An Experimental Study on Coconut Fiber Reinforced Concrete

Sanjay Kumar Yadav[1], Avinash Singh[2]

[1]M.Tech Student, Structural Engineering, Faculty of Engineering & Technology, Rama University, Kanpur, India
[2]Assistant Professor, Department of Civil Engineering, Faculty of Engineering & Technology, Rama University, Kanpur, India

---***---

Abstract - *Fibers have the property to enhance the toughness of concrete. The cost of construction has skyrocketed together with the deteriorative impact on setting. This resulted in the adoption of a more balanced approach with the environment as its nerve centre to create a better world to live in. This has led to the adoption of a fiber like Coconut for the strength sweetening in concrete. Coconut fiber is obtainable in abundance, which makes it quite viable as a reinforcement material in concrete. This paper presents a experimental discussion on the subject of coconut fiber-reinforced concrete, CFRC. It discusses usually used terms and models of behavior that kind a basis for understanding material performance with presenting mathematical details. In this research it is shown that flexural strength of coconut fiber reinforced concrete is directly proportional to the coconut fiber content and inversely proportional to the water-cement ratio.*

This study aimed toward analyzing the variation in strength of coconut fiber concrete at variable fiber contents and to establish it with that of conventional concrete. The various strength aspects analyzed are the flexural, compressive and lastingness of the coconut fiber concrete at variable percentages (1%, 2%, 3%, 4%, 5%) by the load of cement of fiber. Result data clearly shows percentage increase in compressive strength for M20 grade of concrete in 7 days and 28 days with respect to the variation in % addition of coconut fibers. This research is based on the use of coconut fibers in structural concrete to enhance the mechanical properties of concrete.

***Key Words*: Fiber, Coconut Fiber Reinforced Concrete, Strength, Coconut, Concrete**

1.INTRODUCTION

One of the undesirable characteristics of the concrete as a brittle material is its low lastingness, and strain capability. Therefore, it needs reinforcement so as to be used because the most generally construction material. Conventionally, this reinforcement is within the kind of continuous steel bars placed within the concrete structure within the acceptable positions to face up to the obligatory tensile and shear stresses. Fibers, on the opposite hand, ar usually short, discontinuous, and every which way distributed throughout the concrete member to provide a composite construction material called fiber ferroconcrete (FRC). Fibers utilized in cement-based composites ar primarily made from steel, glass, and chemical compound or derived from natural materials. Fibers can control cracking more effectively due to their tendency to be more closely spaced than conventional reinforcing steel bars. It ought to be highlighted that fiber used because the concrete reinforcement isn't a substitute for standard steel bars. Fibers and steel bars have totally different roles to play in advanced concrete technology, and there ar several applications during which each fibers and continuous reinforcing steel bars ought to be used. Coconut fibers (Coir fibers) are one of the most popular type of fibers used as concrete reinforcement. Coconut fiber being the most ductile among all natural fibers has the potential to be used as a reinforcement material in concrete. It is biodegradable so the impact on environment will be minimal. This is also a way to dispose of the fibers which are derived as waste materials from coir based manufacturing units to produce high strength materials .They are also non-abrasive in nature ,cheap and easily available. Initially, CFs are used to prevent/control plastic and drying shrinkage in concrete. Further research and development revealed that addition of CFs in concrete significantly increases its compressive strength, the energy absorption capacity, ductile behavior prior to the ultimate failure, reduced cracking, and improved durability. This study reviews the effects of addition of CFs in concrete, and investigates the mechanical properties, and applications of coconut fiber reinforced concrete (CFRC).

Concrete containing cement, water, fine aggregate, coarse aggregate and discontinuous coconut fibers are called fiber reinforced concrete. Coconut fiber reinforced concrete is a composite material having fibers as the additional ingredients, dispersed uniformly at random in small percentage in between 0.3% and 5% volume in plain concrete. CFRC products are manufactured by adding coconut fibers to the ingredients of concrete in the mixture and by transferring the green concrete into mould the product is then compacted and cured by the conventional method.

Segregation or boiling is one of the problems encountered during mixing and compacting CFRC. This should be avoided for uniform distribution of fibers. The energy required for mixing, conveying, placing and finishing of CFRC is slightly higher.

Fig -1: Coconut Fiber Reinforced Concrete

1.1 Types of fibers used in construction

Most commonly used types of fibers are:

1. Steel Fiber Reinforced Concrete
2. Plastic fibers
   i. Polyester
   ii. Poly propylene
   iii. polyethylene
3. GFRC Glass Fiber Reinforced Concrete
4. Asbestos Fibers
5. Carbon Fibers
6. Organic Fibers
   i. Bamboo Fiber
   ii. Coconut Fiber

1.2 Areas of Application of fibers

The areas in which the reinforced fiber concrete is generally used:

1. Plastering
2. Pipes
3. Thin sheets
4. Shot Crete
5. Curtain walls
6. Precast elements
7. Tiles
8. CFRC Boards
9. Flat slabs
10. Highway and airport pavements
11. Canal lining, sewer lining
12. Stabilization
13. Factories
14. Aircraft hangers
15. Aprons and taxiways
16. Parking areas

1.3 Requirement of fiber reinforced concrete

1. It increases the tensile strength of the concrete.
2. It reduces the air voids and water voids the inherent porosity of gel.
3. It increases the durability of the concrete.
4. Fibers such as graphite and glass have excellent resistance to creep, while the same is not true for most resins. Therefore, the orientation and volume of fibers have a big influence on the creep performance of rebars/tendons.
5. Reinforced concrete itself could be a material, where the reinforcement acts as the strengthening fiber and the concrete as the matrix. It is so imperative that the behavior below thermal stresses for the materials be similar so the differential deformations of concrete and also the reinforcement area unit reduced.
6. It has been recognized that the addition of little, closely spaced and uniformly spread fibers to concrete would act as crack restraint and would well improve its static and dynamic properties.

2. FACTORS AFFECTING PROPERTIES OF FIBER REINFORCED CONCRETE

There are few factors which are responsible for the properties of fiber reinforced concrete, which are as follows:

2.1 Relative fiber matrix index

The modulus of snap of matrix should be abundant not up to that of fiber for economical stress transfer. Low modulus of fiber like nylons and polypropene area unit, therefore, unlikely to grant strength improvement, however the assistance within the absorption of huge energy and thus, impart bigger degree of toughness and resistance to impart. High modulus fibers such as steel, glass and carbon impart strength and stiffness to the composite.

2.2 Volume of fibers

The strength of the composite for the most part depends on the amount of fibers utilized in it. It can be seen that the increase in the volume of fibers, increase approximately linearly, the tensile strength and toughness of the composite. Higher percentage of fiber is likely to cause segregation and harshness of concrete and mortar.

2.3 Aspect ratio of fiber

One of the most important factor which guides the properties and behavior of the composite is the aspect ratio of the fiber. It has been observed that up to aspect ratio of 75, increase on the aspect ratio increases the ultimate concrete linearly. In various research it is also found that beyond 75, relative strength and toughness is reduced.

2.4 Orientation of fiber

Shape and orientation of fiber is very important as it is found as raw and processed. To see the effect of randomness, mortar specimens reinforced with 0.5% volume of fibers were tested. In one set specimens, fibers were aligned in the direction of the load, in another in the direction perpendicular to that of the load, and in the third randomly distributed.

2.5 Workability and Compaction of concrete

Incorporation of Coconut fiber decreases the workability considerably. This situation adversely affects the consolidation of fresh mix. Sometimes prolonged external vibration fails to compact the concrete. The fiber volume at which this situation is reached depends on the length and diameter of the fiber.
The workability and compaction standard of the mix is improved through increased water/ cement ratio or by the use of some kind of water reducing admixtures.

2.6 Size of coarse aggregate

Maximum size of the coarse combination ought to be restricted to 20mm, to avoid considerable reduction in strength of the composite. Fibers also in effect, act as aggregate. Although they need an easy pure mathematics, their influence on the properties of fresh concrete is complex. The orientation and distribution of the fibers and consequently the properties of the composite governed by the inter-particle friction between fibers and between fibers and aggregates

2.7 Mixing

Mixing of fiber reinforced concrete needs careful conditions to avoid balling of fibers, segregation and in general the difficulty of mixing the materials uniformly. It is important that the fibers are dispersed uniformly throughout the mix; this can be done by the addition of the fibers before the water is added. When combining during a laboratory mixer, introducing the fibers through a wire mesh basket will help even distribution of fibers. For field use, some other suitable methods should be adopted.

3. METHODOLOGY TO BE ADOPTED

In this process for the preparation of cubes, cylinder and beams cement, sand, coarse aggregate, water and coconut fibers are to be used.

3.1 Properties of reinforcement

When steel fibers square measure another to mortar, Portland cement concrete or refractory concrete, the flexural strength of the composite is exaggerated from twenty fifth to 100 percent - betting on the proportion of fibers added and the mix design. Catastrophic failure of concrete is virtually eliminated because the fibers continue supporting the load after cracking occurs. And while measured rates of improvement vary, coconut fiber reinforced concrete exhibits higher post-crack flexural strength, better crack resistance, improved fatigue strength, higher resistance to spalling, and higher first crack strength, it shows concrete flexural strengths when reinforced at various fiber proportions.

Additionally, deformed fibers provide a positive mechanical bond within the concrete matrix to resist pull-out. Locally available waste materials were collected from different and properly shaped in the form of fibers. Uniform length of fibers was obtained by using cutting machine. Typical properties of fiber shown in table:

S.No.	Property	Values
1.	Diameter	0.48 mm
2.	Length of fiber	60 mm
3.	Appearance	Brown as thin wire
4.	Average aspect ratio	104.2
5.	Deformation	Uneven at both ends
6.	Water absorption in %	104.2
7.	Specific gravity	0.87

Table -1: Properties of coconut fibers

3.2 Mix Proportion

S.No.	Property	Values
1.	Grade Designation	M20
2.	Type of cement	PPC
3.	Maximum nominal size of aggregate	20mm
4.	Minimum water required	300kg/m³
5.	Maximum water cement ratio	0.50
6.	Workability	100 mm(slump)
7.	Exposure condition	Mild (for reinforced concrete)
8.	Method of concrete placing	Normal
9.	Degree of supervision	Good
10.	Type of aggregate	Angular aggregate
11.	Maximum cement content	450kg/m3
12.	Chemical admixture type	Superplasticizer

Table -2: Stipulations for proportioning

3.3 Slump Test

A slump test is a method used to determine the consistency of concrete. The consistency, or stiffness, indicates how much water has been used in the mix. The stiffness of the concrete mix should be matched to the requirements for the finished products quality. The test measures consistency of concrete in the specific batch. It is performed to check consistency of freshly made concrete. The test is popular due to the simplicity of the apparatus used and simple procedure. Types of slump are as follows:

Collapse shear- In a collapse slump the concrete collapses completely.

Shear slump- In a shear slump the top portion of the concrete shears off and slips sideways.

True slump-In a true slump the concrete simply subsides, keeping more or less to shape.

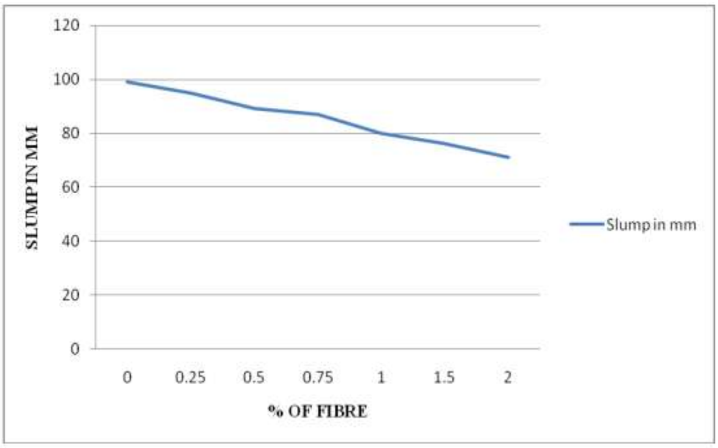

Chart -1: Variation in slump of concrete with respect to % of fiber content

4. RESULT

Compressive strength test, split tensile strength test and flexural strength tests are performed on the cube, cylinder and beam specimen after curing for 7 days and 28 days, respectively. The result of above tests is as follows:

4.1 Compressive Strength

Coconut fiber reinforced concrete was added to concrete at varying proportions (1%, 2%, 3%, 4%, and 5%, of that of weight of cement) at a water cement ratio of 0.5. The desired slump value and compressive strength was obtained for conventional concrete at this ratio.

Percentage Of Coir	Strength After 7 Days (N/mm^2)	Strength After 28 Days(N/mm^2)
0%	13.65	22.73
1%	11.65	23.25
2%	11.87	23.84
3%	11.75	23.44
4%	11.78	25.7
5%	15.02	26.20

Table -3: Compressive strength after different % addition of fiber

4.2 Split Tensile Strength

Split tensile strength tests were conducted on standard cylinders of dimension 15cm diameter and 30cm depth Fig 5.13 specimens each for plain concrete, coconut fibre reinforced concrete (both raw and processed fibre) were cast at varying percentages of fibre (1%, 2%, 3%, 4%, and 5%) For each case 28day strength values were obtained by loading under a compression testing machine.

Three samples of PCC are checked during the test, the average of their strength was 3.44. After addition of different % of coir, the strength is as:

Percentage Of Coir	Strength After 28 Days
1%	2.88
2%	3.17
3%	3.28
4%	3.80
5%	4.57
Average	**3.54**

Table -4: Split tensile strength after different % addition of fiber

4.3 Flexural Strength

Flexural strength tests were conducted on standard beams of dimension 15cm x 15cm x 70cm specimens each for plain concrete, coconut fiber reinforced concrete were cast at varying percentages of fiber (1%, 2%, 3%, 4%, 5%). For each case the 28day strength values were obtained by loading under apparatus for flexural strength.

Three samples of PCC are checked during the test, the average of their strength was 3.67. After addition of different % of coir, the strength is as:

Percentage Of Coir	Strength After 28 Days
1%	2.98
2%	3.37
3%	3.78
4%	4.16
5%	4.83
Average	**3.82**

Table -5: Flexural strength after different % addition of fiber

5. CONCLUSIONS

While testing the specimen, the plain cement concrete specimens have shown a typical crack propagation pattern but when CFRC specimen were tested, cracks gets ceased which results into the ductile behaviour of CFRC.

When the fiber content is increased there is an increase in split tensile strength with a maximum at 5%. However when the fiber content is increased beyond this value a reduction in tensile strength is observed.

This is due to the fact that tensile failure occurs due to the dislocation of atoms and molecules present in concrete. When fiber content is increased there is an increase in flexural strength with a maximum at 5% of fiber. However when the fiber content is increased beyond this value a downward slope of the graph is observed. This is also due to the binding properties of coconut fiber owing to its high tensile strength of 21.5 MPa.

It is observed that CFRC can be used to increase ultimate strength, durability because the satisfactory improvement in strength is observed with the inclusion of coconut fibers but the gain in strength is found to depend upon the amount of fiber content.

The tensile properties and cracking pattern of CFRC shows that it can be particularly useful in construction activities in seismic zones due to its high tensile strength and post peak load behaviour, which offers sufficient warning to the inhabitants before complete collapse of the structure. It can be used to manufacture building blocks at relatively lower costs in comparison to plain concrete blocks thus making it suitable for rural residential buildings upto 10m height or as protection walls around buildings because higher strength is attained at a lower design mix.

Due to its relatively higher strength and ductility, it can be good replacements for asbestos fibers in roofing sheets, which being natural in origin pose zero threat to the environment

FUTURE SCOPE OF STUDY

The effect of coconut fibers on high strength concrete should be studied and thus the use of CFRC can be extended to industrial and commercial buildings. Since the corrosion study is not done, the applicability of CFRC in reinforced constructions could be tested.

Coconut fiber is a good insulator in itself and as such it can improve the thermal properties of concrete. This is particularly useful in a tropical country like India where the mercury levels are quite high for most part of the year, so as to maintain the room temperatures within comfort levels of its inhabitants. It can also reduce the load on air conditioning systems thus reducing the power consumption.

The acoustic properties of concrete reinforced with other natural fibers have been studied in the past using an impedance tube apparatus and the results are fair enough to justify the use of coconut fibers as an alternative which is a good absorbent due to the presence of surface pores.

REFERENCES

[1] Paramasivam P, Nathan G. K., Das Gupta N. C., "Coconut fiber reinforced corrugated slabs", International Journal of Cement Composites and Lightweight Concrete, Volume 6, Issue 1, pp 19-27. 1984.

[2] Ramakrishna,G., and Sundararajan,T. (2005). "Studies on the Durability of Natural Fibres and the Effect of Corroded Fibres on the Strength of Mortar." Cement and Concrete Composites, 27(5), 547-553.

[3] Reis J.M.L (2005),"Fracture and flexural characterization of naturalfiber-reinforced polymer concrete", Construction and Building Materials 20 (2005) 673–678.

[4] Asasutjarit C., Hirunlabh J., Khedari J., S. Charoenvai,B. Zeghmati , U. Cheul Shin (2006),"Development of coconut coir-based lightweight cement board", Construction and Building Materials vol.21, pp.277–288.

[5] Mansur M. A and Aziz M. A, "Study of Bamboo-Mesh Reinforced Cement Composites" Int. Cement Composites and Lightweight Concrete", 5(3), 1983,pp. 165–171.

[6] Yuhazri M.Y., and Dan M.M.P., (2007) Helmet Shell Using Coconut Fibr (Deco- Helmet). Journal of Advanced Manufacturing Technology, Vol. 1 (No.1 pp. 23-30. ISSN 1985-3157.

[7] Li, Z., Wang, L., and Wang, X. (2006). "Flexural characteristics of coir fiber reinforced cementitious composites". Fibers and Polymers. 7(3), pp. 286-294.

[8] Ali Majid, Anthony Liu, "Mechanical and Dynamic Properties of Coconut Fibre Reinforced Concrete." Construction and Building Materials". Reed Business Information, Inc. (US). 2012.

[9] Kshitija Nadgouda, "Coconut Fibre Reinforced Concrete" International Journal of Mechanical And Production Engineering, January 2015, Vol. 3(1), Pages 26-28, January 2015

[10] Nawawi Chouw (2012),"Experimental investigations on coconut-fibre rope tensile strength and pullout from coconut fibre reinforced concrete", Construction and Building Materials, 41, 681–690.

[11] Joanna M Ferraz, Sabrina A Martins, Claudio H.S Del Menezzi (2013), "Effect of coir fibre treatment and coir-fibre ratio on properties of cement bonded composites", Bio Resources 6(3), 3481-3492.

[12] Achudhan, M.J.Ienamul Hasan Ali, S.Senthamizh Sankar, K.Saikumar," Experimental Study On Coir Fibre Mixed Concrete". International Journal of Pure And Applied Mathematics, Vol. 3(12), Pages 118-20, 2018.