

# Repair And Rehabilitation of RCC Structures Using FRP

Abrar Ishaq

<sup>1</sup>M.Tech Scholar, Department of Civil Engineering, RIMT University, Mandi Gobindgarh, Punjab, India

Correspondence should be addressed to Abrar Ishaq; [abrarlone6150@gmail.com](mailto:abrarlone6150@gmail.com)

Copyright © 2023 Made to Abrar Ishaq. This is an open-access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

**ABSTRACT-** This paper analyses the conditions that cause restored concrete structures to operate less well, as well as the diseases that they suffer from and the remedies that can cure them. In this work, the various surface preparation techniques widely used in Indian circumstances are discussed, along with their drawbacks. In this work, we've made an effort to talk about the characteristics, varieties, and application methods of grouts. The goal of the study is to provide the ways for fixing and rehabilitating structures that have inadequacies and flaws that call for repair. The effectiveness of a holistic system approach is examined along with the effectiveness of the already employed repair and rehabilitation techniques.

**KEYWORDS-** Rehabilitation, Repair, RCC, FRP etc.

## I. INTRODUCTION

Rehabilitating a structure meant returning it to its original state in the broad sense of the word. Modifying a structure to meet new functional or other criteria may be done using a technique established for rehabilitation. Generally, a structure could require rehabilitation for one of the following reasons: New functional or loading requirements requiring alterations to a structure, normal deterioration brought on by environmental effects Accident-related damage. The specialist discipline of repair and rehabilitation engineering necessitates knowledge and skills that go beyond those needed for design and construction engineering. It is vital to take a methodical approach to structural deterioration, and technology management and economics should coexist in harmony. When a structure exhibits cracking, spalling, or any other evidence of deterioration, the first duty is to ascertain if the damage is structural or non-structural. The engineer in charge of rehabilitation should possess investigative, structural, and material technology skills, as well as knowledge of application methods.

The Repair and Rehabilitation of structures include the following:

1. Techniques for inspection, evaluation, supervision, and structure maintenance
2. Bridge fatigue problems, laboratory investigations, dynamic testing, and analysis of durable concrete.
3. Seismic strengthening
4. General repairs

Structure repair and rehabilitation is the process of enhancing an existing structure to improve the likelihood that it will

endure for a long time and withstand seismic effects. Base isolators, new structural elements, strengthening of current structural elements, and other methods can all be used to achieve this. The reinforced concrete structure may become structurally unsound due to concrete deterioration and corrosion of the embedded reinforcement. By fixing chloride, applying a protective coating (powder coatings based on thermosetting epoxy, polyester, or acrylic technology are electrostatically sprayed), or using cathode protection, corrosion can be somewhat controlled. Once this has Happened, two alternatives of fixing the problem are to replace the structure or to strengthen it. Economically, repair and strengthening are often the only viable solution.

## II. LITERATURE REVIEW

**Wael W. El-Dakhakhni et al.[1]**, described advanced composites for seismic retrofit of masonry infill walls. According to the authors, the interaction between panel and frame significantly alters the dynamic characteristics of composite buildings under lateral loads, hence it is important to consider the strength, stiffness, and ductility of masonry infill walls when designing composite structures. Prisms loaded normally, parallel to bed joints, and direct shear conditions were used to test the specimens. They end by saying, FRP walls in engineered masonry provide the compressive strength necessary to stabilise out-of-plane buckling, limit in-plane tensile failure, increase load carrying capacity, more effectively dissipate energy, seem to be post-peak strong, and reduce anisotropic joint behaviour.

**Bhattacharya Shubhamoy et al.[2]** A critique of masonry constructions without reinforcement's retrofitting techniques According to the authors, URM structures are widespread throughout the Himalayan region and the Indian subcontinent. They noticed that these structures frequently collapse in a brittle manner and are unable to handle the lateral load exerted by the earthquake. They have gathered data on numerous retrofitting techniques. After careful consideration, they came to the conclusion that this study will help decision-makers in policy, planning, design, architecture, and engineering select the best methodology.

**Vivek Kumar Yadav[3]** they emphasise the repair and rehabilitation techniques that should be used for structures having flaws and shortcomings that require rehabilitation. The effectiveness of a holistic system approach is examined along with the current state of knowledge on repair and

rehabilitation techniques. Instead of looking at both visible and unseen problems as well as their potential causes, this paper concentrates on the symptoms of the problem that are readily apparent. This essay focuses on the materials and methods for repairs that are necessary for the successful operation of the repaired structure.

**Ankur Gupta[4]** explain his papers the many types of construction developments, reinforced concrete is the primary building material used. However, it is recognised that a major issue is the corrosion of reinforced concrete structures. On the one hand, it needs ongoing upkeep, while on the other, numerous structures necessitate extensive repairs, rehabilitation, and retrofitting. As these structures get older and more worn down over time, we see some dilapidation or weakening, which is followed by distress that manifests as delamination, cracking, corrosion, and splitting, among other things. By using a variety of admixtures and innovative repair materials, such degraded structures can be restored, rehabilitated, and retrofitted. With the aid of a case study in which the author participated at every stage, the goal of this research is to provide techniques for the repair, rehabilitation, and retrofitting of RC-framed structures. The determination and correlation of the outcomes of various non-destructive tests were emphasised in the case study of the concerned structure with the aim of recommending appropriate sustainable solutions for the rehabilitation of the structures.

**Manish Kumar[5]** Since a century ago, reinforced cement concrete has been widely employed to build various kinds of constructions. We have used this construction material to build numerous structures during this time, including buildings, bridges, industrial structures, pavement, water tanks, etc. A significant amount of resources have been used to build these constructions. Keeping those structures in good working order is crucial. It is necessary to have a comprehensive plan, technique for structural repair and rehabilitation to be in place for dealing with such difficulties because deterioration in RCC Structures is a common and natural event. It is crucial to understand the precise cause, nature, and appropriate manner of repair for concrete buildings. According to the categories of distress that can be repaired, many restoration techniques are outlined in a study. The study's key finding is that in order to protect our structures, we must maintain them frequently and use the right materials while making repairs. Additionally, for a perfect repair, the workmanship must be done with the utmost care.

**J. Bhattacharjee[6]** defined the different sorts of construction projects, reinforced concrete is the primary construction material employed. However, it is widely acknowledged that the deterioration of reinforced concrete structures is a serious issue. Many structures require substantial Repair, Rehabilitation, and Retrofitting in addition to routine maintenance. As these buildings get older, we see gradual deterioration or degradation in them, which causes distress that manifests as cracking, splitting, delaminating, rusting, etc. By using various admixtures and contemporary repair materials, such degraded structures can be renovated and adapted.. The document highlights the current condition of concrete structures, the key areas that require improvement during their service life stage, as well as the procedure for carrying out Repair, Rehabilitation, and Retrofitting. The report goes into

more depth on this and includes case studies where the author was intimately involved in the design and execution of the jobs.

### III. MATERIAL AND METHODOLOGY

At RIMT University, an experimental study was carried out. Ten small scaled reinforced beams were examined for this experimental study using standard beams with a rectangular cross-section measuring 150x150x750 mm in size. For the initial trial testing, #3 (10mm) and #4 (13mm) Glass FRP rods were inserted into the grooves carved out of the bottom concrete surface, and the spaces were then filled with a viscous epoxy-resin paste. Three distorted 10-mm steel rebars on the tension side, two deformed 10-mm steel rebars on the compression side, and stirrups with a diameter of 8-mm made up the internal steel flexural reinforcement. For the first and second trial tests, respectively, the retrofitted and strengthened beams were compared to a control beam, Bo-1 and Co-1. In the first test, two 10mm GFRP rods were used to reinforce the test beams B-1 and B-2. Locally accessible, the space between the concrete and the FRP rod was filled with epoxy resin. as shown in Figure 1. The cross-sectional details of the specimen beams B-3 and B-4 are shown in Figure 2 One 10 mm GFRP rod was used to reinforce the test beam B-5, as shown in Figure 3. Epoxy resin is also poured into the prepared gap between the FRP and the concrete. Only Glass FRP rods of #3 (about 10mm) were used for the second trial tests, and they were subsequently filled with cement mortar. The specimen beam C-1 underwent strengthening during the second trial tests, as depicted in Figure 4, by having a 10 mm insert positioned at the beam's bottom surface.

In order to suggest additional repair techniques, The experiment was expanded to include the groove preparation of test beams C-2 and C-3, whose configuration differs from that of the FRP material's installation on its near surface. As seen in Figure5, the bottom reinforcement of these beams was strengthened by inserting a 10 mm piece of cement mortar as a filler material between them. For this experiment, the concrete strength and GFRP rods used were the same for each specimen.

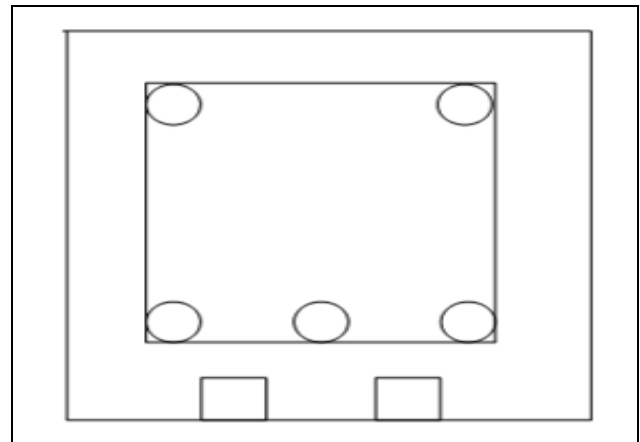


Figure 1: Beam Cross-section for B-1 and B-2

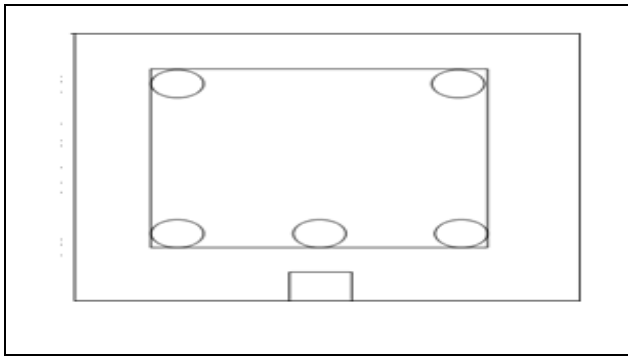


Figure 2: Beam Cross-section for B-3 and B-4)

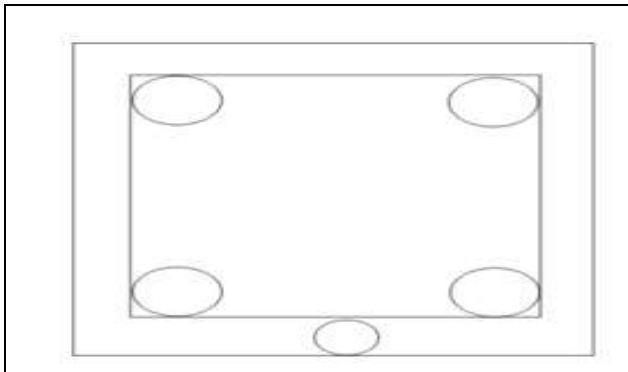


Figure 3: Beam cross section for B-5

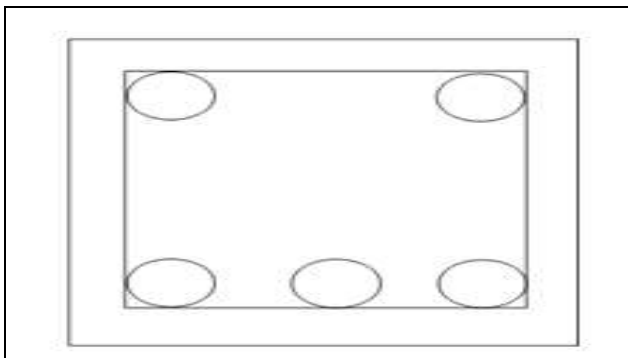


Figure 4: Beam Cross-section for C-1

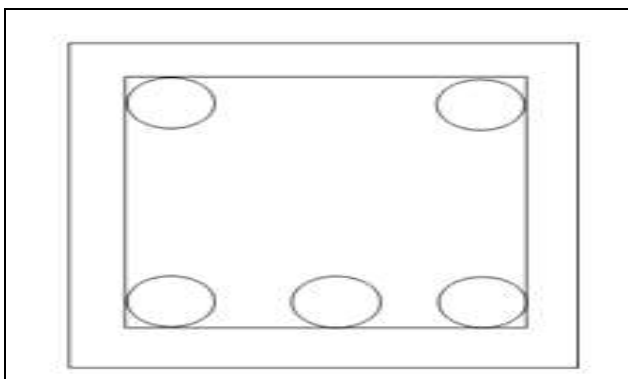


Figure 5: Beam Cross-section for C-2 and C-3

To replicate a true circumstance where the rods would enter the adjacent structural components, the NSM FRP rods were extended till the beam ends (De Lorenzis, 2002).

**A. Material Property Concrete**

The concrete samples were taken out of the molds after the casting process had taken place for 24 hours, and they were submerged in a water tank for seven days. After that, all samples were taken out of the water curing tanks and kept in the laboratory air at a temperature of 25 C until testing began after 28 days. Three 150 mm cube-shaped concrete specimens and three 150 mm dia. by 300 mm cylinder-shaped concrete specimens had their compression strengths examined; the average strength of the concrete produced by the mix ratio was 33 Mpa.

**B. Reinforced Steel Bar**

For the initial test beams, longitudinal steel reinforcing bars with a deformed, high-yield strength, 10 mm diameter, and stirrups spaced 50 mm apart, were used. Second trial beams were constructed using 8mm longitudinal steel reinforcing bars and stirrups placed 30mm apart. Each type of steel bar has three coupons that were tested. Under a uniaxial tension test, the yield strength of steel reinforcements is determined. The specimens for 8 mm steel bar had average ultimate and yield tensile strengths of 559 Mpa and 430.89 Mpa, respectively. The corresponding values for that of 10 mm are 520.09 Mpa and 369.04 Mpa.

**FRP ROD** Glass FRP rods with wrapped surfaces and diameters of 10 mm (#3) and 13 mm (#4) were employed to reinforce the beams' flexural integrity. 86 mm<sup>2</sup> and 139 mm<sup>2</sup> are the nominal areas of #3 and #4 Glass FRP rods, respectively. The ultimate tensile strength of #3 is 1000 MPa, while its effective yield strength is #4 800 MPa, per manufacturer statistics. The FRP for the glass is 965 MPa and 772 MPa, respectively, for #4.

**C. Epoxy Resin**

The primary determinant is how well the epoxy glue connects the FRP to the concrete surface. determining the effectiveness of the strengthening approach (Naveen, 2013). Epoxy resins come in a large variety of kinds and have a wide range of mechanical qualities.

**IV. MIX DESIGN VALUES AND PROCEDURES**

Concrete must have a 33 MPa at 28-day compressive strength to be considered solid. Ordinary Portland cement was used of 32.5grade. According to Table 1 of ACI211.1-81(Revised 1985), the mixing water content is determined at 184 kg/m<sup>3</sup>.

Table 1: Mix Proportion

Water	Cement	Fine Aggregates	Coarse Aggregates
184	408 kg	828kg	1054 kg
0.45	1	2.02	2.59



Table 2: Concrete mix design quantities

Grade of concrete: C-30	Coarse aggregate(20mm): 2.51
Type of exposure: Normal	Fine Aggregate: 3.22
Sp. Gravity of cement: 3.15	Maximum Water Cement Ratio: 0.45

Table 3: Quantity of Materials for casting beams considering 20% wastages

Materials	One mould (in kg)	Five moulds (in kg)
Cement	8.28	41.43
Fine aggregate	17.441	87.209
Coarse aggregate	20.068	100.345
Water	3.909	19.534
Total	49.676	248.488

**A. Flexural Testing Procedures**

**• Tests and setups**

The RC beams were subjected to a center-point bending test while being spaced 590 mm apart from their supports. Using a Simple Beam with Center-Point Loading, the ASTM C293 Standard Test Method for Flexural Strength of Concrete" test method is used to assess the flexural strength of specimens that have been prepared and cured (ASTM C293). A hydraulic jack attached to an electric pump was used to apply the load, and a load cell was used to measure it. Two LVDT were installed at mid-space on both sides of the concrete beam to instrument each beam. Strain gauges are instrumented at the mid-span on the bottom face of the steel rebar and FRP rods. The loading arrangement was the same for all of the beams. A cracking load is the weight at which the first noticeable crack appears. loading was carried out until failure.

**B. Preparation and casting of GFRP onto the bottom surface.**

When the strengthening processes were performed, the beams were in a hardened state .In order to begin installing the NSM FRP rods for the initial trial test beams, a series of grooves with specified and At the tension side of the beam sample, longitudinal holes with predetermined size were drilled into the concrete cover. Apparently, De Lorenzis used a chisel to carve these grooves (De Lorenzis, 2002). Based on the findings of bond tests with square grooves ( $b_g=h_g$ ) and the definition of  $k = b_g/ d_b$ , it was suggested that for round bars,  $k$  should have Smooth or lightly sandblasted bars should have a minimum value of 1.5, while deformed bars should have a minimum value of 2.0. The groove cross-section for the wrapped GFRP bars with  $d_b=13\text{mm}$  employed in this investigation would be  $b_g=20\text{mm}$  and  $h_g=20\text{mm}$  if  $k=1.5$ . (De Lorenzi set al., 2006).

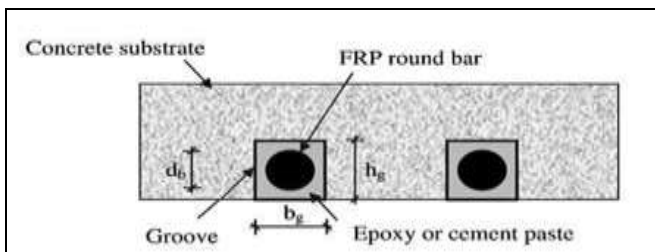


Figure 1: NSM system and nomenclature

The grooves were cut using a specialized concrete saw with a diamond blade, according to the Figure 1, recommended proportions 2 .The extra sides of grooves are removed once the appropriate sides have been cut off. To remove all dirt and debris, the concrete surface is made rough using a coarse sandpaper texture. Before inserting the FRP reinforcing bars, the glue is ready and placed into the groove. In line with the manufacturer's instructions, After being thoroughly mixed, the epoxy resin is sprayed over the grooved concrete surface.The epoxy resin is applied to the grooved concrete surface after being well mixed. After being thoroughly mixed, the epoxy resin is showered over the grooved concrete surface.The epoxy resin coating is subsequently applied to the GFRP rod. A constant, uniform pressure is applied while the epoxy is curing to ensure good contact between the epoxy, the concrete, and the GRFP rods shown in Figure 3. At room temperature, this procedure is performed. Once the epoxy resin in the groove had hardened after 24 hours, testing of the beams resumed.



Figure 2: Groove preparation saw cut and chiseled



Figure 3: FRP rod inserted into epoxy resin at the bottom surface of the beam

As shown in below figure 4, pipes were inserted at the bottom surface of the second trial tests before casting the beams and were then pulled out to make room for the placing of FRP materials. Instead of incise, these pipes were used to compare, investigate, and demonstrate the impacts of that procedure, including tiny cracks and the wearing away of the concrete's top layer, which weakens the concrete. The pipes for beam C-1 were put below the stirrup, which is close to the bottom surface. The stirrup, which is situated between the bottom tension reinforcement, and the pipes were erected above it. for beams C-2 and C-3. By utilizing pipes in the structural components that are

vulnerable to damage, With the intention of providing room for additional repairing and rehabilitation processes, this was done in order to examine and compare the results with the first trial beams



Figure 4: pipes casted in the bottom surface of the beam

Table 3: Trial 1 specimens Summary and Results

Beam	Flexural Reinforcement (Tension)	FRP Reinforcement	Ultimate Load (KN)	Failure mode	% Increase over control
B0-1	3Ø -10		82.2	Flexure	-
B-1	3Ø -10	2Ø -10	97.2	Flexure, DB	18.28
B-2	3Ø -10	2Ø -10	93.9	Flexure, DB	14.26
B-3	3Ø -10	2Ø	103.2	Shear before SY	25.59

Table 4: Trail 2 specimen summary and specimen

Beam	Flexure Reinforcement (Tension)	FRP Reinforcement	Ultimate Load (KN)	Failure Mode	% Increase over Control
C0-1	2 Ø-8	-	45.4	Flexure	-
C-1	2 Ø-8	1 Ø-10	56.7	Flexure	24.88
C-2	2 Ø-8	1 Ø-10	59.3	Flexure	30.63
C-3	2Ø-8	1 Ø-10	61.6	Flexure	35.69

**C. Analysis of the failure modes**

The observed failure modes are shown in Figure 5 to 9. Flexure with steel yielding was the main form of failure for beams Bo-1, B-1, B-2, and B-5. According to Figure.3, the loss of bond (debonding) between the GFRP rod and the concrete surface occurs when the tensile steel reinforcement yields, indicating that the beam has reached its maximum level of flexural strength. Shear failure, like in the case of B-3 and B-4 beams, was the second observed mode of failure. The tension zone insertion of GFRP rod increased the reinforcing ratio for these beams. which, as shown in Figure.2, was high, causing the concrete to be compressed before the tensile reinforcement gave way, which led to the RC element failing. Flexure failure was the mode of failure for the second trial's concrete beams, Co-1 to C-3, as shown in Figures.8 to 9.

**V. RESULTS AND DISCUSSION**

This chapter would discuss the experimental findings for the evaluated concrete beams. Here is a presentation of the various characteristics and behaviors of the tested beams during the experiment. Each beam's failure modes and crack pattern would also be detailed.

**Test Result.**

The load on the concrete beam samples was applied until they broke. NSM GFRP was used to reinforce all beams in a hardened state. The same kind of load arrangement was used to load these beams. Tables 3 and 4 show a summary of the test results for the samples from trials 1 and 2, respectively.



Figure 5: Failure Photo of Beam Bo-1



Figure 6: Failure Photo of Beam B-3



Figure 7: Debonding of GFRP rod shown on Photo of Beam B-5



Figure 8: Failure Photo of Beam Co-1



Figure 9: Failure Photo of Beam C-1

## VI. CONCLUSION

The flexural strengthening provided by NSM GFRP rods was evaluated on ten small scale reinforced concrete beams, including two control beams and seven strengthened beams. According to the test results, the strengthened beams had a greater capacity to carry the maximum load than the control beam, with increases ranging from 14.25% to 25.58% for the first trial beams and from 24.89% to 35.68% for the second trial beams. When compared to the control beam, the strengthened beams indicates an development in strength and stiffness as well as a depletion in deflection. These findings indicates that NSM GFRP rods can be used to significantly raise the flexural load carrying capacity of RC elements, indicating that this technique may be used to strengthen and repair RC beam members that have been damaged.

## REFERENCES

- [1] Wael W. El-Dakhkhni1, Ahmad A. Hamid and Mohamed Elgaaly, 13th wcee August 1-6, 2004 Paper No. 3093 "Seismic retrofit of masonry in fill walls using advanced composites." The authors state that the
- [2] Bhattacharya Shubhamoy, Nayak Sanket, Datta Sekhar Chandra, (IJDRR, V-7, March 14) A critical review of retrofitting methods for unreinforced masonry structures.
- [3] Vivek Kumar Yadav "Repairs And Rehabilitation of R.C.C. Structures by Fiber Reinforced Plastic- A Review" ISSN: 2277-9655 [Yadav\* Et Al., 8(2): February, 2019]
- [4] Ankur Gupta "A Case Study' On Repair Rehabilitation & Retrofitting of RC Framed Structure" International Journal of Innovative Research in Science, Engineering and Technology (A High Impact Factor, Monthly, Peer Reviewed Journal) Visit: [www.ijirset.com](http://www.ijirset.com) Vol. 6, Issue 11, November 2017
- [5] Manish Kumar "Structural Rehabilitation, Retrofitting and Strengthening of Reinforced Concrete Structures" World Academy of Science, Engineering and Technology International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering Vol:10, No:1, 2016

- [6] J. Bhattacharjee "Repair, Rehabilitation & Retrofitting Of RCC for Sustainable Development with Case Studies" Civil Engineering and Urban Planning: An International Journal (CiVEJ) Vol.3, No.2, June