International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 03 | Mar 2019 www.irjet.net p-ISSN: 2395-0072

Retrofitting of Reinforced Concrete Structures

S. Karuppasamy[1], K. Shriram[2], S. Pradeep Kumar[2], K. Vijayakumar[2], D. Rohithbabu[2]

[1]Assistant Professor: Civil Engineering Department, Prathyusha Engineering College, Thiruvallur, Tamil Nadu
[2]U. G Student: Civil Engineering Department, Prathyusha Engineering College, Thiruvallur, Tamil Nadu

---***---

Abstract – *The reinforced concrete structures should have satisfactory performance during earthquakes and other disasters. For this purpose they are being repaired or retrofitted. Repair can lead to increased stiffness, strength, and failure deformation. . A large number of reinforced concrete structures located seismic prone areas are not capable of withstanding earthquake action according to the current codal provisions. Furthermore the seismic behavior of the existing buildings are affected due to design deficiency, construction deficiency, additional loads, additional performance demand, etc. Recent earthquakes have clearly demonstrated an urgent need to upgrade and strengthen these seismically deficient structures. The retrofitting is one of the best options to make an existing inadequate building safe against future probable earthquake or other environmental forces. Retrofitting reduces the vulnerability of damage of an existing structure during a near future seismic activity. This project deals with the inspection and verification of performance of existing structures, selection of the retrofitting methods, choosing the best retrofitting material available and execution for retrofitting. Testing is done for the reinforced concrete beams that are retrofitted by overlaying method using Carbon Fibre Reinforced Polymer (CFRP) to find their strengths and results are interpreted.*

***Key Words*: Seismic action, loads, Retrofitting, Overlaying method, Carbon Fibre Reinforced Polymer**

1. INTRODUCTION

Reinforced Cement Concrete structures are the most abundantly used construction technique in this world. They are often found to exhibit distress and suffer damage, even before their service period is over, due to several causes such as improper design, faulty construction, change of usage of the building, change in codal provisions, overloading, earthquakes, explosion, corrosion, wear and tear, flood, fire, etc. To meet up the requirements of advance infrastructure new innovative materials/ technologies in civil engineering industry has started to make its way. The structures are becoming old and they are in greater need for additional repairs. Retrofitting is defined as the process of modification of existing structures like buildings, bridges, heritage structures to make them more resistant to the seismic activity and other natural calamities.

1.1 Need for Retrofitting

Retrofitting of structures like building, which includes rehabilitation, maintenance and strengthening of the structure, is not only a need in construction and management in urban areas, but also a problem which arises to structural engineers in property management disciplines. It is not financially possible to replace every building that is weakened due to failure of the members, natural disasters or other causes and therefore retrofitting will have an important role in the civil field. Thus this reconstruction method will provide us that extra lifespan for the building and prove beneficial. In retrofitting, the structure must be designed so it is in keeping with its purpose of use and is both safe and durable.

1.2 Benefits of Retrofitting

- Retrofitting is the seismic strengthening of existing damaged and undamaged structure.
- It will be an improvement over the original strength which may be insufficient for the building in the future seismic actions.
- Increasing the global capacity (strengthening). This is typically done by the addition of cross braces or new structural walls.
- Increasing the local capacity of structural elements.
- In retrofitting, the structure must be designed so it is in keeping with its purpose of use and is both safe and durable.
- There are considerable number of buildings that do not meet the requirement of current design standards.
- The serviceability of the structure will increase with retrofitting.

1.3. RETROFITTING METHODS

There are several factors that govern the selection of the retrofitting methods like the existing concrete strength, accessibility to work areas, the extent of damage, cost, etc.

Thus, selecting the right method will vary with each structure.

- Fibre Reinforced polymer(FRP) composites using Overlaying Method
- External plate bonding
- Near Surface Mounted FRP bars or Strips
- External post-tensioning
- Grouting
- Epoxy Injection

1.4. MATERIALS FOR RETROFITTING

The materials that are used for retrofitting have their own properties, advantages and disadvantages. These materials are retrofitted over the reinforced concrete elements and tested for their Young's modulus, yield strength, tensile strength and strain. In this project CFRP and epoxy resin adhesive were used to retrofit the reinforced concrete structures. Some of the most commonly used materials are:

- Ferrocement
- Polymer Modified Concrete
- Epoxy Resins
- Carbon Fibre Reinforced Polymer(CFRP)

1.4.1 CARBON FIBRE REINFORCED POLYMER(CFRP)

CFRPs exhibit several improved properties, such as high directional strength, higher stiffness, superior fatigue properties, corrosive resistance and suitable for complex designs.

Tensile strength = 1700-3700 MPa
Modulus of Elasticity = 120-580 GPa
Density = 1800-2100 Kg/m3
Modulus of elasticity to density Ratio = 31-33
Strain at break = 0.5-1.9
Creep Rupture stress limit = 0.55

1.4.2 EPOXY RESINS

Silicone is a non-corrosive neutral cure industrial grade silicone sealant which can be used to meet a variety of sealing and gasketing needs. It provides excellent adhesion, low odour, non-corrosive, UV- resistance, fast cure and remain flexible.

Uncured specific gravity = 1.03

Setting time = 1 hour

Full cure = 7 days

Density = 0.8-1 Kg/m3

2. REVIEW OF LITERATURE

Yasmeen Taleb Obaidat, Susanne Heyden, Ola Dahlblom (2010) [1] presented a finite element analysis which is validated against laboratory tests of eight beams. All beams had the same rectangular cross-section geometry and were loaded under four point bending, but differed in the length of the carbon fibre reinforced plastic (CFRP) plates. Linear elastic isotropic and orthotropic models were used for the CFRP and a perfect bond model and a cohesive bond model was used for the concrete–CFRP interface.

Shibi Varghese, Binusha Majeed (2016) [2] on their paper have analysed the performance of retrofitting techniques and reviewed the materials properties and their performance. The test results of the FRP AND GFRP retrofitted beams were compared and studied. Soumya Gorai, P.R. Maiti [3] reviewed about the various techniques and advancements that are implemented for retrofitting of reinforced concrete structures. All the methods used are explained and the papers that were published on retrofitting were reviewed.

Faisal M. Mukthar, Rayhan M. Faysal (2018)[4] published a paper on studying the FRP-Concrete Behaviour. The externally bonded FRP-Concrete behaviour is studied using five major approaches, namely, single shear-lap tests, double shear lap tests, bending type test, mixed mode-loading tests and tension pull-off tests and the resulting data was collected by using strain gauges.

The literature about the various testing procedures of materials, reinforced concrete elements and bonding between the materials and concrete are studied. The various methods of retrofitting techniques and their results are studied to have an overview of the retrofitting procedures that have been done in the past and to help with the improvement of those techniques in various aspects.

3. METHODOLOGY

The following flowchart illustrates the methodology by which retrofitting is carried out in reinforced concrete structures.

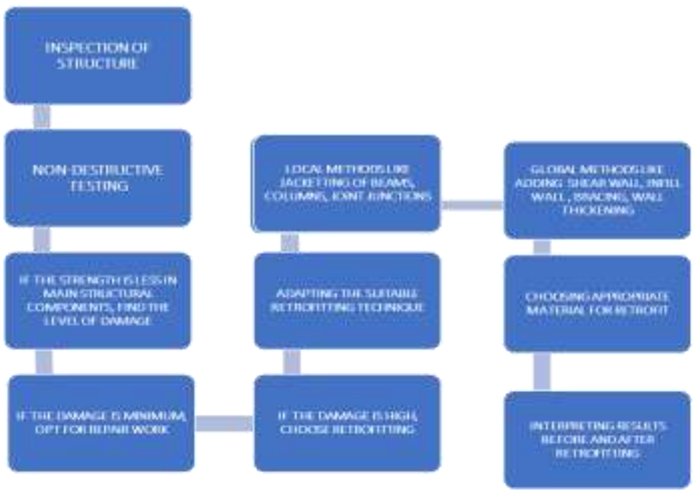

Chart-1: methodology

3.1 INSPECTION OF THE STRUCTURE

The element at which the structure has weakened has to be analysed and then physical inspection must be carried out for the whole structure. The visibility of the cracks and deflections at the important joints and structural elements will give a rough idea for carrying out further tests.

3.2 NON-DESTRUCTIVE TESTING

Since the structure is already weak and unstable destructive testing methods will not be suitable for it. Some of the basic and commonly used Non-Destructive tests are as follows:

- Schmidt's rebound hammer test
- Ultrasonic Pulse velocity test

3.2.1 SCHMIDT'S REBOUND HAMMER TEST

The rebound hammer is a surface hardness tester for which an empirical correlation has been established between strength and rebound number.

The only known instrument to make use of the rebound principle for concrete testing is the Schmidt hammer, which weighs about 4 lb. (1.8 kg) and is suitable for both laboratory and field work. It consists of a spring-controlled hammer mass that slides on a plunger within a tubular housing.

The hammer is forced against the surface of the concrete by the spring and the distance of rebound is measured on a scale. The test surface can be horizontal, vertical or at any angle but the instrument must be calibrated in this position.

Several readings are taken, well distributed and reproducible, the average representing the rebound number for the cylinder. This procedure is repeated with several cylinders, after which compressive strengths are obtained.

TABLE 1: Rebound Hammer test

AVERAGE REBOUND NUMBER	QUALITY OF CONCRETE
>40	VERY GOOD HARD LAYER
30 TO 40	GOOD LAYER
20 TO 30	FAIR
<20	POOR CONCRETE
0	LAMINATED

3.2.2 ULTRASONIC PULSE VELOCITY TEST

The pulse velocity method is an ideal tool for establishing whether concrete is uniform. It can be used on both existing structures and those under construction.

Usually, if large differences in pulse velocity are found within a structure for no apparent reason, there is strong reason to presume that defective or deteriorated concrete is present. High pulse velocity readings are generally indicative of good quality concrete. A general relation between concrete quality and pulse velocity is given in Table 2.

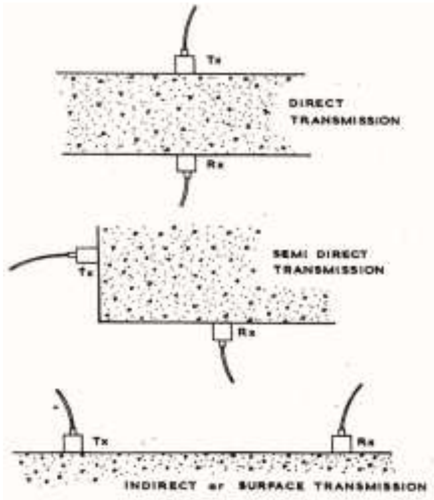

Fig-1: Methods of propagating ultrasonic pulses

TABLE 2: Ultrasonic Pulse Velocity Test

PULSE VELOCITY(Km/Sec)	CONCRETE QUALITY (GRADING)
ABOVE 4.5	EXCELLENT
3.5 TO 4.5	GOOD
3.0 TO 3.5	MEDIUM
BELOW 3.0	DOUBTFUL

Based on these tests the concrete structure will be classified and the further process is done.

3.3 RETROFITTING USING CFRP WRAPPING

The wrapping or overlaying method is chosen for the retrofitting of reinforced sample beam and carbon fibre reinforced polymer is used as the material for retrofit.

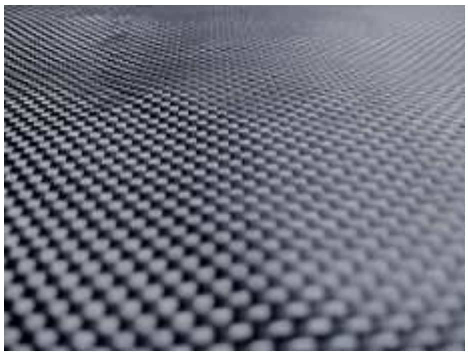

Fig-2: Carbon Fibre Reinforced Polymer(CFRP)

3.3.1 SURFACE CLEANUP AND REPAIR

Remove all contaminated area with debris, grease or oil, by grinding and repair cracks or damaged section by injecting epoxy resin (Grind the corner to have R=30mm radius). The proper temperature in working space is between 10ºC and 35ºC.

3.3.2 REMOVING THE EXISTING PLASTERING

The plastering is also removed before the actual surface is treated. They are removed until the actual cracked element is fully seen. The cracks are then tested and investigated so that the correct treatment can be done in order to cover the cracks and retrofit them using CFRP.

3.3.3 CRACK INJECTION

Epoxy based grouting is preferred to cement due to property of quick setting, very low shrinkage, excellent adhesion, high strength, low viscosity to penetrate even hair cracks and good resistance to most of the chemicals.

Epoxy grouting is done based on the type of crack, width and depth of crack in concrete structure. Grouting of wide cracks requires large quantity of grout materials. In such cases fillers are used to fill the cracks before epoxy grouting. Silicon four is one of the filler material used. The filler material to be used should be based on the manufacturers specification.

Very low viscosity epoxy resin and hardener composition is used for injection grouting of cracks. Based on the width of crack, depth and extent of cracks and other relevant details, the viscosity of the resin hardener mix, their proportions, pot life, application procedure etc. is selected in consultation with the manufacturer.

Equipment Required for Epoxy Injection Grouting

- Hole drilling equipment, pneumatic or electric based.
- Pressure injection equipment of standard make with control valves and gauges.
- Air compressor of capacity 3 to 4 cum/min. and pressure of 10 kg/cm2.
- Polythene or metal pipe pieces 6 – 9mm diameter.
- Polythene / plastic containers for mixing the epoxy formulation.
- A portable generator.

Then cracks in concrete is cut open into a 'V' groove about 10mm deep by mechanical or manual method. Loose materials are removed by using compressed air. The 'V' groove cut is fully sealed with epoxy mortar at least one day in advance before epoxy injection.

Nails are driven into the cracks at 15 cm to 50cm intervals along the crack.

Holes of 7 – 10 mm diameter is then drilled along the cracks and Copper or Aluminium or polythene pipe pieces of 6 – 9 mm diameter is fixed as grout nipples around the nails and allowed to rest on them.

Epoxy formulation is injected from the bottom most pipe. All other pipes, except the adjacent ones are blocked by wooden plugs. The injection is done using suitable nozzles connected to air compressors or by hand operated modified grease guns. Pressure of 3.5 to 7 kg /cm^2 is normally used.

As soon as the epoxy comes out from the adjacent open pipes, they are plugged and the pressure is increased to the desired level and maintained for 2 to 3 minutes. The injection nozzle is then withdrawn and the hole sealed with epoxy mortar.

3.3.4 PREPARATION OF CARBON FIBRE WRAPS

- Primer Application:
  Apply primer a couple of times on the position of concrete surface which will attach the carbon fiber. (Standard amount of primer : 0.3kg/m^2)
- The Bent Surface Control
  Apply epoxy putty with spatula to step area which waviness is over than 1mm.
- Top Coat Resin Application (1st)
  After drying primer, apply the top coat resin for adhesion evenly with a roller or a brush (standard amount : 0.5kg/m^2)
- Attaching Carbon Fiber Sheet
  Attach Carbon fiber sheet on a concrete structure and rub the surface a couple of times with roller or rubber scoop toward the fiber direction. Make sure no-air pocket inside the sheet.
- Top Coat Resin Application (2nd)
  Apply top coat resin on the sheet surface and let resin be penetrated into sheet by rubbing a couple of times to the fiber direction (standard amount of resin : 0.3kg/m^2). In case of adding more sheets, repeat steps.

Fig-3: Beam Specimen After Retrofitting

3.3.5 INSTALLATION OF CARBON FIBRE WRAPS

There are two methods by which the carbon fibers are wrapped or overlaid over a reinforced concrete structure.

3.3.5.1 WET-LAYING METHOD

Wet lay-up is a molding process that combines layers of reinforced fiber material with liquid resin to create a high quality laminate.

- **Wet Lay-up Technique**

This process involves the positioning of reinforcement material into or against a mold in layers. These layers are then impregnated with a liquid resin system, either with a brush or roller, to ensure a good wet-out of the reinforcement material. The step is repeated until reinforcement thickness is achieved.

Curing can be performed at room temperature or under heat, depending on the selection of the resin system. This can be accomplished with or without the use of a vacuum bagging process (recommended for a higher quality part).

Benefits of Wet Lay-up

- Easy processing
- Low capital investment
- Convenient for low-volume production

3.3.5.2 DRY-LAYING METHOD

A dry carbon fiber sheet is laid over the part or mold and resin is applied by hand. The resin provides the stiffness for the dry sheet, and it is the bonding agent for a carbon fiber wrap. The second process is known as "pre-impregnated carbon-fiber lay-up." This method uses fiber that is impregnated with resin. Pre-impregnation provides much better penetration of the resin and more uniform resin thickness than the wet lay-up process. The pre-impregnated roll is frozen by the vendor prior to delivery to prevent the resin from curing. The fiber is thawed at the lay-up site and hand laid over the part or mould.

3.4 TESTING OF BEAM SPECIMEN

The beam specimen are of dimensions 1.50 x 0.10 x 0.15 (in meters).

Control beams of these dimensions are tested and then compared with the beams that are wrapped using Carbon-Fibre-Reinforced Polymer.

They are tested by using the load frame method. The testing is same for all the beam specimens. First, the beams are cured and then they are tested by means of two point loading condition. The load is transmitted through a load cell and the load is spread over two points. The beam is spread over two roller bearing at 150 mm from the end. Proving ring and deflectometers were used to measure the corresponding deflection values for the load provided.

Fig-4: Testing Of Control Beam

The wrapping of the beam can be done in any forms such as full-wrap, U-shaped wrap, Strip Wrapping, etc. in which U-shaped wrapping is being done.

Fig-5: Testing of Retrofitted Beam Specimen

4. RESULTS

The tests are done with proving ring to measure the load that it resists and deflection gauge to measure the deflection occurred for the respective loads.

The control beams are tested without retrofitting and the results are noted.

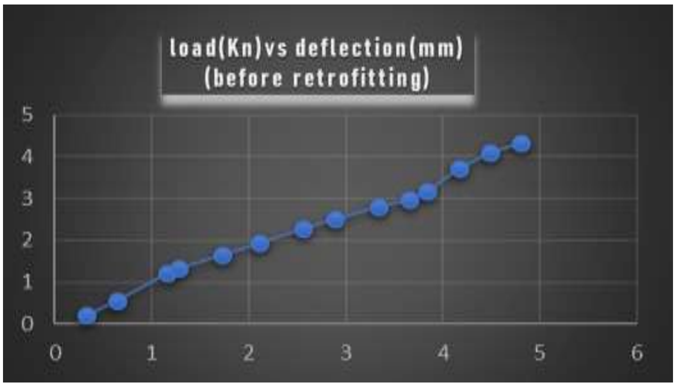

Chart -2: RCC Beam before retrofitting

Then the same control beams are retrofitted using carbon fibre reinforced polymer and allowed to cure. Epoxy resin was used as the binding material between the concrete and the fibre. The curing period to attain its full strength is 24 hours. It will attain its initial strength with four hours after retrofitting. Then, the beam is tested and the results are taken.

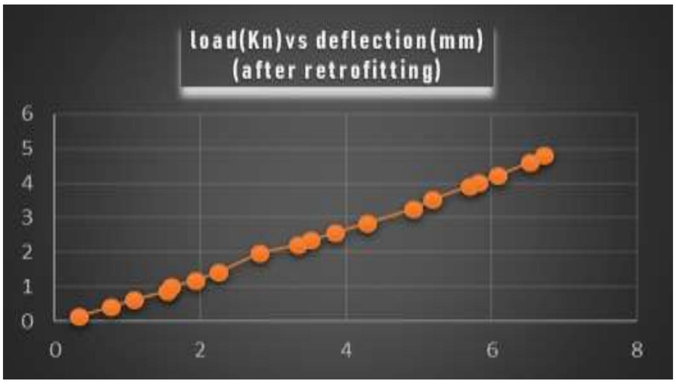

Chart -3: RCC Beam after retrofitting

The results show that the load resisted by the beams after retrofitting are more than that of the control beams.

Chart -4: Load resisted by the beam (Kn)

The deflection occurred due to the corresponding loads are also lesser in the retrofitted beams than the control beams.

Chart -5: Deflection Comparison(mm)

5. CONCLUSIONS

The process of retrofitting a reinforced concrete structure is elaborated and the experimental investigation of the testing beam before and after retrofitting are studied. The results indicate the following conclusions:

- The deflection of the beam is reduced when it is wrapped using carbon fibre and with full wrapping technique it will provide more strength.
- The retrofitted beams have greater flexural strength and ultimate load capacity after external wrapping.
- The carbon fibre reinforced polymer remained intact even after the failure of beam.

Overlaying or wrapping technique is the easiest and quickest way to retrofit a structure and it provides greater strength than other methods. Retrofitting of structures will not only retain the initial strength lost but will also help in increasing it twice-fold. It will increase the building's serviceability and safety against seismic action. Thus, retrofitting will be helpful in rehabilitation and strengthening of reinforced concrete structures.

REFERENCES

[1] Yasmeen Taleb Obaidat, Susanne Heyden, Ola Dahlblom , The effect of CFRP and CFRP/concrete interface models when modelling retrofitted RC beams with FEM (2010) DOI: 10.1016/j.compstruct.2009.11.008

[2] Prof. Shibi Varghese, Binusha Majeed, Habeebullah R,Mitin Mathew, Shabida K.K , Study on the performance of retrofitting techniques in RCC Beams e-ISSN: 2395 - 0056 p-ISSN: 2395-0072 (June 2016) pp.2073-2076

[3] Soumya Gorai, P.R. Maiti, Advanced Retrofitting techniques for Reinforced Concrete Structures: A State Of an art review, (March-May 2016) Vol.5, No.1

[4] Faisal M. Mukthar, Rayhan M. Faysal, A Review of test methods for studying the FRP-Concrete Interfacial Bond Behaviour(February2018)https://doi.org/10.1016/j.conbuildmat.2018.02.163