biopectinase K. The enzyme played a crucial role in removing the undesired compounds like pectin and hemicellulose from the fibre surface.

B. SEM analysis of extracted fibres

SEM images of the pretreated fibres revealed the fibre structure, approximate size and difference in the dispersion of fibres. The difference in fibre volumes and fibre types in the hybrid composite were observed clearly during the analysis. Difference among the banana and thuthi fibre in the hybrid composites were noted in different magnifications (Fig. 5 and Fig. 6).

C. Concrete properties

Concrete is the most widely used structural material world-wide. Due to structural, environmental or economic factors, cracking in the concrete are more common. The inherent weakness of the concrete material to resist tensile forces is also reported as a major reason [16]. Limitations of the conventional concrete paves way for an alternative type of concrete called Fibre reinforced concrete (FRC).

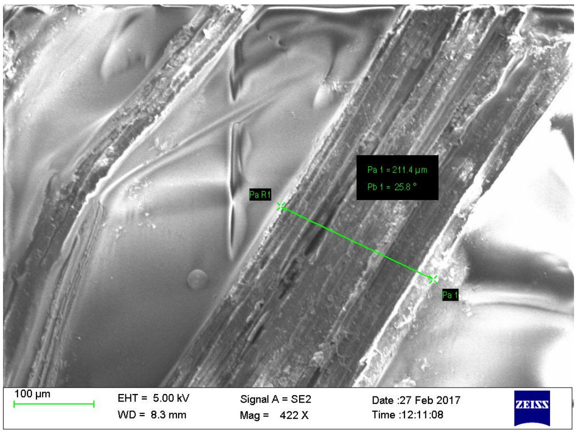

Fig. 5. SEM images of thuthi fibre

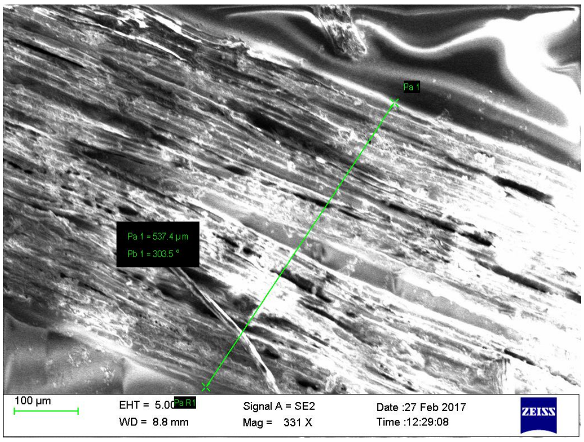

Fig. 6. SEM images of hybrid composite fibre

Natural or synthetic man-made fibres are reinforced with cementing concrete mixtures to increase the tensile and flexural strength; good permeability, impact and frost resistance. The weak matrix in concrete, when reinforced with randomly oriented fibre prevents the crack formation and enhances the strength and ductility. This structural matrix behaves as a composite material with properties significantly different from conventional concrete [17]. The uniform dispersion of fibers throughout the concrete mix provides isotropic properties. Civil and structural engineers take advantage of the dynamic characteristics of this new material to replace the conventional concrete.

Based on these advantages of fibre reinforced concretes, concrete cubes were prepared with and without fibres (thuthi and banana) and its different types of strength was tested as per IS specifications in this research. The compressive strength test, split tensile strength test and flexural strength test were carried out both for thuthi reinforced concrete and hybrid composite reinforced concrete. All the calculated values were compared with the values of M20 Control concrete. Compressive strength of M20 control concrete is 19.5N.mm^2). Thuthi reinforced concrete showed slightly higher compression strength (21.6N/mm^2) than the control concrete.

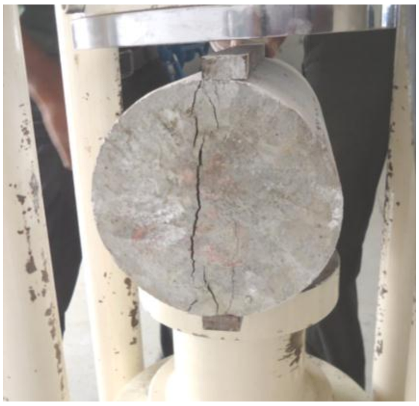

Fig. 7. Compression strength of concrete (without fibre)

Concrete (without fibre) showing big crack indicating that concrete unable to withstand the pressure given in the compression testing machine (2000 KN capacity)

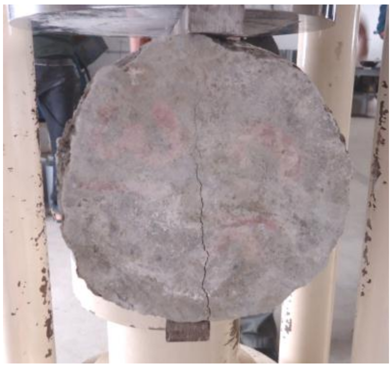

Fig. 8. Compression strength of reinforced concrete

(with HCF fibre)

Concrete (with HCF) showing minor crack indicating, the presence of fibre withstand the pressure given in the compression testing machine (2000 KN capacity)

Interestingly, hybrid composite fibre reinforced concrete showed more compressive strength than the control and thuthi reinforced concrete (25.5N/mm^2). Similar increase in tensile and flexural strength for hybrid composite reinforced concrete was observed during the investigation (Fig. 7 and Fig. 8). M20 control concrete values for split-tensile and flexural strength test were recorded as 2.3N/mm^2 and 3.2N/mm^2 respectively.

Thuthi reinforced concrete exhibited a slight increase over the control M20 concretes. 3.6N/mm^2 and 4.2N/mm^2 of split-tensile and flexural strength test were noted. Hybrid composite fibre reinforced concrete showed more split-tensile and flexural strength of about 4.8N/mm^2 and 6.9N/mm^2 respectively (TABLE III).

Table III. Concrete studies of control and fibre reinforced concretes

S. No.	Concrete studies	Control	Thuthi fiber	HFC[a]
1	Compressive strength (N/mm^2)	19.5	21.6	25.5
2	Split-Tensile strength (N/mm^2)	2.3	3.6	4.8
3	Flexural strength (N/mm^2)	3.2	4.2	6.9

[a]HCF: Hybrid composite fibre (Banana + Thuthi fibre)

The increase in the strength is mainly due to the impact of two fibres in the concrete mix. The impact characteristics which influence the increase in strength of the concretes are reasoned as; the fibers are generally distributed throughout a cross-section in the prepared concrete, the fibers are relatively short and closely spaced, and it is much tougher and more resistant to impact than plain concrete. It was also reported that the fibers are added not only to improve the strength of the concrete but also to control the cracking of fibre reinforced concrete. And also to alter the behaviour of the material once the matrix has cracked, by bridging across these cracks and so providing some post-cracking ductility[16].

CONCLUSION

The findings of the above studies indicate that the addition of plant fibers to concrete improve not only the strength characteristics but also the ductility. Research over the years have shown that fibre reinforcement has sufficient strength and ductility to be used as a complete replacement to conventional steel bars in some types of structures; foundations, walls, slabs. For this to be a reality, the fibers must be distributed and oriented as expected, which is difficult. If fibers can be used without the need of steel reinforcement bars, the reinforcement part of the construction work will be eliminated. Hence, the construction costs will be significantly reduced.

From the test results of compressive strength, split tensile strength and flexural strength, it can be seen that, in the presence of fibre there is an increase in compressive strength, split tensile strength and flexural strength. The crack formation was not observed during the experimentation procedure. Varying the length, composition and geometry of fibre in the concrete preparation, the strength of the concrete along with the durability against deterioration may increase. This is considered as the future application work which may influence in bringing some novel inputs to the field of constructions and structural engineering.

Conflict of interest

Authors declare no conflict of interest.

REFERENCES

[1] M.R. Sanjay, G.R. Arpitha, L. Laxmana Naik, K. Gopalakrishna, and B. Yogesh, “Applications of Natural Fibers and Its Composites: An Overview,” Nat. Res. vol. 7, pp. 108-114, 2016.

[2] O. Adekomaya, T. Jamiru, R. Sadiku, and Z. Huan, “A review on the sustainability of natural fiber in matrix reinforcement – A practical perspective,” J. Reinfor. Plast. Comp. vol. 35(1), pp. 3–7, 2016.

[3] H.N. Tara Sen, and Jagannatha Reddy, “Application of Sisal, Bamboo, Coir and Jute Natural Composites in Structural Upgradation,” Int. J. Inn. Man. Tech. vol. 2(3), pp. 1-5, 2011.

[4] P. Sasikumar, and J. Thivya, “An Investigation of Sisal Fibre Concrete Using Quarry Dust,” Int. J. Inn. Res. Sci. Eng. Tech. vol. 6(4), pp. 1-4, 2017.

[5] E. Mello, C. Ribellato, and Mohamedel Hassan, “Improving Concrete Properties with Fibers Addition,” Int. J. Civ. Environ. Struct. Const. Arch. Eng. vol. 8(3), pp. 249-255, 2014.

[6] D. Jitendra Dalvi, B. Uttam Kalwane, and Pallavi Pasnur, “Effect of fibre length and percentage of sisal on strength of concrete,” Multi. J. Res. Eng. Tech. vol. 3(1), pp. 923-932, 2016.

[7] V. Kunamineni, and U. Chintha, “Sisel Fiber Reinforced Concrete”. Int. J. Adv.

Eng. Res. Sci. vol. 3(3), pp. 14-18, 2016.

[8] Patrick Oguguo Nwankwo, and Emmanuel Achuenu, "Compressive Behaviour of Sisal Fibre Reinforced Ternary Concrete at Elevated Temperatures," Int. J. Adv. Res. Tech. vol. 3(8), pp. 1-4, 2014.

[9] BIS: 8112. Specifications for 43-Grade Portland cement, Bureau of Indian Standards. New Delhi, 1989, India.

[10] BIS: 383. Specifications for coarse and fine aggregates from natural sources for concrete. Bureau of Indian standards. New Delhi, 1970, India.

[11] BIS: 456. Plain and Reinforced concrete Code of Practice (Fourth Edition). Bureau of Indian Standards. New Delhi, 2000, India.

[12] M.P. Westman, L.S. Fifield, K.L. Simmons, S.G. Laddha, and T.A. Kafentzis, "Natural Fibre Composites: A Review; Pacific Norwest National Laboratory: Springfield, IL, USA, 2010.

[13] Gurdeep Kaur, Rafat Siddique, and Anita Rajor, "Properties of concrete containing fungal treated waste foundry sand," Const. Build. Mat. vol. 29, pp. 82–87, 2012.

[14] BIS: 516. Indian Standard Methods of Test for Strength of concrete. Bureau of Indian Standards. New Delhi, 1959, India.

[15] M.P. Kadam, and Y.D. Patil, "The Effect of sieved Coal Bottom Ash as a Sand Substitute on the Properties of Concrete with Percentage Variation in Cement," Amer. J. Civ. Eng. Arch. vol. 2(5), pp. 160-166, 2014.

[16] Aiswarya Sukumar, and Elson John, "Fiber addition and its effect on concrete Strength," Int. J. Inn. Res. Adv. Eng. vol. 1(8), pp. 144 – 148, 2014.

[17] Amit Rai, and Y.P. Joshi, "Applications and Properties of Fibre Reinforced Concrete," Int. J. Eng. Res. App., vol. 4(5), pp. 123-131, 2014.