EVALUAREA REZISTENȚEI BETONULUI ARMAT CU FIBRE HIBRIDE
STRENGTH EVALUATION OF HYBRID FIBER REINFORCED CONCRETE

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The increased demand in energy consumption and the concern with the green house effect has driven the industry to replace conventional construction with alternate approaches, sources and structural systems. In this study, strength properties were investigated by incorporating various combinations of hybrid fibres. In the present experimental work, M40 grade of concrete has been designed with ACI standards with four different proportions of hybrid fibres that are added with concrete ingredients. The proportion of Glass and Nylon – 6 fibres are added by 60% and 40% respectively with different hybridization ratios i.e. 0%, 0.5%, 1.0 %, 1.5% and 2%. Experiments were conducted to study the effect of hybrid fibresunder compression, split tension and flexure in different proportions in hardened concrete specimens and the same were compared with the control concrete. The result shows that the percentage of fibres increases the strength of concrete than control concrete. Hybrid ratio 1.5 % gives maximum results and considered as optimum percentage for all the strength parameters.

***Keywords**:Hybrid fibre reinforced concrete (HFRC), Nylon – 6 fibre, Glass fibre, Compressive strength, Split tensile strength, Flexural strength, Stress- strain curve*

1. Introduction

In last few decades the construction activities have increased many folds almost in all the developing countries of the world. Nowadays concrete has been widely used for different types of structures due to its strength and structural stability. It has better resistance in compression than in tension while steel has more resistance in tension. Plain concrete possesses a limited ductility, very low tensile strength and little resistance to cracking. Inherently internal micro cracks are present in the concrete and has poor tensile strength because of the propagation of such micro cracks, leading to brittle failure of the concrete. It has been recognised that addition of small, closely spaced and uniformly dispersed fibres to concrete would act as crack arrester and would substantially improve its static and dynamic properties. Hence this work explores the feasibility of hybrid fibre reinforcement in high strength concrete at different volume fractions. Mohit Dwivedi [1] had investigated the effect of hybridized fibers on flexural strength of M30 grade concrete by using varying fiber proportions of steel and Polypropylene fiber, steel and Glass fiber and Steel and Nylon fiber.Sudheer Jirobe et.al [2]studied the strength and durability properties of Hybrid fiber Reinforced Concrete of M25 grade concrete with three different proportions of hybrid fibres. The proportion of steel and polypropylene fibres are added by 50% each with different hybridization ratio i.e. 0%,0.5%, 1.0 %, 1.5% For strength parameters compressive, tensile, flexural, impact strength specimens are casted and cured for 28 days and tested for hardened concrete. For durability study Sorptivity test is carried out to know the absorption of water by capillary. The authors found that Hybrid ratio 1.5 % gives maximum results in all the strength parameters compare to other different hybrid ratios. Flexural performance of HFRC by using steel(s) and polyester(p) fibres. In this research the parameters like modulus of rupture, ultimate load, service load, ultimate and service load deflection, crack width, energy ductility and deflection ductility had been investigated. She found that a proportion of S60P40 hybrid fibres improve the performances appreciably [3].Amar et. al [4] investigated the mechanical properties of hybrid fibre reinforced concrete under compression, flexure & tension for M25 grade concrete by using nylon 6 and steel fibres. The total fibre volume was taken 0.75 % of total concrete volume. Maniram Kumar, et.al [5] the mechanical properties (compressive strength, split tensile strength and flexure strength) of hybrid fibre reinforced concrete under compression, tension and flexure for M30 grade concrete by using steel and polypropylene fibres which were taken as 0.50 % of total volume of concrete. Daroleet.al [6] had investigated for a M40 grade concrete at a fibre volume fraction of 0.5% by using polypropylene and steel fibres. Compressive strength, flexural

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strength and split tensile strength tests were conducted and results were analysed and compared. Priyanka Dilipet. al [7] high strength concrete with steel fibers and combination of steel and polyolefin fibers (hybrid) by testing of compressive strength, split tensile strength of cylinders and flexural strength of prisms. They have used the volume fractions of 0.5%, 1.0%, 1.5%, and 2.0%. At each volume fraction Steel – polyolefin fibers were added at 80% - 20% and 60% -40% combinations. Regression analyses were done to predict the test results. Selina Rubyet.al [8] mechanical properties of hybrid fibre reinforced concrete were studied for M25 grade concrete by using steel and polypropylene fibres which were taken as 1.0 % of total volume of concrete.Ranjith Kumar [9] performed research in regression equations for evaluating the strength and toughness of hybrid fibre reinforced concrete (HFRC) by using Steel and Polyolefin fibres in different proportions and studied their impact on strength and toughness. Empirical expressions for predicting the strength and toughness of hybrid fibre reinforced concrete (HFRC) had been proposed based on regression analysis. They obtained that there is a close agreement between the predicted and experimental results.Annadurai and Vikrant[10,11] done research on the mechanical properties for high strength concrete (HSC) of 60 MPa containing hybrid fibres, combination of steel and polyolefin fibres, at different volume fraction of 0.5, 1.0, 1.5 and 2.0%. Eswari and Ravichandran [12,13] strength models had been established to predict the compressive, split tensile strength and modulus of rupture of the fibre-reinforced concrete. They obtained that there is a close agreement between the predicted and experimental results. Previous studies on hybrid fibers shows better strength and durability performance than control concrete.

2.Experimental programme

Experimental investigation was carried out to study the basic strength properties of high strength concrete mixes wereprepared with two different fibers are presented in Table1 and 2. A design mix proportion of 1:1.40:2.54:0.35 was adopted in this investigation. Table 3 shows the exact quantity of the material for each mixIn the case of super-plasticizer, the water-cement ratio was reduced from 0.35 to 0.3. During the preparation of concrete mix, the water quantity was divided approximately into three parts and the admixture was added with the third part so that the interaction of admixture with the water would be more effective than adding it at the beginning itself. Afterwards, Hybrid fibers is shown in Figure 1 and 2 were added to this by 0, 0.5, 1, 1.5 and 2% in weight fractions. Cubes of size 100 mm × 100 mm × 100 mm, cylinders of 100 mm diameter and 200 mm long and prism of size 500 mm x 100 mm x 100 mm were cast. All the specimens were removed from the mould after giving a minimum period of 24 hours as setting time and curing was done using the curing tank.After 7, 14 and 28 days the specimen was then taken from the tank for testing and allowed for surface drying for a minimum period of 5-6 hours.It was placed in ASTM Compressive Testing Machine and allowed to transfer the load at the rate of 2.9 kN/sec.The tests were conducted on concrete specimens for 7, 14 and 28 days of curing. Cubes were tested to evaluate compressive strength of concrete as per IS 516 [14], cylinders were tested as per ASTMC496 [15] to determine split tensile strength and stress strain curve under compression and prismatic specimens of size 100 mm x 100 mm x 500 mm as per IS 516 [14] after 28 days of curing, with the aid of 1000 kN capacity Universal Testing Machine (UTM) by subjecting the concrete specimens under four-point loading for flexural strength.

Materials used and its properties **Table 1**

Materials used	Properties	Value
Cement (PPC 43 grade)	Specific Gravity	3.15
Fine Aggregate	Specific Gravity	2.62
	Fineness Modulus	3.39
Coarse Aggregate (20 mm size)	Specific Gravity	2.74
	Fineness Modulus	5.25
	Water Absorption (%)	1.56
Super Plasticizer (Conplast SP430(G))	Specific Gravity	1.20 to 1.22 at
Water – Tap Water	-	-
E-Glass Fibre Properties	Fibre length	6 mm
	Fibre diameter	14 microns
	Aspect ratio	428.57
	Specific gravity	2.60
	Failure strain	3.0 %
	Elasticity (GPa)	80
	Tensile strength (GPa)	2.5
Properties of Nylon – 6 fiber	Fibre length	18 mm
	Fibre diameter	0.3 mm
	Aspect ratio	60
	Specific gravity	1.14
	Melting point	220 °C

Table 2

Percentage variation of fibres in mix

Mix designation	Percentage of fibre added in overall concrete mix (%)	Glass fibres by weight of Concrete (%)	Nylon – 6 Fibres by Weight of Concrete (%)
M1	0	0	0
M2	0.5	0.3	0.2
M3	1.0	0.6	0.4
M4	1.5	0.9	0.6
M5	2.0	1.2	0.8

Table 3

Mix Proportions

Material	Quantity in kg/m^3
Cement	450
Fine aggregate	630
Coarse aggregate	1145
Water	156

Fig. 1 - E – Glass fibre

Fig. 2 - Nylon – 6 fibre

3. Results and discussion

3.1.Effect of hybrid fibers on compressive strength

The compressive strength of concrete cubes made with different hybrid fibers content was plotted against different days of curing are shown in Figure 3. Three specimens were tested to assess the compressive strength of all mix. From Figure 3, it is found that as the fibre content increases from 0.5 to 1.5% there is an increment in the compressive strength of cubes. Beyond the addition of 1.5% of fiber content there is gradual decrement in compressive strength of HFRC. At the age of 7 days the maximum compressive strength attained at 1.5% addition of hybrid fibers (33.15 N/mm^2) compared to control concrete. At the age of 14 days the maximum compressive strength attained at 1.5% addition of hybrid fibers (49.50 N/mm^2) compared to control concrete and as well at the age of 28 days (55.96N/mm^2).From Figure 4, it is found that when compared with control concrete the increase in the compressive strength with fiber addition in percentages of 0.5%, 1%, 1.5% is 12.08%, 24.89%, 40.39% for 28 days respectively. The failed specimens are shown in Figure 11 and 12.

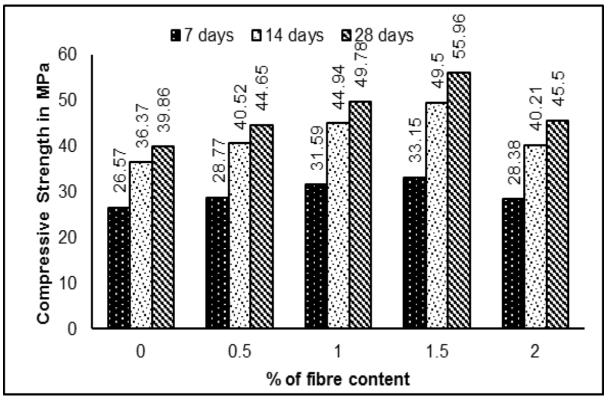

Fig. 3 - Effect of hybrid fibre on compressive strength.

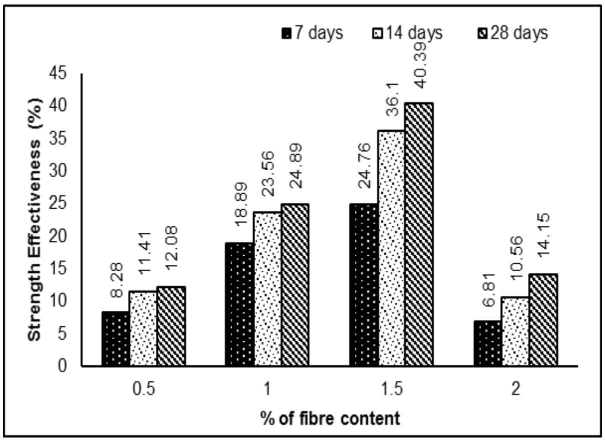

Fig. 4 - Percentage increase in compressive strength of HFRC.

3.2.Effect of hybrid fibers on split tensile strength

From Figure 5, found that as the fibre content increases from 0.5 to 2% there was an increment in the split tensile strength compared to control concrete. Beyond the addition of 1.5% of fiber content there is gradual decrement in split tensile strength of HFRC. At the age of 7 days the maximum split tensile strength attained at 1.5% addition of hybrid fibres (3.03 N/mm^2) compared to control concrete. At the age of 14 days the maximum split tensile strength attained at 1.5% addition of hybrid fibres(3.29 N/mm^2) compared to control concrete and as well at the age of 28 days(3.54 N/mm^2). From Figure 6, the percentage improvements in split tensile strength compared to control concrete are 6.83%, 17.99%, and 27.34% and 9.35% for 28 days.

3.3.Effect of hybrid fibers on flexural strength

From Figure 7, found that as the fibre content increases from 0.5 to 1.5% there was an increment in the flexural strength. Beyond the

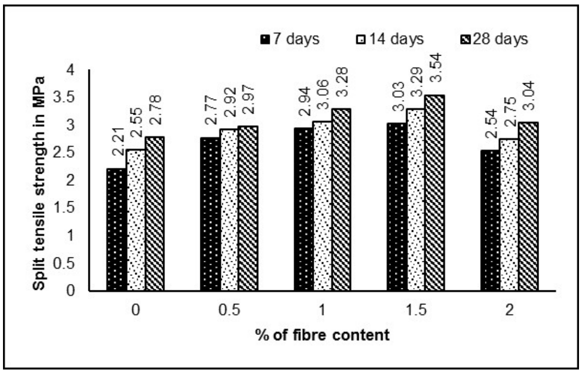

Fig. 5 -Effect of hybrid fibre on split tensile strength

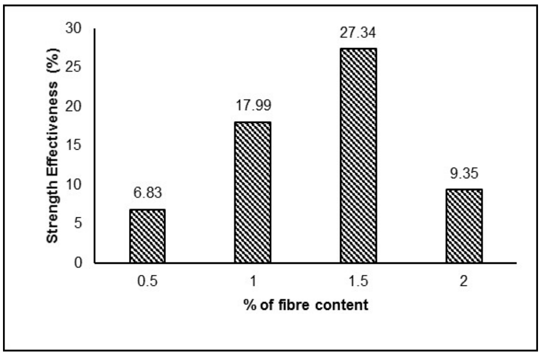

Fig. 6- Percentage increase in split tensile strength of HFRC at 28 days.

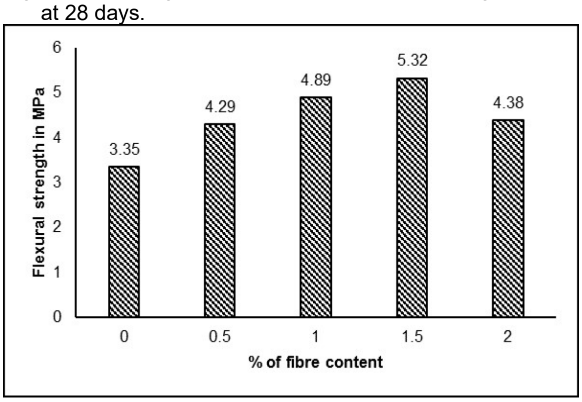

Fig. 7- Effect of hybrid fibre on flexural strength at 28 days.

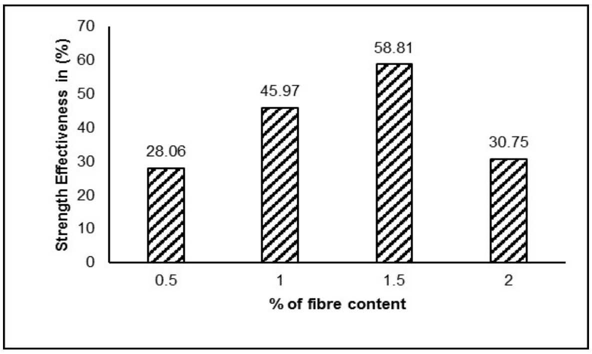

Fig. 8- Percentage increase in flexural strength of HFRC at 28 days.

addition of 1.5% of fibre content there was gradual decrement in flexural strength of HFRC. At the age of 28 days the maximum flexural strength attained at 1.5% addition of hybrid fibres (5.32 N/mm^2) compare to control concrete. From Figure 8, the percentage improvements in flexural strength compared to control concrete are 28.06%, 45.97%, 58.81% and 30.75% for 28 days.

3.4.Comparison of various strength effectiveness at 28 days

Strength effectiveness was calculated for different hybridization ratios for various strengths at 28 days are shown in Figure 9. Hybrid fibres are showing greater effect on strength improvement. Hybrid fibers exhibited superior strength improvement for flexural strength than compressive strength and split tensile strength.

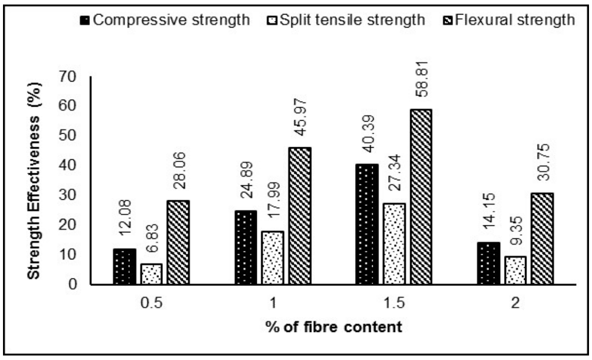

Fig. 9 - Comparison of strength effectiveness of various strengths at 28 days of HFRC.

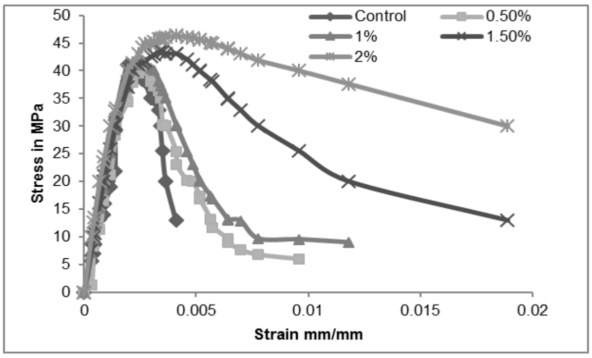

Fig. 10 - Stress- Strain curve for HFRC at 28 days.

Fig. 11 - Failure of control specimen.

Fig. 12 - Failure of HFRC specimen.

3.5.Stress strain curve under compression

A typical stress- strain curve for various hybrid fiber reinforced concrete is shown in figure 10. The stress- strain curves for HFRC in compression with different fiber content shows that the post-peak segment of the curve is affected by the addition of fibers. It can be observed that the increase in concrete strength increases the extent of curved portion in ascending branch and renders the drops in the descending part for control concrete and gradually flatter for hybrid fiber reinforced concrete. From the graph fibers are effective in improving the mechanical properties, and energy absorption at post peak load capacity

4. Conclusions

Experimental investigations on the Hybrid Fibre Reinforced Concrete (HFRC) on strength properties were carried out and the following conclusions are arrived.

1. Addition of hybrid fibres to control concrete was well accepted at all hybrid fibre ratios produces maximum strength when compared with control mix.

2. As the hybrid fibre content increases, the compressive strength, split tensile strength and flexural strength has been increased up to the hybrid ratio of 1.5%.

3. The optimum percentage of hybrid fibre was found to be 1.5% (60% of Glass fibre and 40% of Nylon – 6 fibre). The maximum increase in compressive strength was 12 to 40% when compared to control concrete.

5. Thesplit tensile strength was increased from 6 to 27% with the addition of hybrid fibres when compared to control concrete.

6. The flexural strength was increased from 28 to 59% with the addition of hybrid fibres when compared to control concrete.

7. Strength effectiveness was calculated for different hybridization ratios and exhibited superior strength improvement for flexural strength than compressive strength and split tensile strength.

8. The inclusion of fibers eliminates the sudden failure during compression, split tensile and flexural tests compared to control concrete specimen.

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