Flexural Behaviour of Hybrid Fibre Reinforced Concrete Beam by using (LC3) Cement

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Abstract*: In this paper, the flexural behavior of hybrid fibre reinforced concrete beams was investigated. Two types of hybrid fibres were used. used in this study, one is having high young's modulus steel fibre (Hooked end) and another one is having low young's modulus Polypropylene fibre with different proportions. Nine types of reinforced concrete beams were made by using M50 grade high strength concrete mix a volume factors of hybrid fibres as 1.5%. this beams includes conventional concrete, LC3 concrete and he beam with the following combinations of hybrid fibres such as OPC 100%, LC3 100%, SF100%, SF25% -PF75%, SF40%-PF60%, SF50%-PF50%, SF60%-PF40%, SF75%-PF25 %, PF100%, the working results shows that percentage proportion of combined SF-PF at 75%-25% had the best implementation on its flexural strength. Experimental results also shows that beam with SF75%-PF25% had their structural stiffness, ductility index and energy absorption capacity have been improved the most as compared with the conventional concrete and other fibre combinations of beams.

***Keywords* : OPC, LC3, Hooked End Steel Fiber, Polypropylene Reinforced Concrete.**

I. INTRODUCTION

Cement produced from Portland cement, is generally in compression but weak in tension and tends to be brittle (Banthia N (2012).The weakness in tension can be overcome by the utilization of conventional steel bars support and somewhat by the blending of an adequate volume of specific filaments. The utilization of strands additionally recalibrates the conduct of the fibre-framework composite after it has broken through improving its strength (Nataraja M.C., Dhang N).This paper is means to give data on the properties and uses of the more normally accessible filaments and their uses to create concrete with specific qualities. Another sort of fibre strengthened cement is created which is produced using cellulose filaments. A fibre is a little discrete fortifying material delivered from different materials like steel, plastic, glass, carbon and common materials in different shapes and size (ACI Committee 440. 1996).

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A numerical parameter describing a fibre as its proportion, which is characterized as the fibre length, partitioned by an identical fibre breadth [l/d].Typical perspective ratio[l/d] extend from 30 to 150 for length measurements of 0.1 to 7.62 cm for steel fibre distances across are 0.25 to 0.76 mm for steel and 0.02 to 0.5 mm for plastic. The plain concrete flops all of a sudden when the diversion comparing to a definitive flexural quality is surpassed, then again fibre-strengthened solid keep on supporting loads even at deflection extensively in abundance of the break avoidance of the plain cement concrete.

A. Lime Calcined Clay Cement (LC3*)*

LC3 is a new type of cement that depends on a mix of limestone and Calcined clay. LC3 is low carbon concrete which is option in contrast to the standard (OPC). LC3 can decrease 30% of CO2 outflow. In the concrete plant, by lessening the measure of clinker and supplanting it with limestone and Calcined earth with appropriate extent. Low quality kaolin clay just be utilized for the creation of LC3 which is rich ly accessible in numerous pieces of the world. The generation of LC3 requires either between crushing or mixing of clinker, lime stone, Calcined clay. LC3 is ternary concrete that can accomplish qualities like OPC even at clinker factors as low as 40% to 50%. LC3 takes points of interest of the synergetic hydration of clinker, Calcined clay and squashed limestone to accomplish the presentation required from commercial cement, even at clinker factors as low as 0.40. The segments 50% clinker, 30% Calcined clay, 15% squashed lime stone and 5% gypsum, Its expense is viable and does not require escalated alteration of minding cement industry.

II. METHODOLOGY

A. Materials to be used

- Coarse Aggregate
- Fine aggregate
- OPC
- Lime Stone Calcined Clay Cement (LC3)
- Super plasticizers(poly-carboxylic ether based- conplast SP430)

B. Fibre

- Polypropylene fibre
- Hooked end steel fibre

C. Cement

Cement is binding materials which bind the various component of concrete. The cement used throughout the experimental investigation was OPC 53 grade and LC3. Purchased from TARA cement Pvt Ltd, New Delhi.

D. Fine Aggregate

The fine aggregate is used a river sand of local sources. Care was taken to see that they were uniformly dry and clean. Locally available river sand conforming to grading zone II of IS 383-1970 (1971). Sand passing through IS 4.75mm sieve will be used with the specific gravity of 2.42.

E. Coarse Aggregate

Coarse aggregate that was used in the concrete mix was broken stones of hard granite drawn. A maximum size at 10mm and 20mm. local availability of blue metals were used. Crushed granite stones of size passing through 12.5mm sieve and reinforced on 10mm sieve as per IS 383 –1970(1971) was used for experimental usage.

F. Properties of Fibre

Table 1 shows the properties of fibres at polypropylene and hooked end steel fibre (length, diameter and aspect ratio).

Table- I: Properties of fibers

Properties	Polypropylene	Hooked end steel
Length	6mm	30mm
Diameter	0.1mm	0.5mm
Aspect ratio	60	60

Fig. 1. Polypropylene

Polypropylene (PP) is a thermoplastic "expansion polymer" produced using the mix of propylene monomers. It is utilized in an assortment of uses to incorporate bundling for shopper items, plastic parts for different businesses including the automotive industry, exceptional gadgets like living hinges, and textiles as show that Fig 1. The hooked end steel fiber is made by quality base steel bar, which has fantastic mechanical properties including high rigidity.

Fig. 2. Hooked end steel

Subsequently, the normal elasticity of the fortified fiber outperforms 1100 MPa. Inferable from high quality and uniform conveyance of filaments stresses, can be completely scattered and breaking spread be successfully controlled as show that Fig 2.

The mix proportion for LC3 is 1:1.58:2.9:0.45

Table- II: Material Proportions

Spe cim en Id	Mix Combi nation	Wt. of Cem ent Kg/ m^3	Wt. of fine aggre gate Kg/m^3	Wt. of coarse Aggregat e Kg/m^3	Amou nt of Super Plaste rers Lit/m^3	Amou nt 0f Water Lit/m^3
OP C10 0%	Opc-100%	447	692	1184	4.5	156
LC3 100 %	Lc3-100%	447	692	1184	4.5	156
S10 0%	Steel 100%	447	692	1184	4.5	156
S25 %-75%	Poly 100%	447	692	1184	4.5	156
S40 %-60%	Steel 50% Poly 50%	447	692	1184	4.5	156
S50 %-50%	Steel 60% Poly 40%	447	692	1184	4.5	156
S60 %-40%	Steel 40% Poly 60%	447	692	1184	4.5	156
S75 %-25%	Steel 75% Poly 25%	447	692	1184	4.5	156
P10 0%	Steel 25% Poly 75%	447	692	1184	4.5	156

G. Preparation of Concrete

Based on mix proportion we begin the blending of cement. the materials are gathered according to proportion. the steel fibre added to concrete by 1% volume of concrete and polypropylene included by 1% of by weight of cement.

All other material is included by amount which is determined according to IS mix design. Water is added for each beam as indicated by estimation. A mix design and superplastiszer additionally included for each beams. The polypropylene fibres are included bond at the time of gauging, and steel fibre are blended in blending in machine mixer with aggregates as show in table 3.

Table- III: Calculation of materials

Mix id	Name of specimen	Wt of cement (Kg / m^3)	Wt of fine aggregate (Kg / m^3)	Wt of coarse aggregate (Kg / m^3)	Wt of SF (Kg / m^3)	Wt of PF (Kg / m^3)	Amount of SP (Ltr / m^3)	Amount of water (Ltr/ m^3)
OPC	OPC100 %	447	692	1184	0	0	4.5	156
LC3	LC3100 %	447	692	1184	0	0	4.5	156
SF	S100%	447	692	1184	24	0	4.5	156
PF	S25%-75%	447	692	1184	18	3	4.5	156
SF 50 PF 50	S40%-60%	447	692	1184	14.4	4.8	4.5	156
SF 60 PF 40	S50%-50%	447	692	1184	12	6	4.5	156
SF 40 PF 60	S60%-40%	447	692	1184	9.6	7.2	4.5	156
SF 75 PF 25	S75%-25%	447	692	1184	6	9	4.5	156
SF 25 PF 75	P100%	447	692	1184	.	12	4.5	156

H. Beam Details

Nine beams with size of 1500mm x 230mm x 100mm were used in the work. The beams were mixed with various % of steel fibre & polypropylene fibre. A nine beams were reinforced with 4 no's at 12mm diameter of main rod & 8mm diameter of stirrups at spacing 100mm as shows that Fig 3 and Fig 4.

Fig. 3. Reinforcement

Fig. 4 Beam

I. Flexural Strength Test For M50 Grade Concrete

All beams were tested under four point loading System using a 500 KN testing machine capacity. The beams were simply supported over a span of 1350 mm. The distance between the two point loads was kept a part at 450 mm symmetrical to the centreline of the beam. Loading was applied using a hydraulic jack at the rate of 9 KN/s until failure. Mid-span deflection was measured for every 10 KN loading increment using dial gauge with 0.01 mm accuracy. The deflection of the beam was measured at three points along the beam span; mid-span and 1m from left and 1m from right supports. The beams were instrumented with embedded to monitor the concrete and steel strains at different loading stages. Concrete load cell were installed on the beam surface, while steel load cell were attached at the top and bottom of the longitudinal reinforcing bars, also at mid-span. Both the electrical concrete and load cell were installed at mid- span section of the beam, where maximum bending moment was to occur. At each loading increment, deflections were recorded using a deflection gauge. At the same time, cracking development was also observed and monitored closely. The loading arrangement and instrumentation of the flexural beam test as show in Fig 5.

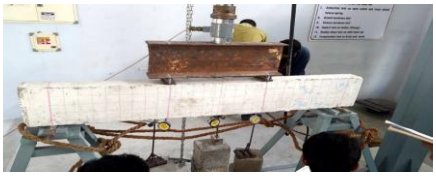

Fig. 5. Testing of Beam

It is defined as the maximum bending stress value that can be sustained before the beam fails. The mould and its base rigidly damped together so as to reduce leakage during casting. The sides of the mould and base plates were oiled before casting to prevent bonding between the mould and the concrete. The specimens were demoulded after 24 hours of casting and were transferred to curing tank where they were allowed to cure for 28 days. A prism of specified dimension 1500*230*100mm is made to fail under bending by applying load along the length of the beam. The beam was tested for their 28th days of strength in flexural testing machine.

J. Test Method and Measurement

The following measurements were recorded during the test:

- All beams were tested under flexure in a loading frame of 500KN capacity for a simply supported condition two point loading was applied on beams at a distance of 433.33mm from each support.

- The load was measure from a digital loading indicated in tones.

- Three deflect meters were placed under the beams one was placed at the L/2 from the support (center of the beam) while the other was placed at L/3 from the support and the last one was placed at L/6 from the support to record deflection at these points
- The deflections at a load increment of every 5KN in digital loading indicated were recorded crack pattern and crack load were measured at every 5KN load increment until the failure load occurs.
- From the load deflection curve seismic parameters deflection ductility and energy absorption capacity have been evaluated.

III. RESULT AND DISCUSSIONS

A. Conventional Beam OPC 100%:

The conventional concrete OPC100% beam under flexure the initial crack was developed at 34KN with initial deflection of 5.10mm. The ultimate failure occurs at 58KN with ultimate deflection of 10.12mm at centre of the beam the flexure crack was developed near the centre of the beam. The number of cracks occurs in the controlled concrete beam as 12. Flexure crack were developed at both sides of the beams and extended up to the top of the beam. The average spacing of cracks in the beam as 10.20cm.

B. Conventional Beam LC3 100%:

The conventional concrete LC3100% beam under flexure the initial crack was developed at 55KN with initial deflection of 5.10mm. The ultimate failure occurs at 67.8KN with ultimate deflection of 9.50mm at centre of the beam the flexure crack was developed near the centre of the beam. The number of cracks occurs in the controlled concrete beam as 11. Flexure crack were developed at both sides of the beams and extended up to the top of the beam. The average spacing of cracks in the beam as 11.09cm.

C. $S_{100\%}$ $P_{0\%}$ BEAM

The S100% P0% beam under flexure the initial crack was developed at 40KN with initial deflection of 2.67mm. The ultimate failure occurs at 124KN with ultimate deflection of 7.48mm at centre of the beam the flexure crack was developed near the centre of the beam. The number of cracks occurs in the S100 P0 beam as 11. The average spacing of cracks in the beam as 11.63cm.

D. *$S_{0\%}$ $P_{100\%}$ BEAM:*

The S0% P100% beam under flexure the initial crack was developed at 35KN with initial deflection of 3.46mm. The ultimate failure occurs at 61KN with ultimate deflection of 10.5mm at centre of the beam the flexure crack was developed near the centre of the beam. The number of cracks occurs in the S0% P100% beam as 11. The average spacing of cracks in the beam as 11.5cm.

E. $S_{50\%}$ $P_{50\%}$ BEAM:

The S50% P50% beam under flexure the initial crack was developed at 70KN with initial deflection of 3.76mm. The ultimate failure occurs at 99KN with ultimate deflection of 7.02mm at centre of the beam the flexure crack was developed near the centre of the beam. The number of cracks occurs in the S50 P50 beam as 14. The average spacing of cracks in the beam as 9.21cm.

F. $S_{75\%}$ $P_{25\%}$ BEAM:

The S75% P25% beam under flexure the initial crack was developing at 80KN with initial deflection of 2.83mm. The ultimate failure occurs at 175KN with ultimate deflection of 8.64mm at centre of the beam the flexure crack was developed near the centre of the beam. The number of cracks occurs in the S75 P25 beam as 19. Shear crack were developed at both sides of the beams and extended up to the top of the beam. The average spacing of cracks in the beam as 6.34cm.

G. $S_{25\%}$ $P_{75\%}$ BEAM:

The S25% P75% beam under flexure the initial crack was developed at 21.5KN with initial deflection of 2.75mm. The ultimate failure occurs at 65KN with ultimate deflection of 9.35mm at centre of the beam the flexure crack was developed near the centre of the beam. The number of cracks occurs in the S25 P75 beam as 13. Shear crack were developed at both sides of the beams and extended up to the top of the beam. The average spacing of cracks in the beam as 9.26cm.

H. $S_{60\%}$ $P_{40\%}$ BEAM:

The S60% P40% beam under flexure the initial crack was developed at 50KN with initial deflection of 0.92mm. The ultimate failure occurs at 142KN with ultimate deflection of 8.6mm at centre of the beam the flexure crack was developed near the centre of the beam. The number of cracks occurs in the S60 P40 beam as 15.The average spacing of cracks in the beam as 8.78cm

I. $S_{40\%}$ $P_{60\%}$ BEAM:

The S40% P60% beam under flexure the initial crack was developed at 35KN with initial deflection of 0.60mm. The ultimate failure occurs at 73KN with ultimate deflection of 7.50mm at centre of the beam the flexure crack was developed near the centre of the beam. The number of cracks occurs in the S40 P60 beam as 15. The average spacing of cracks in the beam as 8.54cm.

J. STRUCTURAL FAILURE MODE:

Table 4 shows the results for beam types, no of cracks, avg spacing of cracks and crack length of structural failure mode.

Table- IV: Structural failure mode

Mix id	First crack load (P_f)(KN)	Ultimate load(P_u)(KN)	First crack deflection (Δ_y)(mm)	Ultimate deflection (Δ_u) (mm)
OPC100%	34	58	5.10	10.12
LC3100%	55	67.8	5.10	9.50
S100%	40	124	2.67	7.48
S25%-75%	21.5	65	2.75	9.35
S40%-60%	35	73	0.60	7.50
S50%-50%	70	99	3.76	7.02
S60%-40%	50	142	0.92	5.11
S75%-25%	80	175	2.83	8.64
P100%	35	61	3.46	10.58

K. RESULT FOR FIRST CRACK LOAD, FIRST CRACK, DEFLECTION, ULTIMATE LOAD AND ULTIMATE DEFLECTION

Table- V: Results of first crack load, first crack deflection, ultimate load and ultimate deflection.

L. RESULT FOR CRACKS AND SPACING

Table 6 shows the results for number of crack, average length of cracks, minimum and maximum spacing of cracks

Table- VI: Results of Crack and Spacing

Mix id	No of cracks (cm)	Ave length of crack (cm)	Minimum spacing of crack (S_{min})	Maximum spacing of crack (S_{max})	Average spacing of crack (S_{min})	S_{min} / S_{min}	S_{max} /S_{avg}
OPC100%	12	11.3	3.5	17	10.20	0.35	1.67
LC3100%	11	10.9	5.5	17.5	11.09	0.50	1.58
S100%	11	12.88	5.5	16.5	11.63	0.47	1.41
S25%-75%	13	10.8	3	11.5	9.26	0.33	1.24
S40%-60%	15	9.99	2	14	8.54	0.23	1.64
S50%-50%	14	10.40	1.5	14	9.21	0.16	1.52
S60%-40%	15	10.40	2	15.5	8.78	0.22	1.77
S75%-25%	19	10.16	2	14.5	6.34	0.31	2.29
P100%	11	9.71	5.5	16.5	11.5	0.48	1.43

M. RESULT FOR DUCTILITY INDEX, STIFFNESS INDEX AND MODULUS OF ELASTICITY

Table 7 shows the results for Ductility Index, Stiffness Index and Modulus of Elasticity for 9 beams

Beams type	No of cracks	Avg crack spacing (cm)	Crack length (cm)
OPC100%	12	10.2	11.03
LC3100%	11	11.09	10.09
$S_{100\%}P_{0\%}$	11	11.63	12.68
$S_{25\%}P_{75\%}$	13	9.26	10.08
$S_{40\%}P_{60\%}$	15	8.54	9.99
$S_{50\%}P_{50\%}$	14	9.21	10.4
$S_{60\%}P_{40\%}$	15	8.78	10.4
$S_{75\%}P_{25\%}$	19	6.34	10.16
$S_{0\%}P_{100\%}$	11	11.5	9.71

Table- VII: Result for Ductility Index, Stiffness Index and Modulus of Elasticity

Mix id	Ductility index (µ)	Stiffness (k) (KN/mm)	Modulus of elasticity (EC) (N/mm2)
OPC100%	1.98	5.73	37016.9
LC3100%	1.86	7.12	37953.9
S100%	2.8	16.57	38200.9
S25%-75%	3.4	6.95	36260
S40%-60%	12.5	9.73	39240
S50%-50%	1.86	14.1	37091.1
S60%-40%	3.55	20.25	36218
S75%-25%	5.05	27.78	38160
P100%	3.03	5.76	35840

IV. CONCLUSION

- The flexural behaviour of hybrid fibre reinforced LC3 beams have investigated experimentally. The experimental results the following conclusions have been drawn.
- A crack pattern of beams for all types of hybrid fibre combination along with conventional concrete beam and LC3 beam shows that it was failed in flexural zone.
- The ultimate flexural load is increases in beams S75% -P25% hybrid fibre combination and also having higher ductility index.
- Beam with S75%-P25% hybrid fibre proportion had the highest structural stiffness compared with conventional concrete and mono fibre concrete.
- Beam with S75%-P25% had the highest toughness index with conventional concrete and mono fibre concrete.
- The ultimate load capacity and stiffness of the beams expanded with SF and PF were added together as compared to mono PF beam.

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