STUDY OF STRENGTH PROPERTIES AND CRACK PATTERNS IN COIR FIBRE REINFORCED CONCRETE MIXED WITH GGBS

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Abstract - *Concrete ever since discovered has proven itself as a versatile building material. Further, its association with steel has given it unmatched strength to build structures beyond one's imagination. But introduction of steel turns out to be costly, especially in small non-load bearing structural element. Present study is made to reinforce the plain cement concrete by introducing 0.5 %, 1 %, 2% and 3% of the raw coir fibre by weight of cementitious material having same aspect ratio. The ideal estimation of fibre content in concrete among the above mentioned percentage of coir added has been studied. The cement is also partially replaced by GGBS to give a more sustainable and green concrete mix . The present study reveals that coir fibre can be an excellent replacement of steel reinforcement for small structural element like lintels, sunshade, arches etc. for taking tensile stresses. The failure and crack pattern of specimen is also been studied, which gives an idea that introduction of coir fibre gives potential reduction in crack development.*

Key Words: **Coir Fibre, Ground Granulated Blast-furnace Slag, Compressive Strength, Split-Tensile Strength, Flexure Strength.**

1. INTRODUCTION

Rapid development in science and technology has revolutionized our society and its demand, leading to drastic expansion of urban area in each and every dimension of society. In between all these, the economically weak section of society, who are also backbone of our development is still struggling to get basic shelter and infrastructure facilities. Thus, it is time to use our science and technology to find a way to provide a much sustainable and economical solution for the low-cost housing facilities.

Concrete is a versatile composite material used in construction of most of our modern infrastructure facilities. But, in spite of its proven capability in many folds it is weak in taking tensile stresses and can only effectively take compressive stresses. To enhance its tensile properties, it is conventionally reinforced with steel which in turn increases the overall cost of the structure making it unaffordable for many. Also, the natural sources of getting steel are depleted at high rate making it an unsustainable material.

Natural fibres are filaments that are good in tension, that can be obtained from plants or animals like silk fibre, jute fibre, coir fibre, etc. These fibres are part of construction since age long. For example, birds use grass fiber for making their nest, also ancient Egyptians used straw to reinforce brick made out of mud. The present study is to find the feasibility of natural fibre as a composite material in concrete. The natural fibre used in the present study is coir fibre.

Shreesail [1] studied the deformation properties of concrete with fibers under static loading condition and the behavior of structural components in terms of compressive strength stating the advantages of coir fibre. Also, as the area of study is South India where coir fibre are locally available in abundant, coir fibre was found to be preferred natural fibre for the present study. The workability of concrete is also increased to some extent as the coir is introduced [2]. According to Chandel [3] strength of the concrete can be increased by introducing concrete composites and to cast the concrete so as to minimize the pollution effect. Among natural fibers, coir fibers give maximum tensile strength and are durable in nature. Also, Sahaya [4] investigated the behavioral study of natural fiber in concrete structure. The coir fiber is treated using natural latex before using in concrete, to prevent moisture content. In this experiment compressive strength and split tensile strength tests are carried out using coir fiber of length 20mm, 25mm and 30mm. Mary Ealias [5] claimed that coconut shell and coir fibers are used in concrete as these are agricultural wastes and also it is economical to a great extent. It will help to produce light weight and economically profitable materials in construction fields. Here, coconut shell and coir fibers are partially replaced as coarse aggregates. Its compressive strength, tensile strength, temperature resistance, water absorption, electrical resistance, chemical resistance and pH tests of the sample are performed. The addition of fly ash is done to increase the strength and workability of the concrete. Shriram Golde [6] elaborated that the coir fibers can be used as reinforcement in place of traditional steel reinforcement for the building components like lintels, over door, window openings and almirah shelves. Steel reinforcement is expensive to many people in most developing countries. In regions where, natural fibers are abundantly available which when utilized will reduce the cost of the construction. Coconut fiber used are 40mm in length. Compressive strength and modulus of rupture of CFRC specimens were determined by following standard procedures at different curing ages and also crack-patterns was monitored by Kolawole [7]. Soni [8] studied the concrete behavior of plastic and hardness variation depending on the concrete materials, mixed proportion, fiber types and length, quantity of fibers added. Bending stress was increased when the sample was cured in NaCl and $MgSO_4$ mix water. According to Santra [9], the experimental study was carried out on the use of coconut fiber reinforced concrete which can reduce conventional building materials' cost for the rural and urban development. Othuman Mydin [10] studied that foamed concrete is good in compression but weak in tension and tends to be brittle. By adding fibers, tensile property can be achieved. The use of fibers also alters the behavior of the fiber matrix composites after it has cracked, thereby improving its toughness.

2. MATERIALS AND METHODOLOGY

The present experimental study is a preliminary work carried out to found the capability and compatibility of coir fibre mixed with concrete. To obtain a more economical and sustainable composite material, cement is also being partially replaced by ground granulated blast-furnace- slag (GGBS). GGBS is obtained by quenching of molten ash from furnace with help of water and has an excellent cementitious property.

The basic constituents of concrete are cement, fine aggregate, coarse aggregate, and water. For the present study, Portland cement by Zuari cement, Ennore sand and 20mm down coarse aggregate has been used. Portable tap water has been used for mixing the various constituents. GGBS is collected from a Ready-Mix Plant located in the outskirts of Bengaluru, Karnataka, India. All the basic testing on material has been carried out at laboratory facility available at the institute, except for GGBS and Coir, for which test are conducted at external laboratories.

Mix design of M30 conforming to IS: 10262 - 2019 has been adopted for the casting of specimens of concrete mixed with GGBS. The previous research has shown that GGBS can replace cement effectively even up to 70% but optimum results are obtained at 25%. Thus 25% of cement has been replaced by GGBS. Coir fibre has been introduced by percentage by weight of total cementitious material. The different model specimen has been casted by varying the percentage of coir fibre as 0%, 0.5 %, 1%, 2 % and 3%. In the present study, the cementitious material include cement and GGBS. Table 1 gives the detail of quantity of various material required for test specimen. Table 2 and Table 3 shows the properties of materials used i.e., coir and GGBS respectively.

Table 1: Quantity of material required for test specimen (M30Mix Design)

Material	Mix 1 Cement + GGBS + 0% Coir	Mix 2 Cement + GGBS + 0.5% Coir	Mix 3 Cement + GGBS + 1.0% Coir	Mix 4 Cement + GGBS + 2.0% Coir	Mix 5 Cement + GGBS + 3.0% Coir
Cement (Kg)	22.08	22.08	22.08	22.08	22.08
GGBS (Kg)	07.34	07.34	07.34	07.34	07.34
Water (litres)	11.76	11.76	11.76	11.76	11.76
Fine Aggregates (Kg)	32.04	32.04	32.04	32.04	32.04
Coarse Aggregates (Kg)	56.99	56.99	56.99	56.99	56.99
Coir Fiber (Kg)	-	0.15	0.29	0.59	0.88

Table 2: Properties of Coir

Properties	Value
Tensile strength (MPa)	133.1
Thickness (mm)	0.27-0.36
Elongation (in %)	15-17.3
Density (in kN/m^3)	11.28
Aspect ratio	47.61
Internal moisture content	7.5
Hemi-cellulose	11.08
Lignin	49.23
Cellulose	26.29

Table 3: Properties of GGBS

Properties	Value
Calcium oxide	40%
Silica	35%
Alumina	13%
Magnesia	8%
Colour	White
Specific gravity	2.85
Bulk density (kg/m^3)	1200

Fineness(m^2/kg)	350

3. SPECIMENS AND TESTING

For studying the different strength parameter of concrete with and without coir various combination of specimens has been casted. The length of the coir as shown in Fig 1, is kept in a varying range from 10mm to 50mm for all the specimens. The strength parameter for all the test specimens has been carried out after 7 days of water curing and 28 days of water curing conforming to IS 456:2000. The test specimens for compressive strength and flexural strength is made as per IS 516:1959. The cubes of standard dimension 150 x 150 x 150 mm had been casted for compressive strength test while beam of standard dimension of 100 x 100 x 500 mm were casted for flexural strength test. The split tensile strength test is conducted conforming to IS 5816:1999. Table 4 gives the detail of test specimen to be casted for each test.

Fig 1: Weighing of Coir Fibre (10mm to 50mm in length)

Table 4: Test specimens for different tests

Composite Material	Number of samples casted for each test (after 7 days of water curing)	Number of samples casted for each test (after 28 days of water curing)
Cement + GGBS	3	3
Cement + GGBS + 0.5% Coir	3	3
Cement + GGBS + 1.0% Coir	3	3
Cement + GGBS + 2.0% Coir	3	3
Cement + GGBS + 3.0% Coir	3	3

4. RESULTS AND DISCUSSION

4.1 Effect on fresh concrete

4.1.1 Workability

The workability of the fresh concrete kept on reducing with increase in coir fibre content in the mix. Up to 1% of coir content, there was fairly not much effect on the workability but after 2% addition of coir, the workability started reducing drastically. To maintain the slump value without altering w/c ratio, superplasticizer admixture was used. The optimum dosage of the admixture was fixed by trial and error method for attaining the required slump and was found to be 0.5% and 0.6% respectively for test specimen with 2% and 3% of coir fibre respectively. The workability test was conducted as per IS :1199-1959.

4.1.2 Mixing

Mixing of various constituent of concrete was done using concrete mixer up to the test specimen having 1% of coir, further with addition of coir formation of lumps were observed in the mixer. Thus, for test specimen having 2% and 3% of coir dry mix was done in pan concrete mixer while mixing of water was done manually. Vibration table machine was used for compaction.

4.2 Effect on Harden Concrete

4.2.1 Effect on strength

The test result of compressive strength, flexural strength and split tensile strength for 7 days and 28 days is given in Table 5 and 6. There is a considerable increase in compressive strength and flexural strength of the fibre reinforced concrete as compared with plain concrete up to 1% of the coir but further addition of coir has shown a declined trend for compressive and flexural strength as shown in Chart 1 and Chart 2. The possible reason as observed could be the low specific weight of coir, due to which it occupies more volume than any other constituent in the concrete and replace the parent constituent of the concrete considerably. Thus, as the volume of coir increases, the volume of concrete decreases leading to decrease in compressive strength beyond addition of 1 % of fibre. While the split tensile has an increasing trend with the increase in % of coir added as the fibre is capable of taking tension, the tension carrying capability of the specimen also kept on increasing with increase of coir fibre content as shown in Chart 3. From the various test conducted on different test specimen it can be concluded that the optimum percentage of coir by weight of cementitious material can be 1% which gives considerable increase in compression, flexural and tension carrying capacity of the given concrete mix.

Table 5: Test result after 7 days of water curing (in N/mm²)

Specimen	Compressive strength	Flexure strength	Split tensile strength
Cement + GGBS	23.1	5.98	1.65
Cement + GGBS + 0.5% Coir	27.56	7.50	2.07
Cement + GGBS + 1.0% Coir	32.22	8.25	2.18
Cement + GGBS + 2.0% Coir	21.5	6.64	1.75
Cement + GGBS + 3.0% Coir	20.5	6.12	1.67

Table 6: Test result after 28 days of water curing (in N/mm²)

Specimen	Compressive strength	Flexure strength	Split tensile strength
Cement + GGBS	34.22	11.42	1.64
Cement + GGBS + 0.5% Coir	36.63	13.35	2.61
Cement + GGBS + 1.0% Coir	40.22	15.0	2.78
Cement + GGBS + 2.0% Coir	34.55	12.2	2.84
Cement + GGBS + 3.0% Coir	27.11	12.0	3.76

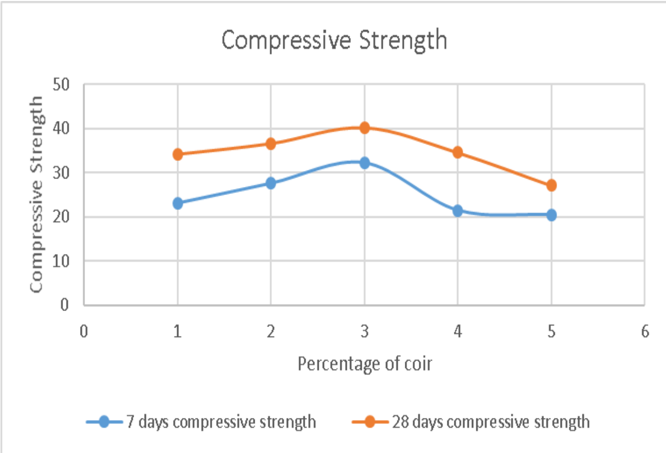

Chart 1: Graph showing variation in Compressive strength with % increase in coir fibre

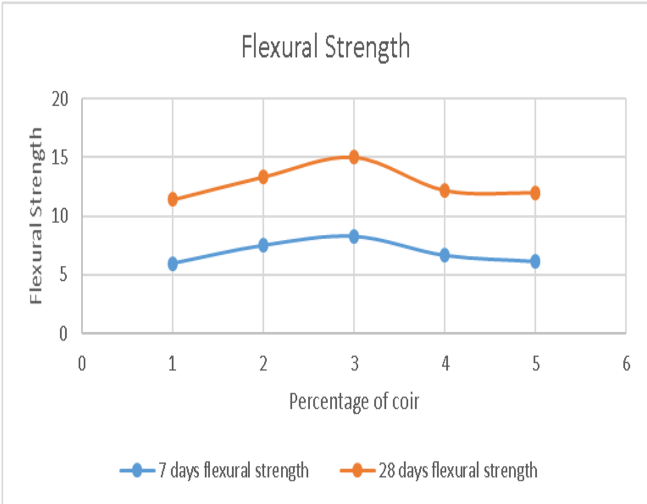

Chart 2: Graph showing variation in Flexural strength with % increase in coir fibre

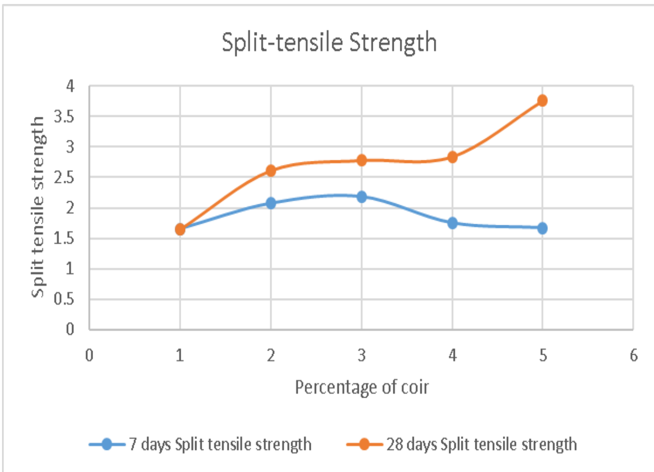

Chart 3: Graph showing variation in Split-tensile strength with % increase in coir fibre

4.3 Effect on Crack Pattern

The crack pattern during the various test has also been studied revealing that apart from enhancing the strength parameter of concrete coir is also capable of reducing the crack effectively. Fig 2, 3 and 4 shows the crack pattern of specimen after failure and it is evident that coir not only increase the strength carrying capability but also hold the concrete together even after failure avoiding complete crushing of harden concrete.

Fig 2: Cube specimen after testing

Fig 3: Cylinder specimen after testing

Fig 4: Beam specimen after testing

5. CONCLUSIONS

The results of the present experimental study show that an economical composite concrete can be proposed using coir fibre which is not only capable of taking additional compressive strength, but also tensile stress without use of conventional steel reinforcement. But as a matter of fact, it is also evident that coir cannot replace the steel for major structures, as addition of coir after certain percentage lead to reduction of the compressive and flexural strength of the mix. Thus, addition of coir fibre to conventional concrete can be used effectively for low cost housing structure or structural element like lintel, sunshade, arches, etc., where the structure is subject to less amount of tension. The further partial replacement of cement with GGBS makes the mix proposed more economical. Also, from the observed failure crack pattern, it can be suggested to adopt the proposed mix for structure at seismic zone to take care of minor seismic forces and avoid tension crack.

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