

Fracture Parameters of Coir Fibre Reinforced Concrete

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Abstract - Coir is an important lignocellulose fiber used for making variety of floor furnishing materials, yarn, rope etc. but they contribute to a very small percentage production of coir. Bending test on notched prisms with a/W (notch depth/beam depth) ratio equal to 0.4 was used. The values of compressive strength, flexural strength, fracture energy and fracture toughness were measured. A total of 120 specimens were prepared using M30 grade coir fibre reinforced concrete and conventional concrete (PCC) of same grade. The fibre content was varied from 0.5 to 1% with an increment of 0.25% with various aspect ratios of 40 and 60 were used. According to the experimental results, coir reinforced concrete exhibited enhanced fracture properties compared to conventional concrete of the same grade. Also the flexural strength is increased with increase in the fibre content.

IndexTerms – flexural strength, fracture energy, fracture toughness, notched prism

I. INTRODUCTION

Concrete is acknowledged to be a relatively brittle material when subjected to normal stresses and impact loads, where tensile strength is approximately just one tenth of its compressive strength. As a result for these characteristics, concrete flexural members could not support such loads that usually take place during their service life. Historically, concrete member reinforced with continuous reinforcing bars to withstand tensile stresses and compensate for the lack of ductility and strength. Furthermore, steel reinforcement is adopted to overcome high potentially tensile stresses and shear stresses at critical location in concrete member. Even though the addition of steel reinforcement significantly increases the strength of concrete, the development of micro cracks must be controlled to produce concrete with homogenous tensile properties. Micro cracking can be defined into two phase; the first phase begins with crack propagation throughout initiated micro-cracks. The second phase is the subject of fracture mechanics. For concrete materials, micro-cracks are constitutive of the material, i.e., they exist prior to the application of a mechanical load.

These substantial micro-cracks can potentially or essentially contribute to micro-crack formation leading to material failure. The introduction of fibres is brought in as a solution to develop concrete with enhanced flexural and tensile strength, which is a new form of binder that could combine Portland cement in bonding with cement matrices. Fibres are most generally discontinuous, randomly distributed throughout the cement matrices.

Fracture is the separation of a component into atleast, two parts. A material fractures when sufficient stress and work are applied on the atomic level to break the bonds that hold atoms together. Failures have occurred for many reasons, including uncertainties in the loading or environment, defects in the materials, inadequacies in the design and deficiencies in construction or maintenance. Failure of a structure occurs due to catastrophic growth of cracks causing localization of stresses. The fracture energy is one of the important material properties for the design of large concrete structures. The fictitious crack model proposed in, the fracture energy G , tensile strength and load deflection relationship completely describe the fracture characteristics. RILEM recommended a method for the determination of G . The fracture energy is defined as the area under the load deflection curve per unit fractured surface area.

The objective of the present work is to determine the fracture parameters of Coir Fibre Reinforced Concrete of M30 grade and to compare the results with that of conventional concrete of the same grade. The fracture parameters include fracture energy (G_f) and Critical stress intensity factor (KIC). G_f is the amount of energy necessary to create a crack on unit surface area projected in a plane parallel to the direction of propagation of crack. It is calculated by the equation (1) [7]. Stress intensity factor is defined to quantify the stresses at the crack tip. A material fails by fracture when the stress intensity factor reaches a critical value KIC, called fracture toughness which is given by the equation (2) [8]. These fracture parameters were determined by conducting bending test on notched prisms.

II. EXPERIMENTAL PROGRAMME

An experimental investigation was carried out to develop Coir Fibre Reinforced Concrete with varying percentages and Conventional Concrete Mixes of grade 30Mpa. With the developed concrete mixes, fresh and hardened properties along with a fracture study have been conducted using notched prisms. The variable considered in this study is volume fraction of fibres.

Materials Used

Cement: Cement used for this study is Portland Pozzolano Cement (PPC). The manufacturer of the cement is Ramco. Various experiments were conducted to find the initial and final setting time.

Coarse Aggregate: Coarse aggregate of nominal size 20mm were used. Aggregates are mainly retained on a 4.74mm IS sieve and conducted various tests like sieve analysis, aggregate crushing value and aggregate impact value were conducted as per IS:2386 (part 3)-1963.

Fine Aggregate: Fine Aggregates are mainly passing through 4.75mm IS sieve. As per IS:2386(part1)-1963 various tests like sieve analysis and specific gravity were conducted.

Coir Fibre: Coir fibre with 0.4 and 0.6 aspect ratios are used. The properties of coir fibre are shown in **Table 1**.

Table -1: Properties of Coir Fibre

Property	Values	
Aspect Ratio	40	60
Length	16 mm	24 mm
Diameter	0.4mm	0.4mm
Specific Gravity	0.95	0.95

Mix Design

The mix design is carried out as per IS 10262:2009. The grade of concrete adopted for this study is M30. Mix proportions for M30 grade are tabulated in **Table 2**. The nomenclatures used in this study are given in **Table 3**.

Table -2: Mix Proportions for M30 Concrete

Materials	Cement	Water	Fine Aggregate	Coarse Aggregate
Weight (kg/m ³)	437.78	197	783.37	1025.79

Table -3: Nomenclature

No:	Mix	Concrete Mix Proportion
1	NC	M30 Conventional concrete
2	CF1	0.5% addition of coir in to the concrete with aspect ratio 60
3	CF2	0.75% addition of coir in to the concrete with aspect ratio 60
4	CF3	1% addition of coir in to the concrete with aspect ratio 60
5	CF4	0.5% addition of coir in to the concrete with aspect ratio 40
6	CF5	0.75% addition of coir in to the concrete with aspect ratio 40
7	CF6	1% addition of coir in to the concrete with aspect ratio 40

Fresh and Hardened Properties

Slump test and compaction factor test was conducted for determining the fresh properties of concrete. For determining the mechanical properties, the test specimens were removed from water bath and surface water was removed using dry cloth immediately before testing. This was to ensure that the test specimens were tested at a saturated surface dry condition. Various tests to be carried out on hard concrete are compressive strength and flexural strength.

Fracture Test

For the fracture study, tests were performed on notched beam specimens with 3mm notch width and notch depth to total width ratio as 0.4. The fracture parameters such as fracture energy and fracture toughness were evaluated. The size of beam is 100mm

x100mm x 500mm with an effective span of 400mm. During testing, the central deflections were noted by the dial gauge in the Universal Testing Machine.

Fracture energy is determined using the following equation,

$$G_f = (W_o + mgd_{\max}) / A_{\text{lig}} \quad (1)$$

Where,

W_o - area under load deflection curve (Nm)

mg - self weight of the specimen between supports (N)

d_{\max} - maximum displacement (m)

A_{lig} - fracture area = $[B (W-a)]$ (m^2)

B, W - Width and depth of beam (m)

A - depth of notch (m)

The critical stress intensity factor (K_{IC}), has been used to represent the fracture toughness. It can be determined using the following equation,

$$K_{IC} = [PS / (BW^{3/2})] f(\alpha) \quad (2)$$

Where $f(\alpha)$ is determined using the equation,

$$f(\alpha) = 3 \alpha^{1/2} [1.99 - \alpha (1 - \alpha) (2.15 - 3.93 \alpha + 2.7 \alpha^2)] / [2(1 + 2 \alpha) (1 - \alpha)^{3/2}] \quad (3)$$

Where,

α - a/W

S - Span of the beam

P - Applied Load

III. RESULTS AND DISCUSSIONS

PROPERTIES OF FRESH CONCRETE

The workability of all the mixes is tabulated in **Table 4**. From the test results, it was found that the workability of the mixes decreased as the fibre content increases.

Table -4: Properties of Fresh Concrete

Mix	Slump (mm)	Compaction factor
NC	80	0.94
CF1	70	0.94
CF2	60	0.90
CF3	50	0.88
CF4	70	0.92
CF5	50	0.90
CF6	50	0.88

Properties of Hardened Concrete

The compressive strength is measured using cubes on compression testing machine. The size of the cube used was 150mm x 150mm x 150mm. 6 concrete cubes were casted for each concrete mix proportions. Compressive strength of all the mixes were obtained as the strength decreases as the fibre content increases but when the addition of coir fibre is 0.75% to the concrete then the compressive strength obtained is similar to that of the normal concrete which is shown in **figure 1**.

The flexural strength is conducted on beam of 500mm x100mm x100mm size. Six concrete beams were casted for each concrete mix proportions for 7 and 28 days. From the results it is obtained that the flexural strength increases with increase in the fibre content and is shown in **figure 2**.

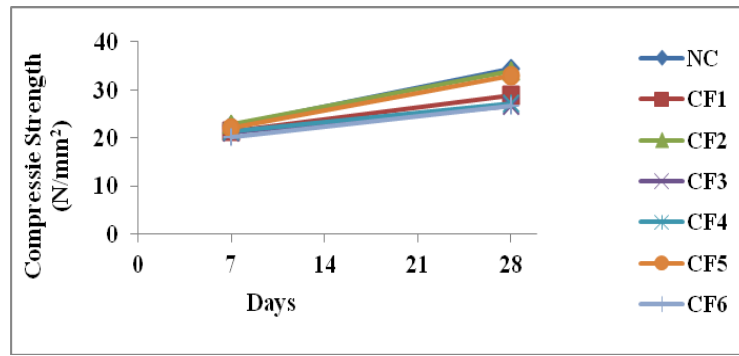


Fig 1: Compressive Strength

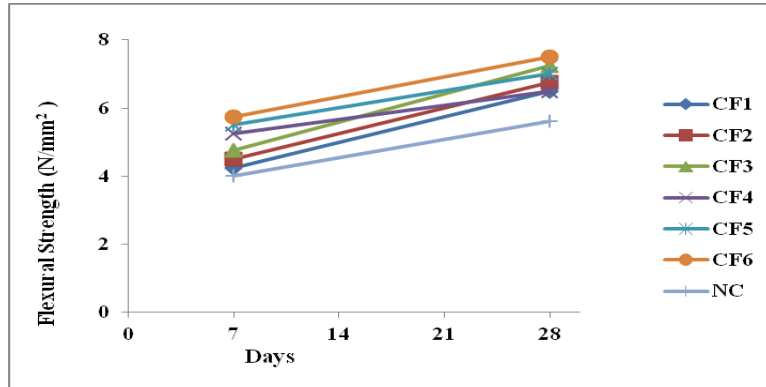


Fig 2: Flexural Strength

Load Deflection Curve

The load deflection curves for all the mixes were evaluated and are shown in **figure 3**. Fracture parameters were calculated from the load deflection curve from the RILEM recommendations. **Figure 4** shows the experimental set up for obtaining the load-deflection curve.

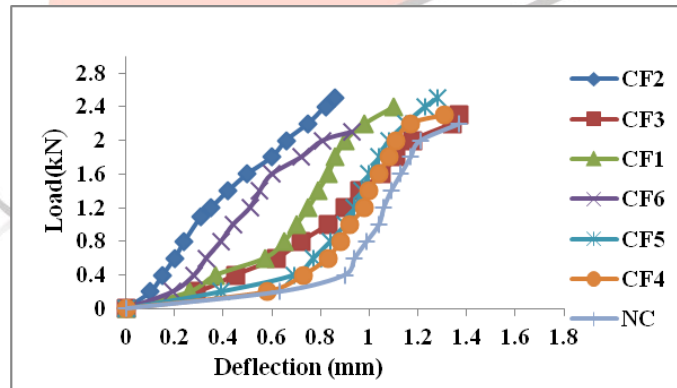


Fig 3: Load-Deflection Curve



Fig 4: Universal Testing Machine

Fracture Parameters

Fracture parameters include fracture energy and fracture toughness was evaluated from the equations. The values of fracture energy and fracture toughness are shown in **Table 5**. From the test it is observed that concrete with coir fibre content increases the fracture properties as that of conventional concrete.

Table -5: Fracture Parameters

Mix	Fracture Energy (N/m)	Fracture Toughness ($\times 10^3 \text{ N/m}^{3/2}$)
NC	26.25	11.036
(1) CF1	43.7	12.04
CF2	50.4	12.54
CF3	47	11.54
CF4	39.8	11.54
CF5	39.6	12.54
CF6	37.96	10.54

V.CONCLUSION

From the study conducted, the following conclusions were made,

1. The compressive strength of conventional concrete is more than coir fibre reinforced concrete but at 0.75% coir fibre strength increases to a limit.
2. The flexural strength increase with increase in the fibre content
3. The load carrying capacity, deflections of coir fibres are more than that of conventional concrete.
4. The fracture energy and fracture toughness are more than that of conventional concrete

REFERENCES

- [1] Peng Zhang et.al., Fracture Properties of Steel Fiber Reinforced High-Performance Concrete Containing Nano-SiO₂ and Fly Ash, *current research*, vol.106, pp 980-987, 2014.
- [2] Anju Mary Ealias et.al, Improvement of Strength of Concrete with Partial Replacement of Corase Aggregate With Coconut Shell and Coir Fibres, *IOSR Journal of Mechanical and Civil engineering*, vol.11, pp 16-24, 2014
- [3] Deepa Raj S et.al., Fracture Properties of Fibre Reinforced Geopolymer Concrete, *International Journal of Scientific And Engineering Research*, vol.4, pp 75-80, 2013
- [4] Saandeepani Vajje et.al, Study On Addition Of The Natural Fibers Into Concrete, *International Journal Of Scientific & Technology Research*, Vol 2, Issue 11, 2013
- [5] Seastiao Ribeiro et.al study of the Fracture Behavior of Mortar and Concretes with Crushed Rock or Pebble Aggregates, *Material Research*, vol.14, pp 46-52, 2011

- [6] Tara Sen et.al, Application of Sisal, Bamboo, Coir and Jute Natural Composites in Structural Upgradation, *International Journal of Innovation, Management and Technology*, Vol. 2, No. 3, June 2011
- [7] L. Bushan Karihaloo, Fracture Mechanics and Structural Concrete, Longman publications, 1995.
- [8] H Eskandari et.al Size Effect in Self Consolidating Concrete Beams with and Without Notches, *Indian Accademy of Science*, vol.35, pp 303-317, 2010
- [9] B.K.Raghu Prasad et.al, Fracture behavior of plain concrete beams – experimental verification of one parameter model, *ICCES*, vol.14, pp65-83, 2010
- [10] A Rama Chandra Murthy et.al State- of –the Art Review on Fracture Analysis of Concrete Structural Components, *Journal of Strucural Engineering*, vol.34, pp 345-367, 2009
- [11] J.M.L. Reis, Fracture and flexural characterization of natural fiber-reinforced polymer concrete, *Construction and Building Materials*, vol.20, pp 673-678, 2006.

