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Retrofitting Of Reinforced Concrete Beams Using GFRP

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I. INTRODUCTION

Many civil structures are no longer considered safe due to changes in load, inferior building material used, increased load specification in the design codes or natural calamities. Hence, structural strengthening and retrofitting of existing structures are currently the major activities in the construction industry. Nowadays, strengthening using FRP composites is gaining popularity due to its high strength to weight ratio, minimal change in structural geometry, easy and rapid installation and corrosion and fatigue resistance.

Reinforced Cement Concrete is very popular construction material used for structural components of a building like beams, columns and slabs etc. One major flaw of RCC is its susceptibility to environmental attack.

AIM AND OBJECTIVE

AIM

The major aim of the project is to study the behavior of R.C.C. beams retrofitted with GFRP over lays so that to obtain best procedures for strengthening of R.C.C. beams using GFRP overlays. To improve the load carrying capacity of the R.C.C Beam using GFRP over lays is the aim of the project.

OBJECTIVES

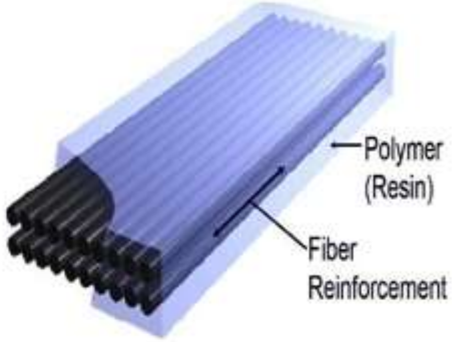
The objective is achieved by conducting the following task

1. To improve the load carrying capacity of both shear deficient beams and flexural deficient beams by retrofitting with GFRP
2. To study the load deflection behavior of flexural deficient beams which are retrofitted with GFRP
3. To study the ductility of flexural deficient beams
4. To study the effect of different sized layers of GFRP, which can be wrapped on flexural deficient beams
5. To compare the strength of various sizes of GFRP sheets which can be wrapped on beams

RETROFITTING OF REINFORCED CONCRETEBEAMS

FRP Material

Fiber reinforced polymer(FRP) composites consist of high strength fibers embedded in a matrix of polymerres in as shown in Figure.



As chematic diagram showing a typical unidirectional FRP plate.

Fibers typically used in FRP are glass, carbon, steel and aramid. Typical values for propertiesof the fibers are given in Table 1. These fibers are all linear elastic up to failure, with no significant yielding compared to steel. The primary functions of the matrix in a composite are to transfer stress between the fibers, to provide a barrier against the environment and to protect the surface of the fibers from mechanical abrasion. Typical properties for epoxy are given below.

The mechanical properties of composites are dependent on the fiber properties, matrix properties, fiber-matrix bond properties, fiber amount and fiber orientation. A composite with all fibers in One direction is designated as unidirectional. If the fibers are woven, or oriented in many directions, the composite is bi or multidirectional. Since it is mainly the fibers that provide stiffness and strength composites are often anisotropic with high stiffness in the fibril direction(s). In strengthening applications. unidirectional composites are predominantly used.

Adhesives are used to attach the composites to other surfaces such as concrete. The most common adhesives are acrylics, epoxies and urethanes. Epoxies provide high bond strength with high temperature resistance, whereas acrylics provide moderate temperature resistance with good strength and rapid curing. Several considerations are involved in applying adhesives effectively. Careful surface preparation such as removing the cement paste,_grinding the surface by using a disc sander, removing the dust generated by surface grinding using an air

II. MATERIALS USED AND THEIR PROPERTIES

CEMENT

In the present work, Puzzalona Portland Cement conforming to IS 1489- Part- I was used. Physical properties of Cement show that properties are within the codal specified range of values. The physical properties of cement are tested in accordance with IS 4031-1968 to know its suitability. Physical properties of Cement show that properties are within the codal specified range of values

FIG.NO.3.1

The ordinary Portland cement was used for project. It is a bluish-gray powder obtained byfinely grinding the clinker made by strongly heating an intimate mixture of calcareous and argillaceous minerals. Conforming to IS 8112:1989 was used. The physical properties of cement obtained as per IS 269/4831 and the requirements as per 4031 -1988 are given in below table. Physical properties of Cement show that properties are within the codal specified range of values.

TABLE.NO.3.1 :-The specific gravity of cement.3.15

Sl.no	Material properties	Test results	Requirementis 81121989
1	Fineness–residueon90	8.5%	Not morethan10%
2	Initial setting time(min)	55	Not less than 30mins
3	Final setting time(min)	245	Not more than 600
4	Standard consistency(%)	34	30 to 35
5	Specific gravity	3.13	-

FINEAGGRE GATE

River sand passing through IS 4.75mm sieve conforming to zone II of IS: 383-1970 is Usedas fine aggregates. The results of sieve analysis and properties offine aggregates are given below.

FIG.NO.3.2

TABLE.NO.3.2:- Sieve analysis results of Fine Aggregates

Sl.no	**Sieve size(mm)**	**Weight retained(g)**	**Cumulative weight retained(g)**	**Cumulative % weightretained**	**Cumulative %passing**
1	4.75	0	0	0	100
2	2.38	0	0	0	100
3	1.18	99	9.9	9.9	90.1
4	0.6	234	23.4	33.3	66.7
5	0.3	503	50.3	83.6	16.4
6	0.15	144	14.4	98	2

TABLE.NO.3.3 :- Properties of Fine Aggregates

Properties	**Observed values**
Specific gravity	2.44
Fine modulus	2.248
Bulk density	1.6197kg/m^3
Loose density	1.5605kg/m^3
Zone	Ⅲ
Water absorption	3.2%

COARSEAGGRE GATE

Crushedgranite,s tone with a maximum size of 20mm was used as the coarse aggregates. The results of sieve analysis and properties of coaseaggregates are given below.

FIG.NO.3.3

TABLE.NO.3.4 :- Sieve analysis results of coarse Aggregates

Sl.no	**Sieve size(mm)**	**Weight retained(g)**	**Cumulative Weight retained(g)**	**Cumulative % weight retained**	**Cumulative %passing**
1	80	0	0	0	100
2	40	0	0	0	100
3	20	2025	40.5	40.5	50.5
4	10	2887	57.74	98.24	1.76
5	4.75	88	1.76	100	0

TABLE.NO.3.5 :- Properties of Coarse Aggregates

Properties	**Observed values**
Specific gravity	2.81
Fine modulus	7.38
Bulk density	1.6197kg/m^3
Loose density	1.5305kg/m^3
Water obsorption	3.2%

WATER

Clean portable water available in the laboratory of university which satisfies the drinking standards was used for the preparation of specimens.

TABLE.NO.3.6

Sl.no	**Description**	**Obtained value**	**Permissible valueasper IS456-2000**
1	P^{H}Value	8.2	Notless than6.0
2	Chloride content	112.5mg/l	500mg/l
3	Total hardness	105mg/l	200mg/l

REIN FORCEMENT

Shear deficient beams were designed by having 3 numbers of 10 mm diameter bars in the tension zone and 2 numbers of 8mm diameter bars in the compression zone. 6mm diameter bars were used as stirrups. The spacing between the stirrups were kept at 365mm along the shear span so that beam was failed only along the shear span. Flexrual deficient beams were designed by having 2 numbers of 10mm diameter bars in the tension zone and 2 numbers of8mm diameter bars at the compression zone. 6mm diameter bar were used as stirrups at the spacing of 175mm in the middle span of the beams were behaved as flexural deficient. Reinforcement cage for shear deficient beam and flexural deficient beam.

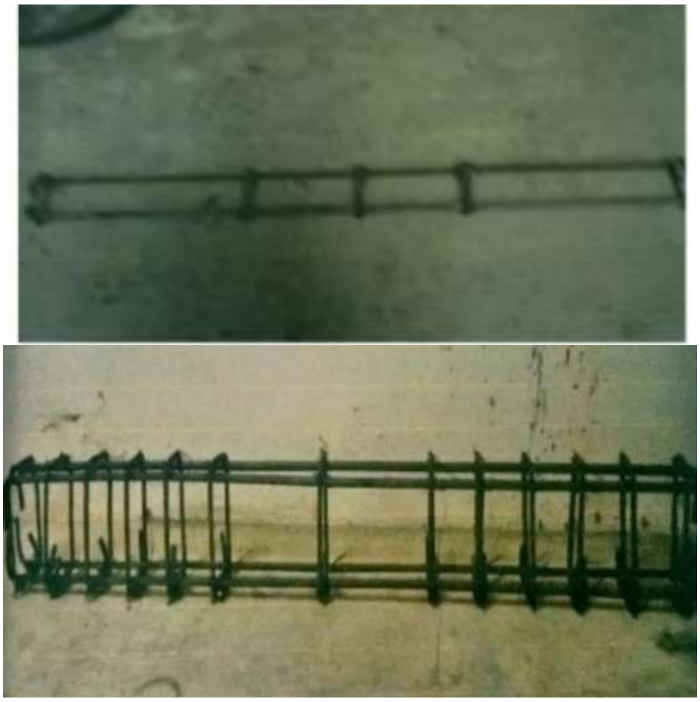


FIG.NO.3.4

GLASS FIBER REINFORCED COMPOSITE (GFRC)

GFRC as are inforcing material: Composites are materials consisting of two or more chemically distinct constituents on a macro-scale, having a distinct interface separating them with properties which cannot be obtained by any constituent working individually. In fibrous polymeric composites, fibers with high strength and high stiffness is embedded in and bonded together by the low modulus of continuous polymeric matrix. Each of the individual phases must perform certain functional requirements based on their mechanical properties so that a system containing them must perform satisfactorily as a composite. In case of FRP composites the reinforcing material form the backbone of the material and they determine its strength and stiffness in the direction of fibers. The polymeric matrix is required to fulfil the following functions:

1. To bind together the fibers and protect their surfaces from damage during handling.
2. Fabrication and service life of the composite.
3. To disperse the fibers and separate them to transfer stresses to the fibers.

Ehsani, Saadatmanesh, and Velazquez-Dimas (1999) built three half-scale unreinforced clay brick walls, retrofitted them with vertical FRP strips and subjected them to cyclic out-of -plane loading. They found that the mode of failure was controlled by tensile failure when wider and lighter composite fabrics were used and by delamination when stronger fabrics were used. They report that although URM walls and composites behave in a brittle manner, the combination resulted in a system capable of dissipating some energy.

Deflections as much as 2.5% of the wall height were observed for walls with unidirectional fabric; these walls deflected almost 14 times the maximum allowable deflection according to the latest masonry specifications. Some of this energy dissipation was attributed to the removal of brick material with the composite as it progressively delaminates. Our study observed deflections up to1.5%for specimens reinforced only with GFRP.

Researchers Marshall and Sweeney (2002) performed in-plane shear tests on 4- foot by 4-foot unreinforced double-wythe brick wall specimens and lightly reinforced single- wythe concrete masonry unit (CMU) wall specimens. These specimens were tested with various configurations of glass and carbon FRP applied to them. They found that the strength of the specimens canbe increased with the application of FRP composites, however in all cases the failure mode changed to a less ductile mode. They felt that the next step in this line of investigation would be to develop configurations of FRP reinforcement that can prevent failure modes such as X-cracking while transferring the failure to a more ductile mode such as bed joint sliding or rocking priortotoecrushing.

Holberg and Hamilton (2002) proposed a system incorporating two materials, glass fiber reinforced polymers (GFRP) and steel, and investigated several configurations on full scale masonry specimens. These utilized two different types of steel connections, internal and external (Figure 1). The drift capacities of these specimens reached up to 1.7%. The lateral capacities were nearly doubled compared to an unreinforced specimen.

The horizontal GFRP strips are designed to provide enough additional strength to enable the pier to resist the shear and flexural stresses imposed on it during a seismic event. The steel is designed to yield at the pier/sillinter face prior to failure of the GFRP composite.

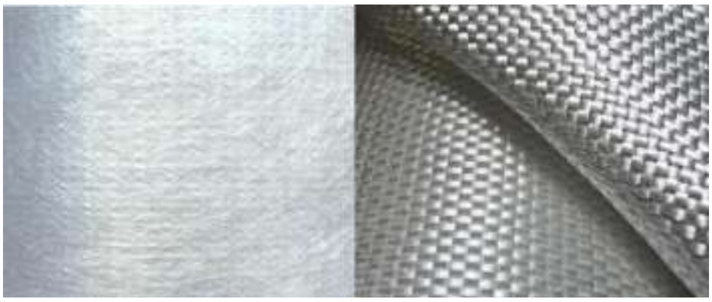


FIG.NO.3.5

EPOXYADHESIVE

The GY 250 epoxy resin is a thixotropic adhesive mortar, based on a two- component solvent free epoxy resin. The mixing ratio was 2:1 of Component A(resin) and Component B (hardener)by weight. The elastic modulus, tensile strength, and shear strength as provided by themanufacturerare11.7GPa,24.8MPa,and 15MPa,respectively.HY140hardenerused.

FIG.NO.3.6

MIX DESIGN PROCEDURE

1. The mean target strength is determined from the specified characteristic compressive streng that 28-dayfck and the level of quality control. ft=fck+1.65S Where Sis the standard deviation obtained from the Table 8 of IS 456-2000.
2. The water cement ratio for the desired mean target is obtained using the empirical relationship between compressive strength and water cement ratio. The water cement ratios chosen is checked against the limiting water cement ratio for the requirements of durability given in table 5 of IS 456-2000 depending

upon exposure conditions and the zones.

3. The water content is selected for the required work ability and maximum size of aggregates (for aggregates in saturated surface dry condition) from table 2 of IS 10262-2009.
4. The cement content is calculated by the ratio of water content to the water cement ratio and further checked by the minimum cement content from table 5 of IS 456-2000 for different exposure conditions. Maximum of both the values is considered.
5. The percentage of coarse aggregate in total aggregate by absolute volume is determined from table for the concrete using crushed coarse aggregate.
6. Volume offine aggregates per unit volume of total aggregates is thus determined.
7. The volume of concrete is considered as one cubic meter and there by the volume of cement, water and aggregates are calculated. Finally, the mass of materials is calculated by the volumes. The concrete mix proportion for the design mix is calculated.

MIX DESIGN CALCULATION

Grade of concrete M_{30} Type of exposure-moderate Slump–100mm

Size of coarseaggregate–20mm Fine aggregate – zone II

Specific gravity of cement–3.15 Specific gravity of water– 1

Specific gravity of coarseaggregate–2.82 Specific gravity of fine aggregate– 2.65

1. Targetmeanstrength–38.25N/mm^2
2. Water cement ratio –0.45
3. Water content – 197.16for100mmslump
4. Cement content –197.16/0.45=438.133kg/m^3
5. Volume of coarseaggregate–0.567
6. Volume of fineaggregate–0.433
7. Volume of concrete–1m^3
8. Volume of cement –0.139m^3
9. Volume of all aggregates– 0.685
10. Massofcoarseaggregate– 0.685*0.567*2.82*1000=1093.67kg
11. Massoffine aggregate – 0.685*0.433*2.65*1000=786kg

PROPORTIONS OF TRIAL MIX

Cement–438.133kg/m^3 Water– 197.16 lit

Fineaggregate–786kg Coarseaggregate–1093.67kg

Water cementratio–0.45

III. CONCLUSION

Based on the analysis of the results the following conclusion can be arrived.

- The results shows that shear capacity and flexural capacity of UW rapped specimens using stitched mat and woven roving increased, as the numbers of layers of the mat increased.
- The improvement ultimate load of retrofitted flexural deficient beams using stitched mat was upto 7.5% for single layer wrap, 17.5% for double layer wrap and 25% for triple layer wrap.
- The improvement in ultimate load of retrofitted flexural deficient beams using woven roving was upto 1.07% for single layers wrap, 10% for double layer wrap, 17.5%fortriple layer wrap.
- The improvement in ultimate load of retrofitted shear deficient beams using stitched mat was upto 2.63% for single layer wrap, 13.5% for double layer wrap and 21.5% for triple layer wrap.
- The improvement in ultimate load of retrofitted shear deficient beams using woven roving was upto 1.25% for single layer wrap, 7.89% for double layer wrap, 13.5% for triple layer wrap.
- For both retrofitted heard efficient beams and retrofitted flexural deficient beams, triple layer of stitched mat and triple layer of woven roving have performed well.
- From this study, it is concluded that stitched mat is a more effective material for retrofitting than the woven roving.

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