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RETROFITTING OF RC BEAMS USING (GLASS FIBRE REINFORCED POLYMER) GFRP

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ABSTRACT: Rehabilitation and strengthening of old structures using advanced materials is a contempory research in the field of structural engineering. During past two decades, much research has been carried out on flexural strengthening of RC beams using different types of Fibre Reinforced Polymer (FRP) and adhesives. Many of the RC structures are in urgent need of rehabilitation, repair or reconstruction. Retrofitting plays important role in rehabilitation of existing structures. Fibre Reinforced Polymer (FRP) has been accepted in the construction industry as a promising substitute for repairing and in incrementing the strength of RCC structures. This paper views the different properties of Glass Fibre Reinforced Polymer (GFRP) composites and adhesives, influence of dimensions of beams and loading rate cause failure and experimental study on retrofitting of RC beams with GFRP composites externally. The objective of this study is to investigate the behavior of retrofitted beam and to compare the results of control specimen and retrofitted specimen.

KEYWORDS: GFRP (GLASS FIBRE REINFORCED POLYMER, EPOXY RESIN, RC BEAM, RETROFITTING, FLEXURAL STRENGTH.

INTRODUCTION:

Structures deteriorate due to problems associated with reinforced concrete. Commonly encountered engineering challenges such as increase in service loads, changes in use of structures, design and construction errors, degradation problems and changes in design code are some of the causes that lead to the need for rehabilitation and retrofitting of existing structures. Complete replacement of an existing structure may not be a cost effective solution and it is likely to become an increased financial burden if upgrading is a viable alternative.

Retrofitting is the modification existing structure to make it more resistant to external forces like seismic forces, wind forces and vibrational forces. In case of increase in live load, accidental loads and in excessive severe environmental conditions; we need to redesign building as per new load combinations. Generally we have to take decision that whether to demolish the building or retrofit it. It will depend up on the stressing level of the structure. Many times it has been seen that with some restoring measures, building can be retrofitted and the age could be increased for more years. Depending up on the conditions there are various types of retrofitting methods used in the field.

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METHODOLOGY

RETROFITTING

Retrofitting is the modification of existing structure to make them more resistant to seismic activity, ground motion, structures deteriorate due to problems associated with reinforced concrete.

METHODS AND TECHNIQUE OF RETROFITTING

- Fibre reinforced polymer (FRP) composites
- External plate bonding
- Section enlargement
- External post tensioning
- Grouting
- Epoxy injection
- Steel caging

FIBRE REINFORCED POLYMER

Fibre reinforced polymer is a composite material made of a polymer matrix reinforced with fibres. The fibres are usually glass, carbon, aramid and basault.

GLASS FIBRE

FRPs use textile grade glass fibre. These textile fibres are different from other forms of glass fibres used to deliberately trap air, for insulating applications. Glass fibre short strands are short 0.2-0.3 mm strands of glass fibres that are used to reinforce thermoplastics most commonly for injection molding.

MATERIALS PROPOSED

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.

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.

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).

Epoxy resins are relatively low molecular weight pre- polymers capable of being processed under a variety of conditions. The main advantage 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.

MIX PROPORTIONS

CEMENT	**483**	kg/m3
WATER	**202.71**	kg/m3
COARSE AGGREGATE	**1009**	kg/m3
FINE AGGREGATE	**753.4**	kg/m3

Design shall be proposed in the ratio of **1:1.5:2.5**with the water cement ratio of **0.42.**

QUANTITY ANALYSIS

Total quantity of materials taken for 9 cubes, 9 cylinders and 27 RC beams for the tests.

MATERIALS	QUANTITY
CEMENT	**368.4 kg**
FINE AGGREGATE	**552.6 kg**
COARSE AGGREGATE	**921 kg**
8 mm BARS	**90m**
12mm BARS	**110m**

CASTING OF SPECIMENS

CUBES

Design mix is proposed as per IS 456:2000 and the concrete is made as per design mix. The size of the mould is 150 *150 * 150 mm. Pour concrete in the moulds in three layers and compact each layer with 35 Nos of strokes with tamping rod. Finish the top most layer by trowel after compacting the last layer. The above process is repeated for 9 Nos cubes. After 24 hours, remove the specimen from mould. Code the cubes with paint or marker with self explanatory. Submerge the specimen in fresh water for 7, 14, 28 days of curing. Test 3 specimens for 7 days, 14 days and 28 days curing. Check the dates of casting and testing for 7, 14, 28 days. Place the cube in testing machine, and the load is applied gradually till specimen fails. Record the maximum load applied to the specimen. Calculate compressive strength by using formula (F=P/A) and take average strength of specimen cubes. This average strength represents the compressive strength of concrete.

concrete cube specimen 15cm

CYLINDER

Design mix is proposed as per IS 456:2000 and the concrete is made as per design mix. The size of the mould is 150 * 300 mm. Pour concrete in the moulds in three layers and compact each layer with 35 Nos of strokes with tamping rod. Finish the top most layer by trowel after compacting the last layer. The above process is repeated for 9 Nos cylinder specimens. After 24 hours, remove the specimen from mould. Code the cylinder specimens with paint or marker with self explanatory. Submerge the specimen in fresh water for 7, 14, 28 days of curing. Test 3 specimens for 7 days, 14 days and 28 days curing. Check the dates of casting and testing for 7, 14, 28 days. Place the cylinder in testing machine, and the load is applied gradually till specimen fails. Record the maximum load applied to the specimen. . Calculate split tensile strength by using formula ($t=2P/\pi dl$) and take average strength of specimen cubes. This average strength represents the split tensile strength of concrete. Since concrete is strong in compression and weak in tension the average tensile strength will be 10% of compressive strength.

BEAMS

According to ASTM the size of the specimen is 150mm width, 150mm depth and the length should not be at least three times the depth of the specimen. Indian standard determined the size of the concrete specimen as 150mm width, 150mm depth, and span of 700mm. It also states that a size of 100mm width, 100mm depth, and span of 500mm can be used if the maximum aggregate size used is not greater than 19 mm. British standards specifies square specimen cross section with 100mm or 150mm dimension and the span ranges from four to five times specimen depth. However, it preferred 150mm width, 150mm depth, and span of 750mm for the specimen.

Determine proportions of materials including cement, sand, aggregate and water. Place molds on horizontal surface and lubricate inside surface with proper lubricant material and excessive lubrication should be prevented. Pour fresh concrete into the molds in three layers. Compact each layer with 16mm rode and apply 25 strokes for each layer or fill the mold completely and compact concrete using vibration table. Cover top of specimens in the molds and store them in a temperature room for 24 hours. Remove the molds and moist cure specimens at 23+/-2 ^{o} C till the time of testing.

The age of the test is 7 days, 14 days and 28 days and three specimens for each test should be prepared. The test should be conducted on the specimen immediately after taken out of the curing condition so as to prevent surface drying which decline flexural strength. Place the specimen on the loading points. The hand finished surface of the specimen should not be in contact with loading points. This will ensure an acceptable contact between the specimen and loading points. Center the loading system in relation to the applied force. Bring the block applying force in contact with the specimen surface at the loading points. Applying loads between 2 to 6 percent of the computed ultimate load. Employing 0.10 mm and 0.38 mm leaf-type feeler gages, specify whether any space between the specimen and the load-applying or support blocks is greater or less than each of the gages over a length of 25 mm or more. Load the specimen continuously without shock till the point of failure at a constant rate (Indian standard specified loading rate of 400 Kg/min for 150mm specimen and 180kg/min for 100mm specimen, stress increase rate 0.06+/-0.04N/mm^2.s according to British standard).



COMPRESSIVE STRENGTH TEST ON CUBES

PERIOD	TRIALS	LOAD (KN)	COMPRESSIVE STRENGTH
7 DAYS CURING	TRIAL 1	590	26.22 N/mm^2
	TRIAL 2	610	27.11 N/mm^2
	TRIAL 3	580	25.78 N/mm^2
	AVERAGE STRENGTH		**26.37 N/mm^2**
14 DAYS CURING	TRIAL 1	650	28.89 N/mm^2
	TRIAL 2	650	28.89 N/mm^2
	TRIAL 3	670	29.78 N/mm^2
	AVERAGE STRENGTH		**29.39 N/mm^2**
28 DAYS CURING	TRIAL 1	700	31.11 N/mm^2
	TRIAL 2	690	30.67 N/mm^2

Industrial Engineering Journal
ISSN: 0970-2555
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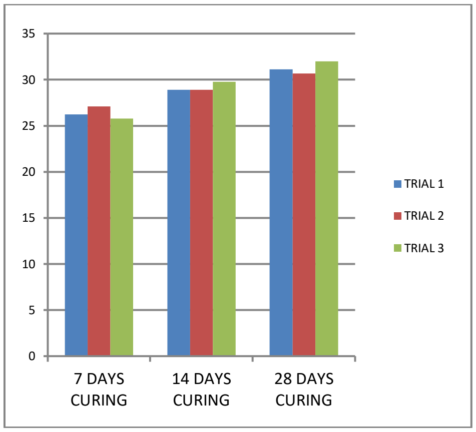
	TRIAL 3	720	32.00 N/mm^2
	AVERAGE STRENGTH		**31.26 N/mm^2**

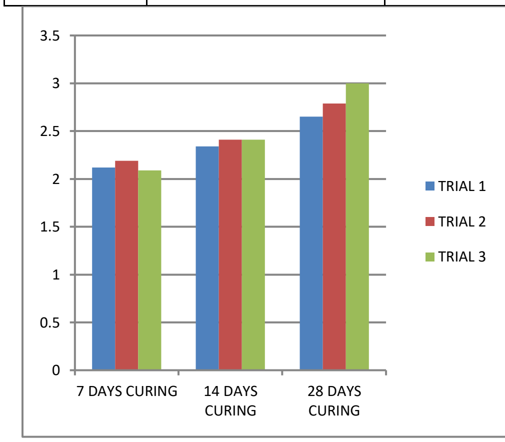
GRAPHICAL REPRESENTATION



From the graph, it is clear that compressive strength increases as per increased number of curing days.

SPLIT TENSILE STRENGTH TEST ON CYLINDER

PERIOD	TRIALS	LOAD (KN)	TENSILE STRENGTH
7 DAYS CURING	TRIAL 1	150	2.12 N/mm^2
	TRIAL 2	155	2.19 N/mm^2
	TRIAL 3	148	2.09 N/mm^2
	AVERAGE STRENGTH		**2.13 N/mm^2**
14 DAYS CURING	TRIAL 1	165	2.34 N/mm^2
	TRIAL 2	170	2.41 N/mm^2
	TRIAL 3	170	2.41 N/mm^2
	AVERAGE STRENGTH		**2.39 N/mm^2**
28 DAYS CURING	TRIAL 1	187	2.65 N/mm^2
	TRIAL 2	197	2.79 N/mm^2
	TRIAL 3	191	2.69 N/mm^2
	AVERAGE STRENGTH		**2.71 N/mm^2**



FLEXURAL STRENGTH FOR RC BEAMS CONVENTIONAL BEAMS

Width of the beam(b) = 150 mm

Failure point depth(d) = 150 mm

PERIOD	TRIALS	LINE OF FRACTURE AND NEAREST SUPPORT (a)	LOAD (KN)	FLEXURAL STRENGTH
7 DAYS CURING	TRIAL 1	170 mm	20	3.02 N/mm^2
	TRIAL 2	168 mm	22	3.29 N/mm^2
	TRIAL 3	171 mm	20	3.04 N/mm^2
	AVERAGE STRENGTH			**3.12 N/mm^2**
14 DAYS CURING	TRIAL 1	174 mm	26	4.02 N/mm^2
	TRIAL 2	180 mm	26	4.16 N/mm^2
	TRIAL	182 mm	25	4.04

Industrial Engineering Journal
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	3			N/mm^2
	AVERAGE STRENGTH			**4.07 N/mm^2**
28 DAYS CURING	TRIAL 1	180 mm	28	4.48 N/mm^2
	TRIAL 2	184 mm	28	4.58 N/mm^2
	TRIAL 3	180 mm	30	4.80 N/mm^2
	AVERAGE STRENGTH			**4.62 N/mm^2**

RETROFITTED BEAMS (SINGLE LAYER)
Width of the beam(b) = 150 mm
Failure point depth(d) = 150 mm

PERIOD	**TRIALS**	**LINE OF FRACTURE AND NEAREST SUPPORT (a)**	**LOAD (KN)**	**FLEXURAL STRENGTH**
7 DAYS CURING	TRIAL 1	174 mm	24	3.71 N/mm^2
	TRIAL 2	176 mm	26	4.07 N/mm^2
	TRIAL 3	174 mm	26	4.02 N/mm^2
	AVERAGE STRENGTH			**3.94 N/mm^2**
14 DAYS CURING	TRIAL 1	178 mm	30	4.75 N/mm^2
	TRIAL 2	178 mm	30	4.75 N/mm^2
	TRIAL 3	180 mm	29	4.64 N/mm^2
	AVERAGE STRENGTH			**4.71 N/mm^2**
28 DAYS CURING	TRIAL 1	180 mm	32	5.12 N/mm^2
	TRIAL 2	182 mm	32	5.18 N/mm^2
	TRIAL 3	182 mm	36	5.82 N/mm^2
	AVERAGE STRENGTH			**5.37 N/mm^2**

RETROFITTED BEAMS (DOUBLE LAYER)
Width of the beam(b) = 150 mm
Failure point depth(d) = 150 mm

PERIOD	**TRIALS**	**LINE OF FRACTURE AND NEAREST SUPPORT (a)**	**LOAD (KN)**	**FLEXURAL STRENGTH**
7 DAYS CURING	TRIAL 1	172 mm	28	4.28 N/mm^2
	TRIAL 2	175 mm	28	4.36 N/mm^2
	TRIAL 3	173 mm	26	4.00 N/mm^2
	AVERAGE STRENGTH			**4.21 N/mm^2**
14 DAYS CURING	TRIAL 1	178 mm	30	4.75 N/mm^2
	TRIAL 2	179 mm	30	4.77 N/mm^2
	TRIAL 3	181 mm	34	5.47 N/mm^2
	AVERAGE STRENGTH			**5.00 N/mm^2**
28 DAYS CURING	TRIAL 1	180 mm	36	5.76 N/mm^2
	TRIAL 2	180 mm	38	6.08 N/mm^2
	TRIAL 3	188 mm	38	6.35 N/mm^2
	AVERAGE STRENGTH			**6.06 N/mm^2**

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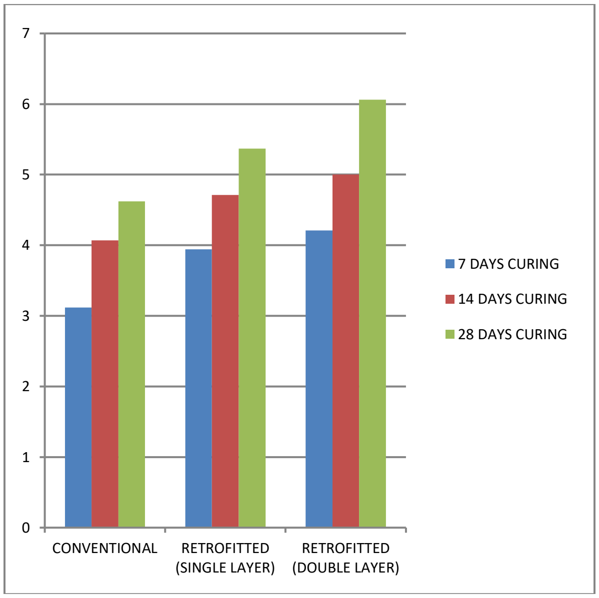

From the graph, it is clear that flexural strength endured in retrofitted beam is more than conventional beam.

BEAM	FLEXURAL STRENGTH N/mm^2		
	7 days	14 days	28 days
CONVENTIONAL	3.12	4.07	4.62
RETROFITTED (SINGLE LAYER)	3.94	4.71	5.37
RETROFITTED (DOUBLE LAYER)	4.21	5.00	6.06

CONCLUSION

The deflections of the beams are minimized due to full wrapping technique. The flexural strength and ultimate load capacity is improved due to external strengthening. Even though the beam strengthened with **CFRP** sheets has maximum load capacity, the cost of the material is high. Retrofitting using **GFRP** sheets tends to be economical since its cost is only **Rs.300/m^2.** As the strength increases cross- sectional area of the beams shall be reduced. The main challenge is to achieve a desired structure at minimum cost. It makes structure more earth quake resistant.

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