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EXPERIMENTAL INVESTIGATION ON HARDENED PROPERTIES OF CONCRETE MODIFIED WITH LIGHTWEIGHT COCONUT COIR FIBER AGGREGATES

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Abstract:

Modern world emerges with new techniques in construction field. Concrete technology has made tremendous strides in the past decade. The development in specifying the concrete according to its performance requirements, rather than its constituents and ingredients has opened innumerable opportunities for both producers and users of concrete to design concrete catering to their specific requirements. One of the most outstanding advances in the concrete technology over the last decade has been "Lightweight Concrete" (LWC).

In this study, Coconut Coir Fiber Aggregates (CCFA) are used as a lightweight coarse aggregate in concrete, by partially and completely replacing the conventional coarse aggregate in concrete. The present experimental work is aimed at studying the behaviour of LWC with different percentages of CCFA in M20 grade of concrete mix with convenient dosage of super plasticizer so that the workability is maintained more or less constant The concrete mix adopted in this investigation is designed with reference to IS 10262 (2009) [1]. Five different concrete mixes namely, one with conventional coarse aggregate in concrete and the remaining four mixes with CCFA replacing the conventional coarse aggregate in 25, 50, 75 and 100 percentages on volume basis are considered in this experimental work. The mechanical properties such as cube compressive strength, splitting tensile strength, flexural strength, impact strength, shear strength in mode-II fracture, modulus of elasticity and density at the age of 28 days are determined. Totally 120 concrete specimens are cast for five types of concrete mixes mentioned above.

Key words: Coconut Coir Fiber Aggregates (CCFA), double centered notch (DCN), flexure, impact, split tension, compression.

1. INTRODUCTION

1.1 Lightweight Concrete

Generally, the density of a normal weight concrete (NWC) will be in the range between 2200 and 2600kg /m^3. In particular cases, where the light weight structural elements are required, then the use of light weight concrete becomes an essential one. The use of concrete modified with LWCA generally results in an overall saving of 10 – 20% of the total cost when compared with that for concrete having conventional coarse aggregate and also the reduction in density allows lighter structural members (Jumaat et al. 2009)[2]. A concrete which is produced with a lesser density than the conventional one is called lightweight concrete (LWC). The density of LWC is in the range between 300 and 2000 kg/m^3 .The usage of LWC for various applications reported by Mindess et al (2003)[3], Neville (1999)[4] and Newman (1993)[5] is shown in Table 1.1.

Table 1.1 Application of light weight concrete

Type of LWC	Density range in Kg/m^3	Compressive strength range in N/mm^2	Applications
Ultra LWC	300-1100	0.7-2.0	Insulation
Moderate strength LWC	1100-1600	7-14	Wall partitions and load bearing walls
Structural LWC	1450-2000	>17	Structural purpose

LWCA concrete has gained popularity due to its superior thermal insulation properties (Weigler and Sieghart 1980)[6]. The advantage of using LWCA concrete over concrete with conventional coarse aggregate reduces self-weight, superior seismic resistance, high sound absorption and good fire resistance. The naturally available LWCA are diatomite, pumice and volcanic cinder etc. The manufactured LWCA are bloated clay, sintered fly ash and foamed blast furnace slag (Gambir 2004)[7].

1.2 Coconut Coir Fiber Aggregates

The Indian agricultural industry, every year produces lot of agricultural wastages after their crop period. One such agricultural solid waste abundantly available in India is CCFA. The main coconut producers in the global market – 2010 are shown in Table 1.2. India is the third largest producer of coconut and 90% of its production is from South India. After the coconut is scraped out, the coconut shell and coconut coir is usually discarded as waste as shown in Figure 1.1. Coconut coir fiber aggregates is mostly used as an ornament in making fancy items, house hold utensils, and is a source for activated carbon from its charcoal. In this experimental work well seasoned coconut coir fiber machine cut material passing through 20mm and retained on 4.75 mm sieves is considered for replacement in partial /complete to conventional coarse aggregates for making light weight concrete.

Figure 1.1 Discarded Coconut coir fiber aggregates

Table 1.2 Top five Coconut Producing Countries

Sl. No.	**Country**	**Production 2010**	**% of World Total**
i	Indonesia	20,655,400 t	33.07%
ii.	Philippines	15,540,000 t	24.88%
iii.	India	10,894,000 t	17.33%
iv.	Brazil	2,705,860 t	4.33%
v.	Sri Lanka	2,238,800 t	3.58%

2. REVIEW OF LITERATURE

2.1 Olanipekun et al. (2006)[8] carried out the comparative cost analysis and strength characteristics of concrete produced using crushed, granular coconut and palm kernel shell as substitutes for conventional coarse aggregate. The main objective is to encourage the use of agricultural waste products as construction materials in low-cost housing. They considered the crushed granular coconut and palm kernel as substitute for conventional coarse aggregate in the following ratios: 0%, 25%, 50%, 75% and 100% .

2.2 Siti Aminah Bt Tukiman and Sabarudin Bin Mohd (2009) [9] replaced the coarse aggregate by coconut shell and palm kernel in their study. They considered the above material replacement in place of coarse aggregate in the percentages of 0%, 25%, 50%, 75% and 100% respectively. They concluded that, the combination of these materials has a potential of being used as lightweight coarse aggregate in concrete and also it reduced the material cost in construction.

2.3 Olutoge (2010) [10] studied the effect of saw dust as a partial replacement for fine aggregate and palm kernel shells (PKS) as a partial replacement for coarse aggregates in reinforced concrete slabs. The replacement ratios considered were 0%, 25%, 50%, 75% and 100%. Compressive and flexural strengths were noted at different time intervals. From his experimental studies, he concluded that with 25% replacement of sawdust as fine aggregate and PKS as coarse aggregate it can produce lightweight reinforced concrete slabs that can be used where low stresses are occurring, and it reduces the cost. He achieved 7.43% cost reduction.

2.4 Prakash Desai et al.[11] proposed several methods and geometries for Mode-II test specimen for cemetitious materials. Prakash Desayi et al [11] evolved double centered notch (DCN) specimen geometry as shown figure (2.1) as the best suited one for conducting the inplane shear strength of concrete. And they conducted inplane shear strength studies on cement paste, cement mortar, plain cement concrete and fibre reinforced concrete.

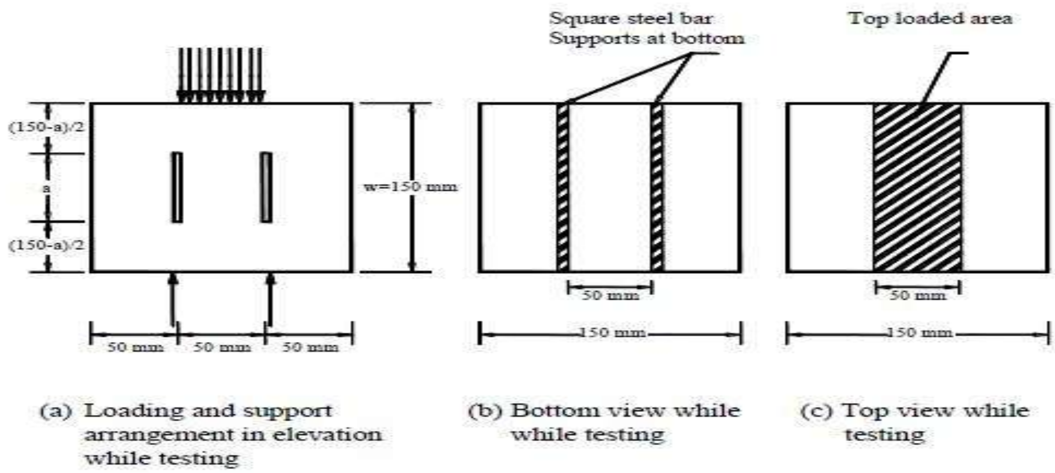

Figure 2.1 Details of DCN specimen geometry

2.5 Bhaskar Desai [12] carried out several experimental studies on cement paste and mortars of for arriving the best suited geometry to represent the Mode-II fracture of cementitious materials, by considering Double Centered Notched specimen (DCN), Double Edge Notched specimen (DEN), Notched Column Footing specimen (NCF) and Modified Double Edge Notched specimen (MDEN). From his experimental studies, he arrived DCN specimen as the best suited geometry to represent predominant Mode – II fracture of cementitious materials and by considering the DCN specimen geometry, he further conducted experimental studies on Mode – II fracture of cement mortar, concrete, no-fines concrete and fibre reinforced cement mortar and concrete along with their stress-strain behaviour in shear. Also they conducted linear finite element analysis on DCN geometry for the above cementitious materials considered and concluded that the specimen fails due to predominant Mode-II fracture.

2.6 Jagan Mohan. D et al. (2013) [13] carried out further Mode-II fracture studies of cementitous materials, such as concrete made with partially/completely replacing the conventional river sand with crushed granite stone fine aggregate, fly ash partially replacing the ordinary Portland cement, silica fume partially replacing the ordinary Portland cement and metallic coarse aggregate such as hematite, partially/completely replacing the conventional granite coarse aggregate using the effective DCN specimen geometry.

3. OBJECTIVE OF THE PRESENT STUDY

From the brief literature survey conducted in this area it appears that much less work is reported earlier in the study of light weight concrete using coconut coir fiber as coarse aggregate and related studies including Mode-II. Hence present study of examining the usage of agricultural waste product such as CCFA is considered as a partial replacement in place of conventional coarse aggregate. In the present experimental work, the mechanical and inplane shear characteristics of CCFA modified concrete in percentages of replacements 0%, 25%, 50%, 75% and 100%. The following are the objectives.

- To evaluate the physical properties of CCFA modified concrete and conventional concrete.
- To study the strength characteristics of CCFA modified concrete and conventional concrete.
- To investigate the flexural and mode-II shear behaviour of CCFA modified concrete and conventional concrete.
- To ascertain the use of CCFA modified concrete and conventional concrete for structural applications.

4. MATERIALS USED AND EXPERIMNENTAL WORK

The following materials were used for preparing the concrete mix

1. ACC cement of 53 grade OPC

2. Fine aggregate i.e., sand

3. Coarse aggregate (natural aggregates, coconut coir fiber aggregates)

4. Super plasticizer (Fosroc Conplast SP 430)

5. Water

4.1 Cement: ACC 53 grade cement with specific gravity 3.10 is used as binder, as shown in figure 4.1 and table 4.2

Figure 4.1 Coconut Coir Fiber Aggregates, Natural Coarse Aggregates, Fine Aggregates and Cement

4.2 Fine aggregates: Locally available river sand has been used as a fine aggregate, which is free from clay, silt and organic impurities and passing through 4.75 mm size I.S sieve. Its specific gravity is found to be 2.54. All the materials considered in this experimental work are shown figure 4.1 and its physical properties are as shown in table 4.3

4.3 Coarse aggregate: The coarse aggregate consists of locally available machine crushed granite metal passing through 20mm size I.S sieve, as shown in figure 4.1 and its physical properties are as shown in table 4.4.

4.4 Coconut coir fiber aggregates: The discarded coconut coir fiber aggregates is procured from Venkateswara Evergreen Cocopeat Industries, Pollachi, Coimbatore, Tamil Nadu. The coconut coir fiber aggregates considered in this work is passing through 20 mm and retained on 4.75 IS sieve. It is alredy shown in figure 1.1 and its physical properties are presented in table 4.5

4.5 Super plasticizer: The super plasticizer used in this experimental investigation is Fosroc made Conplast – SP 430.

4.6 Water: The water used in this experimental investigation is locally available potable water.

4.7 Casting of specimens:

The M_{20} concrete mix is designed using IS 456-2000 [14] method which gives a mix proportion of 1:1.76:3.0 with constant water cement ratio of 0.50. Five different mixes replacing the conventional coarse aggregates with CCFA in the percentages of 0,25,50,75 and 100 which are designated as M0, M1, M2, M3 and M4. Details of mixer are presented in table 4.1

First the weighed quantities of fine aggregates and cement are mixed thoroughly and then this mixture is placed over the thoroughly mixed and weighted quantities of coarse aggregates and coir fiber aggregates, in which the CCFA was initially socked in water for two hours and mixed again thoroughly in surface dry condition. To proceed with the experimental program initially steel moulds of size 150x150x150 mm are cleaned and brushed with machine oil on all inner faces to facilitate easy removal of specimens afterwards. For the above dry mix measured quantity of water with water cement ratio 0.5 and super plasticizer SP conplast 430 with convenient dosage is mixed to have more or less same workability for all mixes. The Vee-Bee time results are represented in table 4.1

Three geometrically similar specimens are cast for each percentage variation. The cubes are with a size of 150 x150x 150 mm, cylinders of size 150 mm diameter and 300 mm length, plain cement concrete beams of size 150 x150 x700mm, small disks of size 150 mm diameter and 75 mm length and DCN specimens of size 150 x150 x 150 mm for each notch to depth ratio of 0.3, 0.4, 0.5 and 0.6 and for each percentage of replacement with CCFA. The concrete is poured into the moulds in three layers with each layer being compacted thoroughly with tamping rod uniformly each time to avoid honey combing. Finally all specimens are kept on the table vibrator after filling up the moulds up to the brim. The vibration is effected for 7 seconds and it is maintained constant for all specimens and all other castings. The steel plates forming notches for DCN specimens are removed after 3 hours of casting carefully and neatly finished. After 28 days of curing the specimens are taken out from water allowed to dry under shade for few hours.

4.8 Hardened properties of concrete

4.8.1 Vee-Bee time of concrete: Vee-Bee time of concrete is measured using Vee-Bee time standard apparatus. The Vee-Bee time at different percentages replacements of coconut coir fiber aggregates are given in table 4.1 and graphical variation is represented in figure 4.3

4.8.2 Compressive strength of cubes: Compressive strength of cubes is calculated by considering ultimate load divided by the loaded area. Values of compressive strength at different percentages of coconut coir fiber aggregates are given in table 4.6 and graphical variation is presented in figure 4.4

4.8.3 Density: Density of concrete specimens are calculated by the total weight divide by specimen volume. These density at different percentages replacement of coconut coir fiber aggregates are given by table 4.7 and graphical variation is presented in figure 4.5

4.8.4 Modulus of elasticity: The theoretical modulus of elasticity has been calculated using two approaches. In one approach IS code formula. $E=5000*\sqrt{f_{ck}}$ Where f_{ck}= Characteristic Compressive cube strength of concrete in N/mm^2 is used The modulus of elasticity values have been calculated from the another empirical formula suggested by Takafumi et al [15] is $E=K1*K2*1.486*10^{-3}*f_{ck}^{1/3}*\gamma^2$ Where f_{ck} = Compressive cube strength in N/mm^2, γ =

Density in Kg/m^3, K1= 0.95 (correction factor corresponding to coarse aggregate), K2= 1.026, (correction factor corresponding to mineral admixtures) and as shown table 4.8 and they are graphical variation is presented in figure 4.6

4.8.5 Flexural strength: Flexural strength is one measure of the tensile strength of the concrete. It is a measure for plane concrete beam without reinforcement to resist failure in bending. The flexural strength can be determined by standard test method of two point loading. In this study, beams of size 150x 150 x 700 mm are used to find the flexural strength. The values are presented in table 4.9 and the results are graphical variation is presented in figure 4.7

4.8.6 Splitting tensile strength: Split tensile strength is one of the tensile strength of the concrete. It is measured for the cylinders to resists the failure at the ultimate loads. These ultimate loads and split tensile strength values are shown Table 4.10 and graph are graphical variation is presented in figure 4.8

4.8.7 Mode II fracture test: For finding the inplane shear behaviour of concrete, DCN specimens of size 150x150x150mm, with notches at one third portion are considered. The inplane shear test loading arrangement on the DCN specimens is shown in the figure 4.2. A uniformly distributed load is applied over the central one third part between the notches and square cross section steel supports are provided at bottom along the outer edges of the notches, so that the central portion could get punched/sheared through along the notches on the application of loading. These tests are conducted on 3000 KN digital compression testing machine, by applying the rate of loading 0.1 kN/sec. The average value of first crack load and ultimate load for three geometrically similar specimens are calculated for each replacement with CCFA and for a particular a/w ratio considered, and the results shown in table 4.11 and these are graphical variation presented in figure 4.9 and 4.10

Figure 4.2 Testing of Specimen for mode-II shear

4.8.8 Impact strength: To find out the impact strength of CCFA modified concrete, small disk specimens are considered. These specimens fail due to decreasing number of hammer blows as the percentage of CCFA increases. The corresponding results are presented in table 4.12 and graphical variation is presented in figure 4.11

5. DISCUSSION OF TEST RESULTS

5.1 Influence of coconut coir fiber aggregates on cube compressive strength

From the limited experimental studies conducted on various percentage replacement of coarse aggregates with coconut coir fiber aggregates, it is observed that the compressive strength of coir fiber aggregate concrete continuously decreases with increase in coir aggregate content. It reduces by 95.79% for 100 percent replacement with CCFA. This could be due to less density of coconut coir fiber aggregates.

5.2 Influence of coconut coir fiber aggregates on density

It is observed that the density of concrete goes on decreasing with increase in percentage of replacement with CCFA. This could be due to lesser density of CCFA when compared with that for the conventional coarse aggregate concrete.

5.3 Influence of coconut coir fiber aggregates on flexural strength of beam specimens

From experimental observations on the flexural strength of beams, it is observed that, the flexural strength reduces with increase in percentage of replacement. This could be due to lesser bonding strength between coir aggregates and mortar and also lesser tensile strength of coconut coir fiber aggregates when compared with that conventional coarse aggregates and cement mortar.

5.4 Influence of coconut coir fiber aggregates on modulus of elasticity

From the experimental studies on cubs, the young modulus of elasticity is calculated and it is observed that young's modulus of elasticity decreases as the percentage of replacement increases. This could be due to decreases in compressive strength with increasing percentage of replacement of coconut coir fiber aggregates. It is also observed that the modulus of elasticity values calculated from IS codes are higher when compared with those calculated using empirical formula as shown table 4.8 and figure 4.6

5.5 Influence of coconut coir fiber aggregates on in-plane shear strength

From the experimental observations it is observed that the inplane shear strength is gets reduced with the increase in percentage of replacement and a/w ratio. The variations of ultimate loads and percentage increase or decrease in ultimate loads verses percentage replacement of normal coarse aggregates with coconut coir fiber aggregates are presented in tables 4.11

5.6 Discussion of crack patterns in cubes, cylinders, beams and DCN specimens:

Cubes: On observation during the experimentation on plain cubes and cubes having replacement coconut coir fiber aggregates, with the increasing the load , the initiation of the cracks patterns are observed on the side faces of the cubes and as the load increases further, failure of the cubes has occurred due to crushing by widening of cracks.

Beams: The beams are tested under two point loads. As the load increases, the initiation of the cracks has occured at the bottom of the beam in the flexure zone (mostly in middle third span of beam), which could be due to uniform bending moment between loads and as the loads increased further, the cracks get widened and extended towards the top of the beam.

Cylinder: In the case of plain and the cylinders specimens modified with CCFA, as the load increased gradually, in most cases, the initiation of the cracks started in vertical direction and in some cases cracks propagated in inclined direction. This could be the random distribution of CCFA in concrete mix.

DCN Specimens: The DCN specimen are tested for their inplane shear strength with varying percentage replacement with CCFA in place of conventional coarse aggregates.(0%,25%, 50%,75%,100%). In the most of the cases, cracks are initiated at either from the bottom or top edges of the notches in the specimens and propagated in more or less vertical direction towards the outer edges to the specimen.

In some cases as inplane shear load cracks are initiated at either at top or bottom edges of the notches and propagated towards outer edges of the specimen with slight inclination. This could be due to random distribution of CCFA and conventional coarse aggregates.

Small disks: In case of small disks with conventional coarse aggregate and the specimens replacing the coarse aggregate with CCFA for the impact test, the cracks are initiated at the outer edges and propagated to the centre point of the specimens in radial direction with the increase in width of the cracks at the outer edges, as the number of blows increases. This could be due to circumferential tensile stress developed in the specimen due to impact on the specimen.

6. CONCLUSIONS

- The target mean strength of M_{20} concrete is 26.60 N/mm^2. The cube compressive strength decreases to 1.192 N/m^2 with 100% replacement with coconut coir fiber aggregate.
- From the experimental study it is observed that the conventional concrete has a density of 2417.78 Kg/m^3, but density of the concrete reduces to 1484.45 Kg/m^3 with 100% of replacement with CCFA. The percentage of reduction of density at zero percentage to hundred percentage is 62.87%.
- From the analysis of test results, it is observed that in both the approaches the young's modulus goes on decreasing with increase in percentage replacement with CCFA.
- Flexural strength of M_{20} grade concrete at zero percentage is 1.63 N/mm^2. Flexural strength of modified concrete with 100% coconut coir fiber aggregate is 0.24 N/mm^2. The percentage reduction of flexural strength from 0% to 100% is 84.28
- Split tensile strength of M_{20} grade concrete at zero percentage is 3.57 N/mm^2. Split tensile strength of modified concrete with 100% coconut coir fiber aggregates is 0.234 N/mm^2. The percentage reduction of split tensile strength from 0% to 100% replacement with CCFA is 94.44
- It is observed that, mode-II shear strength with the increase in the a/w ratio there is decrease in ultimate load. And also as the % of replacement with CCFA increases the ultimate shear strength goes on decreases for all a/w ratios.
- It is observed that the impact strength goes on decreasing with increasing percentage replacement with coconut coir fiber aggregates.
- This type of CCFA lightweight concrete can be recommended to use for internal thin partition walls in multi-storey buildings either in cast insitu form or precast form.

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Appendices

Table 4.1 Vee-Bee time of concrete

S.NO	Name of the Mix	% replacement coarse aggregate with CCFA	w/c ratio	Vee-bee(sec)
1	M0	0	0.5	3
2	M1	25	0.5	3
3	M2	50	0.5	3
4	M3	75	0.5	4
5	M4	100	0.5	5

Table 4.2 Physical Properties of 53 Grade Ordinary Portland Cement

Sl. No.	Physical Property	Test Results of ACC– OPC (53 grade)
1.	Standard consistency (%)	30
2.	Setting time (a) Initial (min) (b)Final (min)	 120 320
4.	Fineness (a) By sieving with IS sieve	 4%
5.	Specific gravity	3.10

Table 4.3 Properties of fine aggregates

S.NO	Property	Value
1	Specific gravity	2.54
2	Bulk density	1693 Kg/m^3
3	Fineness modulus	2.64
4	Bulking of sand	2%

Table 4.4 physical properties of natural aggregates

S.NO	Property	Values
1	Specific gravity	2.72
2	Bulk density i) Loose ii) Compacted	 1368 Kg/m^3 1527Kg/m^3
3	Water absorption	0.4%
4	Impact value	12.5%
5	Abrasion value	8.3%

Table 4.5 Properties of Coconut coir fiber aggregates

S.NO	Property	Value
1	Specific gravity	0.223
2	Water absorption	13%
3	Aggregate impact value	12.5%
4	Fineness modulus	6.91
5	Bulk density (Loose)	94.32 Kg/m^3
6	Bulk density (compacted)	150.9Kg/m^3

Table 4.6 Cube compressive strength (N/mm^2)

S.NO	MIX	CCFA replacement (%)	Compressive strength (N/mm^2)	Percentage increase or decrease compressive strength
1	M0	0	25.680	0
2	M1	25	10.701	-58.32
3	M2	50	3.067	-88.05
4	M3	75	2.096	-91.83
5	M4	100	1.192	-95.35

Table 4.7 Density of concrete

S.NO	Name of mix	% replacement of coarse aggregates	Density (Kg/m^3)	Percentage increase or decrease density
1	M0	0	2417.78	0
2	M1	25	2337.78	-3.42
3	M2	50	2190.51	-10.37
4	M3	75	1766.22	-36.22
5	M4	100	1484.45	-62.87

Table 4.8 Modulus of elasticity of concrete by IS 456-2000 and empirical formula

S.NO	Name of mix	% replacement of coarse aggregates	Modulus of Elasticity as per IS 456-2000 (N/mm^2) $5000 * \sqrt{f_{ck}}$	Modulus of elasticity based on empirical formula (N/mm^2) $E = K1 * K2 * 10^{-3} * f_{ck}^{\frac{1}{3}} * \gamma^2$
1	M0	0	25.33×10^3	24.97×10^3
2	M1	25	16.35×10^3	17.44×10^3
3	M2	50	8.75×10^3	10.09×10^3
4	M3	75	7.238×10^3	5.782×10^3
5	M4	100	5.458×10^3	3.384×10^3

Table 4.9 Flexural strength of concrete beams

S.NO	Name of mix	% replacement of coarse aggregates	Flexural strength (N/mm^2)	% increase or decrease of flexural strength
1	M0	0	1.63	0
2	M1	25	1.09	-33.128
3	M2	50	0.55	-66.26
4	M3	75	0.34	-79.14
5	M4	100	0.24	-85.28

Table 4.10 Splitting tensile strength of concrete

S.NO	Name of mix	% Replacement of coarse aggregates	Splitting tensile strength (N/mm^2)	Percentage increase or decrease split tensile strength
1	M0	0	3.57	0
2	M1	25	1.891	-41.03
3	M2	50	0.830	-76.75
4	M3	75	0.693	-80.58
5	M4	100	0.234	-93.44

Mode-II shear results:

Table 4.11 First crack load, ultimate load and peak deflection of mode-II with respect to different percentages replacement with coconut coir fiber aggregates

S.NO	Name of the mix	% replacement of coarse aggregates	a/w ratio	First crack in mode-II (kN)	Ultimate load in mode-II (kN)	Peak deflection (mm)
1	M0	0	0.3	135	277.5	0.98
			0.4	125.34	261.67	1.15
			0.5	122.67	241	1.22
			0.6	88	227	1.32
2	M1	25	0.3	90	121.67	0.98
			0.4	88.33	126.5	1.15
			0.5	85	107.33	1.22
			0.6	83.33	94	1.32
3	M2	50	0.3	43	50	0.58
			0.4	36.5	48	1.18
			0.5	36	45.33	1.19
			0.6	35.33	41.33	1.02
4	M3	75	0.3	31.67	41	0.52
			0.4	34.67	40.33	1.81
			0.5	29.67	37	0.92
			0.6	27	30.33	0.88
5	M4	100	0.3	24	28.67	2.4
			0.4	25.67	29	1.22
			0.5	22.67	28.67	1.32
			0.6	20.67	28.67	1.48

Table 4.12 impact value of concrete

S.NO	Name of mix	% Replacement of coarse aggregate by coir fiber aggregates	Impact (blows)
1	M0	0	282
2	M1	25	176
3	M2	50	18
4	M3	75	13
5	M4	100	7

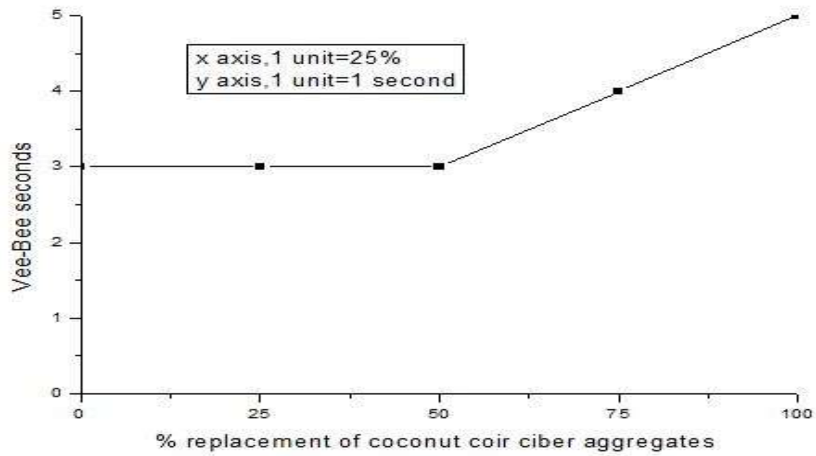

Figure 4.3 Vee-Bee seconds Vs % replacement with CCFA

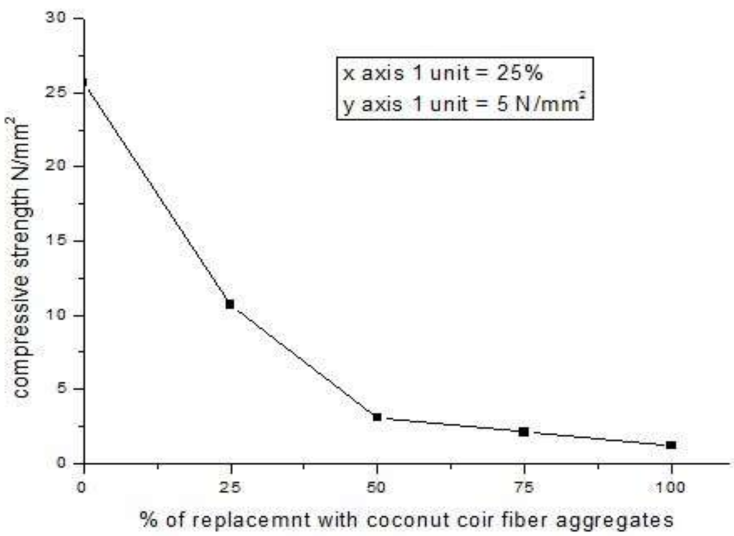

Figure 4.4 cube compressive strength Vs % replacement with CCFA

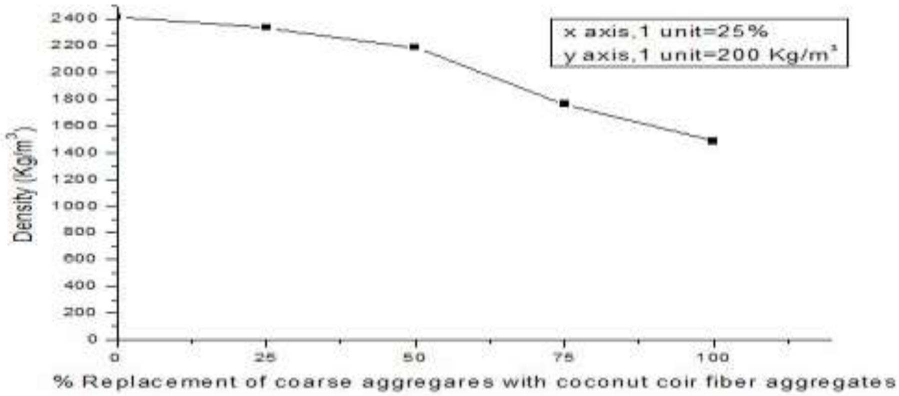

Figure 4.5 density Vs % replacement with CCFA

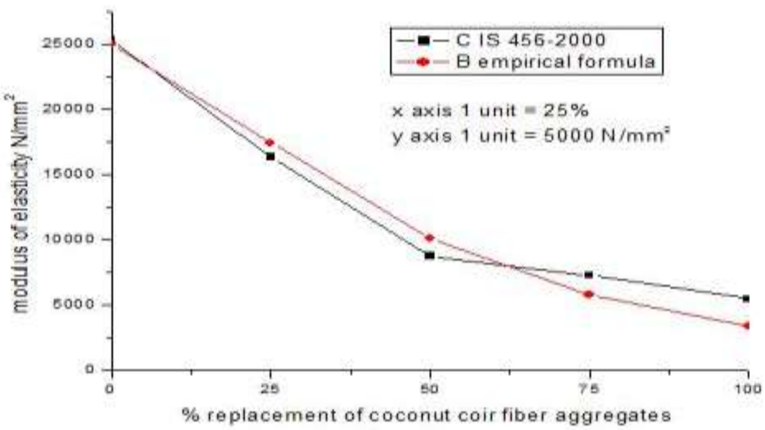

Figure 4.6 modulus of elasticity Vs % replacement with CCFA

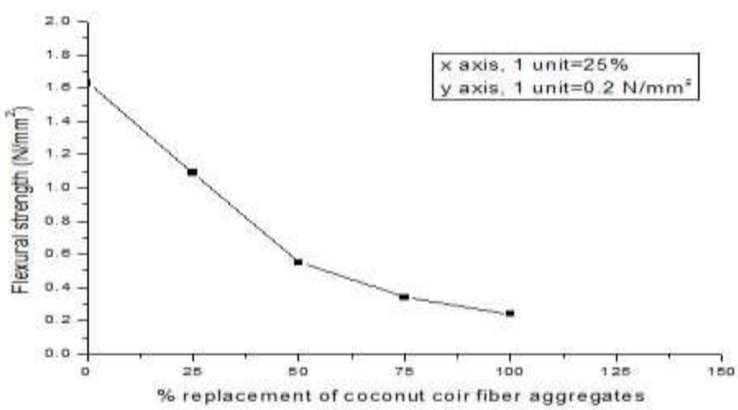

Figure 4.7 flexural strength Vs % replacement with CCFA

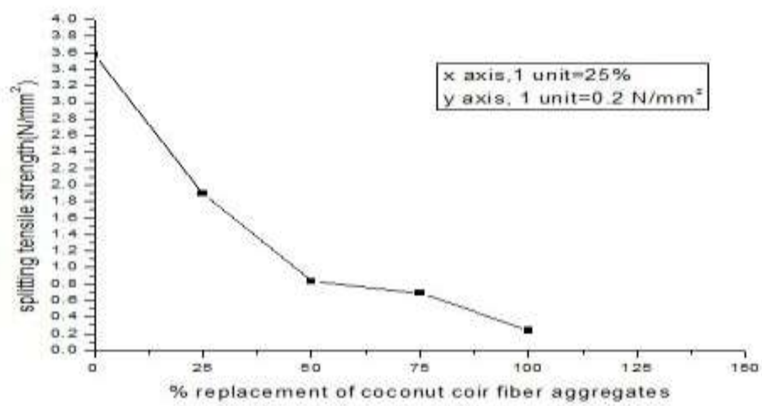

Figure 4.8 splitting tensile strength Vs % replacement with CCFA

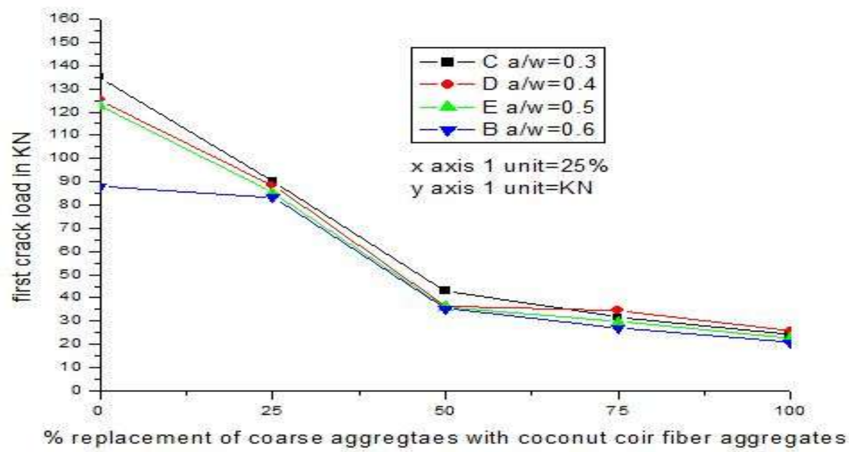

Figure 4.9 first crack load Vs % replacement with CCFA

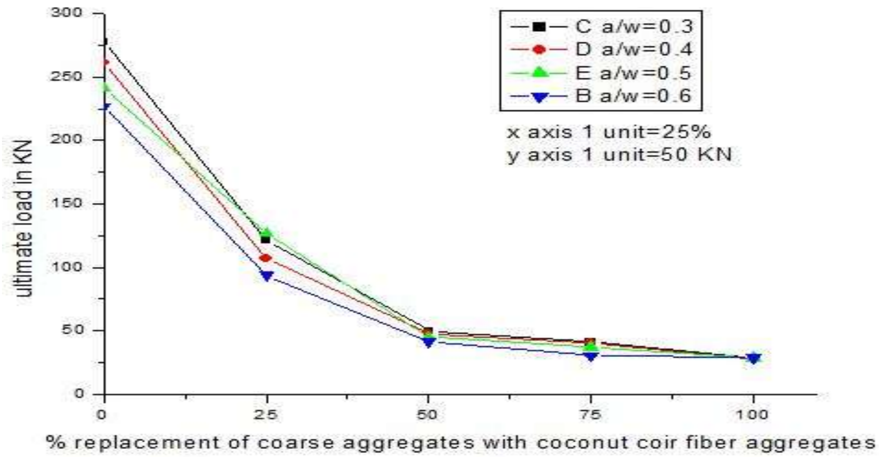

Figure 4.10 ultimate load Vs % replacement with CCFA

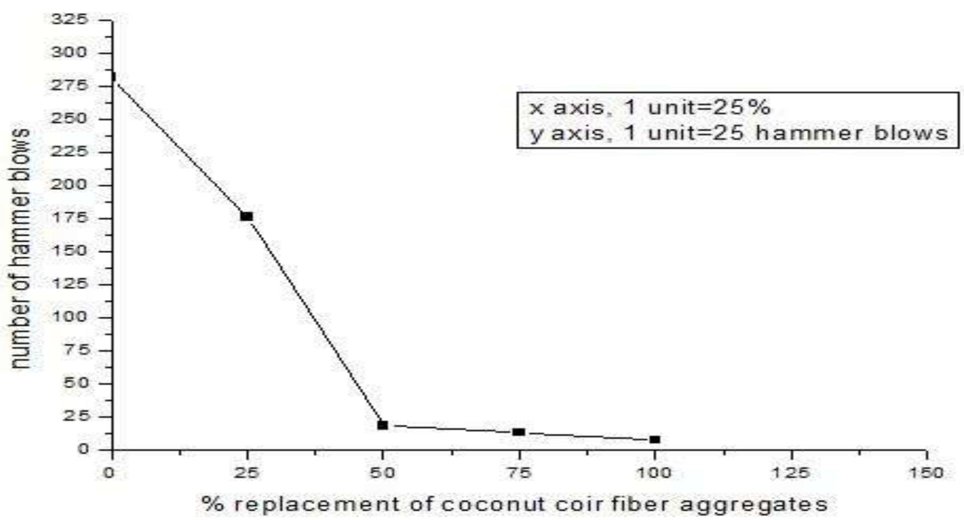

Figure 4.11 impact strength vs % replacement with CCFA