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Evaluation of Strength Parameters of PCC and Hybrid FRC

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Abstract: The present trend in concrete technology is towards increasing the strength and durability of concrete to meet the demands of modern construction. The aim of this paper is to study the effect of hybrid fiber (steel & polypropylene) in concrete and compare its properties with that of plain cement concrete. The findings showed that the addition of hybrid fibers to plain cement concrete improved its mechanical properties.
Keywords: hybrid, FRC, concrete, strength, durability

I. INTRODUCTION

Crack growth due to loading and shrinkage should both be controlled in slab like concrete structures, such as pavements, runways for airports, and continuous slab-type sleepers for high-speed trains. In these types of structures, effective prestressing for crack control purposes will be very difficult, especially in the two principal directions. So, dispersed short fiber reinforcement offers a second approach in this case. The concept of hybridization with two different fibers incorporated in a common cement matrix can offer more attractive engineering properties because the presence of one fiber enables effective utilization of the potential properties of the other fibers. Optimization of mechanical and conductivity properties can be achieved by combining different types and sizes of fibers.

By embedding conventional reinforcements into concrete material, only cracks at certain structural sections and at a single scale can be arrested, although fracturing in concrete is multi-scale. Hybridization means the combination of two or more fibers with different properties in an appropriate manner to take full advantage of the resultant product. Based on the anticipated performance from the final composite material, the fiber properties to be considered are length, diameter, strength, elastic modulus, aspect ratio, specific gravity and so on. It can generally be stated that larger fibers are more effective in bridging macro cracks (providing toughness) while smaller fibers are effective in bridging micro cracks, thus enhancing the behaviour before and/or right after crack formation. With a proper combination of large and small fibers, individual benefits can be achieved simultaneously in a single hybrid cementitious composite.

II. LITERATURE REVIEW

1) *Mohamed & Ahmed (2021):* The ultimate load carrying capacity of MSFRC slabs was seen to increase by 24%, 20% and 23% for interior, edge and corner loading positions in the study conducted.
2) *Radim & Zuzana (2020):* Positive influence of fiber concrete on the increased load capacity and more favourable deformations of the slab on subsoil exposed to a vertical concentrated load was established in this study.
3) *Mageswari et al (2018):* conducted studies and showed that on comparing with steel fibers the synthetic fiber reinforced concrete provided lower impact resistance.
4) Jun Feng & Weiwei Sun (2018)*:* Impact energy property of concrete discs was studied and it was seen that by the incorporation of polymer (PP/PVA) fiber or steel fiber, there was an improvement in the property.
5) *Navilesh & Rahul (2017):* conducted study and showed that the strength of hybrid fiber reinforced concrete is higher than the strength of normal concrete.
6) *Grija et al (2016):* Addition of Recon 3s fibers into concrete mixes improved the compressive strength, split tensile strength and flexural strength at 28 days for fiber mixes when compared with that of control mix.
7) *Arunakanthi (2016):* showed that on adding fiber there was a percentage increase in compressive strength, flexural strength and split tensile strength for 28 days.

8) *Deepa et al (2014):* The study concluded that steel fiber reinforced concrete is an excellent new type of composite material as thickness of road was reduced without affecting the load carrying capacity.
9) *Nassim & Bijan (2013):* The study conducted showed that adding PP fibers to concrete enhanced the toughness and energy absorption characteristics.
10) *Jayeshkumar & Umrigar (2013):* It was seen in this study that water absorption and sorptivity of fly ash concrete showed higher values than that of traditional concrete.

III. OBJECTIVES OF THE STUDY

The following are the objectives of the present work:
1) Evaluate the strength parameters of PCC, FRC & hybrid FRC
2) Compare the mechanical properties of PCC & FRC
3) Determine load carrying capacity and corresponding deformations in PCC & FRC slab

IV. METHODOLOGY

A. Investigations on Materials

The materials to be used in this investigation are: ordinary Portland cement, coarse aggregate, fine aggregate and potable water as well as steel and polypropylene fiber. The detailed properties are given in subsequent contents.

1) *Cement:* Ordinary Portland cement of 53 grade conforming to IS 12269 was used in the investigation.

TABLE I
PHYSICAL PROPERTIES OF CEMENT

Sl. No.	**Particulars**	**Values**
1	Fineness of cement	3%
2	Specific gravity of cement	3.1
3	Consistency of standard cement paste	31%
4	Initial setting time	35mts
5	Final setting time	600mts

2) *Fine Aggregate:* River sand was used as fine aggregate. Laboratory tests were conducted on fine aggregate to determine the different physical properties as per IS 2386 (Part III) 1963.

TABLE II
PHYSICAL PROPERTIES OF FINE AGGREGATE

Sl. No.	Particulars	Values
1	Specific gravity	2.64
2	Sand type	Medium
3	Grade	Zone II

3) *Coarse aggregate:* The size of aggregate between 20mm and 4.75mm is considered as coarse aggregate. Laboratory tests were conducted on fine aggregate to determine the different physical properties as per IS 2386 (Part III) 1963.

TABLE III
PHYSICAL PROPERTIES OF COARSE AGGREGATE

Sl. No.	Particulars	Values
1	Specific gravity	2.5
2	Void ratio	0.78
3	Bulk density (g/cm^3)	1.66
4	Porosity	0.44

4) *Fibers:* Fibers used in this investigation are steel & polypropylene. Steel & polypropylene fibers were obtained from BSS Pvt Ltd, Ernakulam.

TABLE IV
PROPERTIES OF FIBERS

Properties	Steel	Polypropylene
Diameter (mm)	0.5	0.44
Aspect ratio	60	113.6
Specific gravity	7.8	0.91

5) *Super Plasticizer:* The super plasticizer used was Conflo. Conflo is a high performance new generation super plasticizer cum retarding admixture which lowers the surface tension of water and makes cement particles hydrophilic, resulting in excellent dispersion as well as controls the setting of concrete, depending on dosage.

TABLE V
PROPERTIES OF CONFLO

Supply form	Liquid
Colour	Black
Specific gravity	1.2
Dosage	0.3% to 0.4% by weight of cement
Chloride content	Nil to IS 456

B. Casting and Curing of Specimen

1) *Mix Design:* All the mixes were prepared corresponding to M40 grade concrete. The code IRC: 44-2008 will be followed for cement concrete mix designs for pavements with fibers.

TABLE VI
DETAILS OF MIX

Water	Cement	Coarse aggregate	Fine aggregate	Super plasticizer	W/C ratio
167.4 lit	400.47 kg	1101.39 kg	664.25 kg	0.4%	0.418

- Casting & Curing

Specimens of fiber reinforced concrete and conventional concrete are prepared. Thoroughly mixed concrete is filled into the mould in three layers of equal heights followed by tamping. Curing is the process of preventing the loss of moisture from concrete while maintaining a satisfactory temperature.

Fig 1 Casting of specimens

Fig 2 Curing

V. RESULTS

The main purpose of the study is to evaluate the effect of hybrid fiber (steel & polypropylene) in concrete and compare its properties with that of plain cement concrete as well as concrete reinforced with steel & polypropylene fibers individually.

A. *Compressive Strength Test*

The test was conducted as per IS 516-1959. The cube specimen was placed in the machine of 2000 kN capacity. The load was applied at a constant rate until failure of the specimen.

TABLE VII
COMPRESSIVE STRENGTH OBTAINED

Curing Period (days)	Compressive Strength, N/mm^2			
	Conventional	Steel (1%)	Polypropylene (0.75%)	Hybrid Steel – 0.2% Polypropylene – 0.1%
7	26.25	29.4	27.415	27.825
28	41.305	46.644	41.712	43.62

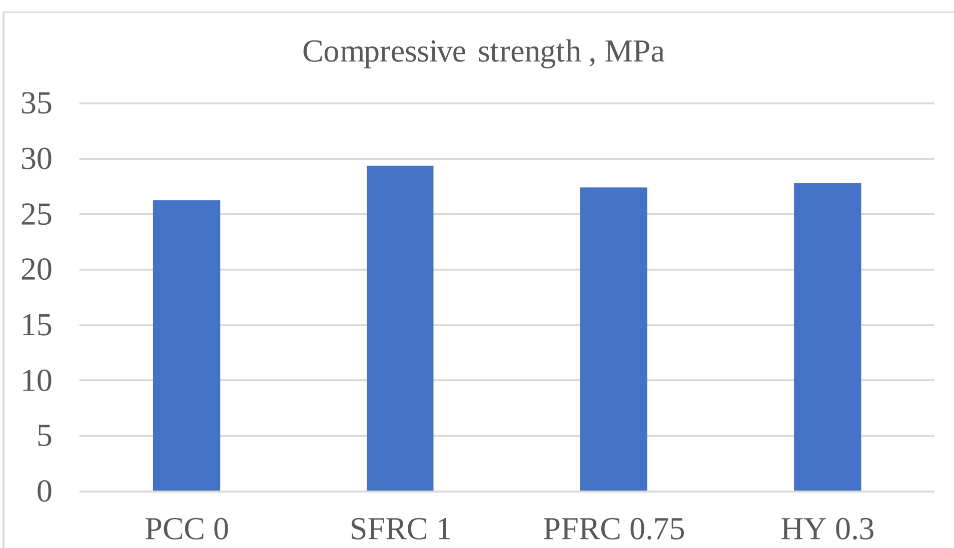

Fig 3 Compressive strength for mixes after 7 days curing

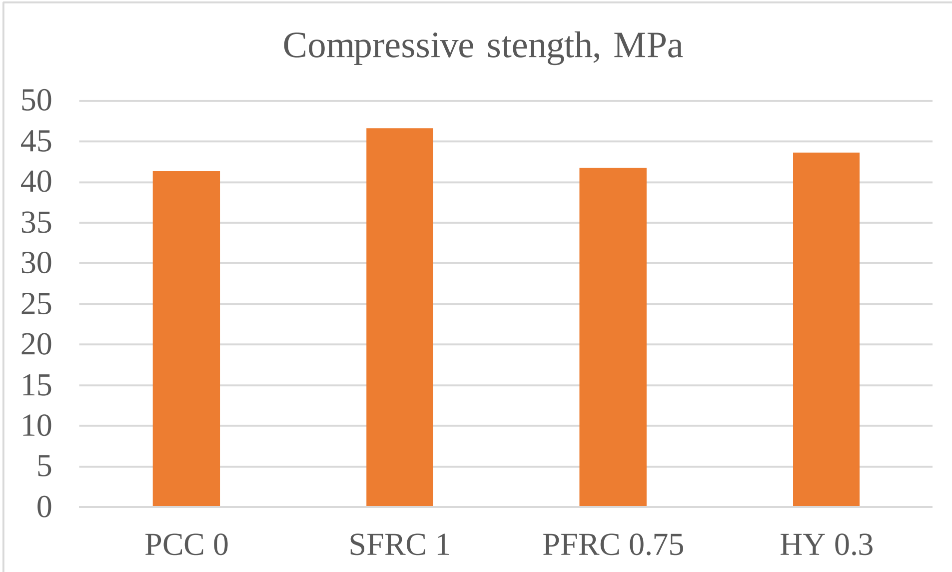

Fig 4 Compressive strength for mixes after 28 days curing

B. *Flexural Strength Test*

The specimens were tested under two-point loading as per IS 516-1959. The specimen was placed in the machine in such a manner that the load was applied to the smooth surface, along two lines spaced 13.33cm apart. The axis of the specimen was carefully aligned with the axis of the loading device.

TABLE VIII
FLEXURAL STRENGTH OBTAINED

Curing Period (days)	Flexural Strength, N/mm^2			
	Conventional	Steel (1%)	Polypropylene (0.75%)	Hybrid Steel – 0.2% Polypropylene – 0.1%
14	6.93	9.24	8.08	8.89
28	12.02	15.98	13.97	15.38

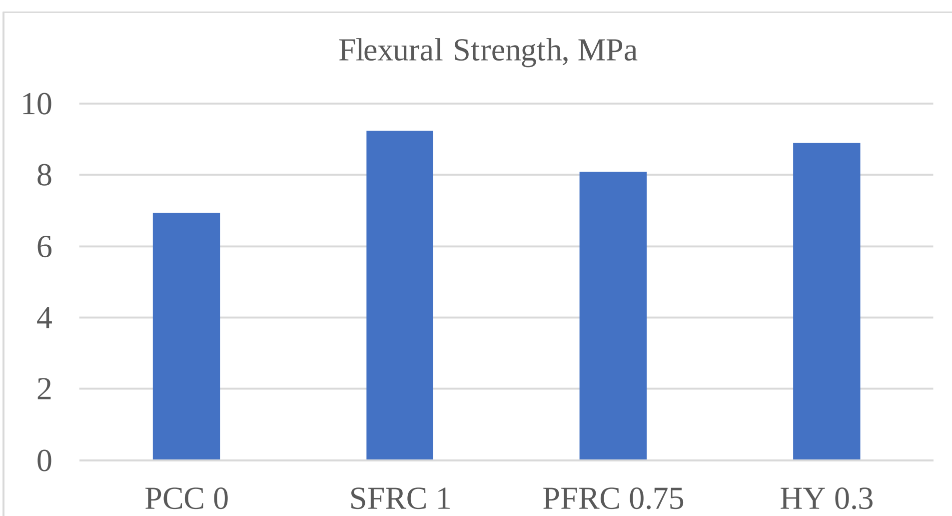

Fig 5 Flexural strength for mixes after 14 days curing

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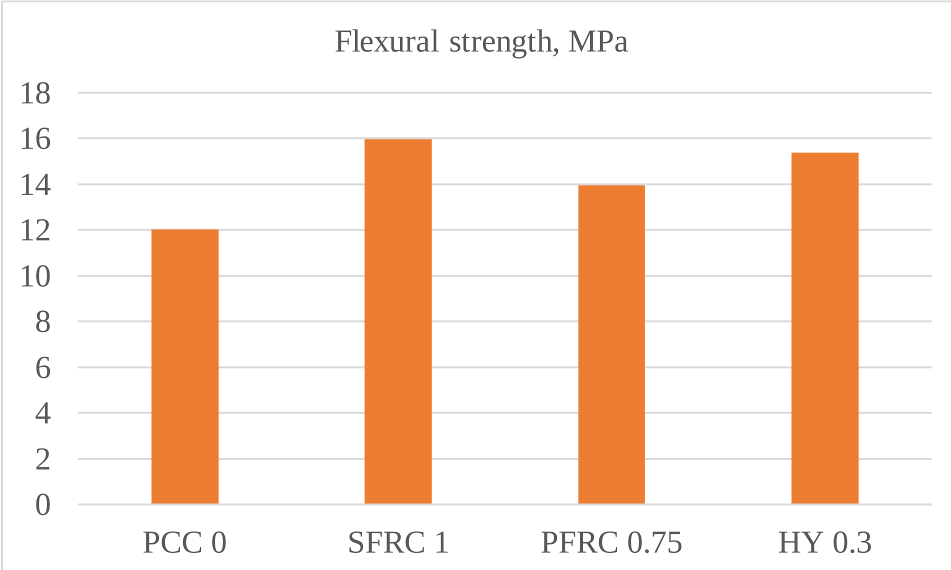

Fig 6 Flexural strength for mixes after 28 days curing

C. Split Tensile Strength Test

The cylinder specimen was placed horizontally in the centre of the compression-testing machine. The load was applied without shock and increased continuously at a nominal rate until failure of the specimen.

TABLE IX
SPLIT TENSILE STRENGTH OBTAINED

Curing Period (days)	Split Tensile Strength, N/mm^2			
	Conventional	Steel (1%)	Polypropylene (0.75%)	Hybrid Steel – 0.2% Polypropylene – 0.1%
14	2.88	4.15	3.23	3.46
28	4.19	6.01	4.68	5.02

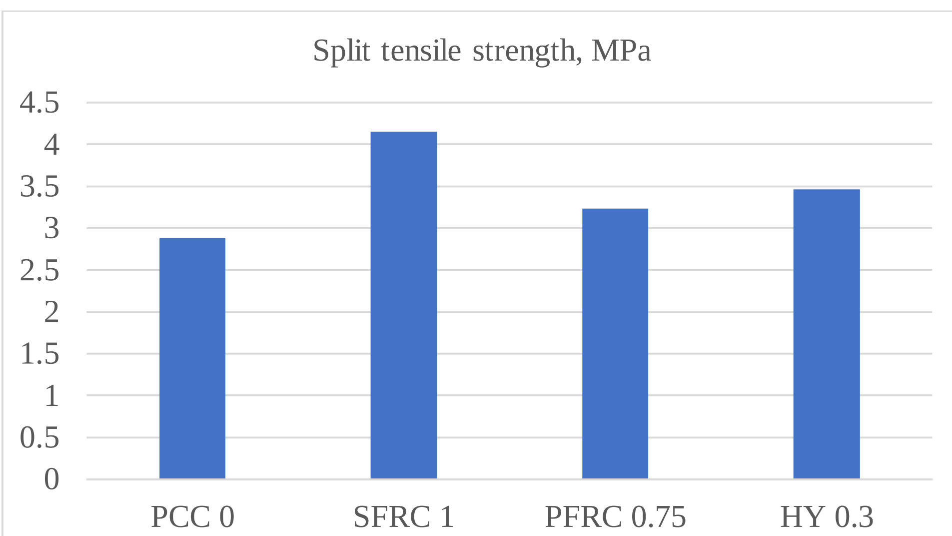

Fig 7 Split tensile strength for mixes after 14 days curing

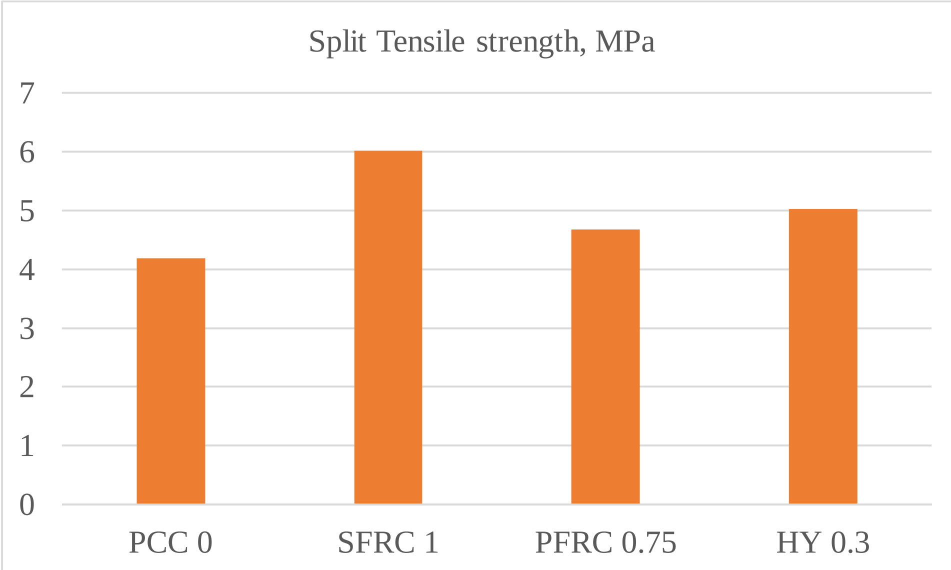

Fig 8 Split tensile strength for mixes after 28 days curing

D. Sorptivity Test

The sorptivity can be determined by the measurement of the capillary rise absorption rate on reasonably homogeneous material. Water was used as a test fluid. The cylinders after casting were immersed in water for 28 days curing. The specimen size 100mm diameter x 50mm height after drying in oven at temperature of 110^{0}C were drowned in water level not more than 5mm above the base of the specimen. Results are presented below.

TABLE X
SORPTIVITY VALUES

Curing Period (days)	Sorptivity, mm			
	Conventional	Steel (1%)	Polypropylene (0.75%)	Hybrid Steel – 0.2% Polypropylene – 0.1%
28	0.1	0.29	0.07	0.18

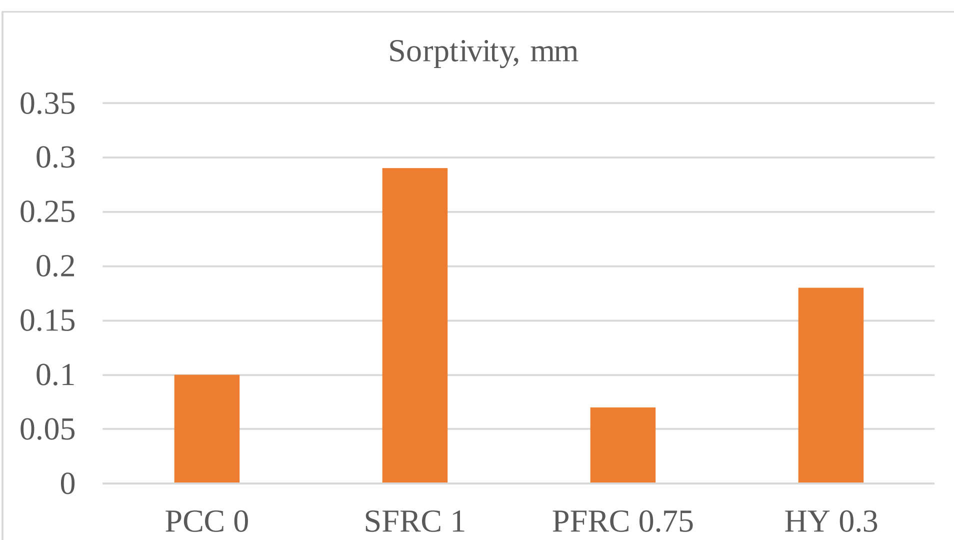

Fig 9 Sorptivity for mixes after 28 days curing

E. Load Deflection Test

Concrete slabs, having dimensions of 750 x 750 x 50 mm were prepared and tested under a static load using UTM. The load was monotonically applied by a hydraulic jack of 1000 kN. The load was applied until the collapse load of the slab was reached. Result for load deflection based on the average values of test data are presented below.

TABLE XI
ULTIMATE LOAD AND CORRESPONDING DEFLECTION FOR EACH CONCRETE MIX

Specimen	Ultimate load, kN	Deflection, mm
PCC	10	0.85
SFRC	16	4.7
PFRC	12	4.8
HY	11	3.45

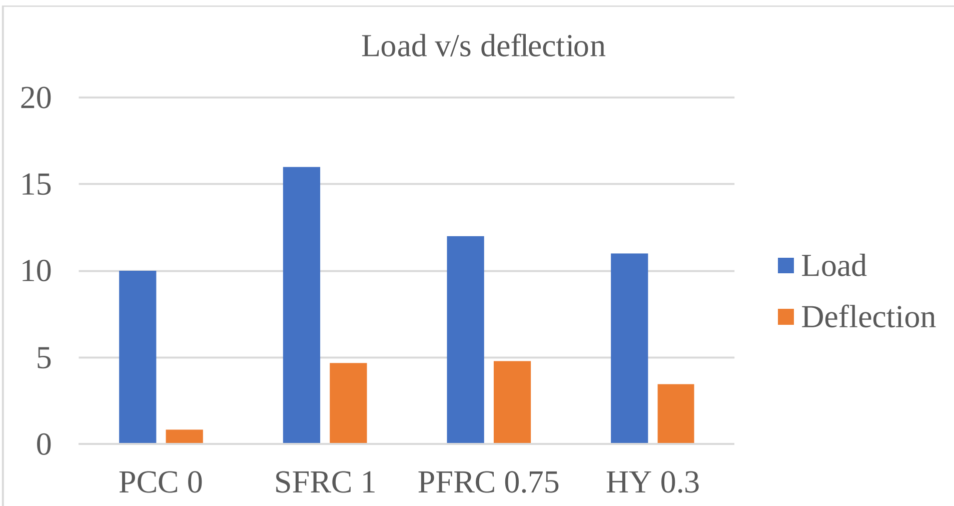

Fig 10 Ultimate load and corresponding deflection for mixes after 28 days curing

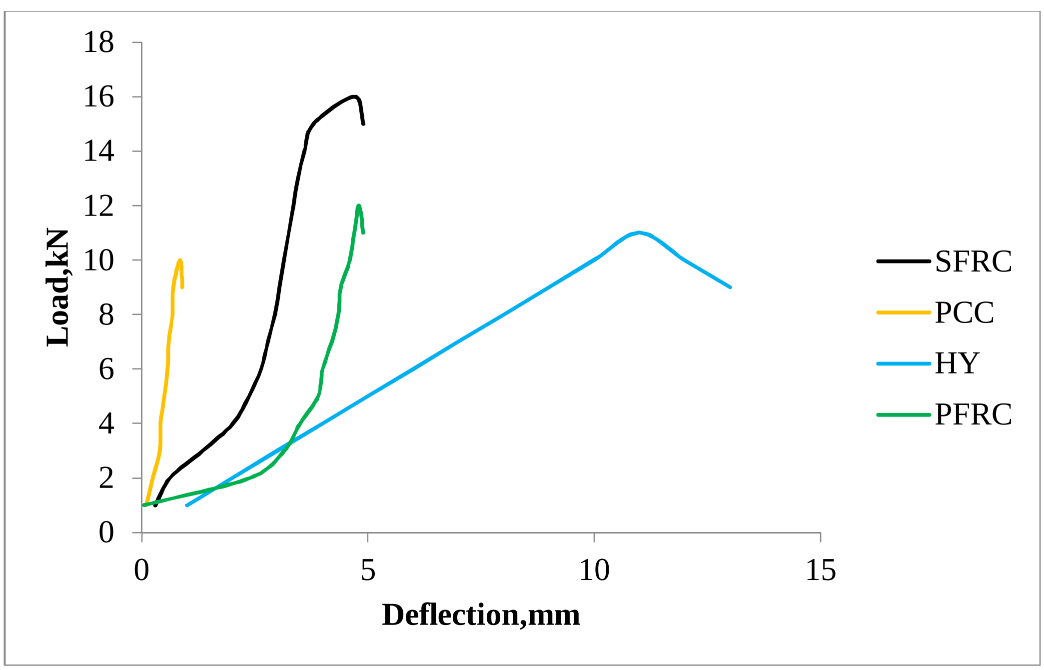

Fig 11 Load v/s deflection curve for mixes after 28 days curing

VI. CONCLUSIONS

From this present work the following conclusions can be drawn:

1) It is clear that the optimum dosages of steel and polypropylene fiber content in concrete improve the mechanical properties of concrete
2) There is a significant increase in compressive and tensile strength with the addition of steel fiber in normal concrete
3) When compared to PFRC and hybrid FRC, SFRC shows higher strength

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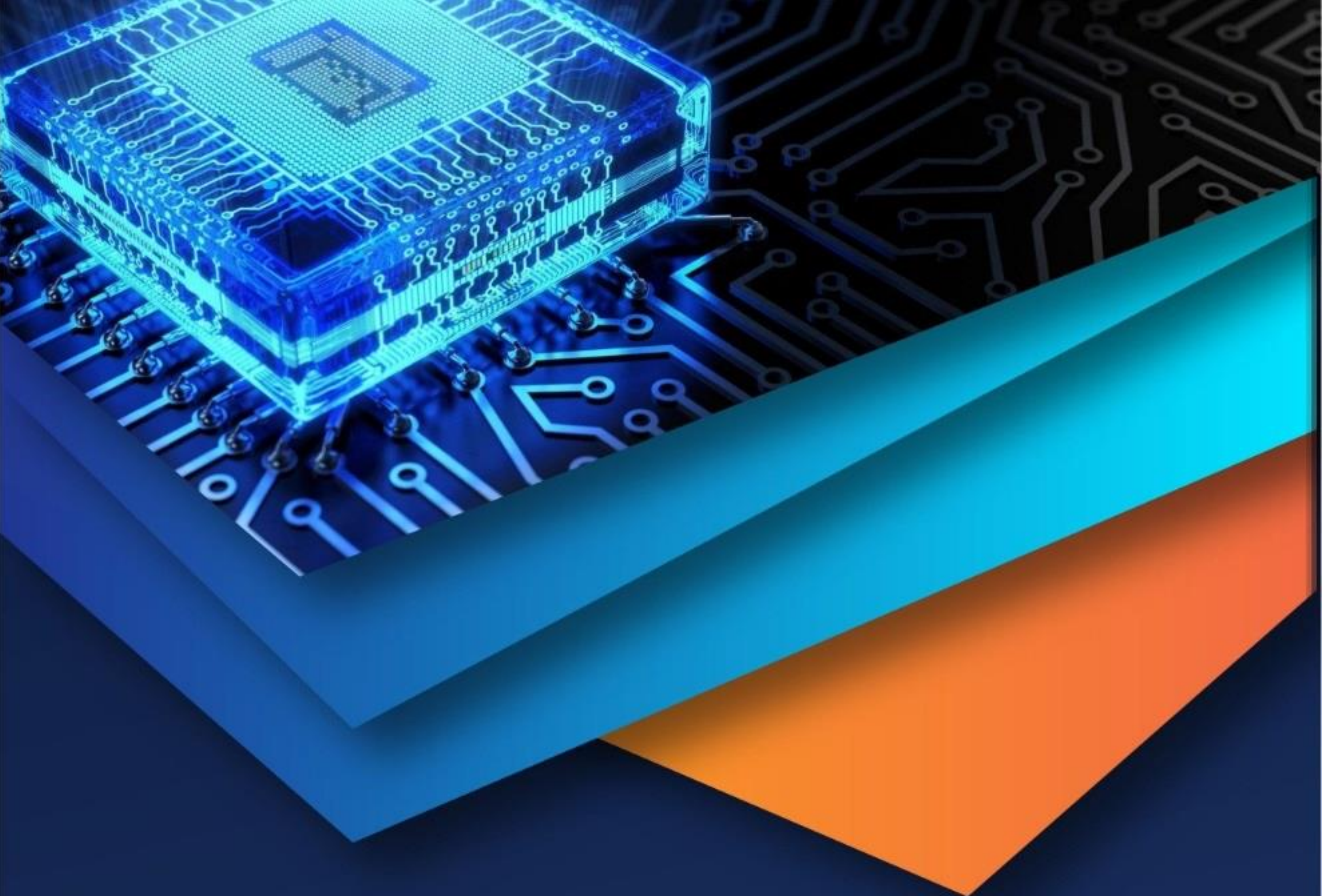

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