PERFORMANCE OF COCONUT FIBER REINFORCED CONCRETE

Abstract

Strengthening of concrete is essential to develop its engineering & mechanical attributes; an experimental operation founded on trials to determine the properties of concrete reinforced with coconut fiber had been performed. The study involves the comparative statement; of properties of FRC (fiber reinforced concrete) and conventional concrete founded on experimental setup in the research laboratory such as compression, tension or flexural, split tensile, cracking and spelling with or without the addition of fibers. The percentages of fiber are maintained (0.25% and 0.50%) by dry mass of concrete having a fixed water-cement ratio 0.42. The coconut fibers of equivalent indistinct length and diameter were employed restricting aspect ratio ranging from 30 to 150**.** However, more effort required studying the accurate efficiency of FRC and this original work will help as a reference for infinite research in same direction.

Keywords: Fibre reinforcement concrete, Flexural strength, Compressive strength, Split-tensile strength, Aspect ratio, and Coconut fibres.

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I. INTRODUCTION AND LITERATURE REVIEW

This study has done to enhance different attributes of concrete by using natural fibers. In this world there are number of different natural fibers such as wooden fibers, hair fibers, and sugarcane fibers etc which are used many times in concrete to improve its engineering and mechanical properties and in many other areas such as in soil to improve its bearing capacity, etc. But in this study, coconut fibers are used as natural fiber as shown in figure 1, which is easily available in market in free of cost or very economical cost, but at same side they have huge negative effect on environment due to their non-degradability so keep this negative effect in mind coconut fiber is used in concrete to make it fiber reinforced concrete (FRC) and to improve its attributes.

Concrete is a leading construction material all over the entire glove. Later, it was found that concrete lacks in tension and flexural strength, and for overcoming this concrete is normally strengthened by steel bars. However, acceptance of steel reinforcement is costly making the construction project uneconomical. Moreover, appreciable efforts have been made for increasing the durability, strength and serviceability by adding fibers to concrete so that it may come in FRC category.

Figure: 1 Coconut Fiber

Fiber Reinforced Concrete (FRC) is continuously gaining acknowledgement from civil engineers but the present of micro cracks at the mortar-aggregate interface is responsible for the inherent of weakness of plain concrete. The weakness can be removing by inclusion of fiber in the mix because fiber helps to transfer the load at the internal micro cracks. Such concrete are called FRC (fiber reinforced concrete). Thus, the composition of materials basically comprising basic conventional mortar reinforced with fibers. Nowadays, a vast participation involves in research and advancement of fibers and matrix materials and production method associated to the construction engineering. These are advantageous over other building materials since they are effective in tensile strength to weight ratio, ability to frame into various shapes and naturally resistance to environmental corrosive condition, resulting in high potentially low preservation cost. Hence, FRC (fiber reinforced concrete) capability collaborated with concrete matrix creating it into a good alternate in innovative building construction.

Coconut Fiber (CF) is natural fibers which are found in between the solid internal shell and the outside coat layer of coconut husk. It is extracted from coconut husk by means of manual labor. Mostly it is found in manufacturing industry of doormats, rope, etc. Coconut fiber has certain physical and mechanical characteristics that can be utilized effectively in the development of reinforced concrete material. In early days, these coconut fibers are dumped as agricultural bed for cultivation and plantation making it available in large quantity hence making them cheap.

Moreover, fiber is of much important use in construction technology, like:

- The coconut fiber reinforced concrete is light in weight due to the reinforced fiber being too low density as compared to steel bars fiber reinforced concrete.
- The fiber obtained from nature is eco-friendly and easily available in bulk at about free of cost.
- Fibers may effect on strength of concrete and its load bearing capacity on different positions and under different loads.

Coconut fibers is free of cost and obtainable in plenty, natural in origin thus ecologically sustainable and can bring down the global carbon footprint quite effectively [1]. The addition of coconut fibers significantly improved many of the engineering properties of concrete such as the notable torsion, toughness and tensile strength [2]. The deformation belongings of concrete beams with fibers under static loading condition and the behavior of structural components in terms of compressive strength for plain concrete (PC) and coconut fiber reinforced concrete (CFRC) have studied [3]. Coconut fiber acts as green construction material and has better chemical and physical property. However, it is capable of taking strain four times more than other fibers [4]. The workability of the concrete decreased as the coconut fiber ash (CFA) content increase and the compressive strength of CFA concrete increased with curing again decrease with increase in the percentage of CFA [5]. The result shows increase in compressive strength of concrete by adding fly ash and coconut fiber together in concrete. However, separately adding of coconut fiber and fly ash does not show significance results [6]. The used of coconut fiber will also lead to better management and the addition of CF will improved the flexural strength of concrete by 12%, they also formed good bonding in the concrete [7]. The used of coconut fiber should valued over steel due to pros outnumbers cons as low cost, non-corrosiveness, low thermal conductivity (natural cooling), high strength and low weight ratio [8]. The addition of coconut fiber in concrete improves various engineering belongings of concrete such as the compressive strength, tensile strength and the flexural strength of concrete. However, the optimum coconut fiber contains to be at 1% (by weight of cement) [9]. To reduce the budget of construction materials, the material like fiber which enhances the properties like workability, durability, flexural strength, compressive strength etc., and the steel, glass can be replaced by coconut fibers which are low cost and easily available in the market [10]. Coir fiber has maximum amount of lignin giving maximum tensile strength as well as are durable in nature [11]. The coir fiber treated using natural latex before using in concrete, so that it is not be affected by moisture content present in the concrete and the compressive strength and split tensile strength are carried out using different coir fiber length of 20mm, 25mm and 30mm respectively of different percentage at 0.5%, 0.75% and 1% [12].

II. OBJECTIVES

The purpose of this research work is to find out the difference in the mechanical properties of FRC concrete i.e., compressive, split-tensile and flexural strength using fiber that have been extracted from the coconut shell at a varying fiber contents and comparing it with conventional concrete. This study can be functional or beneficial in building for achieving economy in concrete and utilize it in an effective environment friendly manner.

III. METHODOLOGY

1. **Materials and their properties**: Quality able materials used in this investigation which are cement in terms of binding material, sand in terms of fine aggregate, coarse aggregate, coconut fibers as reinforcement and highly water reducer type super plasticizer named as BASF of specific gravity 1.425. The detail talk of materials with their properties which has found accurately as per Indian guidelines are as follows:

   Cement: In this experimental examination Ordinary Portland cement (OPC) of 43-grade is used as binding material and the attributes of it as per IS code 12269:1989 are shown in table 1.

   Aggregates: The strength of concrete is depends on type or grade of binding material as well as aggregate which are going to use, because there is a chemical reaction between them when they comes together in contact of water which creates strong bonding and make homogeneous material so aggregates are important term which help concrete to gain its strength and the different physical properties of these as shown in table 2, which are important to find before use of them, has found accurately with keep in mind the guidelines of IS 2386:1963. Mainly two types of aggregates are used which are sand in terms of fine aggregates which passes through 4.75mm sieve and dust free angular shaped course aggregates of 12.5mm as well as 20mm where the major function of sand and course aggregates is to fill the voids of mixture and to provide the strength, respectively.

Table 1: Properties of Ordinary Portland Cement

Sl. No.	Particular Property	Values
1.	Standard Consistency	32 %
2.	Setting time : • Initial • Final	 74 min 265 min
3.	Fineness	98.5%
4.	Specific Gravity	3.143
5.	Soundness	2.9

   Coconut fiber: Unserviceable coconut fiber were collected from local market, then these are extracted and cut into small threads, and maintained their length of 30-40 mm and the aspect ratios is maintained ranging from 100 - 300.

   Highly water reducer: Highly water reducer increases the flow characteristic of suspensions. Additions of water reducer to concrete enhance the declination of the water to cement ratio, without **manipulating** the workability of mixture.

Table 2: Test Results of Fine Aggregates

Sr. No.	Property	Fine Aggregates	Course Aggregates
1.	Specific Gravity	2.61	2.72
2.	Water Absorption	0.67	0.95
3.	Aggregate Size	< 4.75 mm	< 20 mm
4.	Bulking	28%	-----
5.	Sieve Analysis	Zone IV Confirming to IS 383:1970	-----

Table 4: Specimens for conventional, 0.25% and 0.5%

Sl. No.	Specimen	Dimensions (in mm)	1 day (In no.)	7days (In no.)	28 days (In no.)	Total numbers of specimens.	Actual no. of specimens*
1.	Cubes	150x150x150	3	3	3	9	27
2.	Cylinders	D=160 H=320	-	3	3	6	18
3.	Beams	500x100x100	-	3	3	6	18
Grand Total							63

*Actual Number of specimens are including control, 0.25% and 0.50% fiber content.

Preparation of specimens: The mixed-design was organized in relates to gain M-30 grade referencing IS: 10262-2009. The samples sorted with coconut fiber of about 0.25% and 0.5% which are matched with respect to conventional concrete sample. Sample for test are:

Mix design: Materials were sorted and mixed with accurate proportion in drum type mixing machine with proper batching. Super-plasticizers are added in concrete in required amount, initially it mixed with water and then that mixture was added gradually in mixture machine. Mixing was stopped when desired uniform mortar is achieved. Mixtures were conveyed into pan and then it is poured into mould respectively. Vibration is sufficiently done by manual mean so as avoids any voids inside. Oiling was done prior to pour concrete this makes the samples to be detached effortlessly from moulds after 24 hours.

Figure 2: Concerete Mixer (model: sl-cc-077).

Table 5: Mix Proportion

Sl. No.	Materials		Mass of Materials (kg/m³)
1.	Cement		362
2.	Sand		669.93
3.	Aggregate	12 mm	405.76
		20mm	721.35
4.	Water-cement ratio		0.42
5.	Coconut fiber		0%, 0.25% & 0.5%
6.	Highly water reducer		0.6% by mass of cement
7.	Water		197

Placing of mortar into moulds involves temping of three alternate layers and for each layer temping is done for 25 times with assist of steel tamping rod respectively. After 24-hours, once mixture hardened in moulds, de-moulding are initiated and sample are left for curing inside the water tank for required duration.

Testing of Specimens: When the specimens are cured for recommended duration (i.e., 1-day, 7-day, 28-day), sample are taken out for testing and left to get dry under room temperature for few minutes. Weights are being taken for each sample just before taking test in hand.

2. **Compression Test:** The test conducted on hardened concrete by CTM (compression testing machine) having a capacity of 2000kN. The specimens are placed in machine and undergo loading @ 5.2kN/sec until the sample fail. The tests are conducted on one day, seven days and twenty eight days cubes having 0%, 0.25% and 0.5% of coconut fiber. This test is conducted on cubical moulds having size of 150mm x 150mm x 150mm as shown in figure 3.

Figure 3: Testing of cube specimens.

3. **Flexural Test:** Hardened beam sample is placed symmetrically on its length to make certain that the load is acting correctly. The specimen undergo loading @0.1kN/sec until it fail. Tests are conducted on seven days and twenty eight days beams having 0%, 0.25%

and 0.5% fiber after wet curing. Flexural test is also expressed as the modulus of rupture (MR) in Mega Pascal's (Mpa) and in this study the standard test methods used is as per ASTM C 78 (third-point loading). The beam size used to determine the flexural strength of the concrete is of 500mm x 100mm x 100mm as shown in figure 4.

Figure 4: Testing of beam specimens.

4. **Split tensile test:** Hardened cylinder concrete (diameter = 160mm, height =320mm) was placed longitudinally on its length into the compression machine. The specimen undergo loading @5.2kN/sec until it fail. This test conducted on seven days and twenty eight days cylinders having 0%, 0.25% and0.5% of fiber.

Figure 5 : Testing of cylinder specimens.

IV. RESULT AND DISCUSSION

After the experimental work, testing on specimen is executed to find the strength of each specimens i.e., compressive, split-tensile and flexural strength at a period of one day, seven day and twenty-eight day of wet curing and they are discussed below:

Compressive strength: Cubical moulds (150mm x 150mm x 150mm) are used for finding the compressive strength after a required period of wet curing and the specimens are tested with the help of Compression Testing Machine having capacity of 2000KN as per IS516:1959 and their values of compressive strength are given in table-6.

The compressive strength or stress (N/mm^2) is obtained by dividing the maximal load carried by the cubes to its cross-sectional area.

$$\sigma = \frac{P}{A}$$

Where,
P = Maximum load carried by cube before failure
A = Cross-sectional area i.e. 150mm x 150mm = 22500mm^2
σ = Maximum compressive strength (N/mm^2)

Split-tensile strength: Split tensile strength are conducted on cylindrical moulds (diameter=160mm, height= 320mm) after a period of wet curing using CTM (compression testing machine) having capacity of 2000KN under axis load as per IS516:1959. The results obtain for split-tensile strength is the extreme load carried by cylindrical samples before failure. The following equation is used to determine the tensile strength:

$$T = \frac{2P}{\pi DL}$$

Where,
T = Splitting tensile strength
P = Maximum applied load
L = Length or Height
D = Diameter

The average of three cylindrical samples is taken as the maximum split-tensile strength and is shown in table-7.

Flexural strength : Flexural strength also known as the modulus of rupture are carried out on prism or beam specimen (size 100mm x 100mm x 500mm) after curing by the help of Flexural testing machine having capacity of 1000KN under third-point loading as per IS516:1959. Three prism moulds are prepared and the mean of the three is the flexural strength shown in table-8. The flexural strength obtained is the load carried by the beam under third-point loading before it fail under bending. The equation use for finding the flexural strength is given below:

$$f = \frac{3PL}{bd^2}$$

Where,
P = Maximum load carried by prism before failure
L = Supported length
b = Width of specimen

d = Depth of specimen

Table 6: Results for Compressive Strength

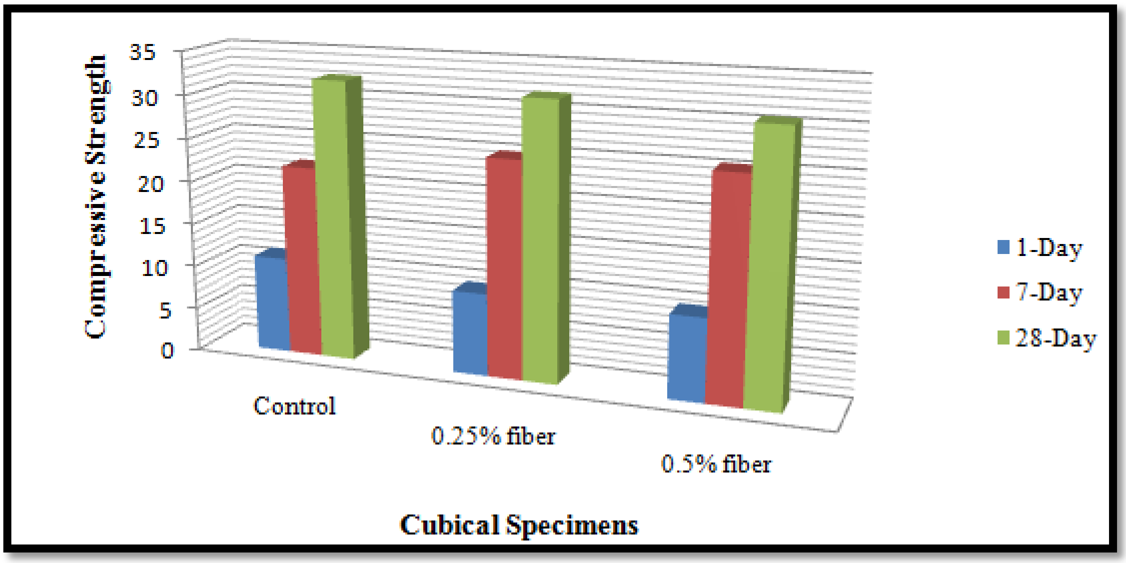
S.No	Mix	Average Compressive Strength (N/mm^2)		
		1-Day	7-Days	28-Days
1	Control	11.084	22.039	32.186
2	0.25% fiber	9.515	24.863	31.668
3	0.5% fiber	9.55	25.317	30.543

Table 7: Results for Tensile Strength

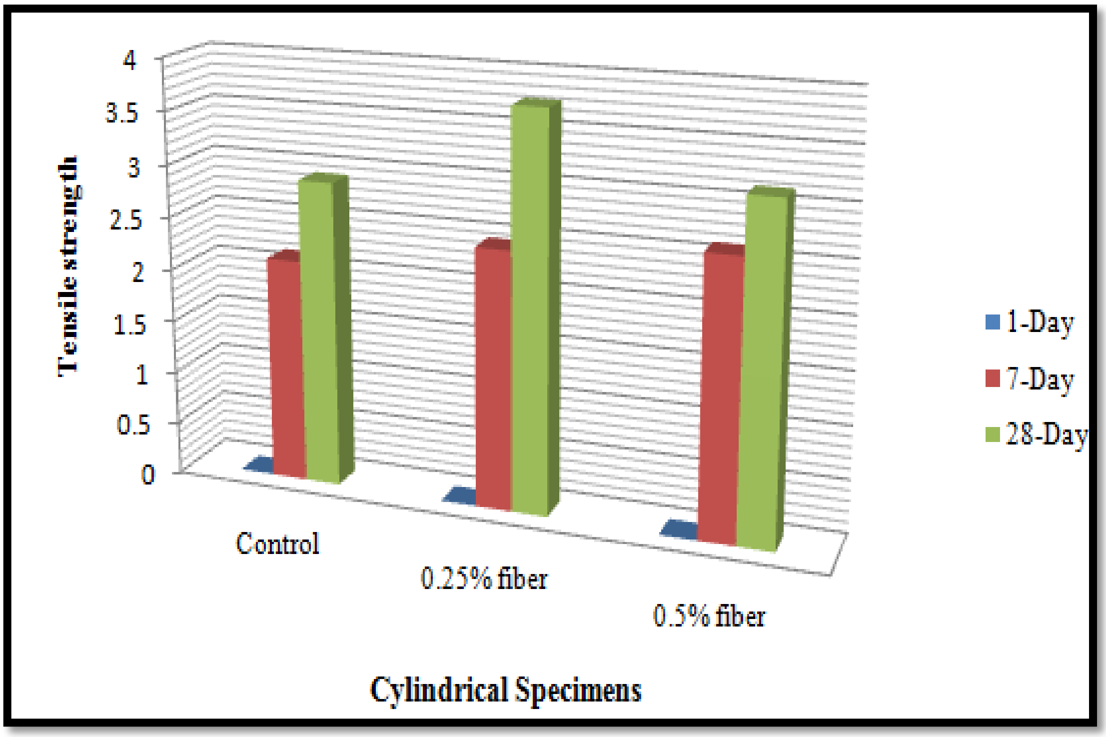
S.No	Mix	Average Tensile Strength (N/mm^2)	
		7-Days	28-Days
1	Control	2.124	2.9
2	0.25% fiber	2.438	3.74
3	0.5% fiber	2.6	3.13

Table 8: Results for Flexural Strength

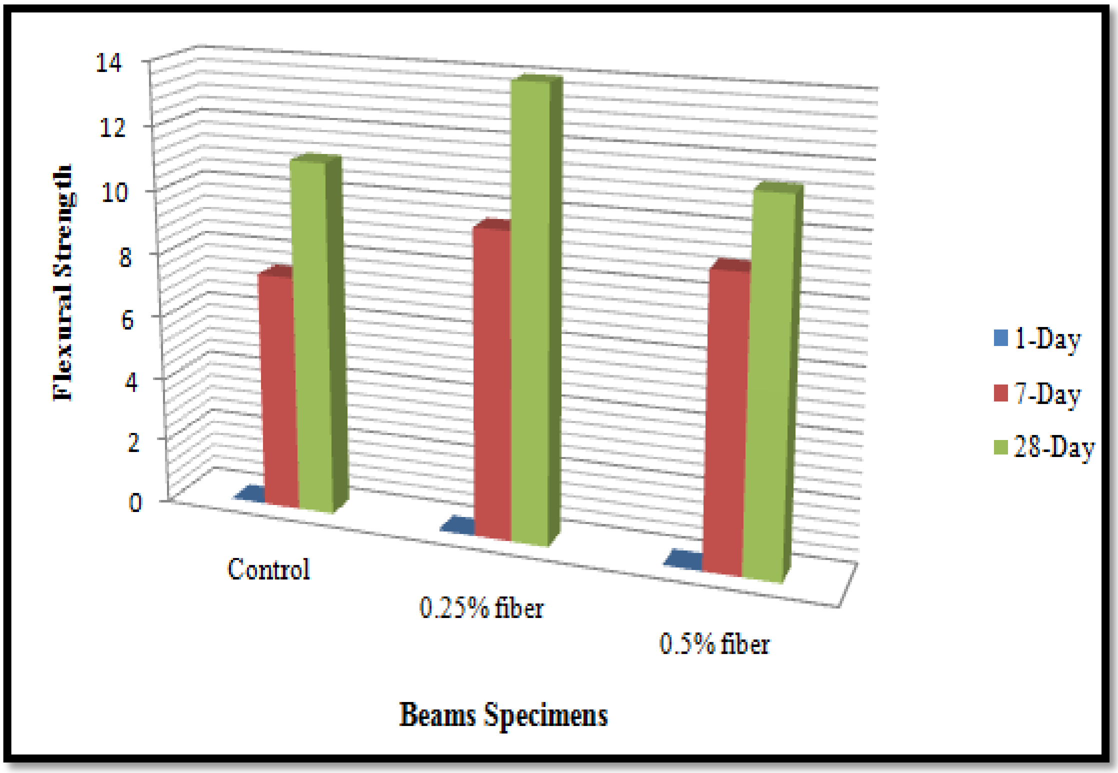
S.No	Mix	Average Flexural Strength (N/mm^2)	
		7-Days	28-Days
1	Control	7.45	11.1
2	0.25% fiber	9.58	13.96
3	0.5% fiber	9.03	11.36



Graph 1: Compressive Strength of Cubical Specimens



Graph 2: Split Tensile Strength of Cylindrical Specimens



Graph 3: Flexural Strength of Beams Specimens

V. CONCLUSION

The following conclusion is drawn out from this research work:

1. Coconut fiber is easily available in abundant since it is a natural fiber. Coconut fiber can be used in concrete to overcome the tendency of cracking.
2. The properties of CRFC were found out to be far better as compared to control or conventional concrete except for compressive strength. From this experiment we found that the compressive strength decreases by 1.6% and 5.1% at the age of 28-days as compared to conventional one.
3. In this research it found that by increasing of fiber percentage there is reduction in strength of concrete because of the problem faced at the time of compaction which often lead to the increase of voids in the concrete.
4. It is observed that the split-tensile strength increases with maximum at 0.25% and on further increasing there is a decreased in strength. This is because of the failure in tension which is due to the displacement of the atoms and molecules that is present in the concrete. Anyhow, the addition of fiber acts as a binder agent holding the materials together. Similarly, in the case of flexural strength at 0.25% it gives the maximum strength and on further increasing the fiber contends there is reduction in strength.
5. Since coconut fiber being a natural fiber poses no threat to the environment and because of its tensile properties it can be very useful in construction of structures in seismic prone areas because of its high tensile strength which gives sufficient or enough time before it collapse.

REFERENCES

[1] Majid Ali. ,11 July (2011): Versatile Material and its application in Engineering, Journal of Civil Eng.& Const. Tech. Vol.2(9), pp.189-197, 2011.
[2] Noor Md, SadiqulHasan, Habiburrahman, Mdshiblee and MdSaifulIslam (2012): The use of Coconut Fibre in the production of Structural Lightweight Concrete. Journal of Applied Sciences 12(9):839.
[3] Shetty M.S : Concrete Technology Theory and Practice.3rd edition, S.ChandCompany Limited, New Delhi.
[4] British Standard Institutions, BS 8110 – Part1,(1997): The structural use of concrete, BSI, London.
[5] ManinderKaur and ManpreetKaur,(2012): A review of utilization of Coconut coir ascoarse aggregate in concrete, International Journal of Applied Engineering Research, 7, pp 05- 09.
[6] Yaw Osei,(2013): Experimental Assessment on coconut coir as aggregate in concrete, International Journal of Engineering Science Research, 05, pp 07-11.
[7] K.U.Rogo,(2010): Exploratory study of coconut coir as coarse aggregate in concrete, Journal of engineering and applied sciences, 02, pp 19-2.
[8] I.S 10262-2009: Recommended guidelines for concrete mix design.
[9] I.S 12269-1987,(1987): Specifications for 53 grade Ordinary Portland Cement.
[10] I.S 383-1970,(1970):Specifications for coarse and fine aggregates.
[11] Othumal,(2015): Effect on the properties of concrete by adding coir fibre, Journal of Applied Sciences 12(9):839.
[12] Jayaprada,(2014): Behaviour of concrete by adding coir fibre, International Journal of Applied Engineering Research.
[13] Dr. M.A. Ismail,(2009): effect on the properties of Portland cement by adding different types of natural fibres, International Journal of Applied Engineering Research.
[14] KrishnaPrasanna P,(2014): Steel Slag as a Substitute for Fine Aggregate in High Strength Concrete,International Journal of Engineering Research & Technology (IJERT).
[15] Mohammed. J and Abbas. O,(2009): Use of Steel Slag in Modification of Concrete Properties, Eng.&Tech. Journal, Vol 37,No 9.
[16] Paul Bosela, Norbert Delatte,(2008):Effect on the fresh and hardened Properties of Paving Concrete with steel slag aggregate, 9th international conference on Concrete Pavements.
[17] Das Gupta, N. C., Paramsivam, P,.and Lee, S. L,(1979): Coir reinforced cement pastes composites, Conference Proceedings of Our World in Concrete and Structure.
[18] Anthony Nakem Ede, Joshua OlaoluwaAgbede,(2014): Use of coconut husk fibre for improvement compressive and flexural strength of concrete,International Journal of Applied Engineering Research.
[19] NandiniSuri and Y. AnandhBabu,(2016): Experimental Investigations on Partial Replacement of Steel Slag as Coarse Aggregates and Eco Sand as Fine Aggregate. International Journal of Civil Engineering and Technology, 7(5), pp.322–328.
[20] Sule, samuel,(2013): structural models for the prediction of compressive strength of coconut fibre-reinforced concrete, international journal of engineering and advanced technology (IJEAT) ISSN:2249-8958, Volume 2, Issue-4.
[21] Cook DJ, Pama RP, Weerasingle HLSD,(1987): Coir fibre reinforced cement as a low cost roofing material, Build Environ, Vol. 13(3), pp.193–198.
[22] Li Z, Wang L, Wang X.(2006): Flexural characteristics of coir fiber reinforced cementitious composites, Fiber Polym, Vol. 7(3), pp.286–294.
[23] Majid Ali, NawawiChouw,(2013): Experimental investigations on coconut fibre rope tensile strength and pull out from coconut fibre reinforced concrete, Vol. 41, pp. 681-690.
[24] Ramakrishna G, Sundararajan T.(2005): Studies on the durability of natural fibres and the effect of corroded fibres on the strength of mortar, CemConcr Compos Vol.27(5), pp.575–582.
[25] Paramasivam P, Nathan GK, Das Gupta NC,(1984): Coconut fibre reinforced corrugated slabs, Int J Cem Compos Lightweight Concrete, Vol. 6(1), pp.19–27.

[26] Naaman, A.E.,(1985): Fibre Reinforcement for Concretes, Concrete international: Design & Construction, V.7, Mar. 1985, pp.21-25.
[27] Gambhir M.L.,(2009): Concrete Technology.
[28] Shetty M.S.,(2009): Concrete Technology.
[29] BalaguruPerumalsamy N., Shah Sarendra P.,(1992): Fibre Reinforced cement composites, McGraw Hill International Editions.