Experimental Investigation of Concrete with CFRP

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Abstract*-This paper presents an experimental study carried out on RCC and PCC beams Strengthened in flexure with different configurations of CFRP (carbon fiber reinforced polymer). Currently many building and other structure are deteriorated due to age or poor construction. There are many techniques used for retrofitting like jacketing, fiber reinforced polymer(FRP) wrapping etc. In this research, beam size is respectively 150*150*1100 mm and 150*200*1100 mm. CFRP are used in 20 elements with 5 different cases externally wrap for PCC (plain concrete cement) and RCC (reinforced concrete cement) and also 4 different cases for internal CFRP as a grid are provided.*

Keywords-Carbon fiber, Moment carrying capacity, Retrofitting, Strengthening, Wrapping

I. INTRODUCTION

A structure is designed for a specific period and depending on the nature of the structure and surrounding environment, its life varies. Depending on usage of structure life of the structure are decided. During the life span of structural deterioration happens. The deterioration can be mainly due to environmental effects, which includes corrosion of steel, gradual loss of strength with ageing, repeated high intensity loading, variation in temperature, freeze-thaw cycles, contact with chemicals and saline water and exposure to ultra-violet radiations. Now to compensate deterioration, structure should be either replaced or properly retrofitted. As complete replacement or reconstruction of the structure costs very high compared to strengthening or retrofitting, so generally it is preferred to retrofit or strengthened the structure.

Retrofitting works are generally done by some techniques like FRP wrapping, Jacketing, near surface mounting reinforcing etc. Till date mainly Glass fibers, carbon fibers, basalt fiber, aramid fiber etc. are used for retrofitting works. Carbon fibers can be used for the same purpose. Carbon fiber has very high tensile strength and is also very lightweight. When it bonded to the exterior of a concrete column, beam, or slab, it can add significant strength without adding weight that would increase the load on foundations and other structural members. Carbon fiber can be bonded to concrete, masonry, steel and wood structures using a specially formulated structural epoxy to increase the load carrying capacity and ductility.

II. PHYSICAL AND MECHANICAL PROPRETIES

A. Physical properties

Carbon Fibre has High Strength to Weight Ratio (also known as specific strength). Carbon Fibre is very rigid. Carbon fibre is very rigid. Carbon fibre reinforced plastic is over 4 times stiffer than Glass reinforced plastic, almost 20 times more than pine, 2.5 times greater than aluminium. Carbon fibre is Corrosion Resistant and Chemically Stable. Although carbon fibre themselves do not deteriorate measurably, Epoxy is sensitive to sunlight and needs to be protected. Carbon fibre is Electrically Conductive. Carbon Fibre has good Tensile Strength and fatigue resistance. Carbon fibre can be made to feel quite soft to the hand and can be made into or more often integrated into protective clothing for firefighting. Carbon fibre low coefficient of thermal expansion. Carbon Fibres are brittle, in other words carbon fibre does not bend much before failing. Carbon is also very good resistor of ultra-violate rays. They do not degrade under ultra-violate rays. Carbon Fibre is Relatively Expensive. The low maintenance requirement of carbon fibre is a further advantage.

B. Mechanical Properties

Mechanical properties of Carbon fibres are as given in following Table 1.

Technical data	300 g/m^2
Weight per unit area of sheet (g/m^2)	330
Elastic modulus (KN/mm^2)	260
Tensile strength (N/mm^2)	3900
Fibre weight (g/m^2) (main direction)	300
Density (g/cm^3)	1.8
Elongation at rupture (%)	1.55
Design thickness (Fibre weight/density) (mm)	0.176

A. Carbon Fiber

Carbon fibre has very high tensile strength and is also very lightweight. When it bonded to the exterior of a concrete column, beam, or slab, it can add significant strength without adding weight that would increase the load on foundations and other structural members. Carbon laminate is a stiff composite plate use to enhance the flexural and moment enhancement for structure. It is available in Rolls of 100 m, 150 m, or cut to size. An unwinding reel is available upon request. Special dimension upon Request. Its elastic modulus is 260 kn/mm2 and tensile strength is 3900 n/mm2.

B. Epoxy

Epoxy resin are generally low molecular weight pre-polymers capable of being processed under a variety of conditions. Two important advantage of these resin over unsaturated polyester are: First they can be partially cures and stored in the state and they exhibit low shrinkage during cure. It is a 100% solids low viscosity epoxy resin able to cure in the presence of moisture and at temperatures as Low as 2 Ċ. The chemical resin has high chemical and corrosion resistance, good mechanical and thermal properties. It has two components, A – resin and B – hardener. Ratio of the components by weight is 100 parts of component B to 50 parts of component A shown in fig 1. Mixing is done thoroughly for 5 min with low speed mixer at 400 rpm until components are thoroughly dispersed. The properties of epoxy are mention in Table 2.

Table-2: Epoxy Properties

Properties (unit)	Value
Density (kg/l)	1.10 + 0.01
Mix Ration (Resin : Hardener)	50:100
Packing size (kg)	15 Kg
Tensile Strength (N/mm2)	22
Flexural Strength (N/mm2)	52
Initial tackiness (hours)	1.0
Final Set (Days)	1 (Days)
Bond strength in concrete	Failure in concrete
Coverage	0.25 – 0.35 kg / sq meter

C. Concrete

Concrete used in this experiment are of M25 grade general concrete. No any admixture is used.

IV. MIX DESIGN

The specified design strength of concrete is 25MPa at 28 days. The specific gravity of Fine Aggregates (FA) and Coarse Aggregates (CA) is 2.61 and 2.84 respectively. The standard deviation can be taken as 5MPa. Ordinary Portland cement was used of 53grade. Coarse aggregate is found to be Absorptive to the extent of 1% and free surface moisture in sand is found to be 2%. According to IS10262-1982 clause 3.3 Table no 3. The mixing water content calculated is 178 kg/m3. Mix proportion of M25 grade is shown in Table 3 & 4.

Table-3: Mix Proportion

Water	*Cement*	*Fine Aggregate*	*Coarse Aggregate*
197	*394 (kg/m3)*	*670*	*1176*
0.50	*1*	*1.70*	2.98

Table-4: Concrete mix design quantities

Grade of concrete: M25	Coarse aggregate(20mm): 2.65
Type of exposure: Mild	Coarse Aggregate(10mm): 2.65
Sp. Gravity of cement: 3.15	Maximum Water Cement Ratio: 0.4 95
Fine Aggregate: 2.65	

V. TEST PROGRAM AND RESULT

A. Test Program

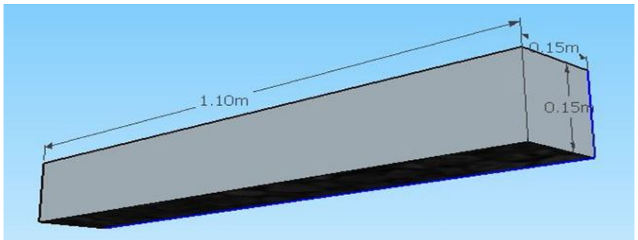
Table 5 summarizes the general experimental test program. This program consisted of testing thirty rectangular beams in order to evaluate the effect of externally bonded CFRP and internally provided as a grid to the different strengthening scheme for the entire beam length. A total of ten reinforced concrete beams having different CFRP configurations were fabricated in the laboratory for the strengthening purposes. First the beam testing in Universal testing machine until the crack was developed and crack repaired with cement paste and retrofitted with different configuration of CFRP and check the flexural strength gain by CFRP.

Table-5: Test Program

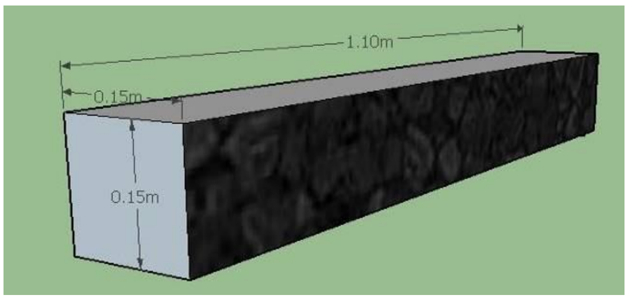
BEAM				
SIZE OF BEAM (B×D×L) (mm)	No. of Externally wrapped specimen		No. of Internally Wrapped Specimen	
	PCC	Reinforced	PCC	Internally CFRP grid
150×150×1100	5	5	1	4
150×200×1100	5	5	1	4

- **Externally wrapped cases**

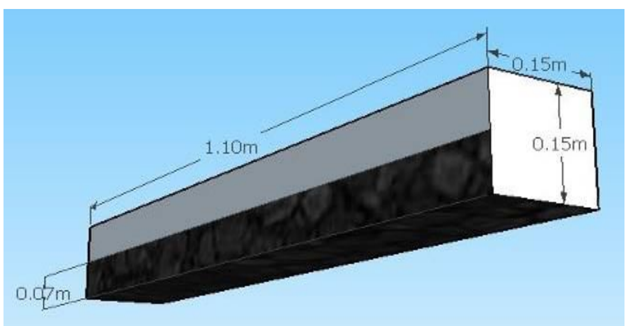
1. Bottom Wrap



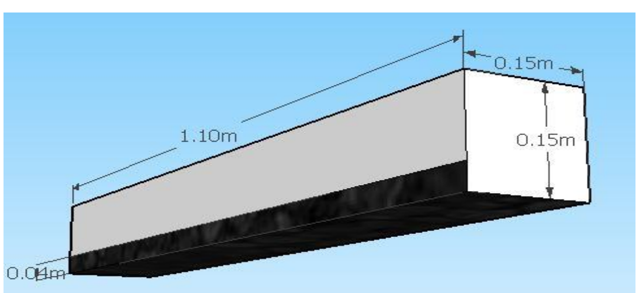
2. Side Wrap



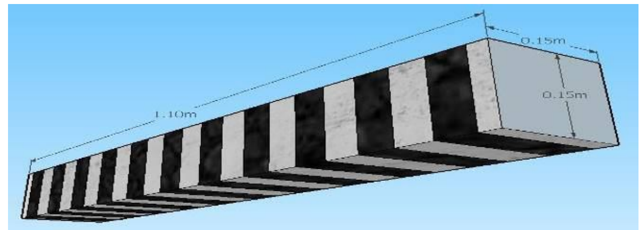
½ U Wrap



3. ¼ U Wrap

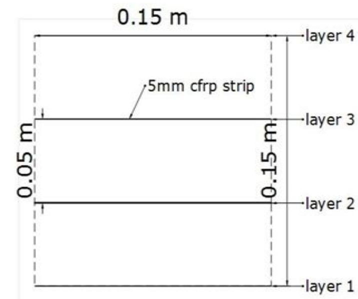


4. 50mm cfrp strip U wrap

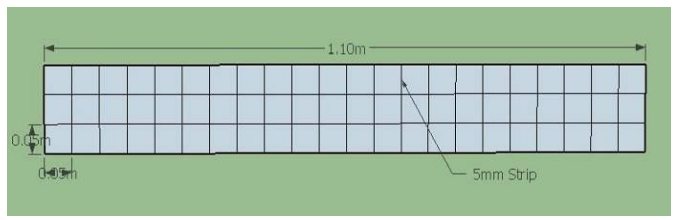


- **Internally wrapped cases**

1. 5mm strip 50mm spacing

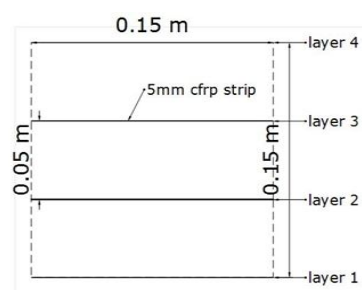


Cross-section



Plan

2. 5mm strip 75mm spacing



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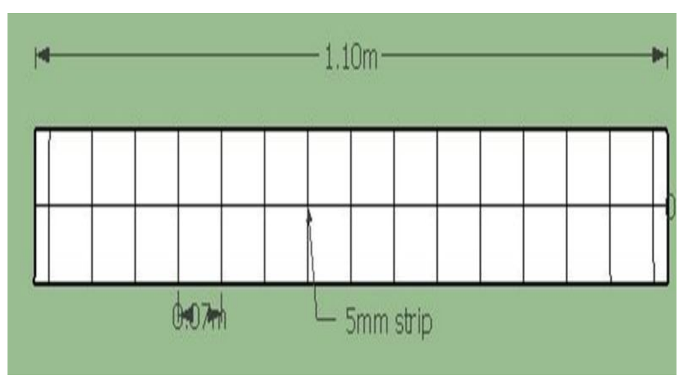
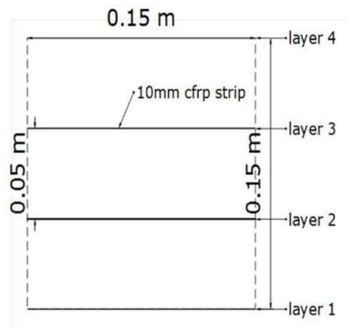


Plan

3. 10mm strip 50mm spacing



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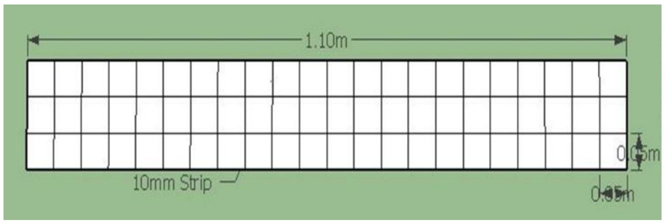
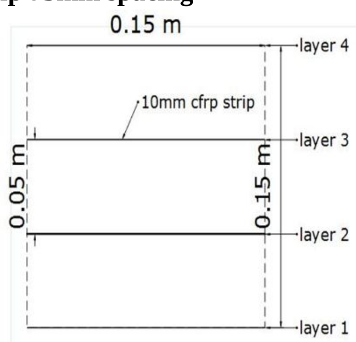
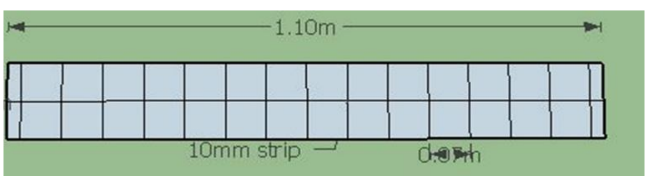


Plan

4. 10mm strip 75mm spacing



Cross-section



Plan

B. Results

❖ **Testing Results of internally cfrp as a Grid**

- Flexural Strength of control beam-1 (150×150×1100) =2.74 (N/mm^2)
- Flexural Strength of control beam-2 (150×200×1100) = 3.63 (N/mm^2)

Table-6 Results of internally cfrp

Case No.	Size of beam (B×D×L)(mm)	Description	Cracking load(KN)	Ultimate load (KN)	Flexural Strength (N/mm^2)
1	150×150×1100	CFRP Strip of 5mm width And 50mm spacing	17	22	4.82
2	150×150×1100	CFRP Strip of 5mm width And 75mm spacing	14.5	20.5	4.5
3	150×150×1100	CFRP Strip of 10mm width And 50mm spacing	20.5	26	5.7
4	150×150×1100	CFRP Strip of 10mm width And 75mm spacing	18	23	5.04
5	150×200×1100	CFRP Strip of 5mm width And 50mm spacing	34	43	5.3
6	150×200×1100	CFRP Strip of 5mm width And 75mm spacing	30	39	4.81
7	150×200×1100	CFRP Strip of 10mm width And 50mm spacing	38	50	6.16
8	150×200×1100	CFRP Strip of 10mm width And 75mm spacing	37.5	45	5.55

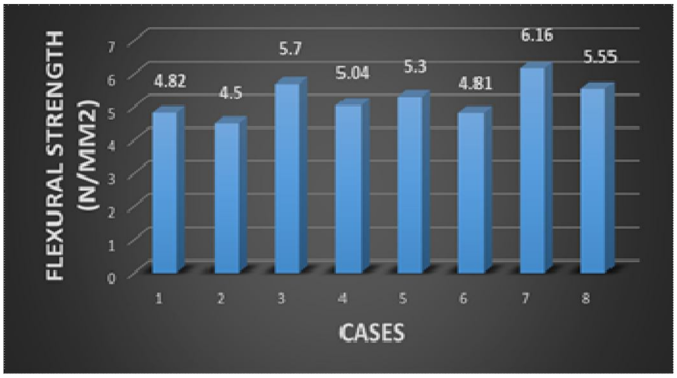


Figure: -1 Flexural Strength of Beams

❖ **Testing Results of Externally wrapped cfrp**

1. Results of PCC beams (150×150×1100) mm

Table-7 Results PCC beams

Wrapping Scheme	Crack load (KN)	After CFRP wrap Load (KN)
Bottom	17	11
Side	18	7
1/4th U wrap	17.5	12.5
1/2 U wrap	19	17
50 mm width U wrap	14	10

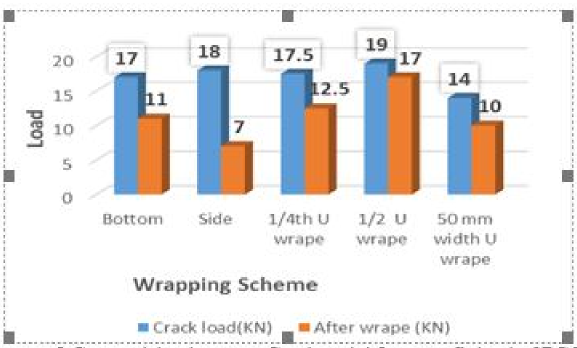


Figure:- 2 Comparision between Crack and After retrofit load of PCC beam

2. Results of RCC beams (150×150×1100) mm

Table-8 Results of RCC beams

Wrapping Scheme	Crack load (KN)	After CFRP wrape Load(KN)
Bottom	126	99
Side	123	84
1/4th U wrape	127	103
1/2 U wrape	131	128
50 mm width U wrape	142	129

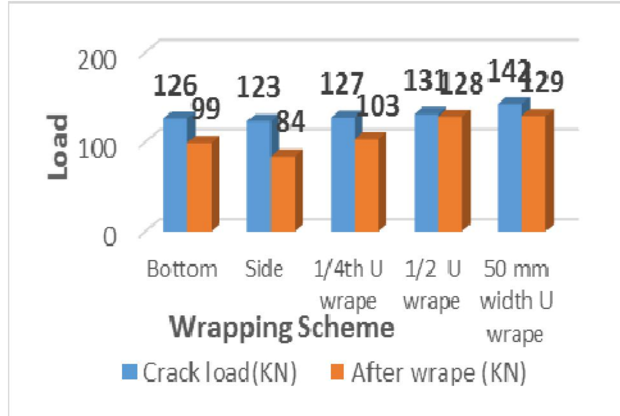


Figure: - 3 Comparision between Crack and After retrofit load of RCC beam

2. Results of PCC beams (150×200×1100) mm

Table-9 Results PCC beams

Wrapping Scheme	Crack load (KN)	After CFRP wrap Load (KN)
Bottom	26	14
Side	23	9
1/4th U wrap	27	18
1/2 U wrap	31	28
50 mm width U wrap	32	23

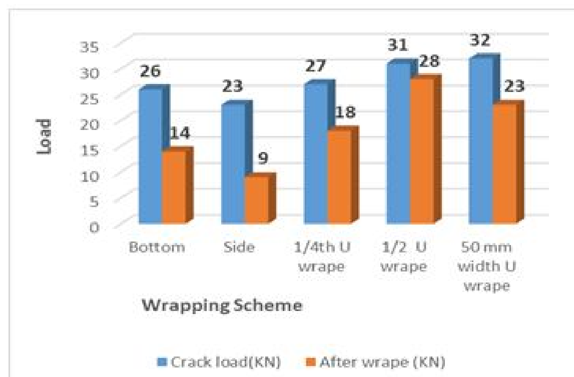


Figure: - 4 2 Comparision between Crack and After retrofit load of PCC beam

3. Results of RCC beams (150×200×1100) mm

Table-9 Results of RCC beam

Wrapping Scheme	Crack load (KN)	After CFRP wrap Load (KN)
Bottom	136	98
Side	141	86
1/4th U wrap	131	110
1/2 U wrap	140	138
50 mm width U wrap	138	126

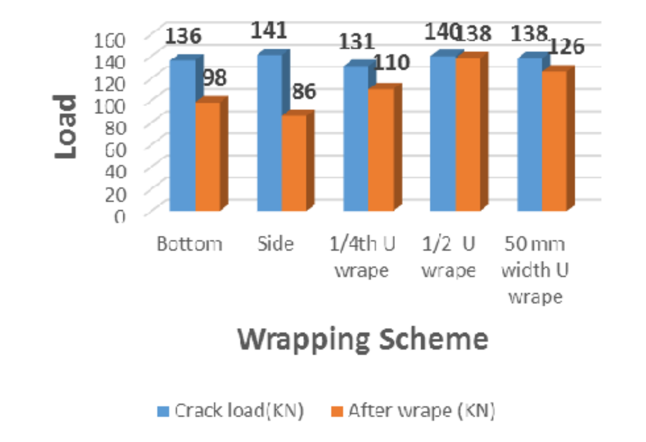


Figure: - 52 Comparision between Crack and After retrofit load of RCC beam

From the above Results and Graph Following Observation are made: -

- Percentage of Strength will be gain by retrofit with different configuration of CFRP and at different depth

Table: - 10 Retrofitted beams Strength in %

Wrap Scheme	Beam size (150×150×1100)mm		Beam size (150×200×1100)mm	
	PCC(%)	RCC(%)	PCC(%)	RCC(%)
Bottom	64.71	78.6	53.85	72.04
Side	41.66	68.2	39.13	60.9
1/4th U	71.43	81.1	66.67	83.9
½ U	89.5	97.7	90.32	98.57
50 mm width U strip	78.5	90.8	71.88	91.3

Also the strength of beam wrapped at ½ U is greater than the other configuration of CFRP. In Internally provided cfrp gave greater strength than the only pcc beams.

VI. CONCLUSION

1) From this research and from the result of this research project we can conclude that the CFRP wrapped at tension side gives better strength as compared to CFRP wrapped at two parallel sides but gives less strength as compared to CFRP wrapped at ½ depth U wrap along the length.
2) CFRP wrapped at ½ depth U wrap along the length gives higher strength but as the CFRP composite is costly it increasing the cost of construction so from an economic point of consideration CFRP wrapped at tension side to the beam is desirable.
3) From the above experimental it is clear that with the help of fabric wrapping strength of the exiting member increases.
4) For the mentioned different size of the beam it is clear that if we wrapped the beam mentioned carbon fiber configuration than strength increases in the case flexure and shear.
5) In RCC beams the Moment carrying capacity of bottom wrap beam, side wrap beam, 1/4th U wrap beam, ½ U wrap beam and 50mm width U strip is increased by 72-78%, 60-68%, 80-83%, 97-99% and 89-91% respectively.
6) In internally provided cfrp as a grid is almost gave double Flexural strength than the control beam.

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