Experimental Investigation on Strengthening of RCC beams by Wrapping Glass Fiber Reinforced polymer Sheet

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Abstract: *Use of Glass fiber reinforced polymer sheets (GFRP) as externally bonded reinforcement, is a technically sound and practically efficient method of strengthen and upgrade concrete members. Externally bonded GFRP sheets help in improving the structure performance by increasing its strength. The capacity of the strengthen beams is controlled by either compression crushing of concrete, rupture of GFRP and flexural shear cracking induced deboning at concrete GFRP interface. For phase 1deals with the use of externally bonded GFRP wraps in PCC beams with or without glass fiber carried out. The glass fiber were arranged externally in wrapping manner here. Epoxy resin is used to wind the glass fiber with concrete beams. GFRP wrapped at bottom side gives better strength as compared to GFRP wrapped at two parallel sides but gives less strength as compared to GFRP wrapped at three sides. It is noted that the flexural strength value where increased with respect to the curing days of 7, 28 days. And for phase 2 deals with the use of externally bonded GFRP wraps in three sides of RCC beams In all a total of 3 beams were tested and the respective reading were recorded. The beams were three sides wrapped and strip-wrapped and tested for flexural behavior analysis. Cracking and deflection of GFRP reinforced concrete beams analyzed experimentally. It was concluded, the wrapping of GFRP sheets increases the ultimate load carrying capacity of RCC beams. Also a cost analysis was done in order to get a cost effective solution for the issue of retrofitting structures.*

***Key Words*: Strength, Flexure, GFRP Sheets, PCC beams RCC beams, epoxy resin**

1. Introduction:

Deterioration of concrete structures is one of the major problems of construction industry now a days. Furthermore, a large number of structure constructed in past using older design codes in different parts of the world are structurally unsafe according to latest design codes and replacement of such deficient structure needs a huge amount of public money and time. Hence, strengthening become the acceptable capacity and extending their useful service life. Fiber reinforced polymer have emerged as promising material for rehabilitation of existing RC structures and strengthening of new civil engineering structures and strength of new civil engineering structures because of their several advantage such as high strength to weight ratio high fatigue residence, flexible nature, ease of handling and excellent durability. There are different types of FRP material are used for strengthening like glass fibers(GFRP), carbon fiber (CFRP),aramid fiber (AFRP)etc. but in terms of cost effectiveness and strength comparison many authors had recommended GFRP sheets among all. The use of external FRP strengthening to beam may be classified as flexural and shear strengthening. The shear failure of an PC beams is completely different from the flexure one as in that the flexural is ductile in nature, where the shear one is brittle and catastrophic, so, in flexural strengthening, FRP sheets are applied on bottom side of PCC beams whereas in shear strengthen, FRP sheets are applied on side face of PCC and RCC beams and three sides of PCC beams using proper epoxy adhesives. A fiber reinforced polymer (FRP) composite is defined as a polymer matrix, either thermo set or thermoplastic that is reinforced with a fiber or other reinforcing material with a sufficient aspect ratio to provide a discernible reinforcing function in one or more direction. FRP composites are different from traditional construction material such as steel or aluminium.FRP composites are anisotropic, therefore FRP composite properties are directional meaning that the best mechanical properties are in the direction of the fiber replacement. Reinforced concrete building may be vulnerable to progressive collapse due to a lack of continuous reinforcement. Glass fiber reinforced

polymer may be used for retro fix existing concrete beams and provide the missing continuity needed to resist progressive collapse. a fiber reinforced polymer matrix, either thermo set or thermos plastic that is reinforced with a fiber or other reinforcing material with a sufficient aspect ratio to provide a discernible function in one or more direction.

The increased applications of these materials to strengthening the reinforced concrete structures are due to their advantageous properties such as; excellent corrosion resistance, non-magnetic, non-conductive, generally resistant to chemicals, good fatigue resistance, low coefficient of thermal expansion, and high strength to weight ratio as well as being lightweight. Although the fibres and resins used in FRP systems are relatively expensive, compared with traditional strengthening materials like concrete and steel, the labour and equipment costs for installing FRP systems are often lower and these systems can be utilized in areas with limited access and where traditional strengthening techniques are impractical

2. Objectives:

The utilization of GFRP in concrete which solve the deterioration of concrete structures problem. It is the effective way to utilize in concrete.

1. It promises a great scope for future studies, following areas are consider for future research.
2. Strengthening of beam weak in shear
3. Effect of torsional strength due to retrofitting.
4. Developing a nonlinear finite element module for the analysis of the strengthened RC
5. Beams using various configuration of FRP strengthened.
6. Variation of beam dimension.
7. Strengthening of beam with different type of FRP(like Glass fiber reinforced polymer).

2.1 Scope of the present work

1. Experimental investigation on the following RC concrete beams.

2. Strengthening of RC concrete beams by retrofitting using GFRP by full wrapping and different percentage of wrapping and comparing results with control beam.

3. Glass fibre reinforced polymer (GFRP)

3.

Glass fibres are considerably cheaper than carbon and aramid fibres. Therefore glass fibre composites have become popular in many applications, the boat industry for instance. The moduli of fibres are 70-85 GPa with ultimate elongation 2-5% depending on quality. Glass fibres are sensitive to stresses corrosion at high stress levels and may have problems with relaxation. Glass fibres are sensitive to moisture, but with the correct choice of matrix, the fibres are protected. The manufacturing process for GRP fibre glass uses large furnaces to gradually melt the sand/chemical mix to liquid form, and then extrude it through bundles of very small orifices. The most common type of glass fibre used in resin matrix composite structures was used in this investigation. The principal advantages of E-glass are low cost, high tensile and impact strengths and high chemical resistance. The principal advantages of E-glass are low cost, high tensile and impact strengths and high chemical resistance. The disadvantages of E-glass, compared to other structural fibres, are lower modulus, lower fatigue resistance and higher fibre elasticity range from 70- 85 GPa with ultimate elongation of 2 – 5 % depending on quality. In general, fibre composites behave linearly elastic to failure.

Table -1: Properties of BASF ® EP (GF)

Properties of GFRP	Value
Density of fiber, g/cc	2.8
Weight of fiber,g/m^2	950
Fiber thickness, mm	2
Tensile strength , N/mm^2	3500
Tensile modulus, N/mm^2	74000

3.1 Applications of GFRP

There are several applications of GFRP in infrastructure as that of automotive and aerospace industries

1) It is used in the reinforced concrete
2) It is used for repair and rehabilitation works
3) It can also be used in hybrid structures
4) It can be used in the smart materials used in the construction industry
5) It can also be a part of the ground anchoring
6) It is used in the making of architectural panels
7) GFRP has got infinite possibilities

3.2 Epoxy Matrix

Epoxy or polyepoxy is thermosetting polymer form Ed From reaction of an epoxies "resin"with polyamine "hardener". Epoxy has a wide range of applications, including fibre-reinforced plastic materials and general purpose adhesives. The matrix should transfer forces between the fibre and protest them from the surroundings. Polymeric matrices are of two types, Thermo sets (Polyester, Phenolics, Epoxy, & Silicones) and Thermoplastic, of which thermo sets, are most widely used. Epoxy resins are generally used and it imparts good mechanical properties.

Epoxy Primer - It consists of BASF 30, a two –part clear solvent free sealer. The surface of the application area should cleaned using sand paper and should be dust free. The primer has a density of 1.14 g/cc and a pot life of 25 min. @ 27° C. The mixed material of BASF 30 epoxy primer is applied over the prepared and cleaned surface. The application shall be carried out using a brush and allowed for drying for about 24 hours before application of saturant.

Epoxy Saturant–The success of the strengthening technique critically depends on the performance of the epoxy resin used. Numerous types of epoxies with a wide range of mechanical properties are commercially available. The saturant provided comprised of BASF 410, a two part system consisting of resin and hardener.

Table -2: Properties of Epoxy Saturant

Colour	Pale yellow to amber
Temperature	15°C - 40°C
Density	1.25 - 1.26 g/cc
Pot Life	2 hours at 30°C
Cure time	3 days at 30°C

3.3 Design of beam

Length of beam =1.5m
F_{ck} = 30N/mm^2
Total length of the beam =1500mm

Clear span (L) =1500-300=1200mm

Effective span =1200mm

D = 200mm
B = 150mm
d =200-25-12-12/2 = 157 mm
After designing with reference to Sp-16

Obtained Reinforcement details – 3#12mm dia bottom 2# 10mm top and shear 2LVS 8mm dia bars @ 150 mm c/c.

4. Experimental work:

4.1 Materials used:

Cement: The cement used in the investigation is Ordinary Portland cement of 53 grade which is conforming to the code as per IS 4031-1988.

Fine Aggregate: The locally available river sand is used as fine aggregate. The fine aggregate used which have fineness modulus of 3.41, specific gravity of 2.62 and conform to grading zone-II as per IS: 383-1970 specification.

Coarse Aggregate: The locally available quarry crushed angular aggregate is used as coarse aggregate of size 20mm.The aggregate used which have specific gravity of 2.48 and fineness modulus of 7.95.

Fig -1: GFRP 10 MICRON SIZE

Fig -2: GFRP TRIAXIAL 1200 GSM

Fig -3: PCC beam

Fig -4: RCC beams

4.2Mix Proportion:

The concrete mix is designed as per IS 10262-2006 and IS 456-2000.Mix ratio of 1:1.66:3.09 with w/c ratio of 0.45.

4.3 Specimen Casting:

Weight batching is made and GFRP fiber is added to wraping of concrete. The prism is compacted well with tampering rod. Finally prism is demoulded and allowed for curing for 7 & 28 days.

4.4 Test Specimens:

4.4.1 Casting of PCC beams:

The test specimens of concrete prism size 700mmx150mmx150mm are casted and cured for 7 and 28 days.

4.4.2 Casting of RCC beams:

1. The beams were designed by limit state method considering the section to be under reinforced according to IS: 456-2000 code.

2. Moulds of 1500*150*200 mm size were prepared by using plywood sheets.

3. Concrete of M30 grade was designed as per IS10262 -2009,the mix proportion is 1:1.66:3.09ratio(cement ,Fine aggregate and coarse aggregate), and the concrete was machine mixed.

4. First the entire mould was oiled. So that the beams can be easily de-moulded from the mould after 24 hours.

5. Cover blocks of size 25mm are used to provide uniform cover to the reinforcement, when the bars have been placed in position.

6. Concrete mix was poured in layers and compacted using tamping rods & vibrator, the compaction is done until the mould is completely filled and there are no voids.

7. The beams were then removed from the mould after 24 hours. Then the beams were cured for 28 days using jute bags.

5. Experimental method:

The flexural tests carried in Universal Testing Machine for PCC beams and Loading frame for RCC beams. The prism is tested for 7 and 28 days. The flexural strength test gives the maximum bearable load that concrete can with stand.

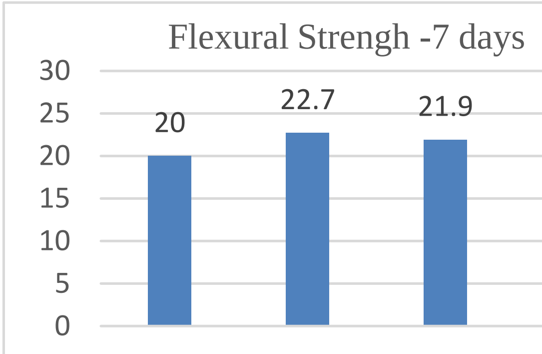
6. Result and Discussion for PCC beams:

The flexural strength of M30 concrete beams B1, B2, B3 cured for 7 and 28 days were tested on Universal Testing Machine. The following results of failure load were found out on plain concrete beams. One side GFRP wrapped concrete beams, two sided parallel GFRP wrapped concrete beams and three side wrapped GFRP

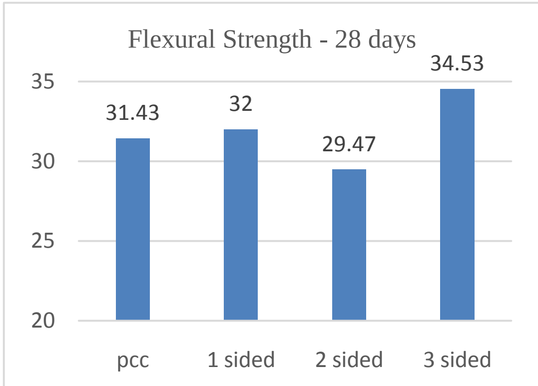
Table -3: AverageFlexural Strength for GFRP 7-days

Beam	PCC beam (kN)	1 side wrap (kN)	2 Side wrap (kN)	3 Side wrap (kN)
B 1	18.6	22.4	21.3	26.6
B 2	19.4	21.1	20.7	24.8
B 3	22	24.6	23.6	25.1
Avg.load	20	22.7	21.9	25.5

Graph 1: **F**lexural Strength of beams (7 Days)



Graph 2: **F**lexural Strength of beams (28 Days)



6.1 Test Programme on RCC beams

The control beam is tested for its ultimate load and deflection and compared with the values of ultimate load and deflection obtained after testing the retrofitted beams.

Fig -5: Test on loading frame

6.2 Results

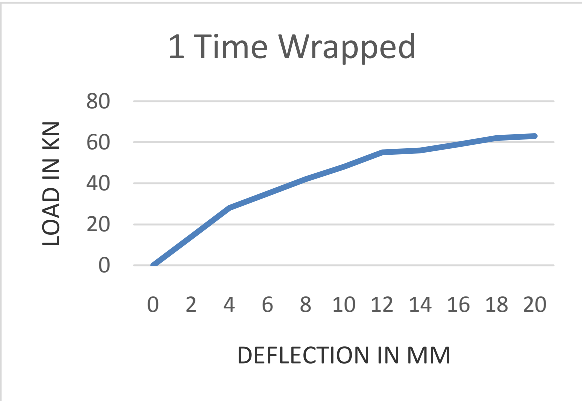
The experiment and analysis has been carried out for three beam structures. Initial analysis and experimentation has been done on control beam. Later they have been carried out for beams with various degree of wrapping or with different patterns of wrapping. The values of the control beam and the retrofitted beam are compared.

6.3 Control Beam

Beam wrapping 1 times

The first crack was appeared at 29 KN and the structure failed at 62 KN with maximum deflection of 19.56mm

Graph 3: Load Vs Deflection Curve (1 Time Wrapped)



Beam wrapping 2 times

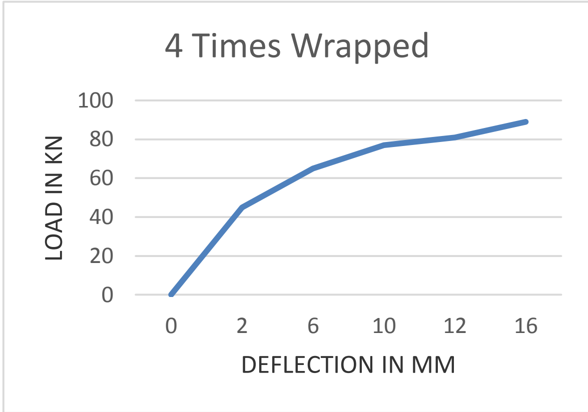
The first crack was appeared at 19 KN and the structure failed at 75 KN with maximum deflection of 16.27mm

Graph 4: Load Vs Deflection Curve (2 Times Wrapped)

Beam wrapping 4 times

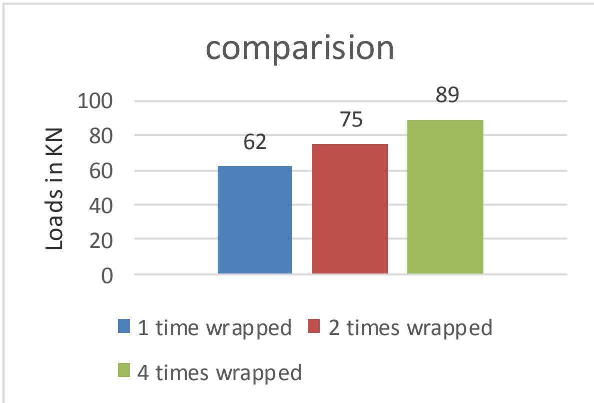
The first crack was appeared at 22 KN and the structure failed at 89 KN with maximum deflection of 15.65mm.

Graph 5: Load Vs Deflection Curve (4 Times Wrapped)



6.4 Beams test comparison:

Graph 6: Ultimate Load (Comparison)



7. CONCLUSIONS

The experimental investigation conclusion from the flexural strength is described here

1. Hence the behaviour of rectangular concrete beam with GFRP wrap has been studied and the strength and behaviour of concrete beams with respect to conventional concrete beams are discussed.
2. From this research and from the result of this research project we can concluded the GFRP.
3. GFRP wrapped at tension side gives better strength as compared to two parallel sides.
4. But gives less strength as compared to GFRP wrapped at three sides.
5. GFRP wrapped at three sides gives higher strength.
6. But as the GFRP composites is costly it is increasing the cost of construction so from an economic point of

consideration GFRP wrapped at tension side to the beam is desirable.

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