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STRENGTEHNING OF R.C.C BEAM BY FRP TECHNIQUES

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ABSTRACT

This paper develops the Strengthening of existing reinforced concrete structure. The upgrading of existing structures is an integral part of structural engineering practice and requires a dedicated solution at hand. Structural repair and rehabilitation of reinforced concrete structures is becoming an increasing important option for all deteriorated/damaged structures to restore, enhance the load carrying capacity and increase the life span of the structure. Some of the main reasons of structural strengthening are increase in dead and live load material aging and corrosion, mechanical damage, design and construction failures, modification of structure scheme and natural disaster due to earthquake and hurricanes.

***Keywords:* Reinoforced concrete,FRP,CFRP.**

I. INTRODUCTION

In recent years, an increased application of new repair and strengthening techniques of reinforced concrete structures has been noted. The problem of strengthening the reinforced concrete structures appeared for the first time when their proper function was modified or they were used in a different manner than previously planned. Assumptions made in the design are closely connected with a specific function of the structure. The designers of the existing reinforced load carrying structures constructed many years ago could not predict their use in practice and determine all deterioration effects produced by external factors during their service. It was not rare to find that in this way some structural members could be deteriorated or even damaged. In most cases the increased dead and live loading that should be safely carried by the structures, as well as their poor technical condition necessitate strengthening procedures. Some of the main reasons of structural strengthening are increase in dead and live load material aging and corrosion, mechanical damage, design and construction failures, modification of structure scheme and natural disaster due to earthquake and hurricanes. Also, it is important for structural members to have adequate strength and stiffness so as to assure stable performance of buildings. As a result, large numbers of structures are in need of rehabilitation, retrofitting or replacement.Strengthening of the reinforced concrete structures is one of the most difficult and important tasks of civil engineering. Individual approach to the problem is a necessity since any ready-made solution can be applied. One of the main objectives is to provide detailed technical and cost-effective analysis. Structures must be carefully examined in order to determine their technical condition, to find reasons for deterioration and strengthening as well as to establish service requirements of the reinforced structures. Cost -effectiveness of each of the proposed strengthening techniques should be considered and compared to the cost of a new structure. The strengthening methods applied should ensure the required safety margin and guarantee a sufficient reliability over time.

1.1 Conventional Methods of Strengthening of Beams

The following methods used for strengthening the reinforced concrete beams can be distinguished according to their application way; Increase of the cross-sectional area of a beam, and modification of the structural static scheme Conventional techniques using the increase of cross sectional area of a beam comprise the following:

Encasement of the existing RC members with an additional layer of concrete plus additional longitudinal and transverse reinforcement i.e., RC jacketing additional steel sections. Adhesively bonded or bolted steel flat sections or sheet elements. Steel plate jacketing and steel plating - encasement of the existing RC members with thin steel plates placed at a small distance from the beam surface, with a gap filled with non-shrink grout. Steel Plate Jacketing provides confinement to RC beam and hence increases the load carrying capacity. Modification of the structural static scheme is accomplished by means of additional steel beams which is transferred to the column through which the load directed to the foundation.The main disadvantages of using steel plates are steel corrosion in the adhesion zone, heavy weight and excessive size of single plates. Consequently, corrosion protection is required and the handling of the heavy steel plates is difficult, and undesirable formation of welding, partial composite action with the surface concrete and de-bonding and difficulties in the other techniques, these disadvantages have led to the use of the fibre reinforced plastic (FRP) composites as the alternative to the steel plates.

1.2 Externally Bonded Frp (Fibre-Reinforced Polymers)

One of the state-of-the-art methods used for strengthening the structural members are those utilizing fibre-reinforced composite materials such as strips, wraps, sheet elements or shapes. Over the last decade new alternative solutions are being developed for civil infrastructure applications to meet the growing demand since a conventional technology is known for its many shortcomings and limitations. For both new construction and strengthening of older reinforced concrete structures, the use of fibre reinforced plastics has increased steadily. New and improved ways of construction, repair, strengthening and rehabilitation are urgently sought. Fibre reinforced polymers offer many beneficial characteristics over steel. Fibre reinforced polymers (FRP), are what people referring to as composites. A composite is a material formed from two or more separate parts with a distinguished phase between them. Composite will in the following refer to fibre-reinforced polymers. This is a composite where polymer matrix is reinforced with many relatively thin and long fibres. These composites are to be found in sports equipment, aircraft and the spacecraft industry. 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 (typical design tensile strength=300MPA) as well as being lightweight. FRPs also possess a high specific stiffness and an equally high specific strength in the direction of fibre alignment. An additional advantage of FRPs is in the endless ways in which polymers and fibres can be combined in a material to suit the specific needs of a structure. Use of FRPs provides a high structural efficiency, and their low density makes physical implementation much easier. FRPs are expensive, but savings in reduced periodic maintenance, longer life spans and of reduced labour costs often offset the higher costs of FRP materials. 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.

1.3 Objectives of the Research

The main objectives of the research include:

- To evaluate the effectiveness of the external CFRP wrapping technique .
- To study the ultimate load carrying capacity for the flexural strength of the specimens retrofitted by FRP wrapping technique.
- To evaluate effect of wrapping patterns of FRP on the ultimate strength of confined concrete.
- To evaluate the efficiency of the FRP fabrics in terms of utilization of the strength and deformation capacity of the FRP materials
- Comparison of the results obtained of the retrofitted and concrete beams with different percentages of wrapped concrete beams.

1.4 Scope of the Present Work

- The scope of the present work is restricted to the following:
- 1. Experimental investigation on the following RC concrete beams.
- A. Strengthening of RC concrete beams by retrofitting using CFRP by full wrapping technique.
- B. Strengthening of RC concrete beams by retrofitting using CFRP by strip wrapping technique.
- 2. To make a comparative study of the results obtained by the experimental investigation of the retrofitted with full wrap and strip wrapping of concrete beams.
- 3. To suggest suitable recommendations for practicing engineers.

II. LITERATURE REVIEW

A lot of research has been done on the FRP as reinforcement in concrete beams. However, the amount of research conducted on FRC as a sheet is quite less. The previous research work considered in this chapter is divided in three parts; the first part is about the effect of FRP on RC beams followed by the analysis of RC beams wrapped with FRP.**Marco et al. (1997)** conducted experiments on strengthened, precracked RC beam specimens. Strengthening was attained with adhesion of CFRP sheets to the concrete surface. The direction of fibres was in most cases arranged in parallel to the axis of beam (longitudinal direction or 0^0) in order to act as flexural reinforcement. To simulate geometry of shallow beams, the height to width ratio (h/b) was kept equal to 0.5; whereas deeper section geometry (h/b)= 2 was considered for simulating the behaviour of deep beams.This is the major conclusion which will be important one for further work. Also FRP strengthening effectiveness depends on cross section shape and amount of steel reinforcement. **Naaman et al. (2001)**studied parameters influencing flexural response of RC beams strengthened using CFRP sheets. The experimental program comprised of 14 RC T beams. It was observed that beams strengthened with CFRP interfacial shear failure that occurs within concrete, instead of tensile failure of CFRP sheet or plate. Ultimate load capacity was increased and deflection was reduced. If cover is less for a strengthened beam then also there is not much need of consideration. Also preloaded and precracked beam beyond reinforcement yielding had no serious influence on strengthening effect, So CFRP bonding technique can be applied to seriously damaged beams. **Duthinh et al. (2002)**studied strength & ductility of RC beams wrapped with CFRP. Referring to work carried out by **Naaman**

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et al. (2001)study was carried out. From the test results, it was observed that Carbon FRP plates are very effective for flexural strengthening of RC beams, provided proper anchorage of FRP is ensured. Clamping or wrapping of the ends of the precured FRP plate enhances the capacity of adhesively bonded FRP anchorage.

III. MATERIAL PROPERTIES

3.1 General:

Laboratory investigations carried out on cement, aggregates, steel and cement mortar and also on concrete which are used for casting test specimens have been presented. The properties of different types of FRPs and bonding materials as given by the manufacturer including bonding applications are discussed.

3.2 Materials

The various materials used in the experimental work are Cement, fine aggregate, coarse aggregate, reinforcing stdeel, CFRP and GFRP sheets, and wire mesh. Each of the material used in the experiment has been discussed in detail below.

3.2.1 CEMENT

In the present work, Ordinary Portland Cement of 53 grade conforming to IS:12269-1987 has been used. The physical properties of the cement obtained on conducting appropriate tests as per IS: 269/4831 and the requirements as per IS 12269-1987 are given in Table 3.1

3.2.2 FINE AGGREGATE

Locally available clean river sand passing IS:480 sieves have been used.(a)Sieve analysis: The results of sieve analysis conducted as per the specification of 383:1970 are given in table 3.2

The fine aggregate was of Zone III.

Fineness Modulus = 218.6/100=2.186

(a) Specific gravity = 2.604

(b) Water absorption = 1.01 %

3.2.3COARSE AGGREGATE

The coarse aggregate used is crushed (angular) aggregate conforming to IS 383: 1970.the maximum size of aggregate considered is 10mm. The coarse aggregate used IS passing 10mm IS sieve and retaining 6mm IS sieve.

- Water absorption of C.A = 0.502%
- Specific gravity of C.A = 2.684.

3.2.4 REINFORCEMENT

The reinforcement for the concrete column is in the form of 8 mm diameter bars of Fe415 grade of steel as longitudinal reinforcement and 6mm diameter plain steel bars were used as lateral stirrups.

3.3 COMPOSITES

Composite materials (or composites for short) are engineered materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct on a macroscopic level within the finished structure. They are reinforcing phase. in the form of fibres, sheets. or particles. and are embedded in the other materials called the matrix phase. The reinforcing material and the matrix material can be metal, ceramic or polymer. Some of the main factors for using the composites are

- Weight reduction
- Corrosion resistance
- Design f1exibility

The strength of the composites depends primarily on the amount, arrangement and type of fibre (or particle) reinforcement in the resin. Typically, the higher the reinforcement content the greater the strength. In some cases, glass fibers are combined with other fibers such as carbon or aramid, to create a hybrid composite that combines the properties of more than one reinforcing material.

3.3.1 FIBRE REINFORCED POLYMERS (FRP)

The composite properties are mainly influenced by the choice of the fibers. In civil engineering three types of fiber dominate. These are carbon, glass and aramid and the composite is often named by the reinforcing fiber e.g., GFRP for Glass fiber reinforced polymer. They have different properties, including price, which make one more suitable than the other for different purposes. All fibres have generally high stress capacity than ordinary steel and are linear elastic until failure.

3.3.2 CARBON FIBRE REINFORCED POLYMER (CFRP)

Carbon fiber (alternatively called carbon fiber, graphite fiber or carbon graphite)is a material consisting of extremely thin fibers about 0.005-0.010 mm in diameter and composed mostly of carbon atoms. Carbon fiber has many different weave patterns and can be combined with a plastic resin and wound or molded to form composite materials such as carbon fiber reinforced plastic (also referenced as carbon fiber) to provide a high strength-to-weight ratio material. The density of carbon fiber is also considerably lower than the density of steel, making it ideal for applications requiring low weight. The properties of carbon fiber such as high tensile strength, low weight, and low thermal expansion make it very popular in aerospace, civil engineering, military, and motorsports, along with other competition sports. Carbon fibers have high modulus of elasticity, 200-800 GPa. The ultimate elongation is 0.3 - 2.5% where the lower elongation corresponds to a higher stiffness and vice-versa. Carbon fibers do not absorb water and are resistant to many chemical solutions. They withstand fatigue excellently, do not stress corrode and do not show any creep or relaxation, having less relaxation high tensile prestressing steel strands. Carbon fiber is electrically conductive and, therefore, might give galvanic corrosion in direct contact with steel. Figure 3.4 shows the carbon fiber sheets used in this study. The carbon fiber supplied by the manufacturer (Fosroc Chemicals (India) Pvt.Ltd.) was designated as Nit wrap® EP(CF) and their properties are summarized in table 3.3.

3.3.3 EPOXY MATRIX

Epoxy or polyepoxide is a thermosetting polymer formed from reaction of anepoxide "resin" with polyamine "hardener". Epoxy has a wide range of applications, including fiber-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, Thermosets (Polyester, Phenolics, Epoxy, & 'Silicones) and Thermoplastic, of which thermosets, are most widely used. Epoxy resins are generally used and it imparts good mechanical properties. The epoxy resin system used comprises of

3.3.3.1 EPOXY PRIMER- It consists of Nitowrap 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 Nitowrap 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.

3.3.3.2 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 Nitowrap 410, a two part system consisting of resin and hardener. The properties of the saturant is listed below:

Table and figures: Properties of cement in table.3.1

SI.No	**Properties**		**Values obtained**	**Requirements as per IS:12269-1987**
1	Fineness		2.8%	Not more than 10%
2	Soundness		1 mm	Not more than 10mm
3	Setting Time	Initial	42 mins	Not less than 30 min
		Final	385 mins	Not more than 600 min
4	Compressive strength: 3 days		$32N/mm^2$	Not less than $27N/mm^2$
	7 days		$48N/mm^2$	Not less than $37N/mm^2$
	14 days		$66N/mm^2$	Not less than $53N/mm^2$
5	Standard consistency		31%	----
6	Specific gravity		3.15	

Table 3.2 Grading of fine aggregate

IS sieve size (mm)	Weight retained(gm)	Cumulative weight retained(gm)	Cumulative % weight retained	Cumulative % passing
4.75	50	50	5	95
2.36	20	70	7	93
1.18	70	140	14	86
600μ	84	224	22.4	77.6
300 μ	494	718	71.8	28.2
150 μ	266	984	98.4	1.6
pan	20	1004	100.4	-0.4

Properties of CFRP	Value
Density of fibre, g/cc	1.8
Weight of fibre, g/m^2	20
Fibre thickness, mm	0.3
Ultimate elongation	1.5%
Fibre orientation	Unidirectional
Nominal thickness per layer, mm	1
Tensile strength, N/mm^2	3500
Tensile modulus, N/mm^2	285000

Table 3.3: Properties of Nitowrap® **EP (CF)**

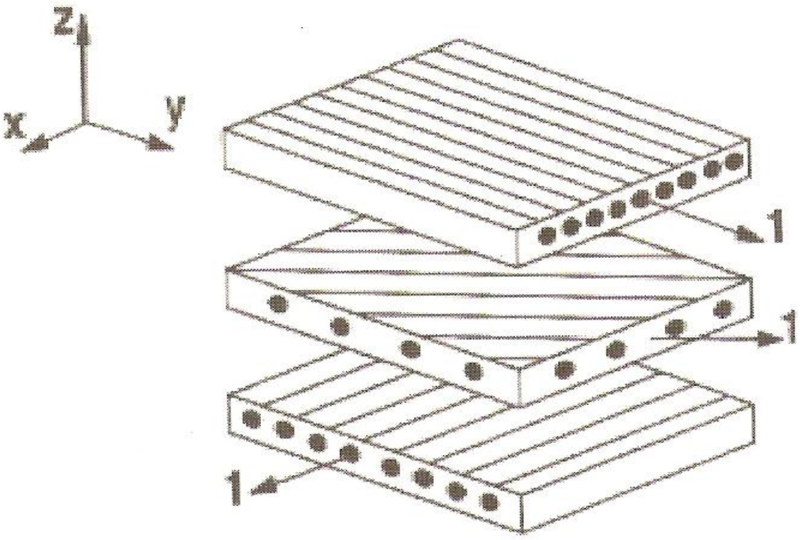


Fig 3.1: Assembly of three layers into a laminate

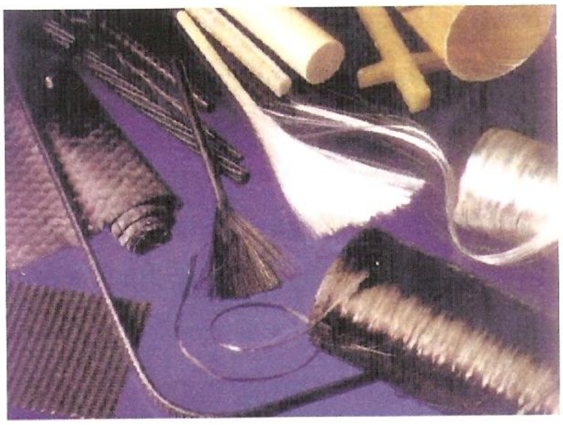


fig 3.2: Common glass and carbon fibers and FRPs used in structural engineering

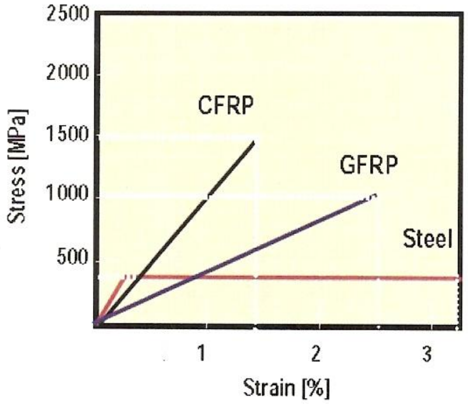


Fig 3.3: Properties of FRP in comparison with steel

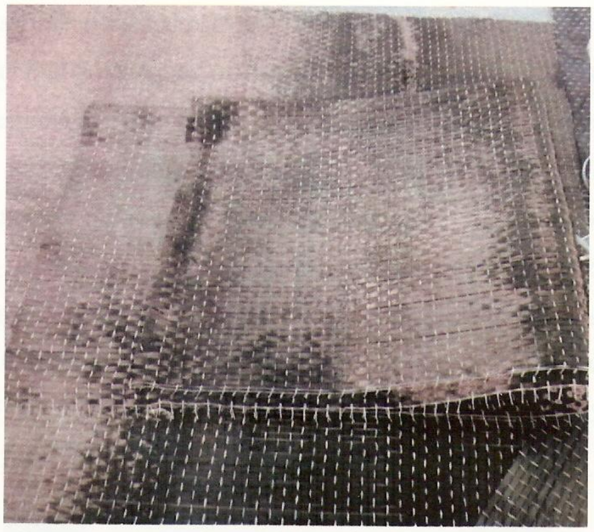
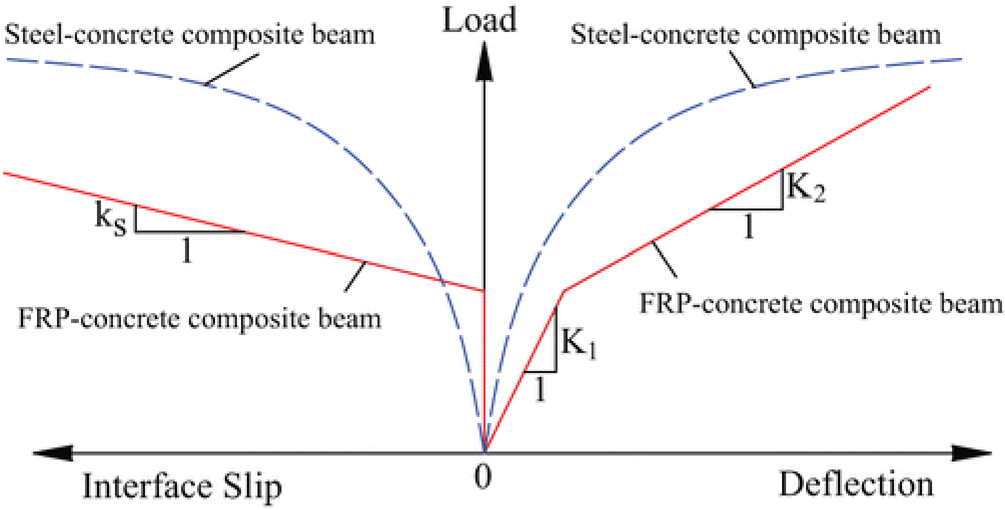


Fig 3.4: Carbon fibre reinforced polymer (CFRP) sheet

Colour	Pale yellow to amber
Application temperature	15°C - 40°C
Density	1.25 - 1.26 g/cc
Pot Life	2 hours at 30°C
Cure time	5 days at 30°C

Table 3.8: Properties of Epoxy Saturant



Analytical load–deflection curves and load–slip curves.

V. CONCLUSIONS

Results of experiments conducted on five reinforced concrete beams which include controlled, retrofitted beams using the techniques, wrapping of Fibre reinforced Polymer(FRP) have been presented.

1. Beam retrofitted with 25% CFRP was found to carry 67.48% more load than the control beam
2. The beam retrofitted with 16% CFRP was found to carry 57.26% more load than control beam
3. The beam retrofitted with 12.5%CFRP was found to carry 42.95% more load than control beam
4. The beam retrofitted with 10.44%CFRP was found to carry 14.375% more load than control beam
5. The load vs deflection curve indicates that the CFRP retrofitted beams are more stiffer
6. CFRP for retrofitting has proven itself to be a better feasible option than other methods. So the future prospects for the utilisation of CFRP in Civil engineering infrastructure are good. Based upon the test results of the experimental study undertaken, the following conclusions may be drawn:
7. Load carrying capacity of retrofitted beam was improved as compared to fresh beams.

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