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An Experimental Study of Flexural Strength of Concrete Beam Reinforced With Fiber Reinforced Polymer

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Abstract - Although the potential of continuous fiber reinforced polymers **(**FRP) was recognized more than 50 years ago, but they are not used in construction excessively. Since 25 years research work is going on to know the properties of FRP that how to utilize this in construction work. FRP used in reinforcement in concrete member majorly in pre-stressing, in soil stabilization, high speed railway tracks, repairs works etc. In this experimental work we used FRP grids in Cement Concrete beam as a reinforcement to carry tensile stresses. FRP grid is used in tensile zone. Beams are casted with four grades i.e. M35, M30, M25, M20 of dimension 150mmx150mmx700mm (in accordance to IS 516-1959) and tested under flexure by two points load in Universal Testing Machine. The concrete used was mix designed according to IS: 10262-2000 and IS: 456-2000. Sample cube were casted and tested for knowing compressive strength. The dimensions of FRP vary in lengthwise with 500mm and 600mm in grid. After obtaining the result of flexural strength of different grade of concrete beam casted with FRP grid, it was concluded that for FRP grid, flexural strength is increased as compared to plain concrete by 426% (for M35 grade). Thus use of FRP grids is very much effective in enhancing the flexural strength of concrete.

Key Words: **Fiber Reinforced Polymers (FRP), Flexural Strength, FRP Grid, Concrete, Pre-Stressing.**

1. INTRODUCTION:

Concrete is the most widely used construction material in the world. This popularity of concrete carries with it an immense environmental cost. Structural application of FRP materials are as internal reinforcement of reinforced concrete structures, external strengthening of reinforced concrete structures, hybrid structures, fully composite structures etc. Fiber Reinforced Polymer (FRP) composites have been used in automobile, electronics, and aerospace engineering for several decades, but their application in concrete engineering as a reinforcing material is relatively recent in origin. Besides the advances in the field of development of new fibers, etc., several developments in the construction industry have accelerated the efforts to apply FRP as a reinforcing material in concrete. One of the chief causes is the realization that the reinforcing steel, both in reinforced and pre-stressed concrete construction, is corrosion prone, though the malady may take more than 20–30 years to show symptoms! This realization obviously prompts the desire to use noncorrosive materials such as FRP, especially in environments where steel has been shown to be vulnerable.

1.1 What is FRP REINFORCEMENT?

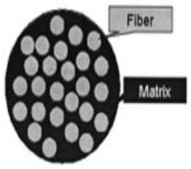
FRP composite materials are comprised of high strength continuous fibers, such as glass, carbon, or steel wires, embedded in a polymer matrix. The fibers provide the main reinforcing elements while the polymer matrix (epoxy resins) acts as a binder, protects the fibers, and transfers loads to and between the fibers.

FRP composites can be manufactured on site using the wet lay-up process in which a dry fabric, made of carbon or glass, is impregnated with epoxy and bonded to prepared concrete substrate. Once cured, the FRP becomes an integral part of the structural element, acting as an externally bonded reinforcing system. FRP composites can also be prefabricated in a manufacturing facility in which the material is pultruded to create different shapes that can be used for strengthening applications, such as rods, bars and plates.

1.2 Constituent fibers

Fibers made from carbon, aramid, glass, and polyvinyl alcohol are commonly used for the manufacture of FRP. As can be seen, the specific gravity of the fibers ranges between 1.4 for aramid fibers to about 2.6 for glass fibers. The diameters of the fibers range from about 6 microns for carbon fibers to about 15 microns in the case of aramid and glass fibers. Figure 1 shows the schematic representation of cross section of FRP composite.

Figure 1 Schematic Representation of Cross Section of FRP Composite.



2. OBJECTIVES OF THE STUDY

The main objectives of the present experimental dissertation work is to assess the flexural strength of different grades of

concrete beam with fiber reinforced polymer grids of different length having constant thickness 2.5 cm.

3. MATERIALS USED

In conducting the experimental studies in the laboratory following material are used

CEMENT: - A commercially available Ordinary Portland cement of 43 grade (Bangur cement) conforming to the requirements of IS: 1489 (part-1) 1991 and IS 8112:1989, is used throughout the study. Various tests were conducted in the laboratory and the results are tabulated in Table 1.

Table 1 shows the properties of cement tested in laboratory

Characteristics		Test Results*	Permissible Value As Per IS: 1489 (part-1)
Specific Gravity		3.15	3.15
Setting Time(minutes)	Initial	32 min.	30min.
	Final	610 min.	600min
Compressive Strength (MPa)	7days	32.1 MPa	30.1MPa
	28 days	44.4 MPa	43MPa
Soundness		10.0 mm	10.0mm

COARSE AGGREGATE: - The aggregate used were the standard coarse aggregate compliant with IS: 383-1970 specifications which is widely used for cement concrete testing. Two different sizes namely 10 mm & 20 mm were used.

FINE AGGREGATE: - The sand used was standard sand compliant with IS: 2116-1980 specifications which are widely used for mortar testing. The sand uniformly grade with grain size lying between 1-2mm was used as fine aggregate (F.A) throughout the work.

FRP GRIDS: - Fiber reinforced polymer grating is a composites manufactured by combining a matrix of resin and fiber. Fiber grating does not corrode like steel grating and is therefore used in corrosive environments to reduce maintenance costs. It is used in a variety of applications including walkways and overhead platforms. FRP grating is a structural product that can be weight-bearing between spans. Majorly grids are available in 20 mm and 25 mm thickness. A sample of grid of plan dimension 600 mmx1000 mm is tested under MSME Testing centre Mumbai 400072. And the various observations made are given as below in Table 2. A sample of FRP grid is shown in figure 2.

Table 2: Load Test

Test Description	Standard Specification	Test Results	Remarks
LOAD TEST 10 TONNES	10 MT For 30 Sec	Applied Compressive Load Of 10MT For 30 Sec. Observed No Cracks	Satisfactory

Figure 2 sample of FRP Grid

ADMIXTURE:-Admixture is the chemical which is added in order to alter the properties of concrete and make it more suitable for certain conditions where ordinary concrete may fail. Admixture is added along with cement, water and aggregates but the percentage should not exceed 2% by mass of cement. However the effect and result of using admixture is slightly difficult to predict. The effectiveness of admixtures depends on its chemical composition and the percentage of dosage used. The type of admixture which helps in reducing water are called plasticizer & super plasticizer. Plasticizer plays an importance in obtaining higher workability without using overweening quantity of water. Use of super plasticizer is very common these days as it permits the water reduction up to 10% hence reduces water-cement ratio without compromising the workability and thus naturally the strength of concrete gets improved. Here in the experimental study a super plasticizer of BASF chemical company has been used for making M30 and M 35 grade.

WATER:-Water is an important constituent material used for making concrete as it under goes in a chemical reaction with cement hence the quality of the water should be carefully looked into. The portable water from the structure lab of S.G.S.I.T.S, Indore is used for making concrete mix which is free from any sort of turbidity, colour compound and insoluble substances.

4 METHODOLOGIES ADOPTED FOR EXPERIMENTAL WORK

CASTING AND CURING DETAILS OF CONCRETE SPECIMENS:-In mixing process, the pan mixer was charged with the required quantity of coarse aggregate, then sand (S)

and cement (C) respectively. The water was weighed in a separate bucket. Before adding water pan mixer was rotated with solid mixture and allowed them to mix thoroughly then after 5-6 revolutions of mixer water was added slowly into the mixer. The slump was checked in fresh state of concrete by using the slump cone method.

Laboratory pan mixer (AMIL-India made) of 100 liters capacity was used for mixing various ingredients in the entire work. As a pre-treatment, all the aggregates namely: coarse aggregate, cement and sand are washed thoroughly with water and air dried to remove impurities like clay, silt and others.

The concrete mix of required grades were designed as per IS method the required quantities of various ingredients were weighed and placed in concrete mixer.

For each mix specimens like cubes and beams were casted according to the test requirement. The mix compaction was done with laboratory vibrator. Form work of the specimen are removed after 24 hours and cured in water (27°C ± 2°C). The age of cube testing were selected as 7 days & 28 days depending upon the standard testing methods to study the properties of concrete.

In FRP grid beams grid of thickness 25mm is laid on concrete after 20 mm clear cover. The concrete beams were tested after 28 days of curing.

TESTS AND TESTING METHODS OF CONCRETE: - In this experimental work, in addition to the workability flexural strength of different grades of concrete (plain &reinforced with FRP grids) is studied. The details of standard tests, size of specimen and age of test code have been given in Table 3.

Table 3 Tests and Testing Methods of Concrete.

S. No.	Test	Specimen Size(mm)	Age Of Testing	Apparatus
1	Slump Cone	20X30X60(H) (Frustum)	Fresh concrete	Standard slump cone
2	Compressive Strength	150X150X150 (cubes)	7 and 28 days	CTM
3	Flexural Strength	100X100X700 (beams)	28 days	UTM

COMPRESSIVE STRENGTH:-Test was carried out on cube specimen of size150mmx150mmx150mm. The compressive strength test was performed by keeping the cubes on the location marked in cube compression testing machine and load is applied centrally in a continuous uniform manner without shock in a uniform rate of loading of 25 ton/minutes. The applied rate of loading should be continuous until the cube specimen fails in compression.

FLEXURAL STRENGTH: - Test was carried out on beam specimen of size700mmx150mmx150mm. The flexural strength test was performed according to IS: 516 – 1959 using two point load method. The beam is placed is such that support system of UTM are spaced 5mm from both ends of the beam. Load is applied centrally with the help of load gauge which attached to the digital load meter, load is transferred to the in the form of two point load which generated with help of a steel plate and two reinforcement bar placed beneath the plate in a continuous uniform manner without shock in a uniform rate of loading of 25 ton/minutes. The applied rate of loading should be continuous until the cube specimen fails in compression.

METHODOLOGY:-The procedures for an experimental analysis for flexure strength are as follow

1. Procuration of material & testing of materials.
2. Design of trial Mix.
3. Casting of cubes & beam of various grades.
4. Comparison of the trial Mix.
5. Casting of beams reinforced with FRP grid.

MIX DESIGN:-The Mix design of total four grades of concrete viz. M20, M25, M30 and M35 using 43grade of OPC cement has been done. The proportion of various constituent materials like Coarse aggregate, sand, cement, water and admixtures have been calculated as per the mix design procedure explained in IS 10262-2009. The steps involved in mix design are presented in appendix A. The Quantities of different ingredients used for various grades of concrete are shown in Table 4.

Table 4: Quantities Various Grade of Concrete.

S. No.	Grade	Cement (kg)	Sand (kg)	C.A (kg)	Water (kg)	W/C	Density (kg/m³)	Proportion (C:S:CA)
1	M20	320	642	1393	160	.50	2512	1:1.98:4.49
2	M25	345	644	1358	156	.45	2503	1:1.84:3.93
3	M30	390	634	1296	159	.41	2479	1:1.65:3.32
4	M35	410	614	1290	155	.38	2469	1:1.56:3.14

NUMBER OF SPECIMEN CASTED AND CURED:-For testing compressive strength 6 cubes of size 150 mmx150 mmx150mm were casted (3 for 7 days strength and rest three for 28 days strength) for each grade and overall 24 cubes were casted. For testing flexural strength of a

particular grade beam of size 150mmx150mmx700mm were casted. The number of beams casted for flexural strength FRP grid is 8. For each grade two beams are casted which includes beam consisting of 500mm long FRP grid and 600mm long FRP grid. Plain beams are casted for each grade i.e. M35, M30, M25, M20 for comparison of result with beam consisting of FRP grid. Figure shows the fresh casting of beams.

Figure 3 Casting of Beam

5 DICUSSION AND INTERPRETATION

COMPRESSIVE STRENGTH:-The compressive strength of cubes casted for different grades viz. M20, M25, M30, M35 for 7 days and 28 days is calculated and flexural strength of beams reinforced with FRP sheet in single layer, FRP sheets in double layer and FRP grid is calculated by Compressive Testing Machine and Universal Testing Machine respectively.

For flexure strength two point loading method is used in UTM according IS 516(1959).

The crushing strength of concrete is determined by breaking various concrete cubes under CTM at uniform rate of loading. For each set of concrete 3 cubes were tested at end of 7 days curing and 3 cubes were tested at the end of 28 days curing. Table 5 shows the results of 7 days crushing strength (average values of three cubes) while table 6 (b) shows the results of 28 days crushing strength.

Table 5:7 Days strength crushing strength

S.No.	Grade	Mean Strength (MPa)	70% Of Mean (MPa)	Compressive Strength (MPa)
1	M20	26.56	18.60	18.03
2	M25	31.56	22.09	21.94
3	M30	38.20	26.74	26.78
4	M35	43.20	30.24	29.87

Table 6: 28 Days strength crushing strength

S.No	Grade	Mean Strength (MPa)	Compressive Strength (MPa)
1	M20	26.56	26.72
2	M25	31.56	32.43
3	M30	38.20	37.83
4	M35	43.20	42.79

FLEXURAL STRENGTH OF CONCRETE:-Flexural strength of concrete was calculated using two point load method. After 28 days curing of different grades of concrete beams the beams were kept for air drying for 24 hours. Beams are then brought to UTM for testing. In the first step of testing the beams were marked with chokes, two marking at a distance of 5mm from each support and 20 mm from each is marking near the supports. The beam was supported at the marking. Two point loads were provided with the help of steel bars over which steel plate was placed load is transferred with the loading gauge which is placed above the plate. Flexural strength tests on the concrete beam were done as per IS 516-1959.The loading gauge is connected with the digital machine which shows the exact value of load at failure.

The results such as bending moment, flexural strength, and area of steel for different grades i.e. M35, M30, M25, M20 are shown in Table 7 to Table10 and the bar chart of comparison are shown from figure 4 to figure 7.

Table 7: Result for Grade M35

Grade m 35		FRP GRID (CM)	
PARAMETER	PLAIN	2.5X15X50	2.5X12X60
LOAD(kN)	2.25	6.40	13.40
BM(kN-m)	2.47	6.28	13.14
A_{st}(mm²)	46.08	124.2	285.8
FS(MPa)	4.44	11.16	23.37

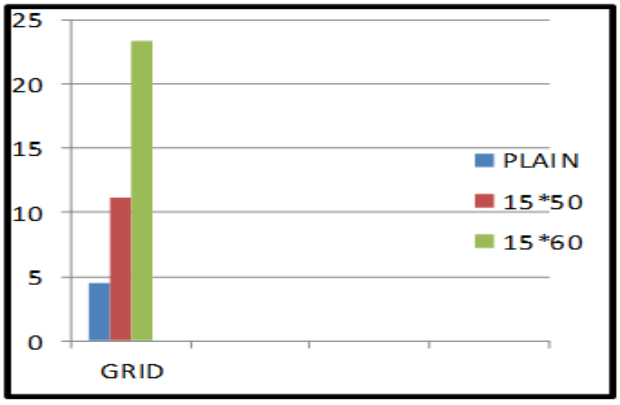


Figure 4 Comparison of Flexural Strength for M35 for different condition grid.

Table 8: Result for Grade M30

Grade m 30		FRP GRID (CM)	
PARAMETER	PLAIN	2.5X15X50	2.5X12X60
LOAD(kN)	2.19	5.95	11.28
BM(kN-m)	2.15	5.84	11.06
$A_{st}(mm^2)$	46.08	121	240
FS(MPa)	3.83	10.38	19.68

Figure 5 Comparison of Flexural Strength for M35 for different condition grid.

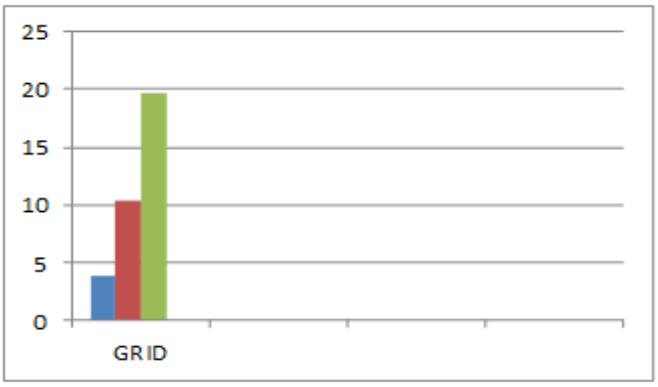


Table 9: Result for Grade M25

Grade m 25		FRP GRID (CM)	
PARAMETER	PLAIN	2.5X15X50	2.5X12X60
LOAD(kN)	2.0	5.69	10.88
BM(kN-m)	1.97	5.58	10.67
$A_{st}(mm^2)$	46.08	112.45	239.4
FS(Mpa)	3.5	9.92	18.974

Figure 6 Comparison of Flexural Strength for M35 for different condition grid.

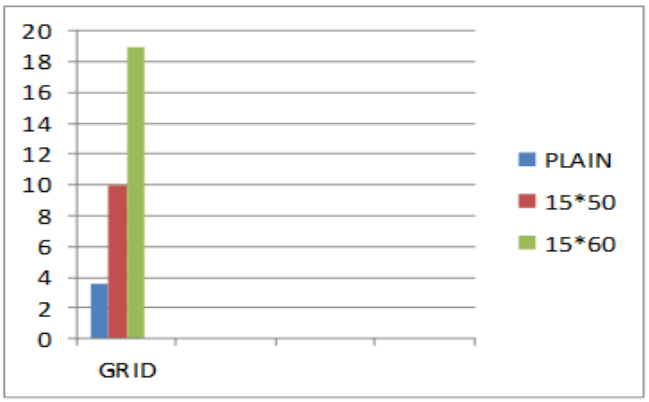
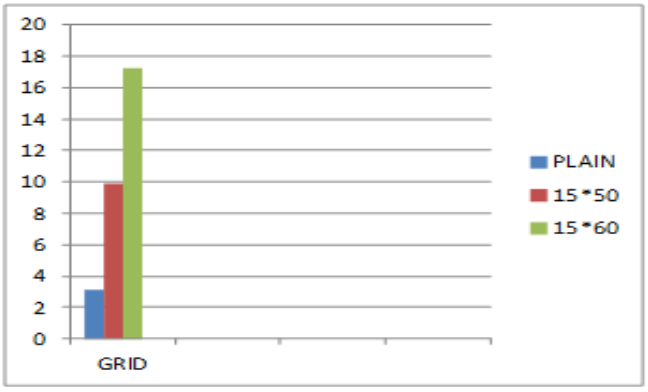


Table 10: Result for Grade M20

Grade m 20		FRP GRID (CM)	
PARAMETER	PLAIN	2.5X15X50	2.5X12X60
LOAD(kN)	1.79	5.65	9.9
BM(kN-m)	1.76	5.54	9.71
$A_{st}(mm^2)$	46.08	114.45	226.9
FS(Mpa)	3.13	9.85	17.26

Figure 7 Comparison of Flexural Strength for M35 for different condition grid.



6. Cost Benefit Analysis

In branch of civil engineering along with stability and strength of structure economic criteria of structure plays an equally important role. As we have observed an increase in flexural strength of concrete with the FRP sheets and grid. The comparison of cost for flexure strength of grid for different grades is tabulated below in table 11.

Table 11 Shows Cost Benefit Analysis

Grade	Dimension of Grid (cm)	Ast Required In Weight (Kg/m^3)	Price Per Unit Cubic Meter	FRP Provided In Weight (Kg)	Price Of FRP	Saving (Rs)
M 35	2.5*15*60	113.72	43*113.72=4890	13.8	13.8*100=1380	3510
	2.5*15*50	93.39	43*93.93 =4015.72	13.8	13.8*100=1380	2635.72
M 30	2.5*15*60	95.27	43*95.27 =4096.9	13.8	13.8*100 =1380	2717

	2.5*15*50	44.89	43*44.89 =1930.22	13.8	13.8*100 =1380	550.22
M 25	2.5*15*60	96	43*96 =4128	13.8	13.8*100 =1380	2748
	2.5*15*50	43.6	43*43.6 =1875.27	13.8	13.8*100 =1380	495.27
M 20	2.5*15*60	93.44	43*93.44 =4018.11	13.8	13.8*100 =1380	2638
	2.5*15*50	44.72	43*44.72 =1923	13.8	13.8*100 =1380	543

7. CONCLUSIONS:

In the laboratory different combination of FRP grid are used in concrete beam. After obtaining the result of flexural strength of different grade of concrete beam casted with FRP grid. Following are the conclusion:

For FRP grid:

- The flexure strength increases by using the FRP grid. It is concluded that the % increase in flexural strength ranges between 404 & 426 for M20 & M35 of concrete.
- As length of FRP grid increases strength is also increase.
- For higher grade of concrete higher flexure strength is obtained.

8. Future Scope

- As grid are formed in square or rectangle shape it is used as shear reinforcement in beam.
- FRP bars are used as reinforcement in column and as tie in column.
- FRP poses good strength as having light weight so it is used for member for light weight structure

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