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Study of Bond Strength of Fibre Reinforced Concrete

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Abstract: Bond strength has great significance in structural properties of reinforced concrete structure because bond strength is responsible for transfer of forces between two composites materials i.e. steel and concrete. Insufficient bond can decrease the load carrying capacity and resistance of the structure when subjected to different loading conditions. To study the bond strength different tests were carried out using plain and with addition of steel fibers. Pullout tests were carried out to study the effect of steel-polypropylene hybrid fibres on the bond strength and bond stress–slip response of deformed reinforcement bars embedded in high performance concrete. A total of 144 specimens were cast and tested in the present investigation. The main variables considered were the volume fraction of crimped steel fibres, volume fraction of hook end fibres, gloved fibres and the diameter of reinforcement bars. The variation in steel fibre percentage is considered in this study to check the effects of them on bond strength & also the effect of bar diameter. Various percentages of fibres as 1%, 1.5% & 2% of the total volume of the concrete is used in the recent study.

Keywords: High strength concrete; Steel fibres; Pullout test; Bond strength.

I. INTRODUCTION

Bond strength is an important structural property of reinforced concrete which is responsible for transfer of forces between concrete and reinforcing steel thereby ensuring strain compatibility and composite action. Insufficient bond can lead to a significant decrease in the load carrying capacity and stiffness of the structure when subjected to different loading conditions. Basically, bond between a reinforcing steel bar and the surrounding concrete depends on chemical adhesion, friction and mechanical interaction between the ribs of the bar and the surrounding concrete. Previous studies on bond performance indicate that bond strength is governed by different factors such as the strength of the concrete, the thickness of the concrete surrounding the reinforcing bar, the confinement of the concrete due to reinforcement and the bar geometry. Several investigations were carried out to study the effect of using steel fibres on the bond between concrete and deformed steel bar. The use of steel fibre reinforced concrete is known to improve the mechanical properties, control the crack formation and increase the ductile behavior of the concrete. Researchers found that such enhanced properties lead to an increase in the bond between concrete and deformed steel

bar in steel fibre reinforced concrete. Fibres, if randomly dispersed throughout the concrete matrix, provide better distribution of both internal and external stresses due to the formation of a three dimensional reinforcing network. Fibre reinforced concrete (FRC) used in practice generally contain only one type of fibre.

The characteristics of fibre reinforced concrete depend upon the properties and volume fraction of fibres and each type of fibre can be effective with regard to some specific function.

The most important function of the fibres in concrete is to bridge across the cracks and delay the propagation of cracks which provides post-cracking ductility. However, it is known that failure in concrete is a gradual, multi-scale process. Under an applied load, pre-existing micro cracks in concrete grow and join together to form macro cracks. Review of literature shows that a number of studies were carried out in the past on the bond strength and behavior of reinforcement bars in fibre reinforced concrete.

The effects of steel fibres on the bond strength of deformed bars in normal and high strength concrete was studied and they observed that adding fibres to concrete substantially improves the bond-slip behavior of reinforcing bars after the development of splitting cracks. The slip at maximum bond stress increases with increase in fibre content and the contribution of fibres to bond strength is considerable for larger diameter bars as compared to smaller diameter bars.

The presence of fibers (steel or polypropylene) in concrete restricts the growth of the splitting cracks and leads to a much higher bond resistance.

In the present work, the bond behavior was studied using pullout test method which is commonly adopted to compare the relative bond behavior of different types of reinforcement bars and concretes.

II. NEED

A. To study the bond strength using high strength concrete with various aspect ratios of steel fibers-

There are various types of steel fibres available at market. Each & every fibre have there own properties which varies with there percentage used in concrete. To study that effect the various aspect ratios are used in concrete.

B. To study the effect of bar diameter on bond strength-

The bar diameter also affect the bond between steel & concrete. To check that the different sizes of bars are used in the study

C. To study the effect of % variation in Steel fiber on Bond strength-

Variation in steel fibre % allows the concrete to behave more homogeneously. To study that variation in steel percentage is used.

III. TYPES & PROPERTIES OF STEEL FIBER

A. Crimped steel fibre

1) Properties

Material	Low Carbon drawn wire
Aspect ratio	30 to 60
Length (mm)	15mm to 40mm
Diameter (mm)	0.45 mm to 0.8 mm
Tensile strength	750 Mpa to 1100 mpa
Appearance	Clear, bright andundulated along the length
ASTM SPCS	ASTM A820 M04 TYPE I

B. Hook end loose steel fibre

1) Properties

Material	Low Carbon drawn wire
Aspect ratio	65
Length (mm)	35 mm
Diameter (mm)	0.55 mm
Tensile strength	>1100 Mpa
Appearance	Clear, bright, loose unglued with hook end anchorage
Conforms to	EN 14889-1, ASTM A820 M04 Standards
Suitable application	Tunnel shotcrete, slope stabilization precast pipes

C. Hook end glued

1) Properties

Material	Low Carbon drawn wire
Aspect ratio	80
Length (mm)	60 mm
Diameter (mm)	0.75 mm
Tensile strength	>1100 Mpa
Appearance	Clear, bright, glued fiber with hook end anchorage
Conforms to	EN 14889-1, ASTM A820 M04 Standards
Suitable application	Industrial & Warehouse floorings, roads & pavements.

IV. DETAILS OF SPECIMEN

The test specimens shall consist of concrete cubes of size given below, with a single reinforcing bar embedded vertically along a central axis in each specimen. The bar shall project down for a distance of about 10 rom from the bottom face of the cube as cast, and shall project upward from the top face whatever distance is necessary to provide sufficient length of bar to extend through the bearing blocks and the support of the testing machine and to provide an adequate length to be gripped for application of load.

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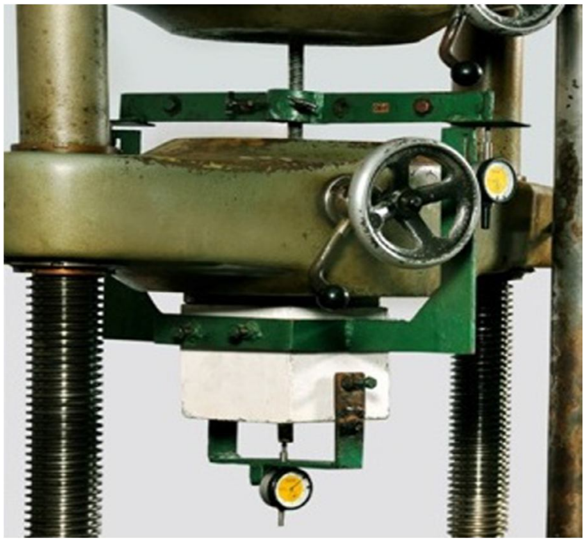

V. TESTING OF SPECIMEN

The test was conducted as per IS 2770 Part I: 1967 – (reaffirmed 2002) using a Universal Testing Machine. After 28 days of curing, the test specimen was mounted in the testing machine such a manner that the bar is pulled axially from the specimen. For measuring the movement of the reinforcing bar with respect to the concrete at both the loaded and free ends of the bar, dial gauges having least count 0.0025 mm were used at both locations. Load was applied to the reinforcing bars monotonically at a rate not greater than 22.5 kN/min. The loading was continued until the specimen failed either by yielding of the steel or by excessive slip between the bar and concrete at 0.025mm and 0.25mm resp.

Assuming a uniform bond stress distribution over the embedded length in concrete, the average bond stress between the reinforcing bar and the surrounding concrete was calculated as,

$$\tau = \frac{F}{\pi \, d_b l_e}$$

where:

τ = experimental bond strength (MPa)
F = ultimate axial tension force (kN)
d_b = nominal rebar diameter (mm)
l_e = embedment length (mm).

VI. BEHAVIOR OF SPECIMEN

Two different types of failures such as pullout failure and yielding failure were observed in the specimens. Pullout mode of failure generally occurs in confined concrete in which the bond failure is due to the pullout of the bars. In the pullout type of failure, crushing of concrete near the bar and shearing of the concrete between the ribs were observed. Fig. shows the pullout failure of HPC specimens without fibres, in which there were substantial cracking of concrete surrounding the bar. However, in the case of HFRHPC specimen, shown in Fig., there was no significant cracking of concrete, which shows the ability of fibres in maintaining the integrity of the specimen. In some specimens, due to the development of high bond strength, the bars yielded at the loaded end. Fig. shows such yielding failure in which the steel bar reached its maximum stress before reaching the ultimate bond stress. In the case of yielding failure, the bar was intact and there were only minor cracks on the surface of the specimen just outside the reinforcing bar.

VII. TEST RESULTS

The pullout test have to take using UTM Machine. The specimen is placed in machine as shown. Two gauges are attached to check the slip at 0.025mm & 0.25mm. These gauges are having least count 0.0025mm. the results are recorded at slip of 0.025 & 0.25mm respectively.

A. *Crimped steel fibre*

Table no. 6.1-Crimped fiber - 7 days curing

Mix	% of fiber	Diameter of bar	.025 mm slip	0.25 mm slip	failure type
M0.0_12	0.0%	12.00	7.74	11.80	slip
MHE1.0_12	1.0%	12.00	9.45	13.54	slip
MHE1.5_12	1.5%	12.00	9.28	13.38	slip
MHE2.0_12	2.0%	12.00	9.54	13.58	slip
M0.0_16	0.0%	16.00	9.00	9.28	slip
MHE1.0_16	1.0%	16.00	8.39	10.91	slip
MHE1.5_16	1.5%	16.00	8.60	10.36	slip
MHE2.0_16	2.0%	16.00	7.93	10.62	slip

Table no. 6.2-Crimped fiber - 28 days curing

Mix	% of fiber	Diameter of bar	.025 mm slip	0.25 mm slip	failure type
M0.0_12	0.0%	12.00	10.61	15.27	slip
MHE1.0_12	1.0%	12.00	13.22	18.36	yield
MHE1.5_12	1.5%	12.00	13.19	18.61	yield
MHE2.0_12	2.0%	12.00	13.54	16.62	slip
M0.0_16	0.0%	16.00	11.07	13.01	slip
MHE1.0_16	1.0%	16.00	12.24	16.35	slip
MHE1.5_16	1.5%	16.00	12.66	16.32	slip
MHE2.0_16	2.0%	16.00	11.28	15.23	slip

B. *Hook end steel fibre*

Table no. 6.3-Hook end fiber - 7 days curing

Mix	% of fiber	Diameter of bar	.025 mm slip	0.25 mm slip	failure type
M0.0_12	0.0%	12.00	7.74	11.80	slip
MHE1.0_12	1.0%	12.00	10.70	14.74	slip
MHE1.5_12	1.5%	12.00	9.28	13.38	slip
MHE2.0_12	2.0%	12.00	9.54	13.58	slip
M0.0_16	0.0%	16.00	9.00	9.28	slip
MHE1.0_16	1.0%	16.00	9.03	11.47	slip
MHE1.5_16	1.5%	16.00	7.91	10.36	slip
MHE2.0_16	2.0%	16.00	7.93	10.62	slip

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Table no. 6.4-Hook end fiber - 28 days curing

Mix	% of fiber	Diameter of bar	.025 mm slip	0.25 mm slip	failure type
M0.0_12	0.0%	12.00	10.61	15.27	slip
MHE1.0_12	1.0%	12.00	13.19	18.30	yield
MHE1.5_12	1.5%	12.00	13.23	18.42	yield
MHE2.0_12	2.0%	12.00	13.53	17.90	yield
M0.0_16	0.0%	16.00	11.07	13.01	slip
MHE1.0_16	1.0%	16.00	12.19	16.29	slip
MHE1.5_16	1.5%	16.00	12.26	16.50	slip
MHE2.0_16	2.0%	16.00	11.59	15.51	slip

C. *Glued steel fibre*

Table no. 6.5-Glued steel fibre - 7 days curing

Mix	% of fiber	Diameter of bar	.025 mm slip	0.25 mm slip	failure type
M0.0_12	0.0%	12.00	7.74	11.80	slip
MHE1.0_12	1.0%	12.00	10.65	14.19	slip
MHE1.5_12	1.5%	12.00	10.64	14.99	slip
MHE2.0_12	2.0%	12.00	10.70	14.40	slip
M0.0_16	0.0%	16.00	9.00	9.28	slip
MHE1.0_16	1.0%	16.00	9.03	11.67	slip
MHE1.5_16	1.5%	16.00	9.17	12.39	slip
MHE2.0_16	2.0%	16.00	9.08	11.87	slip

Table no. 6.6-Glued steel fibre – 28 days curing

Mix	% of fiber	Diameter of bar	.025 mm slip	0.25 mm slip	failure type
M0.0_12	0.0%	12.00	10.61	15.27	slip
MHE1.0_12	1.0%	12.00	12.23	16.86	slip
MHE1.5_12	1.5%	12.00	13.02	16.33	slip
MHE2.0_12	2.0%	12.00	12.77	15.78	slip
M0.0_16	0.0%	16.00	11.07	13.01	slip
MHE1.0_16	1.0%	16.00	11.20	14.70	slip
MHE1.5_16	1.5%	16.00	12.09	14.05	slip
MHE2.0_16	2.0%	16.00	11.47	14.19	slip

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VIII. RESULTS & DISCUSSION

A. Crimped steel fibres

1) 7 Days curing

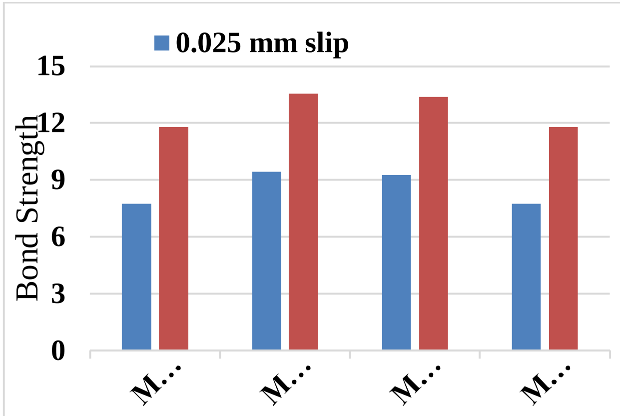

Fig. no. 7.1 Bond strength of 12mm Bar

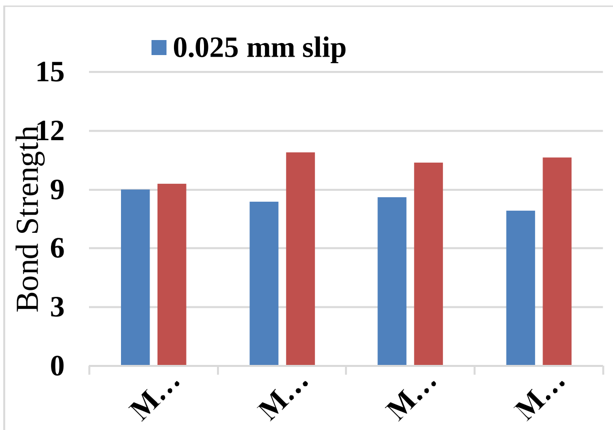

Fig. no.7.2 Bond strength of 16mm Bar

2) 28 Days curing

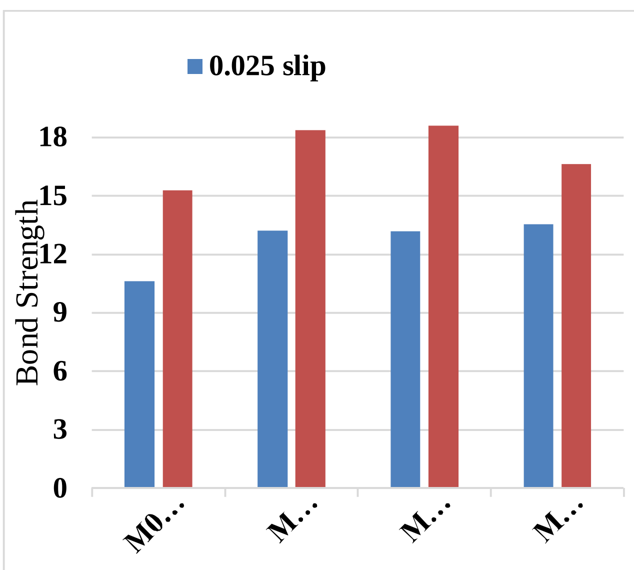

Fig. no.7.3 Bond strength of 12mm Bar

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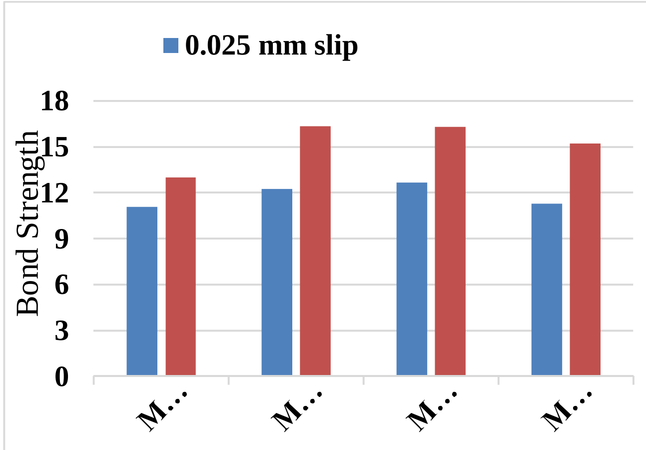

Fig. no.7.4 Bond strength of 16mm Ba

B. Hook end steel fibres

1) 7 Days curing

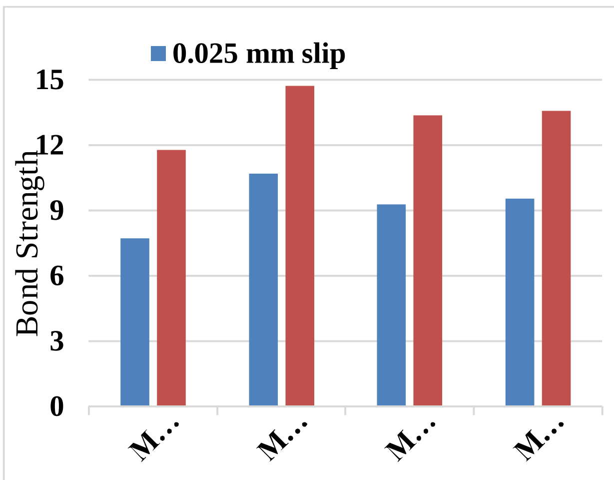

Fig. no.7.5 Bond strength of 12mm Bar

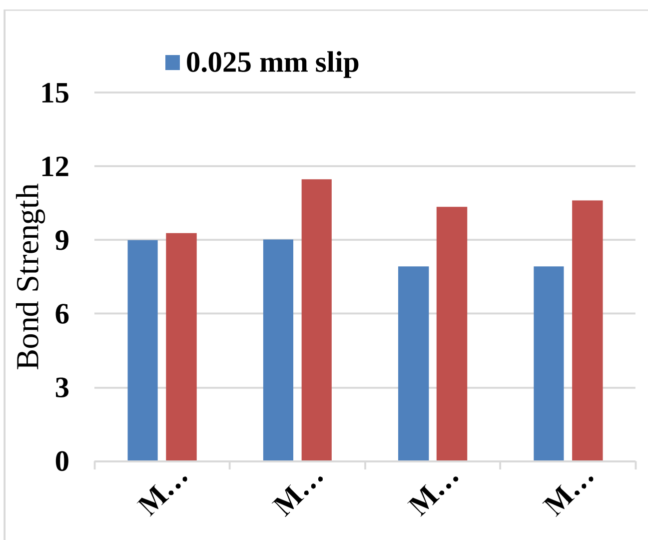

Fig. no.7.6 Bond strength of 16mm Bar

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2) 28 Days curing

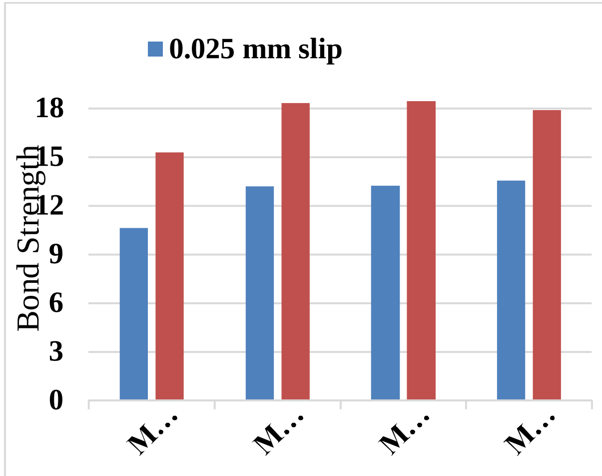

Fig. no.7.7 Bond strength of 12mm Bar

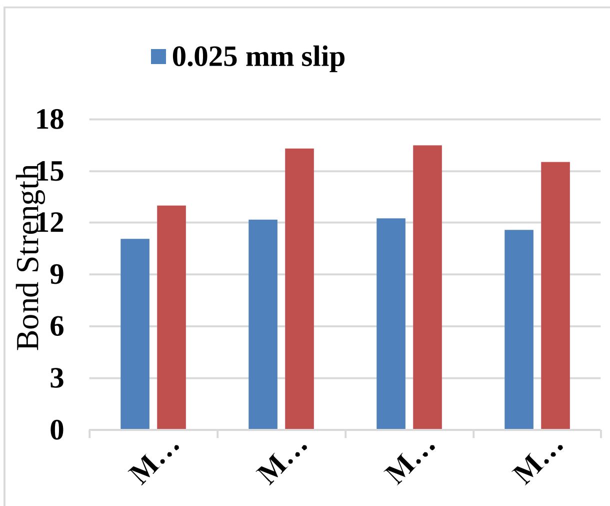

Fig. no.7.8 Bond strength of 16mm Bar

C. Glued steel fibres

1) 7 Days curing

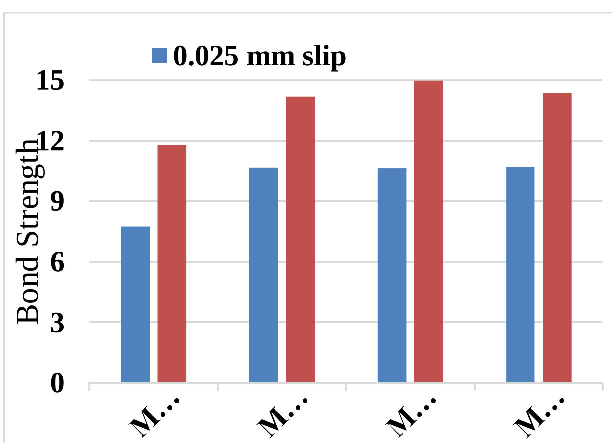

Fig. no.7.9 **B**ond strength of 12mm Bar

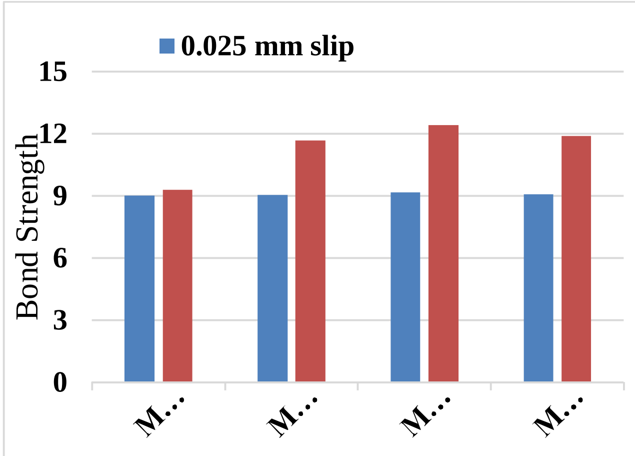

Fig. no.7.10 Bond strength of 16mm Bar

2) 28 Days curing

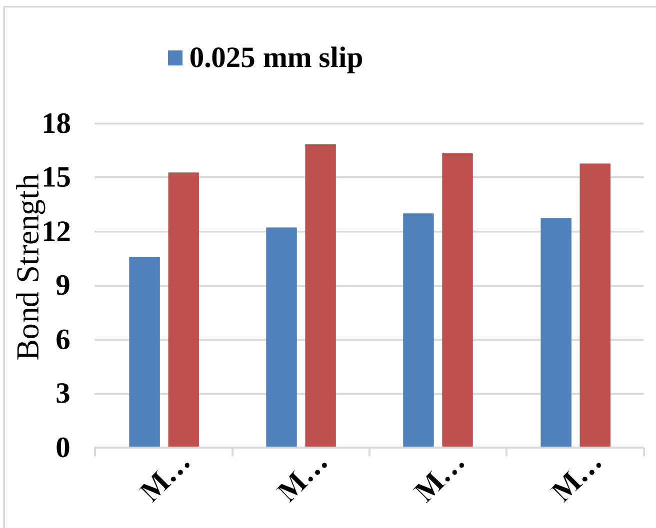

Fig. no.7.11 Bond strength of 12mm Bar

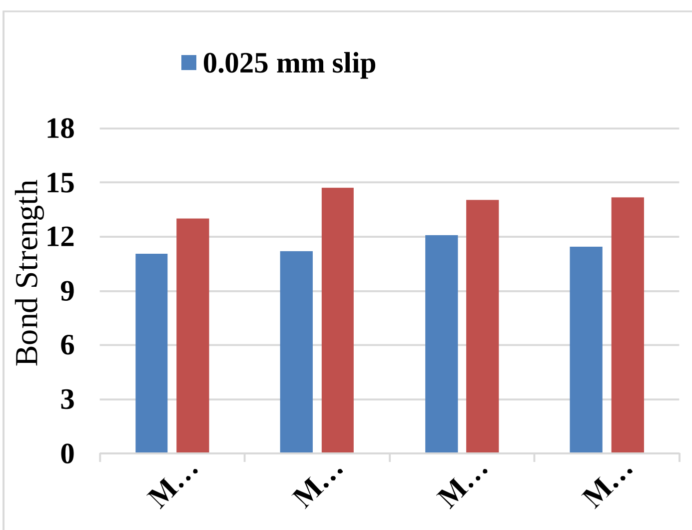

Fig. no.7.12 Bond strength of 16mm Bar

IX. CONCLUSION

High performance fibre reinforced concrete should posses good capacity on compaction & static properties, such as compressive strength & bond strength. Therefore this project first investigates the optimization of cementatious matrix, fibre types, fibre content, effect of bar on bond strength, & effect of percentage variation on bond strength.

The following conclusions about the bond strength of FRC are obtained:

A. Increase in the compressive strength due to addition of steel fibres-

The average compressive strength has increased by almost 30% due to the addition of steel fibres the hook end steel fibres shows better results as compared to the crimped & glued steel fibres.

B. Increase in bond strength-

The bond strength is also increased as compared to the plain concrete. The hook end fibres here also shows good results in comparison.

C. Reduction in developments of cracks-

Due to the addition of steel fibres the creck development in the specimen is reduced in the compressive test.

D. The bond strength is affected by bar diameter-

The bond strength is affected due to the bar diameter. As the bar diameter reduces the bond strength, hence the bond strength is more for the bar of 12mm diameter than the 16 mm diameter.

E. Comparison in the types of steel fibre-

The results for the Crimped & Hook end steel fibre is comparatively good as compared to the Glued steel fibre. The bond strength is more for the Crimped & Hook end steel fibre. Hence these are good for the use as compared to Glued steel fibres.

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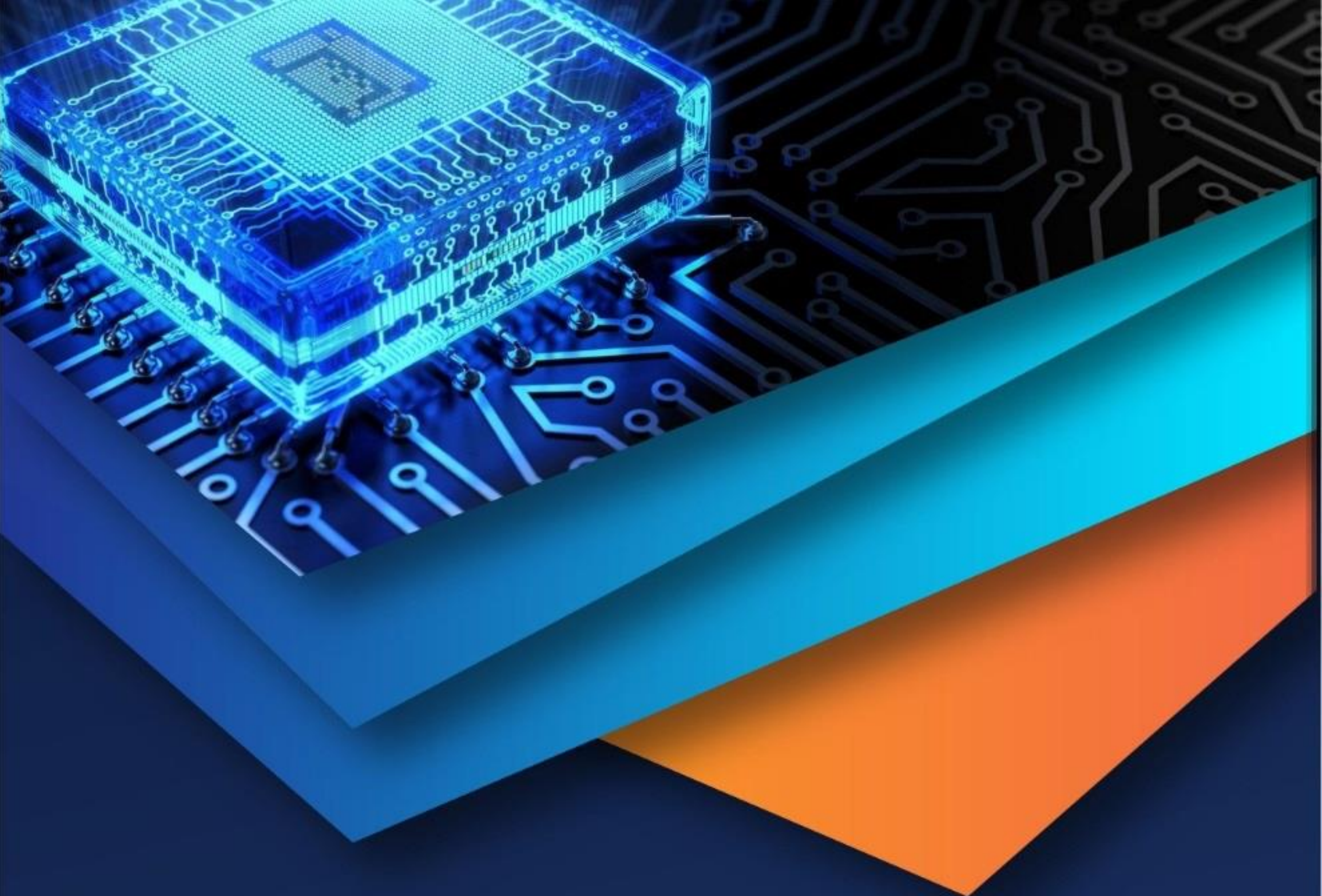

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