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# Confinement of Concrete by Carbon Fiber Wraps by Varying the L/D Ratio, Geometry and Grades of Concrete

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***Abstract*— The objective of this research is to investigate the effectiveness of carbon fiber wrapping for improving the compressive strength of concrete members .We have considered cubic, cylindrical and prism shaped specimens of different heights having same plan dimensions and also three different mixes were considered . To understand the effect of grade of concrete on compressive strength mix designs was carried out as per IS recommendations. unidirectional carbon fibers were used for wrapping .maximum number of wrapped layers was 3, all samples were cured for 28days and the specimens with wrapping were tested for compressive strength and results were analyzed in terms of increase in compressive strength for various conditions by comparing with normal concrete specimen without wrapping hence the results obtained from these comparison shows increase in compressive strength with increase in number of layers of wrapping.**

***Keywords*— Carbon fiber,wrapping,confinement, compressive strength Structural repair, and strengthening.***

## 1. INTRODUCTION

Fiber Reinforced Composite (FRC) materials, originally developed for the aerospace industry, are being considered for application to the repair of buildings due to their low weight, ease of handling and rapid implementation. A major development effort is underway to adapt these materials to the repair of buildings and civil structures. Appropriate configurations of fiber and polymer matrix are being developed to resist the complex and multi-directional stress fields present in building structural members. At the same time, large volumes of material are required for repair of building; the low cost of the traditional building materials create a mandate for economy in the selection of FRP materials for building repair. Analytical procedures for reinforced and pre-stressed concrete and masonry reinforced with FRC materials need to be developed, validated, and implemented, through laboratory testing, computational analysis, full-scale prototyping, and monitoring existing installations.

## *STRUCTURAL DAMAGE DUE TO EARTHQUAKE*

Earthquake generates ground motion both in horizontal and vertical directions. Due to the inertia of the structure the ground motion generates shear forces and bending moments in the structural framework. In earthquake resistant design it is important ensure ductility in the structure, i.e. the structure should be able to deform without causing failure. The bending moments and shear forces are maximum at the joints. Therefore, the joints need to be ductile to efficiently dissipate the earthquake forces. Most failures in earthquake-affected structures are observed at the joints. If the concrete lacks confinement the joint may disintegrate and the concrete may spall. All these create a hinge at the joint and if the number of hinges is more than the maximum allowed maintaining the stability of the structure the entire structure may collapse. If the shear reinforcement in the beam is insufficient there may be diagonal cracks near the joints. This may also lead to failure of the joint In most of the structures in Gujarat lack of confinement and shear cracks have been found to be most common causes of failure. Rehabilitation and retrofitting strategy must alleviate these deficiencies from the structures.

Figure 1 (a) failure at construction Joint.

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*CORROSION PROBLEMS IN INDIA*

Cement concrete reinforced with steel bars is a commonly used construction material. One major flaw with this is its susceptibility to environmental attack that will severely reduce the strength and life of these structures. In humid conditions, atmospheric moisture percolates through the concrete cover and reaches the steel reinforcements. The process of rusting of steel bars is then initiated. The steel bars expand due to the rusting and force the concrete cover out resulting in spalling of concrete cover. This exposes the reinforcements to direct environmental attack and the rusting process is accelerated and this will weakens the concrete structure to a high degree. The spalling reduces the effective thickness of the concrete. In addition, rusting reduces the cross sectional area of steel bars, thereby reducing the strength of the reinforcements. Moreover, the bond between the steel and the concrete is reduced which increases the chances of slippage. The rusting related failure of reinforced concrete is more frequent in saline atmosphere because salinity leads to a faster corrosion of the steel reinforcements. In a tropical country like India, where approximately 80% of the annual rainfall takes place in the two monsoon months, rusting related problems are very common, especially in residential and industrial structures. India also has a very long coastline where marine weather prevails. Typically, a building requires major restoration work within fifteen years of its construction.

*EARLY METHODS OF REPAIR:*

The three main weaknesses of RCC structures that require attention are:

- Deterioration of concrete due to attack of multiple environmental factors.
- Loss of reinforcement due to corrosion.
- Lack of confinement in concrete especially at the joints.

*COMPOSITE MATERIALS AS POST REINFORCEMENT*

- Recent developments in the field of fiber reinforced composites (FRCs) have resulted in the development of highly efficient construction materials. They have been successfully used in a variety of industries such as aerospace, automobile and ship building. The FRCs are unaffected by electro-mechanical deterioration and can resist corrosive effects of acids, alkalis, salts and similar aggregates under a wide range of temperatures. FRCs thus holds a very distinct advantage over steel plates as an external reinforcing device. Moreover, FRCs is available in the form of laminas and different thickness. Orientation can be given to different layers to improve its strength according to specific requirements. The difficulties encountered in using steel plates as reinforcement lead us to the use of fiber reinforced composite materials as post-reinforcements.

- Due to their high specific strength (strength/weight ratio) the composite reinforcements are very light and easy to handle. The composite materials are available as unidirectional fibers of a large length. Therefore, joints in the reinforcement can be avoided very easily. Moreover, the corrosion of the reinforcements can be avoided completely. Research work is gaining momentum on the application of composite materials as post-reinforcement (Nanni et al., 1995). The potential use of fiber reinforced composites in civil structures is manifold. The scope of the present paper is limited to the repair of - existing concrete structures only.

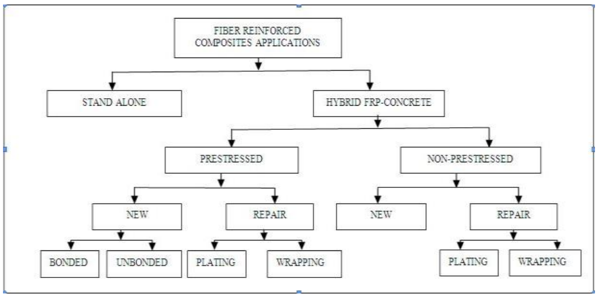


Figure3. Application of fiber reinforced composites in structures

*FRCs can be used in the concrete structures in the following forms:*

- Plates - at a face to improve the tension capacity.
- Bars - as reinforcement in beams and slabs replacing the steel bars.
- Cables - as tendons and post tension members in suspension and bridge girders.
- Wraps - around concrete members to confine concrete and improve the compressive strength.

*FRC'S AS WRAPPING ON CONCRETE ELEMENTS:*

The tensile strength of concrete is much less in comparison to its compressive strength, as a result even the compression members often fail due to the tensile stress that develops in the perpendicular direction of the compressive load. If such a concrete element is confined using a wrapping. (Fig.4) the failure due to tensile cracks can be prevented. The compressive strength of the wrapped concrete element is several times higher than the unwrapped concrete element. Although this is known for a long time effective application of confinement could not be achieved due to a lack of suitable wrapping material. If the wrapping is torn the capacity of the element reduces dramatically. Therefore, the durability of the wrapping material is of utmost importance. In addition, the wrapping material remains exposed to environmental attack. Therefore, steel is unsuitable for this purpose. FRCs due to their non-corrosive nature offers an attractive alternative. Moreover, the light weight FRC fibers can be very easily wrapped around an existing concrete column.

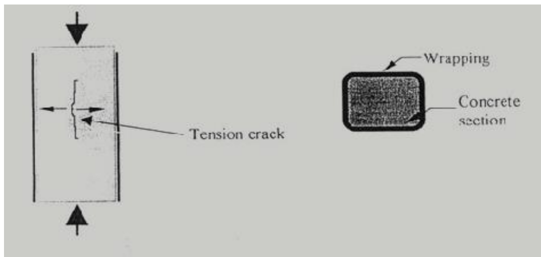


Figure4. FRC wrapping around concrete elements

2. EXPERIMENTAL INVESTIGATION

- *Composite Materials*
- Portland cement:

- Aggregates
- Water
- Composite Fiber System
  For the experimental work the composite fiber system used was
- M-Brace CF 230
- M-Brace Primer and M-Brace Saturant

| Properties of carbon fiber | Technical data |
|---|---|
| Fiber orientation | Unidirectional |
| Weight of carbon fiber (main direction) | 200g/m$^2$ |
| Total Wt. of sheet | 230g/m$^2$ |
| Density | 1.7g/m$^3$ |
| Fiber thickness in mm for static design Wt./density | 0.117 |
| Modulus of elasticity (N/mm$^2$) | 240 |
| Tensile strength(N/mm$^2$) | 3800 |
| Safety factor for static design (Manual lamination/ 4d –product) | 1.2 (recommended) |

## EXPERIMENTAL SETUP

In the present investigation concrete cubes, prisms, and cylinders of different sizes were considered, special moulds confirming to various sizes (as detailed below) were fabricated.

- *Fabrication of moulds*
- *Cast iron moulds of the following sizes*
- *Cylinders of*

1. *150*300mm*
2. *150*600mm*
3. *150*900mm &*

- *Prisms of*

1. *150*150*300mm*
2. *150*150*600mm*
3. *150*150*900mm.*

### *Test set up:*

*The compression tests were carried out on samples of various shapes and sizes using automatic compression testing machine of capacity 2000KN.This is a micro processor controlled automatic loading machine. It applies uniform loading at a rate of 5KN/ sec. the test set up consists of data acquisition system. This has built in software for analysis of results .*

## SPECIMEN PREPARATION

Weigh batching was adopted and the concrete mix proportion of M20, M30, and M40 with corresponding water cement ratio used. Machine mixing was adopted, initially fine aggregate and cement were added to mixer then coarse aggregate was added and mixed in the dry condition. Then initially 0.5% admixture was added to get a slump between 80 to 100mm and a flowing mix. Until a good flow mix and required slump is obtained, the extra 0.1% admixture was added to the same mix and mixed again.

The concrete was compacted in the mould by using vibrating table for specimens. For larger specimens of 600mm and 900mm height, needle vibrator was used for compaction. The curing was carried out for 28 days.

After curing carbon fiber was wrapped to the specimen using Saturant. The specimens were prepared to have smooth surface by rubbing using sandpaper A thin coat of low viscosity M Brace primer was applied with the brush until the substrate is locally saturated. This was done to prevent the surface from drawing resin from the FRP. The M Brace primer should be applied with in 10 min and it should be allowed to dry for 6hrs. The components of resin was mixed in the proportion of 3:2 and stirred with a stirrer for a stipulated period. This epoxy resin was applied to the primed concrete surface by using brush within 15 minutes.

In a clean area away from the resins, the fabric was carefully measured and cut in accordance with the specification. Immediately after the application of the M Brace Saturant, the fiber should be applied to the surface of the member by hand by exerting a uniform tensile force that is distributed across the entire width of the fiber. All the air bubbles or air pocket shall be squeezed out uniform and smooth final appearance is ensured by using rollers. A lap length of at least 100mm is required in the longitudinal direction of the fiber for effective stress transformation.

After the final coat, the specimen with FRP composites the material was allowed to cure in atmosphere for a period of about 27 days to gain its strength. Both control and carbon fiber wrapped specimens were tested and the results are tabulated in the following sections. A total of 168 samples were cast.

## TEST RESULTS AND DICUSSIONS

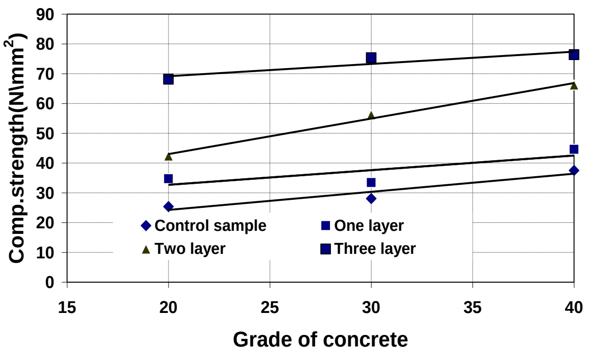


**Figure 2.1.** Shows comparison of increase compressive strengths with increase in grades of concrete for samples cube, control samples, one, two and three layer wrapped prisms.

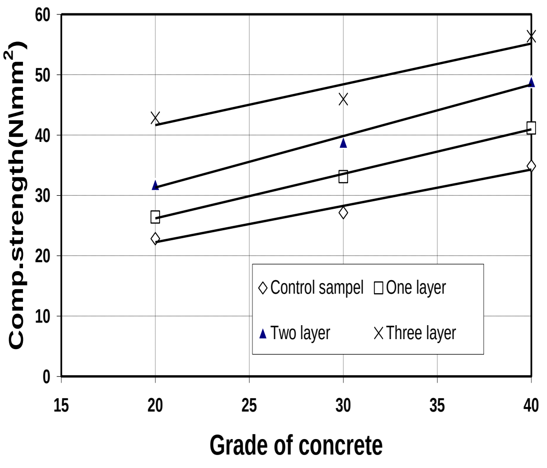


**Figure** Shows Comparison of increase compressive Strengths with Increase in Grades of Concrete for Samples Cube, Control Samples, One, Two And Three Layer Wrapped Cylinders

## CONCLUSION REMARKS

From the present investigation the following concluding remarks are made.

1. It has been found that wrapping of carbon fibers is very effective and there is a significant increase in the compressive strength of all types of samples.
2. For a particular grade of concrete the increase in compressive strength with number of layers is linear.
3. The percentage improvement in strength was found to be higher for cylinders when compared to prisms.
4. Increase in compressive strength with number of layers of wrapping is independent of grade of concrete.
5. It was observed that for the composite samples wrapped with carbon fibers, the fibers were stressed initially and were subjected to failure where after the core started yielding.

## SUMMARY

The carbon fiber wrapping seems to be very promising method for retrofitting of structures in distress and rehabilitation of structures due to earth quake loading etc. it also found to be advantageous in repair of structures under corrosion effect.

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