STUDY OF BOND STRENGTH ON VARIOUS FIBRE REINFORCED CONCRETES

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Abstract

Concrete is basically the most important material concerning with the construction and infrastructural procedures, for which it should be of good strength and durability. In conventional concrete, micro-cracks develop before structure is loaded because of drying shrinkage and other causes of volume change. When the structure is loaded, the micro cracks open up and propagate because of development of such micro-cracks, results in inelastic deformation in concrete. Fibre reinforced concrete (FRC) is cementing concrete reinforced mixture with a numbers of small fibres are dispersed and distributed randomly in the concrete at the time of mixing, and thus improve concrete properties in all directions. The fibres help to transfer load to the internal micro cracks. The behavior of reinforced concrete (RC) structures depends up on the type of bond developed between the steel reinforcement and the surrounding concrete. Maintaining composite action requires transfer of load between the concrete and steel. Proper bond between the steel reinforcement and the surrounding concrete is also crucial for the overall strength and serviceability of RC members. The failure of RC structures may be due primarily to the deterioration of the bond. Hence it is necessary to study the bond characteristics. As per IS 456:2000 the bond between steel and concrete fails during severe to extreme environmental conditions. This paper evaluates the Bond behavior of reinforcement bar of 16mm on various grades of FRC. A study on effect of steel and fibres on the bond strength of deformed steel bars embedded in fibre reinforced concrete was carried out experimentally by conducting Pull out test.

Key words: bond strength, FRC, micro cracks, pull out test, RC

1. INTRODUCTION

Nowadays large and complicated structures are being constructed and advancements are made for their construction and maintenance. Failure of building became a worst issue faced by the civil engineers. The failure of reinforced concrete (RC) structures may be due primarily to the deterioration of the bond [2] [17]. Many experiments and developments had made to maintain proper bond between steel and concrete. To improve the structural strength and reduce cracks concrete is now reinforced with fibres. Various types of fibre like Aramid Fibre (AF), Basalt Fibre (BF), Glass Fibre (GF), Polypropylene Fibre (PPF) are added to concrete. Also Fibre Reinforced Concrete (FRC) can improve the bond strength between reinforcement and concrete [17].

The behaviour of RC structures depends up on the type of bond developed between the reinforcement and the surrounding concrete [2] [17]. Bond stress is the tangential shear or friction developed between the reinforcement and the surrounding concrete that transfers the force onto the reinforcement. To ensure the integrity of various constituent or composite action of concrete and steel reinforcement, sufficient bond should be developed by the surrounding concrete with the reinforcement. It is also crucial for the overall strength and serviceability of RC members [7] [9] [10] [11] [15] [18] [17].

The pull out tests is more popular method of testing bond strength. The Pullout behavior is a function of the reinforcement characteristics (geometry and steel type). Characteristics of the surrounding matrix and level of lateral confinement (Core thickness or the presence of stirrups). The main advantage of adding fibres to concrete is that it induces an increase in compressive and flexural strength, toughness and ductility of concrete. Also it provides a bridging of cracks on the concrete [1] [9] [19].

2. LITERATURE REVIEW

All the studies and experiments conducted on Fibre Reinforced Concrete concluded that addition of each fibre within a range of 0.3% to 1% of the total concrete mix resulted in;

- Increase in compressive strength of concrete from 20-25% [8] [12] [14] [18]
- Increase in split tensile strength of concrete from 15-20% [3] [8] [12]
- Reduction in bleeding in fresh concrete improves the surface integrity of concrete. [8] [12]
- Increase in the bond between steel and concrete. [8] [14] [19]
- Improves homogeneity and reduces micro cracks. [14] [18]
- Ductility characteristics of concrete have improved. [8] [12]

Hence we decided to adopt the fibre dosage as 0.3% of total concrete mix.

All the studies based on bond strength mainly investigated on the influence of bar diameter, embedment length, surface type of reinforcing bars, grade of concrete, age of concrete, different environmental conditions etc.

From previous researches it identified that;

- Bond strength increased with decrease in diameter and increase in compressive strength of concrete. [5] [7] [16]
- Slip decreases with increase in bond strength. [1] [11] [17]
- The predominant mode of failure is splitting mode of failure for all tested specimens. [1] [17]
- The bond strength of reinforcement bars decreases as its embedment length increases. [1] [7]

A lot of researches are conducted on the bond strength between steel and concrete. But very few researches get an open eye towards the bond strength of FRC. In this paper bond strength between steel and concrete using different fibres with various grades of concrete have to be analyzed by the experimental manner as per IS 2770 (PART 1) 1967.

3. EXPERIMENTAL PROGRAMME

3.1 GENERAL

Objective of this paper is decided to study the variations in bond strength in various grades of plain concrete and FRC. Testing of material for the purpose of calculating mix design is conducted. A mix proportions for various grades of concrete is calculated (M20, M30). Three samples of each mix is produced for the test.

3.2 MATERIALS USED

The key materials used in this study were OPC of 43 grade, fine aggregate used is artificial sand (M sand) confing to zone III is selected, coarse aggregates retaining on 4.75mm sieve and generally ranges between 9.5mm to 37.5mm in diameter are selected. Fibres used are Aramid fibre, Basalt Fibre, Glass fibre and Polypropylene fibre. 16mm reinforcement bars (as per IS 2770 (part 1) 1967) is chosen. The potable water from well is used for mixing and curing the concrete

3.3 CONCRETE MIX DETAILS

The concrete mix design is prepared as per the recommendations given in IS 10262-2009 and IS 456:2000. The grade of concrete chosen is M20 and M30. The materials were tested for the preparation of mix and various trial mixes were prepared and tested. The proportioning for the mixes are given in Table I and the average compressive test result of 30 specimens in each grade is given in Table II.

Table I Concrete mix ratio

Mix	Water cement ratio	Cement	Fine aggregate	Coarse aggregate
M 20	0.5	1	1.88	2.9
M 30	0.45	1	1.52	2.53

Table II Compressive test result

Mix	28th day avg. Strength(mPa)
M20	26.8
M30	36.65

3.4 PREPARATION OF TEST SPECIMEN

The specimen is prepared as per IS 2770 (part I) 1967. 30 specimens are prepared with 0.3% dosage of fibre on each grade of concrete and allowed curing for 28 days.

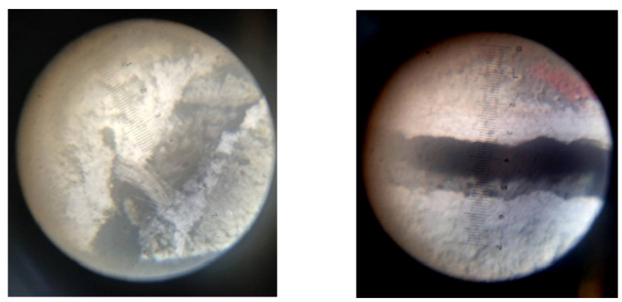
3.5 PULL OUT TEST

Test set up used for the study is shown in the Fig 1. The specimens were tested in Universal Testing Machine of capacity 1000kN. The strength at which the bond failure occurred was measured from the dial gauge of the machine. The slip values were recorded using the dial gauge attached to the UTM as shown in Fig 2.

Fig 1: Pull out test setup

Fig 2 Deflection meter setup on UTM

The microscopic view of the crack occurred after pull out test were given in Fig 3.



(a) **(b)**

Fig 3: Microscopic view of crack (a) M20 GF (b) M20CC

3.6 DETERMINATION OF BOND STRESS

Average bond stress was obtained from the equation below

$$\tau_{bd} = \frac{P}{\pi D L}$$

where, τ_{bd} is the average bond stress in N/mm^2, P is the pullout strength in N, D is the diameter of the bar in mm and L is the embedment length in mm.

4. RESULTS AND DISCUSSIONS

The average results obtained from Pull out test is represented in graphical form as Fig 4 to Fig 17.

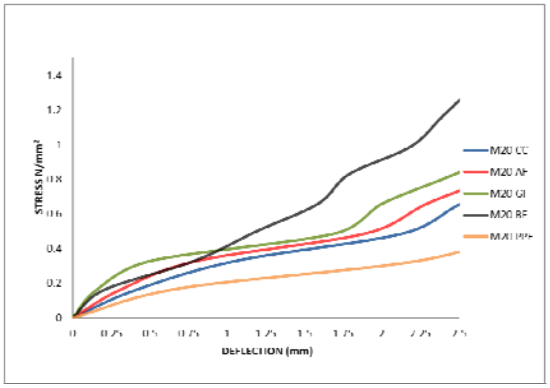


Fig 4: Deflection of M20 CC and M20 FRC up to 2.5mm

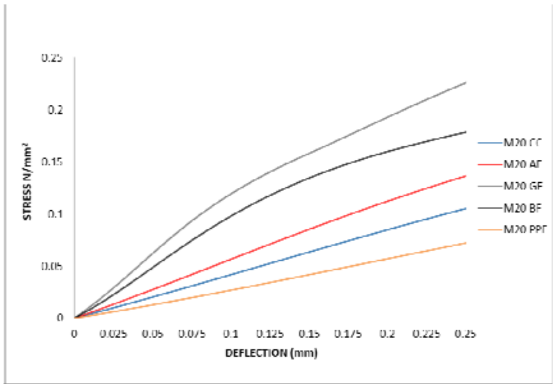


Fig 5 Deflection of M20 CC and M20 FRC up to 0.25mm

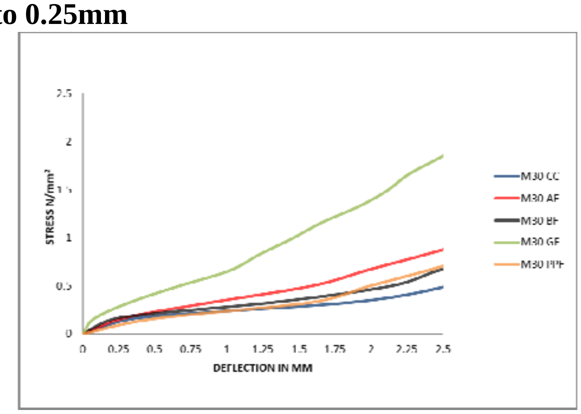


Fig 6: Deflection of M30 CC and M30 FRC up to 2.5mm

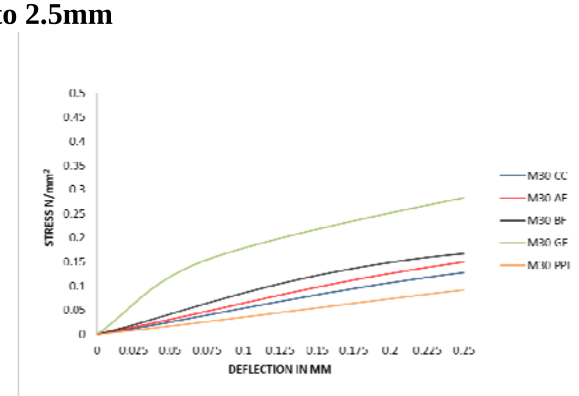


Fig 7: Deflection of M30 CC and M30 FRC up to 0.25mm

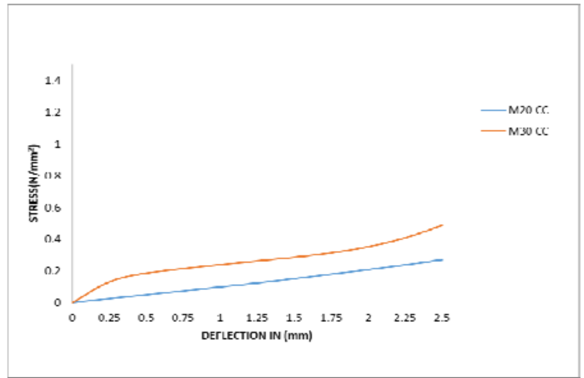


Fig 8: Deflection of M20 CC and M30 CC up to 2.5mm

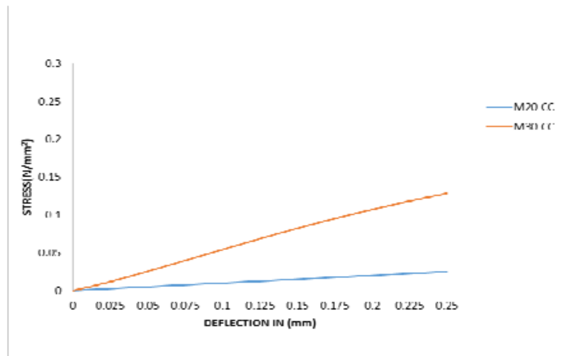


Fig 9: Deflection of M20 CC and M30 CC up to 0.25mm

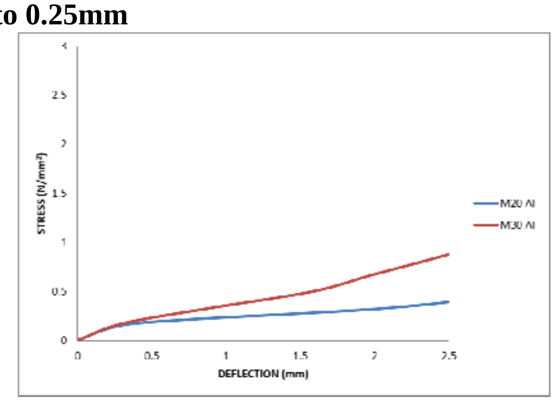


Fig 10 Deflection of M20 AF and M30 AF up to 2.5mm

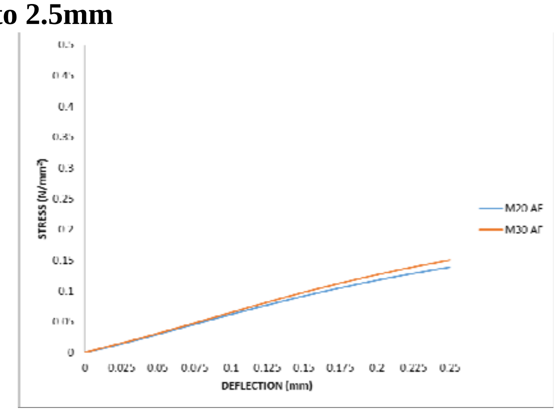


Fig 11 Deflection of M20 AF and M30 AF up to 0.25mm

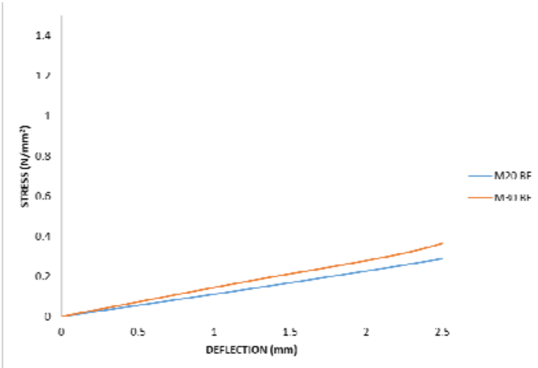


Fig 12: Deflection of M20 BF and M30 BF up to 2.5mm

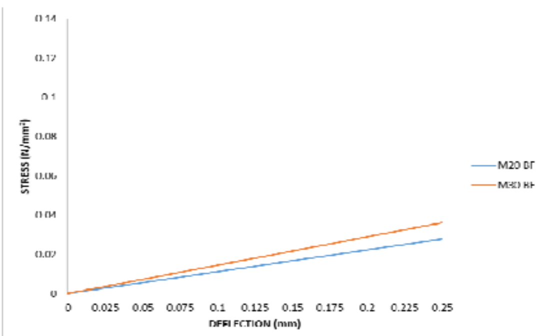


Fig 13: Deflection of M20 BF and M30 BF up to 0.25mm

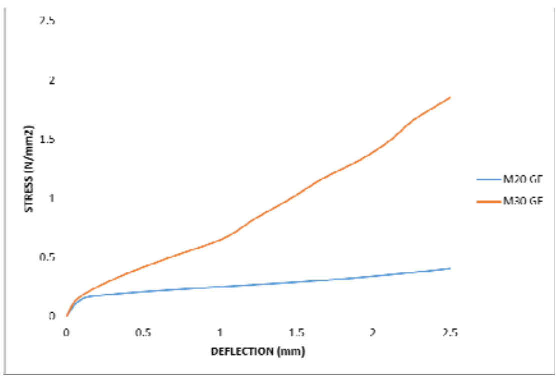


Fig 14: Deflection of M20 GF and M30 GF up to 2.5mm

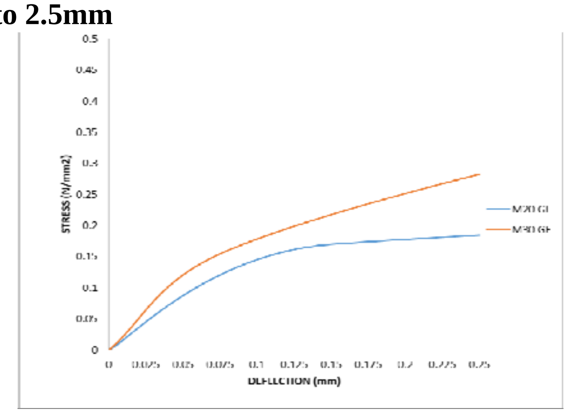


Fig 15: Deflection of M20 GF and M30 GF up to 0.25mm

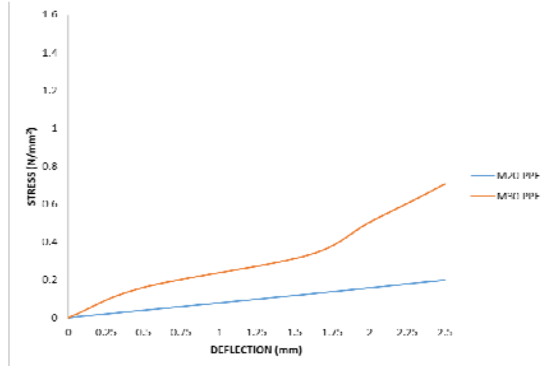


Fig 16: Deflection of M20 PPF and M30 PPF up to 2.5mm

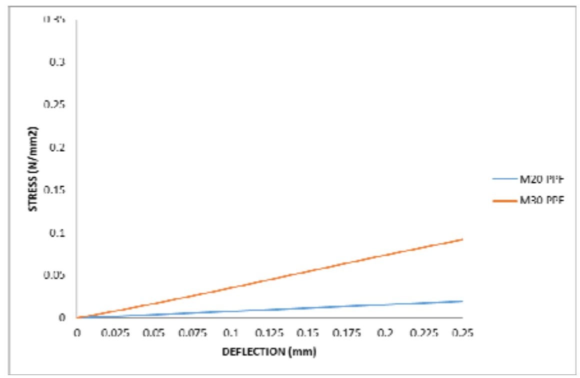


Fig 17: Deflection of M20 PPF and M30 PPF up to 0.25mm

Note:
M20 CC: M20 grade Controlled Concrete; **M20 FRC**: M20 grade Fibre Reinforced Concrete; **M20 AF**: M20 grade Aramid Fibre Reinforced Concrete; **M20 BF**: M20 grade Basalt Fibre Reinforced Concrete; **M20 GF**: M20 grade Glass Fibre Reinforced Concrete; **M20 PPF**: M20 grade Polypropylene Fibre Reinforced Concrete; **M30 CC**: M30 grade Controlled Concrete; **M30 FRC**: M30 grade Fibre Reinforced Concrete; **M30 AF**: M30 grade Aramid Fibre Reinforced Concrete; **M30 BF**: M30 grade Basalt Fibre Reinforced Concrete; **M30 GF**: M30 grade Glass Fibre Reinforced Concrete; **M30 PPF**: M30 grade Polypropylene Fibre Reinforced Concrete

From the graphs plotted using the obtained values from the pull out test conducted as per the codal provisions of IS 2770 (Part 1) 1967, the stress value at 0.025mm and 0.25mm deflection are given below.

Table III Maximum stress and stress at 0.25mm and 0.025mm slip

SL NO	SPECIMEN NAME	COMPRESSIVE STRENGTH (MPa)	AGE (DAYS)	STRESS AT SLIP (MPa)		MAXIMUM STRESS (MPa)
				0.025mm	0.25mm	
1	M20 CC	26.8	28	0.05	0.025	2.97
2	M20 AF	28.1	28	0.01	0.14	3.65
3	M20 BF	28.6	28	0.002	0.028	3.32
4	M20 GF	30.8	28	0.15	0.195	3.82
5	M20 PPF	26.5	28	0.005	0.02	3.52
6	M30 CC	36.65	28	0.015	0.13	3.14
7	M30 AF	36.5	28	0.015	0.15	2
8	M30 BF	38.5	28	0.004	0.036	3.49
9	M30 GF	41.04	28	0.06	0.28	4.15
10	M30 PPF	34.3	28	0.01	0.09	2.32

From Fig 4 the BF shows a deviation compared to other fibres may be due to its high tensile strength (4100Mpa to 4840Mpa) while the tensile strength of other fibres lies below this range [14].

From Fig 4 and Fig 5 addition of PPF had showed unsatisfactory results. It may be due to the lack of sufficient fibres i.e. addition of 0.3% of fibre will not give satisfactory result. Hence we need to increase the fibre content to 0.5% or more [3].

From Fig 6 the PPF fibre shows more satisfactory result than BF for 2.5mm deflection on M30 grade concrete as compared to M20 grade concrete. Change in grade of concrete with use of different fibres will change the matrix structure of concrete. Due to this the strength of the specimen may also vary [17] [12] [13]. Also this may be the reason that addition of GF on M30 grade concrete produced more satisfactory results compared to M20 grade concrete. Also the GF can prevent bleeding in concrete effectively than any other fibre. Reduction in bleeding increases the surface integrity of concrete [8].

From Fig 7 all the fibres follows a same trend up to deflection of 0.25mm with GF showing more satisfactory result than BF, AF and CC. PPF showed unsatisfactory result and it may be due to the lack of fibre content [3].

From Fig 8 to Fig 17 showed the variation in results of CC and FRC with the change in grade of concrete. All the graphs showed satisfactory results. All the graphs exhibited to sustain more stress for the concrete specimen with fibre content since addition of fibre increases the density of concrete and improves the surface integrity of concrete [8] [16] [17] [19]. Also M30 specimens exhibited more strength than M20 specimens.

From Table III specimens with GF exhibits more compressive strength while comparing to other specimens and the same had exhibited the capacity to withstand maximum stress.

5. CONCLUSION

Following conclusions are drawn based on the results obtained from experiment

- The pull out test on CC and FRC is conducted and the values are plotted in graphical form. Variation in strength by introduction of different fibres on different grade of concrete can be verified through the graphs.
- There is an increase in bond stress for FRC than compared to CC specimen. GF showed higher bond stress than other fibres.
- The bond strength also depends upon several factors like fibre content, compaction conditions, curing age of concrete, temperature variation, water content etc.
- An optimum value of fibre content is not advisable for all fibres since each fibre vary in its strength and other properties. Optimum value of each fibre has to be found out by trial and error method.
- There is an increase in 10-15% on 28 days compressive strength of various grades of FRC compared with CC specimens.
- FRC did not contribute much to the bond strength but prevents development of micro cracks to macro cracks formation.
- Slip decreases with increase in bond strength.
- Concrete mostly fails due to bond failure during severe to extreme weather conditions. Hence it is essential to determine the bond characteristics.

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