# COMPARATIVE STUDY IN REPAIRS AND MAINTENANCE OF CONCRETE STRUCTURES BY GFRP & CFRP TECHNIQUE

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***Abstract*—The objective of the paper is to study the behavior of continuous R.C. beams under static loading. The beams are strengthened with externally bonded glass fibre reinforced polymer (GFRP) sheets and carbon fibre polymer sheets (CFRP). Different scheme of strengthening has been employed. The project consists of Twenty simply supported beams with overall cross-section of 200mm×200mm×1000mm. The present study examines the responses of RC beams, in terms of failure modes, enhancement of load capacity and load deflection analysis. Various different beams are cracked under UTM and then repaired with the help of Fiber Reinforced Sheet prior to the application of Primer and epoxy and also a comparison is being made between single, double and triple wrapped fiber sheets. Fibre materials are used to strengthen a variety of reinforced concrete elements to enhance the flexural, shear and axial load carrying capacity of elements. The results indicate that the flexural strength of R.C. beams can be significantly increased by wrapping GFRP and CFRP sheets to the tension face**

**Keywords— Glass Fibre Reinforced Polymer (GFRP), Carbon Fibre Polymer Sheets (CFRP), externally bonded, Single Wrap, Double Wrap, Triple Wrap.**

## I. INTRODUCTION

A structure is designed for a specific period and depending on the nature of the structure, its design life varies. For a domestic building, this design life could be as low as twenty-five years, whereas for a public building, it could be fifty years. Deterioration in concrete structures is a major challenge faced by the infrastructure and bridge industries worldwide. 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. As complete replacement or reconstruction of the structure will be cost effective, strengthening or retrofitting is an effective way to strengthen the same. A new technique has emerged recently which uses fibre reinforced polymer (FRP) sheets to strengthen the structural member which have a number of favourable characteristics such as ease to install, immunity to corrosion and high strength. Fibre materials are used to strengthen a variety of reinforced concrete elements to enhance the flexural, shear and axial load carrying capacity of elements. The results obtained that the FRP strengthening technique is highly efficient and effective. Beams are the critical structural members subjected to bending, torsion and shear in all type of structures. Similarly, columns are also used as various important elements subjected to axial load combined with/without bending and are used in all type of structures. Beams are the critical structural members subjected to bending, torsion and shear in all type of structures. Similarly, columns are also used as various important elements subjected to axial load combined with/without bending and are used in all type of structures. Fiber Reinforced Polymers (FRP) have emerged as promising material for rehabilitation of existing RC structures and strengthening of new civil engineering structures because of their several advantages such as high strength-to-weight ratio, high fatigue resistance, flexible nature, ease of handling and excellent durability. There are different types of FRP materials are used for strengthening like Glass Fiber Reinforced Polymer (GFRP), Carbon Fiber Reinforced Polymer (CFRP).

## I. REVIEW OF LITERATURE

In 2006, **M. A. Safaan e**xperimentally investigated the efficiency of GFRP composites in strengthening simply supported reinforced concrete beams designed with insufficient shear capacity. Total 18 beams were tested with different shear strengthening schemes like U – jacket, Full wrapping of sides and rectangular side wrap of (130 × 300 mm) etc. and variable longitudinal reinforcement ratio. Results showed that the serviceability performance of strengthened beam was expected to be superior with regard to increased cracking loads and the limited number of cracks and small cracking width. They also showed that GFRP composites developed sufficient ductility despite their brittle nature through proper design. While **Dr. Gopal Rai And Yogesh Indolia (2011)** mentioned that beams, plates and columns may be strengthened in flexure using FRP composites bonded to their tension zone using epoxy as a common adhesive. The direction of fibers was kept parallel to that of high tensile stresses. Both prefabricated FRP strips, as well as sheets (wet-layup) were applied. Hence, FRP composites was found out to prove effective and economical aspect at the same time. If the cost constraint was kept aside, the fiber wrapping system has been proved to be a system which has many added advantages over conventional strengthening processes. **M. C. Sundarraja et. al. (2009)** experimentally found the role of glass fiber reinforced inclined strips epoxy bonded to the beam web for shear strengthening of RC beams. This study aimed to check effectiveness in terms of width and spacing of inclined GFRP strips on shear capacity of the RC beams. A two-point loading method was adopted for the test. No. of failure mode had observed in the experiments of RC beams strengthened in shear by FRPs. These include shear failure due to FRP rupture, shear failure without FRP rupture, crushing of concrete at the top and flexure failure. Finally, they found that the use of GFRP strips are more effective in the case of strengthening of the structures in shear and inhibited the development of the diagonal cracks. They also found that the load deflection behavior was better for strengthened beams and load carrying capacity was found to be greater than that of the control beams.

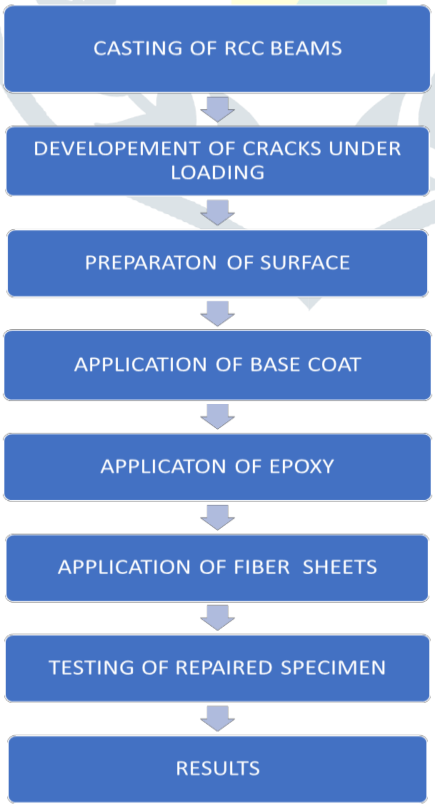
## I. OBJECTIVE OF STUDY

The Objective of this study is to Cast Twenty number of R.C. Beam of cross-section 200mm X 200mm X 1000mm and to test all the beams under UTM and according to the gaps found in the Literature review none of the authors have compared the percentage of increase in the Shear Strength of the R.C. Beam after wrapping them fully in U – Shape wrap with two different Fiber materials i.e. Glass and Carbon and also to compare the percentage of increase in strength in both repaired and fresh beams. The Twenty number of beams have been divided accordingly for Single, Double and Triple Wrap of the Glass and Carbon Fiber and comparison had being done considering the Ultimate Failure Load and Deflection values.

## II. METHODOLOGY

FRP is used in designs that require a measure of strength or modulus of elasticity that non-reinforced plastics and other material choices are either ill-suited mechanically or economically. This means that the primary design consideration for using FRP is to ensure that the material is used economically and in a manner that takes advantage of its structural enhancements specifically. This is however not always the case, the orientation of fibres also creates a material weakness perpendicular to the fibres. Thus, the use of fibre reinforcement and their orientation affects the strength, rigidity, and elasticity of a final form and hence the operation of the final product itself. Orienting the direction of fibres either, unidirectional, 2-dimensionally, or 3-dimensionally during production affects the degree of strength, flexibility, and elasticity of the final product. Fibres oriented in the direction of forces display greater resistance to distortion from these forces and vice versa, thus areas of a product that must withstand forces will be reinforced with fibres in the same direction, and areas that require flexibility, such as natural hinges, will use fibres in a perpendicular direction to forces.

The experimental study is concluded by casting Twenty number of simply supported rectangular reinforced concrete beams. All the beams are tested for flexure. The beams were grouped into two series labeled fresh beams (Direct FRP) and cracked beams (Repaired with FRP). All beams had the same geometrical dimensions: 200 mm wide × 200 mm deep × 1000 mm long.



Methodology Flow – Chart.

Beams were externally bonded by single wrap and double wrap of both CFRP and GFRP sheets for both the groups. Experimental data on load, deflection and failure modes of each of the beams are obtained. The change in load carrying capacity and failure mode of the beams are investigated for different types of strengthening pattern.

| Sr. No. | Ingredients | Materials in kg/ cum |
|---|---|---|
| 1 | Cement | 385 |
| 2 | Dry 20 MM | 588 |
| 3 | Dry 10 MM | 485 |
| 4 | Dry Crush Sand | 795 |
| 5 | Total Water | 224 |
| 6 | Admixture | 3.85 |

TABLE 1 MIX DESIGN DATA

**Table 2 Beam Specification**

| | |
|---|---|
| Design for | 2-point load of 25 KN |
| No of beams | 20 Beams |
| Beam dimension | 200mm X 200mm |
| No of bars | Main Steel: - 3 Bars of 12mm dia. & |
| | Anchor Bar: - 2 Bars of 10 mm dia. |
| Stirrups | 8mm 2-legged stirrups @ 100mm c/c. |
| Span | 1 meter |
| | (Fe415 and M25 Concrete) |

**Table 3 Reinforcement Details**

| | |
|---|---|
| Top anchor bar | : 2 bars of 10 mm diameter |
| Main steel | : 3 bars of 12 mm diameter |
| Stirrups | : 8mm 2legged stirrups @ 100mm c/c distance |

Figure No. 1. Beam Reinforcement

Figure No. 2. Beam Formwork.

### PREPARATION OF BEAM SURFACE FOR APPLYING FIBER SHEET: -

In many repair situations, the proposed repair requires only surface roughening, exposure of coarse or fine aggregate, removal of a thin layer of damaged concrete, or cleaning of the concrete surface.

### EPOXY AND PRIMER (BONDING AGENTS) :-

At the time of bonding of fibre, the concrete surface is made rough using a coarse sand paper texture and then cleaned with an air blower to remove all dirt and debris. The fabrics are cut according to the size and after that the epoxy resin is mixed in accordance with manufacturer's instructions. The mixing is carried out in a plastic container. After the uniform mixing, the epoxy resin is applied to the concrete surface.

Then the GFRP sheet is placed on top of epoxy resin coating and the resin is squeezed through the roving of the fabric with the roller. Air bubbles entrapped at the epoxy/concrete or epoxy/fabric interface are eliminated. This operation is carried out at room temperature.

### APPLICATION OF BASE COAT (PRIMER) :-

Primer is a base material and can be used to fill minor cracks. It is the base preparation before applying of epoxy material and fibre.

Ratio = 2: 1

(2 base: 1 hardener)

SRM-PRIMER SYSTEM is a two-part epoxy polyamino adduct product with a low viscosity recommended for improving the bonding of the SRM FRP system to the substrate, with a pot life of 20 mins. The coat should be left to dry for nearly 6 – 8 hrs before application of any other coat.

### APPLICATION OF EPOXY AND FIBER SHEETS: -

An epoxy is a saturant applied at the time of placing of fibre.

- Ratio = 10 : 1 (base to hardener).
- Fibre = Glass fibre and Carbon fibre
- SRM-SATURANT is a 100% solid,

With a pot life of 10 – 15 mins, blue pigmented, epoxy resin for saturation of fibre sheet to form in situ FRP composites. The coat should be left to dry for nearly 12 hrs before application of any other coat.

EXPERIMENTAL SETUP :-

The beams are tested on UTM set up done personally on the rental basis through the help of Government Contractor. The testing procedure for the all the specimen is same. The two-point loading arrangement is used for testing of beams. Two-point loading is conveniently provided by the arrangement.

The load is transmitted through two-point arrangement on the test. The specimen is placed over the two steel rollers bearing leaving 100 mm from the ends of the beam. The remaining 800 mm is divided into two equal parts of 500 mm. Two dial gauges are placed just below the center of the mid span of the beam i.e. just below the load point for recording the deflection of the beams

In this study, beam is designed to carry a load of 50KN and Fe 415 grade steel as internal reinforcement, M 25 grade concrete. As two-point loads of 25 KN each that is a load of 50 KN is applied on the beam at a distance of one- third of the span from either side of the supports

Figure No. 3. Beam tested under UTM

## II. RESULTS AND DISCUSSION

TABLE 4 DETAILS OF BEAM TESTED

| | |
|---|---|
| Depth | 200mm |
| Width | 200mm |
| Length | 1000mm |
| **Reinforcement Details** | |
| Top Anchor Bar | 2 bars of 10mm diameter |
| Main Steel | 3 bars of 12mm diameter |
| Stirrups | 8 mm 2 – legged stirrups @ 100mm c/c distance |

**Table 5 Results of Beam tested**

| Sr. No. | Beam | | Ultimate Load (kN) | Ultimate Deflection (mm) |
|---|---|---|---|---|
| **B - 1** | SWGF | B/f Wrap | 237.00 | 6.0 |
| | | A/f Wrap | 284.64 | 7.4 |
| **B – 2** | | B/f Wrap | 224.61 | 6.5 |
| | | A/f Wrap | 269.31 | 7.8 |
| **B – 3** | DWGF | B/f Wrap | 192.08 | 7.4 |
| | | A/f Wrap | 253.92 | 9.5 |
| **B – 4** | | B/f Wrap | 178.46 | 6.9 |
| | | A/f Wrap | 241.53 | 8.4 |
| **B – 5** | SWCF | B/f Wrap | 146.92 | 6.9 |
| | | A/f Wrap | 166.68 | 4.7 |
| **B – 6** | | B/f Wrap | 198.81 | 5.7 |
| | | A/f Wrap | 223.63 | 6.9 |

| | | | | |
|---|---|---|---|---|
| **B – 7** | DWCF | B/f Wrap | 154.28 | 6.2 |
| | | A/f Wrap | 198.16 | 6.6 |
| **B – 8** | | B/f Wrap | 169.81 | 5.7 |
| | | A/f Wrap | 206.91 | 6.9 |
| **B – 9** | SWGF | | 258.84 | 10.1 |
| **B – 10** | | | 273.47 | 9.7 |
| **B – 11** | DWGF | | 232.24 | 8.2 |
| **B – 12** | | | 250.53 | 8.4 |
| **B – 13** | SWCF | | 283.72 | 8.8 |
| **B – 14** | | | 294.81 | 8.7 |
| **B – 15** | DWCF | | 230.84 | 9.2 |

## III. CONCLUSION

The paper presents and experimental and analytical investigation carried out to show the behavviour of the R.C. Beam after repiaring of the Beam with Glass Fibers and Carbon Fibers and the foloowing conclusions were drawn from based on the UTM results :-

1. After the repairing of the beam with Single – Wrap Glass Fiber (SWGF) prior to epoxy and polymer, the strength of the beam is increased by 25% and when applied to Fresh Beam, 23.4 % increase in strength is observed.
2. After the repairing of the beam with Double – Wrap Glass Fiber (DWGF) prior to epoxy and polymer, the strength of the beam is increased by 33.8% and when applied to Fresh Beam, 28 % increase in strength is observed.
3. After the repairing of the beam with Single – Wrap Carbon Fiber (SWCF) prior to epoxy and polymer, the strength of the beam is increased by 18% and when applied to Fresh Beam, 27 % increase in strength is observed.
4. After the repairing of the beam with Double – Wrap Carbon Fiber (DWCF) prior to epoxy and polymer, the strength of the beam is increased by 29% and when applied to Fresh Beam, 49.5 % increase in strength is observed
5. After the repairing of the beam with Single – Wrap Glass Fiber (SWGF) prior to epoxy and polymer, the strength of the beam is increased by 25% and when applied to Fresh Beam, 23.4 % increase in strength is observed. From the above results it can be concluded that, the percentage of increase in the strength after wrapping FRP is almost same for both Glass and Carbon Fiber Sheets although the Glass Fiber used is of 600GSM and Carbon Fiber used is of 300 GSM, ultimately stating the superiority of Carbon Fiber over Glass Fiber

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