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STUDY ON THE STRENGTH PERFORMANCE AND PROPERTIES OF HYBRID FIBER REINFORCED CONCRETE

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ABSTRACT: High performance fiber reinforced concrete is developing quickly to a modern structural material with a high potential. As for instance testified by the recent symposium on HPFRC in Kassel, Germany (April 2008) the number of structural applications increases. Hybrid fiber reinforced concrete formed by addition of fiber with diffferent properties.in this work coir and glass fiber are added in the ratio of 0.5%,1%1.5%.Moreover it should be consistent with existing design recommendations for structural concrete. Keywords: Glass fibres, Coir fibre, Hybrid fibre, Volume fraction

Key Words: Silica fume, Steel slag, Cement.

INTRODUCTION

Concrete is the most widely used construction material. It is obtained by mixing cementitious materials, water, aggregate and sometimes admixtures in required proportions. Fresh concrete is freshly mixed material which can be moulded into any shape hardens into a rock-like mass known as concrete durability of concrete structures, built during the first half of the last century with ordinary Portland cement (OPC) and plain round bars of mild steel.Strength was emphasized without a thought on the durability of structures.

Micro cracks in concrete are formed during its hardening stage. When the load is applied, micro cracks start developing along the planes which may experience relatively low tensile strains, at about 20-35 % of the ultimate strength in compression.

During the past decades the concrete construction fields has experienced a growing interest in the advantages fibre reinforcement has to offer. Between the different fibres available, eg.Steel, synthetic, glass and natural fibres. Some of the potential benefits of fibres in concrete are improved crack control and the possibility of designing more slender structures.

EXPERIMENTAL INVESTIGATION

CEMENT

Cement is the most important ingredient in concrete. Some of the important factor that play a vital role in selection of cement are compressive strength.

There are different types of cement, out of that mostly used two types are:

1) Ordinary Portland cement
2) Portland slag cement

Ordinary Portland cement (OPC) is the basic portland cement and is best suited for use in general concrete construction. It is of three types 33grade, 43 grade, 53 grade.

Portland slag cement is obtained by mixing Portland cement clinker, gypsum and granulated blast furnace slag in suitable

Table 1: Properties of Cement

Property	Values
Fineness Of Cement	7.5%
Specific gravity	3.15
Initial Setting Time	30 Minutes
Final Setting Time	600 Minutes

FINE AGGREGATE

According to IS 383:1970 the fine aggregate is being classified into four different zone, that is Zone-I, Zone-II, Zone-III and Zone-IV. Fine aggregate are material passing through an IS sieve that is less than 4.75mm gauge beyond which they are known as coarse aggregate. The most important function of the fine aggregate is to provide workability and uniformity in the mixture.

Table 2: Properties of Fine Aggregate

Property	Values
Specific gravity	2.75
Fineness Modulus	2.68
Water Absorption	1 %
Bulk density (kg/m3)	1654

COARSE AGGREGATE

The coarse aggregate is the strongest and the least porous component in concrete. It is also chemically stable material. Presence of coarse aggregate reduces drying shrinkage and other dimensional changes. Ordinary blue granite crushed stone aggregate confirming IS-383:1970 was used as a coarse aggregate in concrete. Optimum size of the coarse aggregate in most situations was about 20mm was adopted, low absorption value and least porosity.

Table 2: Properties of Coarse Aggregate

Physical properties	Values
Specific gravity	2.86
Fineness Modulus	7.53
Water Absorption	0.75%
Bulk density (kg/m^3)	1590

WATER

Water is an important ingredient of concrete as it actively participates in chemical reactions with cement to form the hydration product, calcium-silicate-hydrate (C-S-H) gel. The strength of the cement concretedependsmainly from the binding action of the hydrate cement paste gel. Algae in mixing water may cause marked reduction in strength of concrete either by combining with cement to reduce the bond or by causing large amount of air entrainment in concrete.

E-GLASS FIBRE

E-Glass or electrical grade glass was originally developed for stand off insulators for electrical wiring. It was later found to have excellent fibre forming capabilities and is now used almost exclusively as the reinforcing phase in the material commonly known as fiberglass. Glass fibres are generally produced using melt spinning techniques. The quality and other features of this particular type of cement. We offer the 53 Grade OPC Cement which gives even higher cement strength to match the rising demands of higher strength building material in the urban world. Property of cement details given below the table 3

Table 3: Properties of E-Glass Fibre

S.NO	TEST	VALUE
1	Specific Gravity	3.15
2	Bulk density	1330 kg/m^3
3	Normal Consistency	34%
4	Initial Setting Time	30 Min
5	Final Setting Time	10 Hrs

COIR FIBER

Coir is a versatile natural fibre extracted from mesocarp tissue, or husk of the coconut fruit Generally fibre is of golden color when cleaned after removing from coconut husk; and hence the name " The Golden Fibre". Coir is the fibrous husk of the coconut shell. Being tough and naturally resistant to seawater, the coir protects the fruit enough to survive months floating on ocean currents to be washed up on a sandy shore where it may sprout and grow into a tree, if it has enough fresh water, because all the other nutrients it needs have been carried along with theseed.

These characteristics make the fibers quite useful in floor and outdoor mats, aquarium filters, cordage and rope, and garden mulch. Some mattress fibre is allowed to retain more moisture so that it retains its elasticity for 'twisted' fibre production.

Table 4: Properties of COIR Fibre

Specification	Values
Length(mm)	12
Diameter(mm)	0.12
Aspect Ratio	100
Mean elongation,%	27.2

EFFECTS ON HARDENED CONCRETE PROPERTIES

When modern fibre-reinforced concrete research began, many believed fibre-reinforced concrete would be able to improve every aspect of concrete performance. Over the years, this has not been found to be true. In actuality, fibre reinforcement has been found to have little or no effect on the static properties of concrete. What fibre reinforcement does improve is the dynamic performanceof concrete (fatigue, impact) and the post-cracking behaviour of concrete by improving toughness and controlling crack widths. The following sections will discuss these various hardened HFRC properties in more detail.

COMPRESSIVE STRENGTH

The compressive strength of hybrid fibre-reinforced concrete has been well documented, because no matter which aspect of concrete research is being conducted, the compressive strength is a parameter that is often related to the characteristics being investigated. At best there may be a slight gain of ultimate compressive strength ranging from 0 to 15 percent when up to 1.5 percent by volume fibre reinforcement is used (ACI Committee 544 1997).

TENSILE STRENGTH

While there is a general consensus regarding the effects of fibre reinforcement on compressive strength, the effects of fibre reinforcement on tensile strength are ambiguous. On the other hand, there has been research showing up to an 80 percent gain in tensile strength. Most likely this phenomenon can be attributed to the higher dosages (2 percent by volume) that were used, which were able to control micro-crack propagation by providing load transfer over the cracks.

FLEXURAL STRENGTH

There is no consensus regarding the effect of fibre reinforcement on flexural strength. As with tensile strength, higher dosages of fibre reinforcement will control crack widths and improve load transfer across cracks to give an apparent increase in flexural strength by redistributing stresses. Data recorded in the 1960s and 1970s showed anywhere from a 50 to 70 percent increase in flexural capacity in FRC when compared to plain concrete in 3-point flexure tests..This is why understanding the post-cracking flexural behavior of FRC in terms of flexural toughness is much more useful than attempting to determine the flexural strength performance of FRC.

FLEXURAL TOUGHNESS

Flexural toughness is the primary parameter used to quantify the improvements that fibre reinforcing imparts on plain concrete. Toughness describes the post-cracking behavior of concrete in flexure through interpretation of the load-deflection plot at a prescribed mid-span deflection. There are various methodologies for interpreting the load-deflection plot to quantify toughness.

The stiffness of the fibre used will also have a significant impact on the toughness of the concrete. In FRC, Fracturing of individual fibres is not desired and will lead to a more brittle failure of the concrete.

EFFECT OF FIBRES IN CONCRETE

Fibres are usually used in concrete to control plastic shrinkage cracking and drying shrinkage cracking. The amount of fibres added to a concrete mix is measured as a percentage of the total volume of the composite (concrete and fibres) termed volume fraction (V_f). V_f typically ranges from 0.1 to 3%. Aspect ratio (l/d) is calculated by dividing fibre length (l) by its diameter (d). However, fibres which are too long tend to “ball” in the mix and create workability problems. Some recent research indicated that using fibres in concrete has limited effect on the impact resistance of concrete materials.

EXPERIMENTAL INVESTIGATION

This report presents the experimental investigation carried out on the test specimen to study the strength related properties and characteristics of concrete containing glass fibre and coir fibre. The experimental test for strength properties of concrete are compressive strength, split tensile strength and flexural strength. Based on the test procedure given in IS 516-1959 code, tests were conducted on specimens. Then for the optimum mix, flexural tests were conducted.

Table 5: M20 Grade concrete mix design value

Cement (kg/mm³)	Fine aggregate (kg/mm³)	Coarse aggregate (kg/mm³)	Water (kg/mm³)
383	867.79	1177.1	191,6
1	1.98	2.93	0.5

FIBER CONTENT IN CONCRETE

Three different volume fractions of fiber will added to concrete such as 0.5%, 1% and 1.5% by weight of cement. Fiber content less than 0.5% doesn‟t have strength improvement and fiber content beyond 4% reduces the strength of concrete.

Table 6: The mix proportion of Coir and Glass fibers such as follows.

% of fibre added in concrete	**Mix**	**Coir fibers (%)**	**Glass fibers(%)**
0.5% -1.0% -1.5%	CM	-	-
	C100G0	100	0
	C75G25	75	25
	C50G50	50	50

Material	**rcentage of Coir Fiber and Glass Fiber**			**Conventional concrete**
	0.5%	**1.0%**	**1.5%**	
Cement (Kg/m³)	383	383	383	383
Fine aggregate (Kg/m³)	867.79	867.79	867.79	867.79
Coarse aggregate (Kg/m³)	1177.1	1177.1	1177.1	1177.1
Coir fiber(Kg/m³)	0.0037	0.0075	0.0113	-
Glass fiber(Kg/m³)	0.0112	0.0225	0.0338	-
Water (Kg/m³)	191.6	191.6	191.6	191.6

DETAILS OF TEST SPECIMENS

In this study, totally four beams were cast, two control concrete beams and two hybrid fibre reinforced concrete beams of 1% fibre were added at the mix ratio of 75:25 (i.e., 75% coir fibers and 25% glass fibers) to the weight of concrete. The size of the beam is 1000mm x 100mm x 150mm.

REINFORCEMENT DESIGN DETAILS

The reinforcement details were arrived by adopting IS 456 – 2000 design procedure. For main reinforcement 10mm dia. bars were used. In compression zone 8mmdia.bars were used. For shear reinforcement 6mm dia. bars were used. The reinforcement design details are given below.

Reinforcement details:

Dia. of rod at compression zone – 8mm Dia. of rod at tension zone – 10 mm Dia. of stirrups – 6 mm

DESIGN OF BEAM

Size of the beam = 100mm x 150mm Grade of concrete = M20

Grade of steel = Fe415

B = 100mm

D = 150mm

Effective cover to reinforcement = 25+10/2 = 30mm Effective depth of beam = 150 – 30 = 120mm Assuming 2 nos of 10mm dia bar as main reinforcement

Ast= 2 x (π/4) x 10^2 = 157.07 mm2 To determine the depth of neutral axis

Xu/d = 0.87 fyAst/0.36 fckbd = 0.291 For Fe 415

Xumax/d = 0.48 Xumax/d > Xu/d

Hence the section is under reinforced Ultimate moment of resistance

Mu = 0.87 fyAst d (1 – (fyAst/fckbd))

= 0.87 x 415 x 157.07 x 120 (1- (415 x 157.07/20 x 100 x120))

= 6.1891 kNm

Bending moment = Wl/3

Load (W) = (6.1891 x 106 x 3)/1000 Load (W) = 18.567 kN.30

Check for shear

Total design load = 18.567 x 1.5

= 27.85 kN

Nominal shear stress = 27851/ (100 x 120) = 2.321 N/mm2 Area of tension steel Ast= 157.07 mm2

Percentage of tension steel = 157.07 x 1000 / 100 x120

= 1.309 %

τ_c for 1.309% = 0.7518 N/mm2

τ_{cmax}= 4.0 N/mm2

Design of shear reinforcement Vu = 27851

Vus = Vu – $\tau_c$bd

= 27851 – 0.7518 x 100 x 120

= 18829.4 N

For vertical stirrups of Fe 415

(Asv/Sv)min = Vus/(0.87 x fy x d) = 0.4345 Minimum shear reinforcement

(Asv/Sv)min = (0.4b/0.87fy) =(0.4x 100/0.87 x 415)

= 0.11

Therefore Provide = (Asv/Sv) = 0.4345 Assume 6mm dia 2 legged stirrups

Asv = 2 x π/4 x 62 =56mm2 Spacing Sv = 140 mm C/C

Therefore provide 6mm dia 2 legged stirrups at 140mm C/C.

CASTING OF BEAM SPECIMENS

The beams were cast in structural engineering laboratory. The wooden beam mould of size 100mm X 150mm X 1000mm were used for casting of beam specimens machine. 3 sample conventional concrete beams are castedand average results are taken.

RESULTS

To investigate different basic properties of fibre reinforced concrete such as compressive strength, splitting tensile strength and flexural strength test at the results of different proportioning by performing laboratory test.

Compared HFRC with ordinary concrete at 28 days

COMPRESSIVE STRENGTH TEST:

S.No.	Percentage of fibre added	Average strength in Mpa		
		7 days	14 days	28 days
1.	Conventional concrete	15.30	16.20	23.24
2.	0.5%	16.80	22.73	22.73
3.	1.0%	21.74	29.32	29.32
4.	1.5%	16.77	22.69	22.69
Specimen size of 150x150x150mm (No. of days curing: 7 & 28 days)				

SPLIT TENSILE STRENGTH TEST ON BEAM

S.No.	Percentage of fibre added	Average strength in Mpa		
		7 days	14 days	28 days
1	Conventional concrete	2.16	2.43	2.55
2	0.5%	3.47	3.81	3.34
3.	1.0%	4.13	4.51	4.25
4.	1.5%	3.16	2.69	2.59
Specimen size: 150mm Dia. X 300mm Height (Curing: 28 days				

FLEXURAL STRENGTH TEST ON PRISMATIC BEAMS

S.No	Percentage Of Fibre Added	Avarage Strenth In Mpa		
		7 days	**14 days**	**28 days**
1	Conventional concrete	3.69	3.50	3.58
2	0.5%	5.15	5.51	4.71
3	1.0%	5.41	6.00	5.31
4	1.5%	5.31	4.73	5.20
Specimen size 150mm dia X 300 mm height (28 days)				

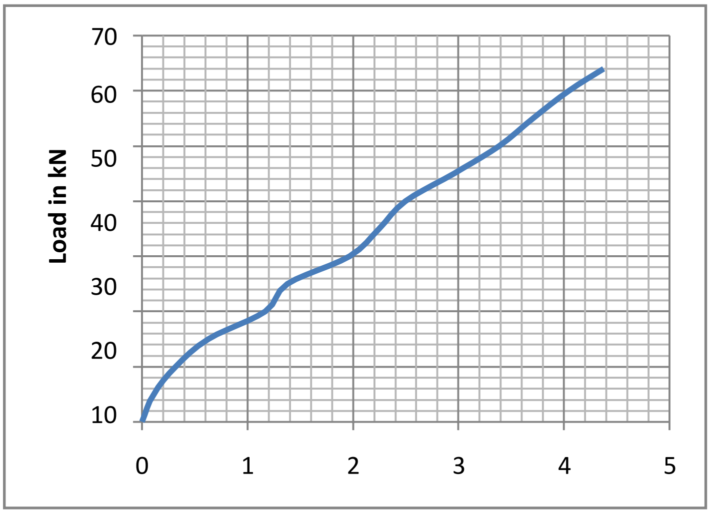
HYBRID FIBRE REINFORCED CONCRETE BEAM (HFRC -1% fibre added)

The load deflection data of the beam with 1 of hybrid fibres in Ultimate Load = 64 Kn Mid Span Deflection at Ultimate Load = 4.45mm

Load - Deflection of HFRC -1% fibre added

Load in kN	Deflection (mm)		
	Left	**Center**	**Right**
0	0.00	0.00	0.00
5	0.09	0.11	0.06

10	0.18	0.32	0.13
15	0.31	0.63	0.29
20	0.59	1.17	0.53
25	1.05	1.38	0.98
30	1.24	1.97	1.18
35	1.58	2.25	1.50
40	2.15	2.50	1.99
45	2.50	2.96	2.42
50	3.10	3.39	2.91
55	3.49	3.71	3.29
60	3.98	4.05	3.80
64	4.23	4.45	4.08



Graph 1: Load vs Mid span Deflection

At ultimate load, the failure of beam occurred. Large numbers of fine cracks were observed during failure. The beam takes ultimate load of 64 kN.

CONCLUSION

The optimum fibre percentage will be 1.0% fibres were added in concrete of the weight of cement and this percentage is enough to reduce the cracks and increases the ductility of the structure. From the above said conclusions it is clear that the presence of two fibres in concrete significantly improves the ultimate load carrying capacity and ductility of the beams.

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