# Experimental Analysis of Retrofitting of Reinforced Concrete Beam

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***Abstract— Retrofitting materials like aluminum bars, steel laminates and glass fiber compounds has been used in the construction field for many decades. Carbon fiber compounds are the recent addition to the retrofitting materials. These studies are a comparison of flexural and shear strength of retrofitted beams with conventional beam. It also compares the experimental results with the analytical results. Analysis is done using the software ANSYS workbench. Carbon fiber fabric wraps are used for retrofitting test beams. Epoxy resin is used to bind the fabric to the beam in u – shaped wraps which binds the flexural face and the web of the beam. Total number of 4 beams of size (1500 × 200 × 250) mm including conventional beam is used for the experimental tests (Two point loading). Difference in ultimate load, critical load, flexural strength and shear strength are observed in experimental tests, and are being compared with analytical results. The beams were wrapped with five layers of carbon fiber fabric strips of different widths, 300 mm, 250 mm and 200 mm respectively. The highest flexural strength was observed in the two point load testing of beam retrofitted with 300 mm wide strips (BU30).***

***Index Terms- Critical load, Ultimate load, Flexural load, Shear stress, Deflection CFRP.***

## 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 structurewill be cost effective, strengthening or retrofitting is an effective way to strengthen the same.

- *Retrofitting*

Retrofitting is the addition of new technology or features to older systems. Retrofits can happen for a number of reasons, for example with big capital expenditures like naval vessels, military equipment or manufacturing plants, businesses or governments may retrofit in order to reduce the need to replace a system entirely. Other retrofits may be due to changing codes or requirements, such as seismic retrofit which are designed strengthening older buildings in order to make them earthquake resistant.

Retrofitting is also an important part of climate change mitigation and climate change adaptation: because society invested in built infrastructure, housing and other systems before the magnitude of changes anticipated by climate change. Retrofits to increase building efficiency, for example, both help reduce the overall negative impacts of climate change by reducing building emissions and environmental impacts while also allowing the building to be healthier during extreme weather events. Retrofitting also is part of a circular economy, reducing the amount of newly manufactured goods, thus reducing lifecycle emissions and environmental impacts.

- *Uses of Retrofitting*

The most important reason for retrofitting is to increase safety. These retrofit ordinances are designed to create safer buildings for people to live and work in, while reducing the public's concern of what will happen when the next earthquake strikes. Earthquakes unleash massive amounts of energy without warning and can cause significant building damage and potential loss of life. Even if a building is retrofitted to current building codes, that simply means it is designed so the building will not collapse. Significant shaking inside the building can cause non-structural items to be damaged or fall including furniture, plumbing or ventilation, and other debris, all leading to the possibility of injury and loss of life.

## II. REVIEW OF LITERATURE

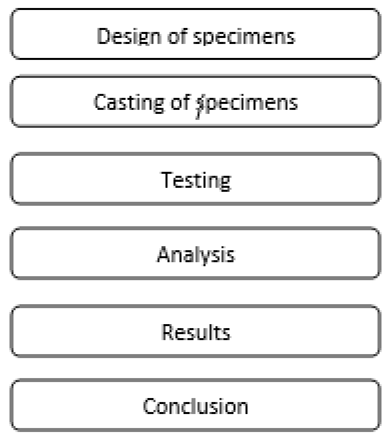
F. Ceroni(2010) investigated the experimental program on Reinforced Concrete (RC) beams externally strengthened with carbon Fibre Reinforced Plastic (FRP) laminates andNear Surface Mounted (NSM) bars under monotonic and cyclic loads, the latter ones characterized by a low number of cycles in the elastic and post-elastic range. Comparisons between experimental and theoretical failure loads are discussed in detail.

In another research, Hee Sun Kim (2011) carried on experimental studies of 14reinforced concrete (RC) beams retrofitted with new hybrid fibre reinforced polymer (FRP) system consisting carbon FRP (CFRP) and glass FRP (GFRP). The objective of this studywas to examine effect of hybrid FRPs on structural behavior of retrofitted RC beams and to investigate if different sequences of CFRP and GFRP sheets of the hybrid FRPs have influences on improvement of strengthening RC beams. The beams are loaded with different magnitudes prior to retrofitting in order to investigate the effect of initial loading on the flexural behavior of the retrofitted beam. The main test variables are sequences of attaching hybrid FRP layers and magnitudes of preloads. Under loaded condition, beams are retrofitted with two or three layers of hybrid FRPs, then the load increases until the beams reach failure. Test results conclude that strengthening effects of hybrid FRPs on ductility and stiffness of RC beams depend on orders of FRP layers.

## III. METHODOLOGY

Use of carbon fiber based retrofitting sheets or mats have been in use for the past decade. Even though sufficient studies has to be carried out to optimize the cost involved in retrofitting since carbon fiber compounds are expensive. Carbon fiber fabric is abi-directional anisotropic compound. Retrofitting using carbon fiber fabric mat requires proper binding using epoxy resins. Epoxy resin plays a key role in the experiment by avoiding debonding failure during the experimental tests. The carbon fiber fabric as compared to carbon fiber woven sheets are very thin loosely arranged, minimum of five layer is required for adequate strength (Murali and Pannirselvam, 2011; Norris, et al., 1997; Antonopoulos and Triantafillou, 2002). In this study, carbon fiber fabric mats having three different widths [30, 25, 20] cm are u – wrapped constant intermediate gap of 10 cm to the beam specimens.

Methodology Flow Chart




- *Materials used*
- *Cement*

Ordinary Portland Cement (OPC) (Brand: Birla) is used for the experiment. It is tested for its physical properties in accordance with Indian Standard specifications. It is having a specific gravity of 2.96.
(i) Specific gravity: 3.15
(ii) Normal Consistency: 32%
(iii)Setting Times: Initial : 40 minutes, Final : 535 minutes.
(iv) Soundness: 2 mm expansion
(v) Fineness: 1 gm retained in 90 micron sieve

- *Fine Aggregate*

The fine aggregate passing through 4.75 mm sieve and having a specific gravity of 2.67 are used. The grading zone of fine aggregate is zone III as per Indian Standard specifications.

- *Coarse Aggregate*

The coarse aggregates of two grades are used one retained on 10 mm size sieve and another grade contained aggregates retained on 20 mm sieve. It is having a specific gravity of 2.72.

Water

Ordinary tap water is used for concrete mixing in all the mix.

- *Composite Materials*

The type of CFRP material used for flexural strengthening is composed of Tyfo SCH-41 Composite. the bonding agent used is Tyfo S Saturant Epoxy and Epoxy hardener as shown in below table

| Product Name | TYFO S COMPONENET A | TYFO S COMPONENET B |
|---|---|---|
| Chemical Name | **Modified Epoxy Resin** | **Epoxy Hardener** |
| Chemical Family | Bisphenol-AEpichlorohydrin Polymer | Polyetheramine Polyoxypropylenediamine |
| Appearance | Clear to Amber | Pale yellow to clear-liquid |
| Odour | Viscous liquid with slight odour | Ammonia-like odour |
| Boiling Point (760 mmHg) | 320 C (608F) DSC | 500F/26C |

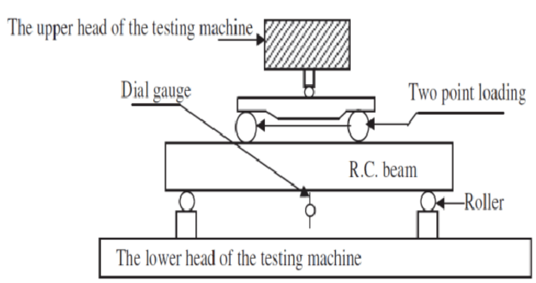



Figure No 1 Experimental setup

*Mix Design*

The specified strength of the concrete is 35 mpa in 28 days. The specific gravity of cement, coarse aggregate and fine aggregate are 3.15, 2.76 and 2.72 respectively. Grade of the cement used for the casting is OPC 53. The water cement ratio adopted is 0.45. The mix proportion of the concrete has been obtained by the code [IS 10262-1982].

Table No-2. Mix Proportions

| Water (Litre) | Cement (kg) | Fine aggregate (kg) | Coarse aggregate (kg) |
|---|---|---|---|
| 186 | 132 | 232.32 | 410.83 |
| 1.40 | 1 | 1.76 | 3.17 |

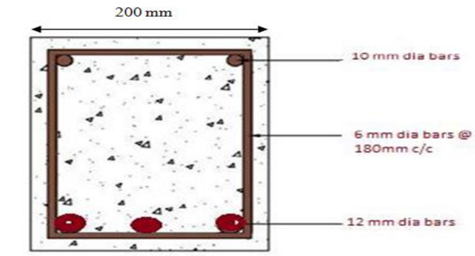



Figure No 2 Cross section of a beam

Figure No 3 Test setup

## IV. OBJECTIVE

1. To compare the difference in critical load, ultimate load and flexural strength of beam specimens retrofitted with carbon fiber fabric wrap ($B_{u30}$,$B_{u25}$, $B_{u20}$) at different widths, i.e., 30 cm, 25 cm and 20 cm respectively.
2. To compare the experimental values of retrofitted beam specimens with conventional beam specimen's (Bconv) test results.
3. To analyze the specimens tested experimentally in ANSYS software and to compare the analytical results with the experimental results.
4. To find the beam specimen with highest flexural strength and to compare its analytical values with the experimental values.
5. To check the shear stress distribution in the specimens using ANSYS software and find the maximum shear values of the specimens and the points at which shear concentration is higher

## V. RESULTS

*Testing of Beam Specimens*

Total number of four beam specimens has been casted for the experimental studies. Beam specimens casted have been cured for 28 days before testing. Sizes of the beams are 1500 mm × 200 mm × 250 mm. Nomenclature of the beam specimens are as given in Table 3. Excellent bonding between the carbon fiber fabric mat and the surface of the beam specimen is required for the efficient increase in flexural strength of the specimen. Epoxy resin provides the adequate bonding strength to avoid debonding failure and the carbon fiber fabric mat act uniformly as the specimen under the loading condition.All the beam specimens are being tested under two point loading condition. The conventional beam ($B_{conv}$) is tested first to find out the critical and ultimate loads. The flexural strength is found out using the formula $\sigma = \frac{F \times L}{b \times d^2}$

Where σ is the flexural stress or the bending stress of the beam; F is the ultimate load exerted on the beam specimen; L is the effective length of the beam specimen; b is the breadth of the beam; d is the depth of the beam. Similarly, the retrofitted test beams, $B_{u30}$, $B_{u25}$, and Bu20 are also tested respectively.

Table No 3 and 4 The experimental test results of each beam which has been recorded are tabulated in below table

| Specimen | Critical load (KN) | Ultimate load (KN) | Flexural stress(KN/ mm$^2$) |
|---|---|---|---|
| Bconv | 56 | 112 | 0.011 |
| Bu20 | 64 | 144 | 0.014 |
| Bu25 | 68 | 152 | 0.015 |
| Bu30 | 76 | 168 | 0.017 |

| Specimen | Ultimate load (KN) | Maximum deflection (mm) |
|---|---|---|
| Bconv | 112 | 9.92 |
| BU20 | 144 | 8.88 |
| BU25 | 152 | 9.18 |
| BU30 | 168 | 9.20 |

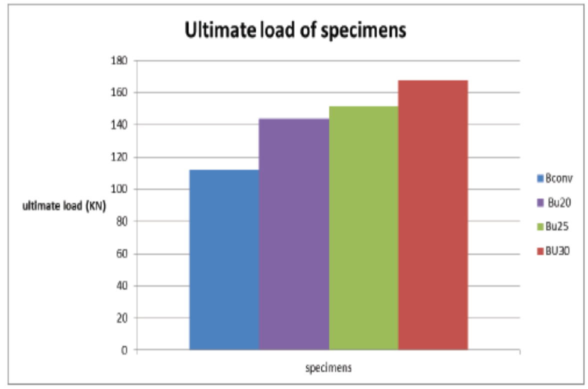



Figure No 4 Ultimate load of specimen chart

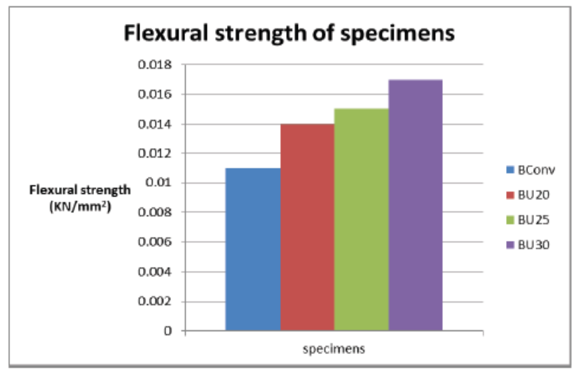



Figure No 5 Flexural strength of specimens chart

## CONCLUSION

1. The ultimate load carrying capacity of all the strengthen beams is higher when compared to the control beam.
2. The initial cracks in the strengthened beams are formed at higher load compared to control beam.
3. The total deformation was highest for $B_{U30}$ both in experimental as well as analytical results. Thus the beam wrapped with 300 mm wide strips has the largest deflection among the three retrofitted beams.
4. Beam wrapped with 300m wide strips has the maximum flexural value (0.017 KN/mm$^2$). While the beam retrofitted with 20 mm wide strips has the least value for flexural stress (0.014 KN/mm$^2$).
5. The maximum equivalent stress value was observed in beam wrapped with 250 mm wide strips. While the least equivalent stress value was observed in beam retrofitted with 200 mm wide strips.

6. The experimental values and the analytical values of deflection have slight variation. This might be caused by the quality of materials, quality of casting, errors occurred during testing.
7. As compared with the ultimate load of conventional beam, the percentage increase in $B_{U20}$, $B_{U25}$ and $B_{U30}$ are 28.57%, 35.71% and 50% respectively. Similarly, as compared with the conventional beam, the percentage increase in flexural strength of $B_{U20}$, $B_{U25}$ and $B_{U30}$ are 27.27%, 36.36% and 54.55%. Thus the most effective mode of retrofitting is clearly with 30 cm wide strips at 100 mm spacing.

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