"EXPERIMENTAL INVESTIGATION ON STRENGTHENING OF RC BEAM BY GFRP WRAPPING"

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ABSTRACT

Deterioration in reinforced concrete structures is a major issue faced by the infrastructures and bridge industries all over the world. One of the suitable solutions is to modify and to improve the performance of the structure by introducing a new technique called "Strengthening".Previously a steel plate was used as external reinforcement but in last fifteen years, FRP sheets have been used to replace steel because of their superior properties. These materials are an excellent option for use as external wrapping, because of their light weight, resistant to corrosion and high strength. The main aim of this study is to investigate the flexural characteristic of RC beams using GFRP sheets. It is not only cost effective but also helps in improving the service life of structures. To strengthen deficient RC structures beams are wrapped with single, double, and triple GFRP sheets. Test specimens were prepared for flexural strength. The grade of the concrete used for this investigation is M25.The strength properties of these beam are found at 28 days respectively.

INTRODUCTION

Civil Engineering structures are an important part of infrastructures and provide good service to the user; they experience distresses on account of reason and need of strengthening and retrofitting to bring them back to their originally intended service condition. Fiber-reinforced polymer (FRP), also Fiber-reinforced plastic, is a composite material made of a polymer matrix reinforced with fibers. The fibers are usually glass, carbon, or aramid, although other fibers such as paper or wood or asbestos have been sometimes used. The polymer is usually an epoxy, vinyl ester or polyester thermosetting plastic, and phenol formaldehyde resins are still in use. FRPs are commonly used in the aerospace, automotive, marine, and construction industries. The strengthening of concrete structures with externally wrapping is generally done by Glass Fiber Reinforced Polymer (GFRP). Each material has its specific advantages and disadvantages. The GFRP wrapping technique is now established as a simple and convenient repair method of enhancing the flexural, shear and compressive performance of concrete structures. Glass Fiber reinforced polymers offer numerous beneficial characteristics over steel including excellent corrosion resistance, nonmagnetic, nonconductive, generally resistant to chemicals, good fatigue resistance, low coefficient of thermal expansion, and high strength to weight ratio as well as being lightweight. GFRPs also possess a high specific stiffness and an equally high specific strength. Use of GFRP provides a high structural efficiency and their low density makes physical implementation much easier.

Repair and strengthening of R.C beam is now becoming more and more important in the field of structural strengthening and retrofitting. Fiber reinforced polymer (FRP) externally bonding with epoxy resin is recently widely used in construction industry to increase the ultimate strength of structures. This paper presents the result of experimental studies carried out to get the effect of side bonded GFRP laminates to RC beams. The result indicates the strengthened beam by GFRP significantly increases more and more load carrying capacity as compared to reference GFRP to concrete surface. From this work, it is concluded that as deflection goes on increasing that is ultimate load directly varies with deflection. All strengthened beam gives sufficient warning compared to normal beam failure**.** RC beams most of the time suffered non-uniform loads which induce combine stress of flexure, shear and torsion.

GFRP

Glass fibers, typical form shown in Fig, are isotropic in nature and most widely used filament. Common types of glass fibers are E-Glass, S-Glass and C-Glass. The characteristic properties of glass fibers are high strength, low cost with good water resistance and resistance to chemicals. Glass Fibers are produced from wild range of glass types, E, S, R glass, which differ only in the proportioning of their contents. Such glass fibers are weak in alkali resistance. To overcome this problem, surface coating of glass fiber is used to reduce alkali effect and increase wearing resistance of fibers. Such glass fibers are known as alkali-resistance glass fiber. Alkali resistant glass fibers give good results when reinforced with alkaline environment of concrete. Nowadays Alkali-resistance glass fibers are used in FRC Many of the existing reinforced concrete structures throughout the world are in urgent need of rehabilitation, repair or reconstruction because of deterioration due to various factors like corrosion, lack of detailing, failure of bonding between beam-column joints, increase in service loads etc, leading to crack, loss of strength, deflection, etc. The recent developments in the application of the advanced composites in the construction industry for concrete rehabilitation and strengthening are increasing on the basis of specific requirements, national needs and industry participation. The need for efficient rehabilitation and strengthening techniques of existing concrete structures has resulted in research and development of composite strengthening systems.

One of the challenges in strengthening of concrete structures is selection of a strengthening method that will enhance the strength and serviceability of the structure while addressing limitations such as constructability, building operations, and budget. Structural strengthening may be required due to many different situations.

Additional strength may be needed to allow for higher loads to be placed on the structure. This is often required when the use of the structure changes and a higher load carrying capacity is needed. This can also occur if additional mechanical equipment’s, filing systems, planters, or other items are being added to a structure.

Strengthening may be needed to allow the structure to resist loads such as additional floor loads, inadequate concrete strength & others i.e. wind, seismic blast etc that were not considered in the original design.

Additional strength may be needed due to deficiency in the structure’s ability to carry the original design loads. Deficiencies may be the result of deterioration (e.g., corrosion of steel reinforcement and loss of concrete section), structural damage (e.g., vehicular impact, excessive wear, excessive loading, and fire), or errors in the original design or construction.

The majority of structural strengthening involves improving the ability of the structural element to safely resist one or more of the internal forces caused by loading: shear and axial. Strengthening is accomplished by increasing the capacity of member to resist the magnitude of these forces

GFRP PROPERTIES

- Weight of GFRP 920 g/m².
- Density of fiber 2.6 g/cc .
- Fiber thickness 0.36 mm .

- Nominal thickness per layer 0.36 mm .
- Tensile strength 3400 N/mm^2.
- Tensile modulus 73,000 N/mm^2.

FRP PROPERTIES

SL.NO.	PROPERTIES	CFRP	AFRP	GFRP
1	Tensile Strength (MPa)	4300-4900	3200-3600	600-1800
2	Specific gravity	1.76 - 1.78	1.44 - 1.46	2.56- 2.58
3	Poisson's ratio	0.2	0.35	0.2
4	Density (kg/m3)	1800	1440	2560
5	Modulus of Elasticity	230 - 240	124 - 130	55 - 70

ADHESIVES

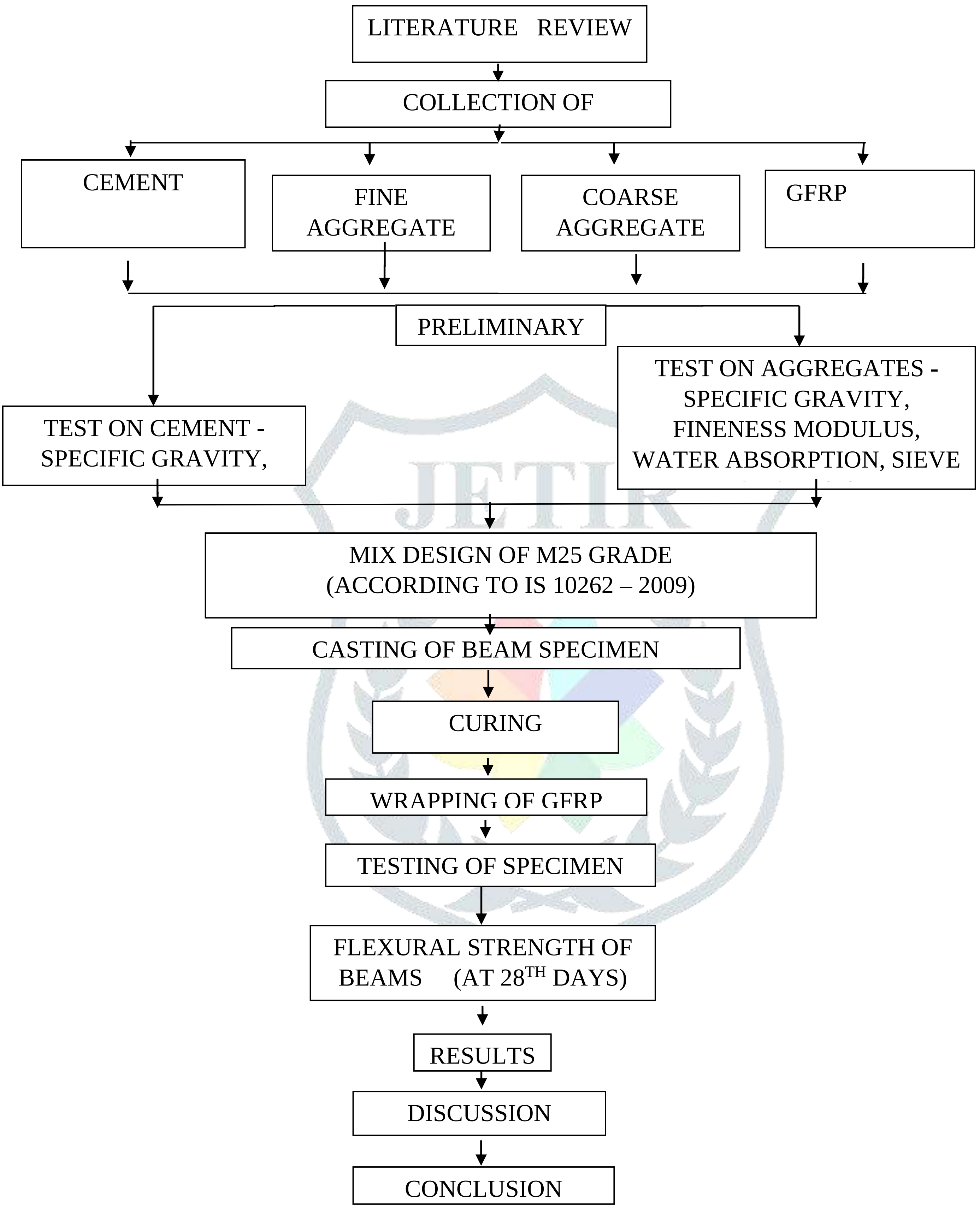
The success of the strengthening technique critically depends on the performance of the epoxy resin used. These epoxies are generally a two part systems, a resin and a hardener. The resin and hardener used in this study were Araldite GY 257and Hardener HY 840 respectively. The purpose of the adhesive is to attach the composites to concrete surface, so that to provide a shear load path. The most common type of structural adhesives is Epoxy and Polyester.

EPOXY RESIN PROPERTIES

In this project araldite and hardener used for bonding the properties of this epoxy resin are given in below table

S.NO	Properties	Araldite	Hardener
1	Density at 25^{o} Cg/cm^3	1.15	0.98
2	Specific gravity	1.8	2.0
3	Flexural strength Kg/cm^2	450-550	300-400

METHODOLOGY



CASTING

The size of beam mould is 1800mmx200mmx150mm. The mix design was computed according to the design specifications mentioned in IS10262-2009. The mix ratio thus obtained is 1:1.52:2.75. The water cement ratio is 0.45.

Casting involves mixing the ingredients together to obtain a homogenous mass of concrete, pouring the concrete into the mould and compacting it adequately so that the concrete fills the entire volume. The first step is mixing. Mixing should ensure that the concrete is homogenous, uniform in colour and consistency. The two types of mixing are hand mixing and machine mixing. The mixed concrete is then transported to the moulding place. Then the concrete is placed in the mould. This should be done carefully so as to ensure that the entire volume of the mould is packed with concrete without any air voids. The pouring of the concrete should also be done in such a way that the concrete does not get segregated while being discharged into the mould. The next step is compaction.

WRAPPING

Beams were designed, so they are failed in flexure and strong in shear. To improve the capacity or performance level of a beam, it is necessary to strengthen or retrofit the beam in flexure. To improve the flexural strength, beams were retrofitted by

- full wrapped
- U wrapping
- Bottom wrapping

SURFACE PREPARATION

Before wrapping the composite fabric onto the concrete surface, special consideration was given to the surface preparation. The concrete surface was slightly grinded off. The grinded was used to remove material for enhancing good bounding. And then it was cleaned with air blower to remove all dirt and debris.

EPOXY RESIN PREPARATION

Once the surface has been prepared to the required standard, the epoxy resin had been mixed in accordance with manufacturer's instructions. Mixing was carried out in a metal container (araldite GY 257 – 100 parts by weight and hardener HY840 – 50 parts by weight).

And it was continued until the mixture of the araldite and the hardener becomes a uniform color. When this was completed, the epoxy resin was applied to the surface. The resin mixture flowed and filled the cracks by gravity. The mixture of araldite and the hardener resin should not already to mix. It should mix at the time of wrapping. Because the resin will become to solid state and it seems useless.

BONDING

Experimental Setup

The beam is placed on the stand. The stand consists of roller support.

The two rollers supported in the 75mm distance from each edges of the beam. And the beam is marked by 550mm each except the edges of the two sides of the beam. The load is applied on the center if the beam and for the deflectometre is placed below the beam. The deflectometer is placed in the distance of 550mm from the left and right side of edges of the beam

The deflection is placed under, where the load is applied on the RCC beam. It is placed inbetween the distance of 550 mm each free from 75mm from the both edges of the beam.

Experimental Setup

Testing

RESULT AND DISCUSSION

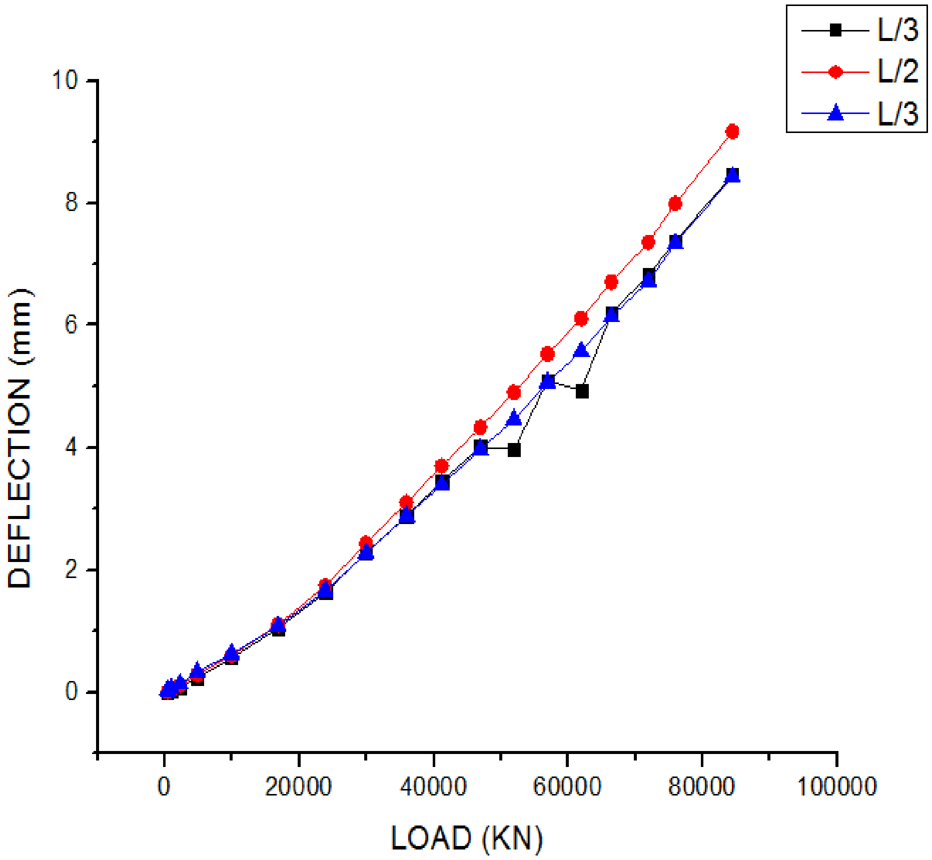
LOAD VS DEFLECTION CURVE

CONTROLLED BEAM

CONTROLLED BEAM TEST RESULTS

SL.NO	LOAD IN N	DEFLECTION AT LEFT SIDE IN mm	DEFLECTION AT MID POINT IN mm	DEFLECTION AT RIGHT SIDE IN mm
1	350	0	0.01	0.03
2	950	0.02	0.04	0.06
3	2250	0.08	0.11	0.14
4	4800	0.24	0.29	0.33
5	9900	0.56	0.6	0.63
6	16800	1.04	1.1	1.08
7	23850	1.63	1.74	1.66
8	29900	2.28	2.43	2.27
9	35900	2.88	3.1	2.88
10	41150	3.45	3.7	3.39
11	46900	4.01	4.33	3.97
12	51900	3.97	4.9	4.46

13	56900	5.09	5.53	5.07
14	61900	4.94	6.11	5.57
15	66400	6.19	6.71	6.14
16	71900	6.83	7.36	6.72
17	75900	7.37	7.99	7.34
18	84400	8.47	9.17	8.43



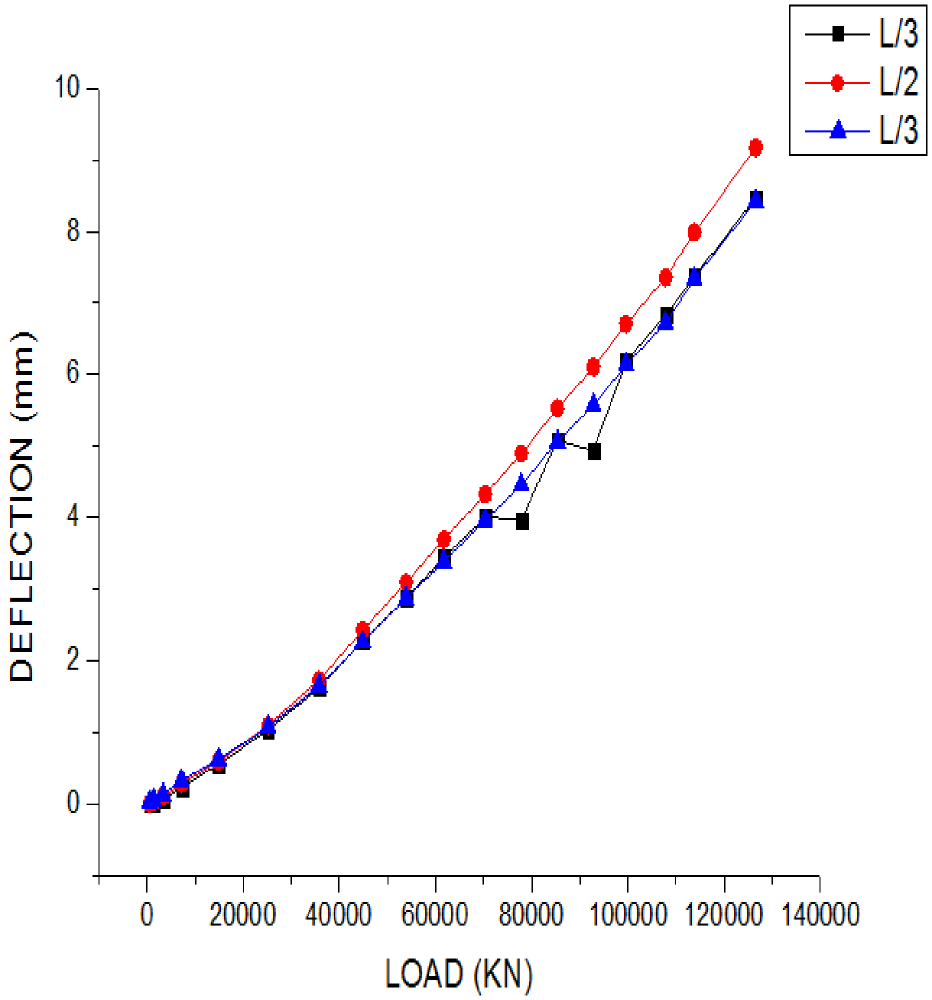
LOAD vs DEFLECTION OF CONTROLLED BEAM

FULL WRAPPING BEAM

FULL WRAPPED BEAM TEST RESULTS

SL.NO	LOAD IN N	DEFLECTION AT LEFT SIDE IN mm	DEFLECTION AT MID POINT IN mm	DEFLECTION AT RIGHT SIDE IN mm
1	525	0	0.01	0.03
2	1425	0.02	0.04	0.06
3	3375	0.08	0.11	0.14
4	7200	0.24	0.29	0.33
5	14850	0.56	0.6	0.63

6	25200	1.04	1.1	1.08
7	35775	1.63	1.74	1.66
8	44850	2.28	2.43	2.27
9	53850	2.88	3.1	2.88
10	61725	3.45	3.7	3.39
11	70350	4.01	4.33	3.97
12	77850	3.97	4.9	4.46
13	85350	5.09	5.53	5.07
14	92850	4.94	6.11	5.57
15	99600	6.19	6.71	6.14
16	107850	6.83	7.36	6.72
17	113850	7.37	7.99	7.34
18	126600	8.47	9.17	8.43

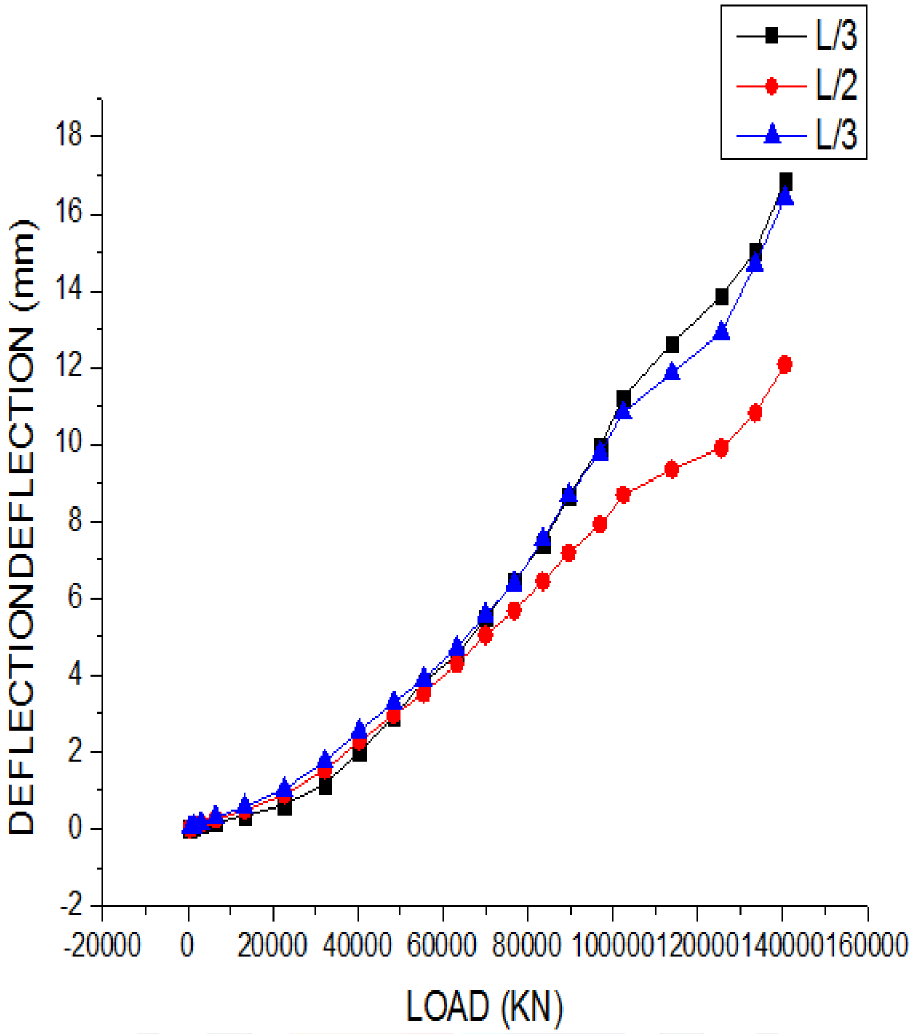


LOAD vs DEFLECTION OF FULL WRAPPED GFRP BEAM

U WRAPPING BEAM

U WRAPPED BEAM TEST RESULTS

SL.NO	LOAD IN N	DEFLECTION AT LEFT SIDE IN mm	DEFLECTION AT MID POINT IN mm	DEFLECTION AT RIGHT SIDE IN mm
1	472.5	0.02	0	0.01
2	1282.5	0.05	0.02	0.03
3	3037.5	0.09	0.06	0.07
4	6480	0.17	0.12	0.15
5	13365	0.34	0.25	0.3
6	22680	0.63	0.48	0.58
7	32197.5	1.16	0.89	1.03
8	40365	1.99	1.53	1.76
9	48465	2.94	2.28	2.55
10	55552.5	3.83	2.97	3.28
11	63315	4.52	3.53	3.9
12	70065	5.5	4.29	4.71
13	76815	6.47	5.04	5.58
14	83565	7.42	5.68	6.38
15	89640	8.67	6.44	7.54
16	97065	9.94	7.18	8.68
17	102465	11.22	7.92	9.78
18	113940	12.63	8.69	10.83
19	126856	13.86	9.35	11.85
20	134659	15.03	9.91	12.92
21	139994	16.86	10.82	14.69
22	148654	19.33	12.08	16.42



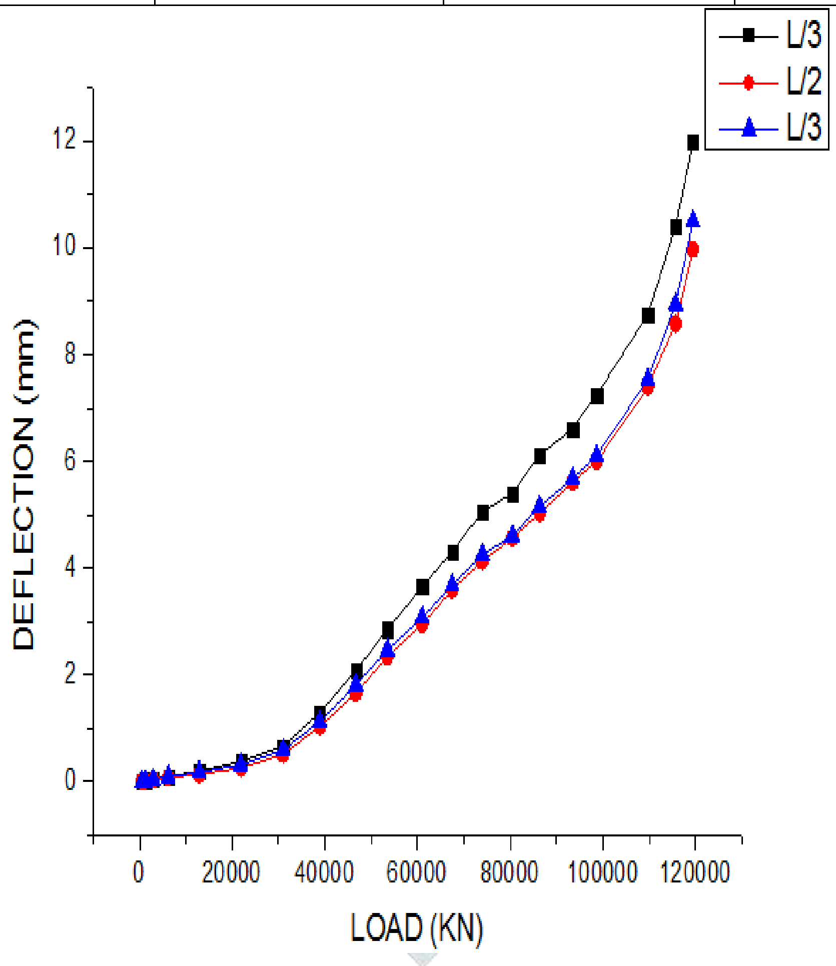
LOAD vs DEFLECTION OF U WRAPPED GFRP BEAM

BOTTOM WRAPPING BEAM

BOTTOM WRAPPED BEAM TEST RESULTS

SL.NO	LOAD IN N	DEFLECTION AT LEFT SIDE IN mm	DEFLECTION AT MID POINT IN mm	DEFLECTION AT RIGHT SIDE IN mm
1	455	0	0	0.01
2	1235	0.02	0.02	0.02
3	2925	0.05	0.05	0.04
4	6240	0.1	0.1	0.08
5	12870	0.19	0.18	0.14
6	21840	0.39	0.32	0.26
7	31005	0.66	0.6	0.52
8	38870	1.3	1.13	1.04
9	46670	2.08	1.81	1.66
10	53495	2.86	2.47	2.34
11	60970	3.65	3.08	2.95

12	67470	4.31	3.68	3.6
13	73970	5.06	4.25	4.13
14	80470	5.41	4.61	4.57
15	86320	6.12	5.16	5.03
16	93470	6.61	5.68	5.62
17	98670	7.25	6.11	6
18	109720	8.75	7.54	7.4
19	116008	10.41	8.95	8.58
20	124659	11.98	10.5	9.97



LOAD vs DEFLECTION OF BOTTOM WRAPPED GFRP BEAM

FAILURE MODES OF BEAMS

Failure modes have been observed in the experiments of RC beams strengthened by GFRP. The GFRP strengthened beams and the control beams are tested to find out their ultimate load carrying capacity. The controlled beam is failed in flexural. The bottom wrapping and U wrapping beam both failed in flexure. The U wrapping and bottom wrapping final crack pattern of this both beams similar to reference beam. The full wrapped beam failed in shear.

BOTTOM WRAPPED GFRP BEAM FAILURE

BOTTOM WRAPPED GFRP BEAM FAILURE

BOTTOM WRAPPED GFRP BEAM FAILURE

CONCLUSION

GFRP is provided to increase the flexural strength existing concrete beams when bonded to the full side, bottom side and U-Shape by using GFRP wrap as compare to control beam, however the mode of failure associates with application of GFRP was more ductile and proceeded by warning signs such as snapping sounds or peeling of the GFRP. Yet the results of this study show that GFRP can be used to increase the flexural strength of beams without causing catastrophic brittle failure associated with this strengthening technique.

Based on results from experimental study for the beams strengthened in flexure with GFRP, the following conclusions are drawn .The flexural strength can be increased by GFRP wrapping by different methods are given below

- By full wrapping 50% of strength will increased by single layer wrapping.
- By U wrapping 35% of strength will increased in RCC beam.
- By bottom wrapping 30 % of strength will increased in RCC beam.

Among these three methods full wrapping of the GFRP over the RCC beam will give better result and strength.

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