Retrofitting of RC Beam using Glass Fiber Reinforced Polymer Composite

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Abstract— *Retrofitting is the modification of existing structure which may or may not be damaged to make them more resistant to external forces. The objectives like Upgraded loading requirements; damage by accidents and environmental conditions, rectification of initial design flaws, change of usage can be achieved by retrofitting. The solutions adopted are generally based on successful prior practice. It is necessary to take a decision whether to demolish a distressed structure or to restore the same for effective load carrying system. Many a times, the level of distress is such that with minimum restoration measures the structural component can be brought back to its normalcy and during such times retrofitting is preferred. One of the techniques of strengthening RC structural elements is through confinement with composite enclosure. FRP material, which are available in the form of sheet or laminates are used to enhance the flexural, shear, and axial load carrying capacity of these elements. The proposed technique consist of wrapping Glass Fiber Reinforced Polymer composite mats on the shear and Flexural zones of the RC beam and studying their characteristics.*

Keywords— Epoxy Resin, Flexural strength, Glass fiber reinforced polymer, shear Strength, Woven mat.

I. INTRODUCTION

There is a pressing need to repair or upgrade the building and civil infrastructure in many parts of the world. For instance with the modernization of buildings, it is sometimes desirable to remove supporting walls or individual supports, leading to the need for local strengthening. The strengthening and enhancement of the performance of deficient structural elements or the structure as a whole is referred to as retrofitting. Retrofit aims to strengthen a building to satisfy the requirements of the current codes for seismic design. The building may not be damaged or deteriorated. The various retrofitting techniques include steel plate bonding, polymer injection followed by concrete jacketing, use of advanced composite materials like FRP, Ferro cement etc. Glass is the most common type of fiber used to reinforce composites. Glass-fiber-reinforced-plastics (GFRP) are commercially available at a fairly low cost. In general, the stress-strain relationship of GFRPs is linear to failure. The strength of certain types of GFRP exceeds that of the conventional steel, Moreover it is cost efficient .Therefore a detailed study is done on its properties by retrofitting beams.

II. MATERIAL

2.1 Concrete

Concrete is a construction material of Portland cement and water combined with sand, gravel, crushed stone, or other inert material such as expanded slag or vermiculite. The cement and water form a paste which hardens by chemical reaction into a strong, stone- like mass. The quality of the paste formed by the cement and water largely determines the character of the concrete. Proportioning of the ingredients of concrete is referred to as designing the mixture, and for most structural work the concrete is designed to give compressive strengths of 15 to 35 MPa. Ordinary portland cement will be used. Ordinary clean portable water free from suspended particles and chemicals will be used for both mixing and curing of concrete.

2.2 Reinforcement

The longitudinal reinforcements used were high- yield strength deformed bars of 12mm diameter and 10mm diameter were used as hanger bars. . The stirrups were made from mild steel bars with 8mm diameter.

2.3 Fiber Reinforced Polymer

Continuous fiber- reinforced materials with polymeric matrix (FRP) can be considered as composite, heterogeneous, and anisotropic materials with prevalent linear elastic behavior up to failure.

2.3.1 Glass Fibers

These are fibers commonly used in the naval and industrial fields to produce composites of medium- high performance. Their peculiar characteristic is high strength. Glass is made up of silicon (SiO_2) with a tetrahedral structure (SiO_4).

FIG.1 GLASS FIBER

2.3.2 Fiber Sheet

Fiber sheet in this experimental investigation was E- glass, Bi directional 2oven woven mat. It was not susceptible to atmospheric agents. It was also chemically resistive and anticorrosive

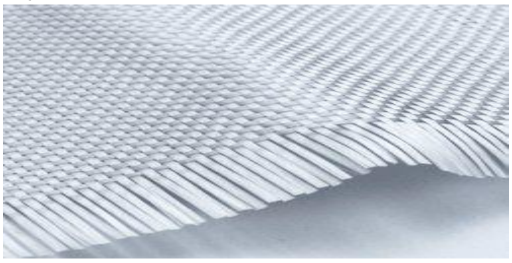


FIG. 2 GLASS FIBER WOVEN MAT

2.4 Epoxy Resin

Epoxy resins are relatively low molecular weight pre- polymers capable of being processed under a variety of conditions.The main advantages is that they can be partially cured and stored in that state and they exhibit low shrinkage during curing.

Viscosity of conventional epoxy resins is higher and they are more expensive compared to polyester resins.

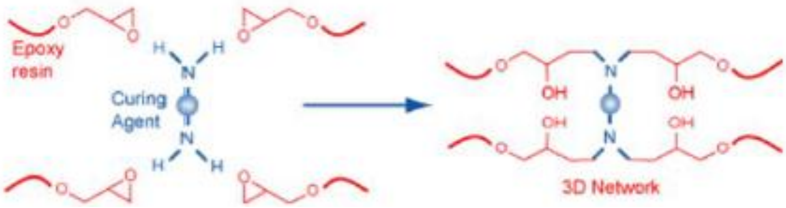


FIG 3 THE CURING OF EPOXY RESIN WITH PRIMARY AMINES

2.5 Retrofiting of beams

Before bonding the composite fabric onto the concrete surface, the required region of concrete surface was made rough using a coarse sand paper texture and cleaned with an air blower to remove all dirt and debris. Once the surface was prepared to the required standard, the epoxy resin was mixed. Mixing was carried out in a plastic container and was continued until the mixture was in uniform colour. When this was completed and the fabrics had been cut to size, the epoxy resin was applied to the concrete surface.

FIG 4 APPLICATION OF EPOXY AND HARDENER ON THE BEAM

FIG 5 FIXING OF GFRP SHEET ON THE BEAM

The composite fabric was then placed on top of epoxy resin coating and the resin was squeezed through the roving of the fabric. This operation was carried out at room temperature. Concrete beams strengthened with glass fiber fabric were cured for 24 hours at room temperature before testing.

2.6 Two-Point Loading

In two point loading the load is transmitted through a load cell and spherical seating on to a spreader beam. This beam bears on rollers seated on steel plates bedded on the test member with mortar, high- strength plaster or some similar spreader plates. The loading frame must be capable of carrying the expected test loads without significant distortion. Ease of access to the middle third for crack observations, deflection readings and possibly strain measurements is an important consideration, as is safety when failure occurs.

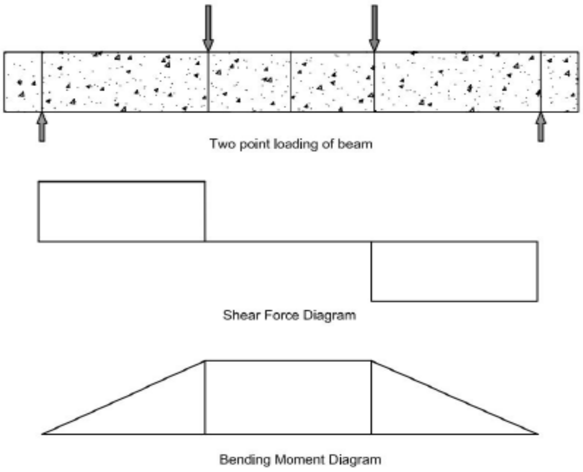


FIG 6 SHEAR FORCE AND BENDING MOMENT DIAGRAM FOR TWO POINT LOADING

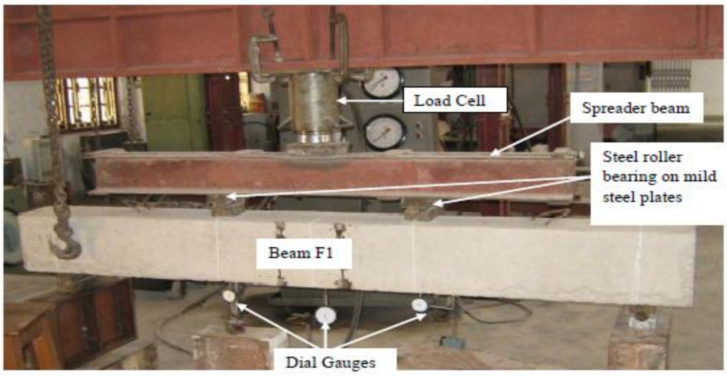


FIG 7: EXPERIMENTAL SETUP FOR TESTING OF BEAMS

III. PROJECT PROCEDURES

3.1 Cube Compressive Strength

Compressive strength is the capacity of a material or the ability of a structure to withstand load tending to reduce size .For compression test cube specimen of concrete and 150 mm x 150 mm were used respectively. Totally 21 cubes were cast for determination of compressive strength. After 24 hours the mould were demoulded and subjected to water curing. Before testing the cubes were dried for 2 hours. All the cubes were tested in saturated conditions after wiping out surface moisture. The load was applied without shock and increased continuously until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load applied to the specimen was then recorded, three cubes each were tested at the age 7 days 21 days and 28 days of curing for concrete compression testing

Compressive strength at failure= $\frac{Load\ at\ failure}{area\ of\ compression\ face}$

FIG 9 COMPRESSION TEST FOR THE CUBE ON 7 DAYS CURING

3.2 Specimen Preparation

Formwork making use of plywood was prepared for the beam as per the required size. A total of 6 beams were cast wherein 2 were controlled specimens and 2 were subjected to U-wrapping and other 2 specimens were subjected to complete wrapping. Each of the specimens were singly reinforced and under reinforced section. Without delay after the beam cast, the beams were covered with plastic sheet to minimize the evaporation of water from the surface of the beam specimen. After 24 hours, the sides of the formwork were removed and the beams were lowered into a curing tank for 28 days, after which the beams were left alone until the time of test. Before testing, beams were whitewashed and then the surface was rubbed with sand paper.

Linear variable displacement transducer (LVDT) was connected midspan of the beam to measure deflection. Crack widths were measured using a hand- held microscope with an optical magnification of 40X and a sensitivity of 0.01mm.

3.3 Shear Zone Wrapping

The beams after curing were wrapped using glass fibre reinforced polymer (GFRP) after applying primer 24 hours prior to wrapping. A mixture of epoxy resin was prepared wherein base, hardener and accelerator in the ratio of 0.5:1:5. During the preparation of the resin gloves and mask are worn as caution against burns.

FIG 10 GFRP WRAPPING ON THE BEAM

FIG 11 BINDING OF WOVEN MAT OVER THE GFRP SHEETS

A coat of the epoxy resin is coated on the shear zone of the beams and on the base of the beams and after that before the resin sets. A coat of GFRP is bonded on the shear zone which is at a distance of $\frac{Wl}{3}$ from either ends of the beam and the base and further poke joined using a paint brush once the GFRP sets on. The woven mat is coated on top of the GFRP coat using polyester resin. After 24 hours the beam is tested in 2 point frame under 2 point loading and 75%of the ultimate load is applied and the beam is cracked and the retrofitted as mentioned above and further tested till peak load and readings are recorded.

FIG 13 CRACKING OF BEAM BEFORE RETROFITTING

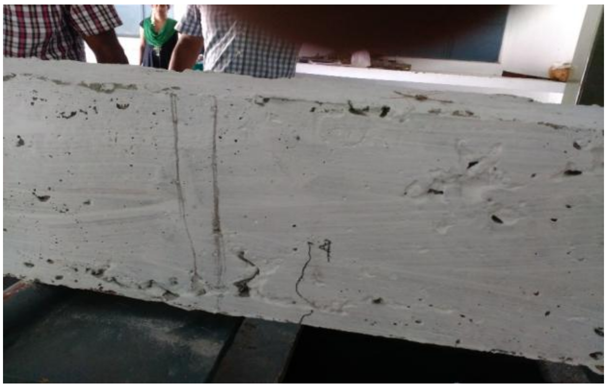


FIG 14 CRACKED SPECIMEN

FIG 15 TESTING OF BEAM AFTER RETROFITTING USING GFRP

3.4 FLEXURAL ZONE WRAPPING

The beams after curing were wrapped using glass fibre reinforced polymer (GFRP) after applying primer 24 hours prior to wrapping. A mixture of epoxy of resin was prepared wherein base, hardener and accelerator in the ratio 0.5:1:5. During the preparation of the resin gloves and mask are worn as caution against burns.A coat of epoxy resin is coated on the entire beam and after that before the resin sets a coat of GFRP is binded on the flexural zone of the beam and poke joined it using a paint brush.

Flexural zone length = $L-(2x\frac{WL}{3})$ Where L – Total length ;W-Total Load

FIG 16 BINDING OF WOVEN MAT OVER THE GFRP SHEETS IN FLEXURAL ZONE

FIG 17 RETROFITTED SPECIMEN AFTER FAILURE

After 24 hours the beam is tested in 2 point frame under 2 point loading and 75%of the ultimate load is applied and the beam is cracked and the retrofitted as mentioned above and further tested till peak load and readings are recorded.

IV. RESULTS AND GRAPHS

4.1 Compressive Strength of Cube

4.1.1 Compressive Strength of cube on 7days for M30 grade Concrete

TABLE 3
COMPRESSIVE STRENGTH OF CUBE ON 7DAYS FOR M30 GRADE CONCRETE
COMPRESSIVE STRENGTH OF CUBE ON 7DAY=26.9MPA

SL.NO	SPECIMEN NO	COMPRESSIVE STRENGTH
1	1	26.9MPa
2	2	26.8Mpa
3	3	26.9MPa

4.1.2 Compressive Strength of cube on 14days for M30 grade Concrete

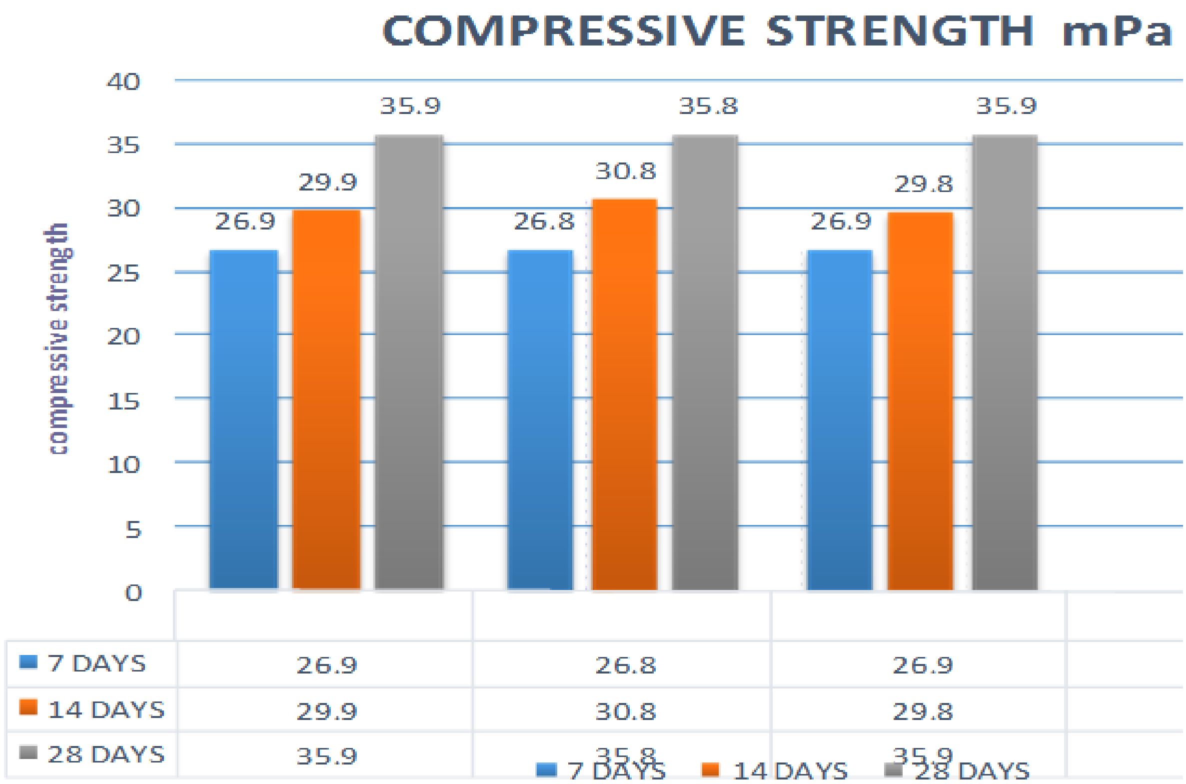
TABLE 4
COMPRESSIVE STRENGTH OF CUBE ON 28DAYS FOR M30 GRADE CONCRETE
COMPRESSIVE STRENGTH OF CUBE ON 14DAY=29.9MPA

SL.NO	SPECIMEN NO	COMPRESSIVE STRENGTH
1	1	29.9MPa
2	2	30.8Mpa
3	3	29.8MPa

4.1.3 Compressive Strength of cube on 28days for M30 grade Concrete

TABLE 5
COMPRESSIVE STRENGTH OF CUBE ON 28DAYS FOR M30 GRADE CONCRETE
COMPRESSIVE STRENGTH OF CUBE ON 28 DAY FOR M30 GRADE CONCRETE=35.9MPA

SL.NO	SPECIMEN NO	COMPRESSIVE STRENGTH
1	1	35.9MPa
2	2	35.8Mpa
3	3	35.9MPa



GRAPH 1: COMPRESSIVE STRENGTH (MPa)

4.2 Beam Result

4.2.1 Ultimate Load and Nature Of Failure

TABLE 6
ULTIMATE LOAD AND NATURE OF FAILURE

Sr.No	Type of Beam	Beam Designation	Load at Initial Crack (KN)	Ultimate Load (KN)	Nature Of Failure
1.	Beam weak in Flexural	Control Beam	134	158.3	Flexural Failure
		F1	134.7	164.5	Flexural failure+ Crushing of Concrete
		F2	133.5	178.5	Flexural failure+ Crushing of Concrete
2.	Beam weak in Shear	Control beam	165.7	178.3	Shear Failure
		S1	107.1	221.8	GFRP rupture +Shear Failure
		S2	105.6	213.8	GFRP rupture +Shear Failure

4.2.2 Comparison Between Experimental and Theoretical Values at Ultimate Stage

TABLE 7
COMPARISON BETWEEN EXPERIMENTAL AND THEORETICAL VALUES

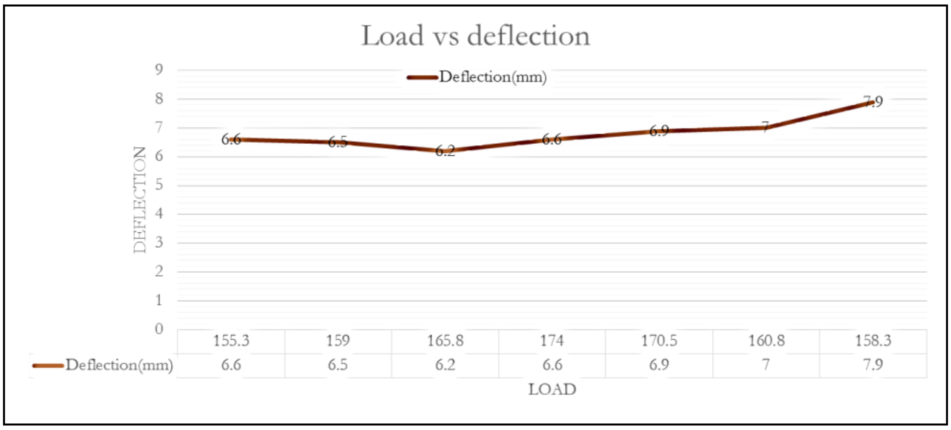
Beam no	Experimental Values		Theoretical Values		Capacity Ratios of beam	
	Load (KN)	Moment (KNm)	Load (KN)	Moment (KNm)	Exp/theo	Exp/theo
F1	164.5	27.41	160.8	26.8	1.02	1.02
F2	178.5	29.75	155.8	25.97	1.14	1.14
S1	221.8	36.96	160.8	26.8	1.38	1.37
S2	213.3	35.63	155.8	25.97	1.37	1.33

4.2.3 Ductility Behaviour

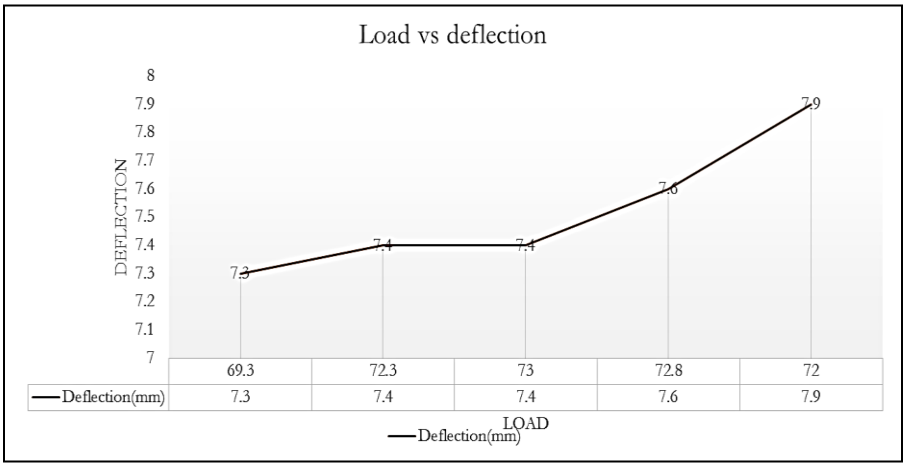
TABLE 8
EXPERIMENTAL DISPLACEMENT DUCTILITY

Beam no	Yield stage displacement Δy		Yield stage displacement Δu		Displacement ductility ratio $(\frac{\Delta u}{\Delta y})$
	Moment (kNm)	Deflection (mm)	Moment (kNm)	Deflection (mm)	
F1	22.45	5.8	27.41	5.8	1
F2	22.6	4.3	29.75	5.4	1.25
S1	17.85	11.2	36.96	11.7	1.04
S2	17.6	10.5	35.63	11.3	1.07

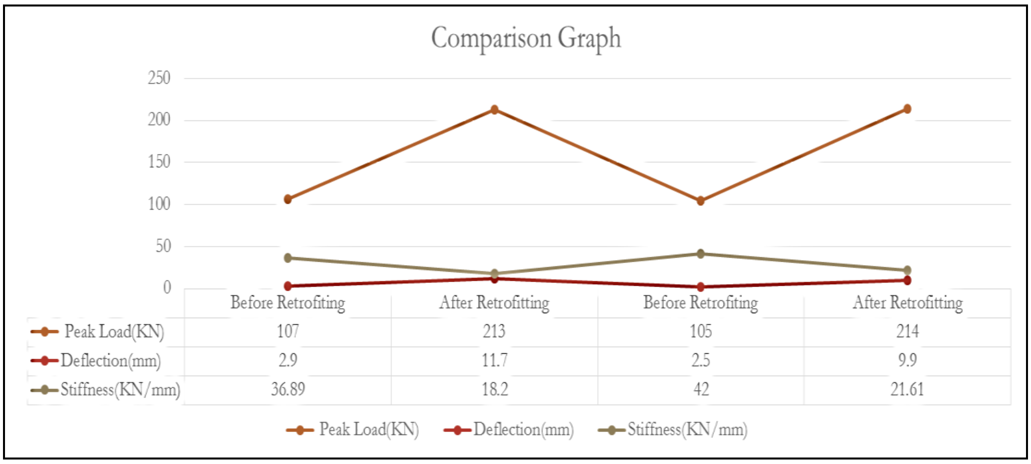
4.2.4 Graphical Results



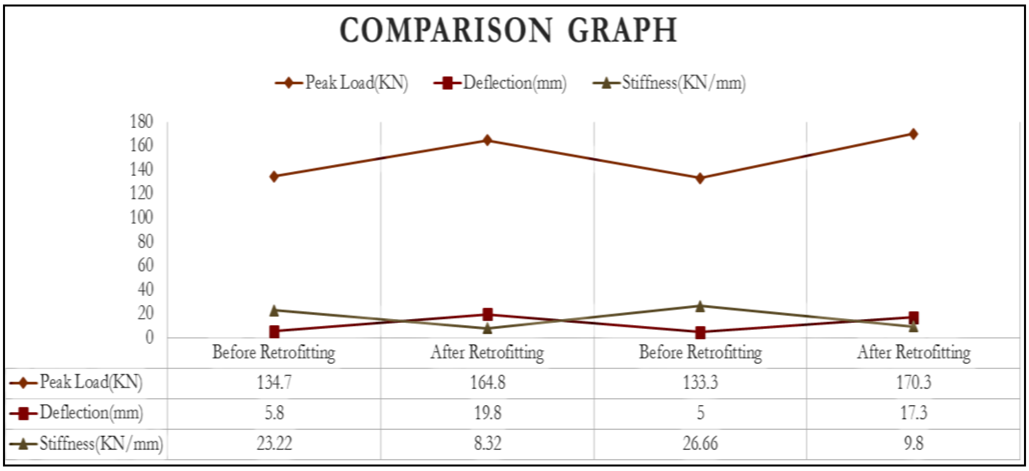
GRAPH 1 : LOAD VS DEFLECTION FOR CONTROLLED SHEAR BEAM



GRAPH 2: LOAD VS DEFLECTION FOR CONTROLLED FLEXURAL BEAM



GRAPH 3: COMPARISON FOR SHEAR SPECIMEN (BEFORE AND AFTER RETROFITTING)



GRAPH 3: COMPARISON FOR FLEXURAL SPECIMEN (BEFORE AND AFTER RETROFITTING)

V. CONCLUSION

A total of six beams were cast out of which two were controlled beams and two were retrofitted in the shear zone and the other two in the flexural zone after applying 75% of the Ultimate Load No horizontal cracks were observed at the level of the reinforcement, which indicated that there were no occurrences of bond failure. There was an increase of the shear load by 9%- 14% and an increase in the flexural load by 10%-14%.There is was considerable decrease in the stiffness of beam after retrofitting Due increased ductile nature.

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