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RESEARCH ARTICLE

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COMPARATIVE EVALUATION OF DIFFERENT RETROFITTING TECHNIQUES

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ABSTRACT

Concrete is an important and successful material in the construction industry for a long time. It has so many applications and utilization in the construction field. Due to advancement in technology and constantly increasing economy, construction industry develops in everlasting leaps and bound day by day. Ferrocement as a retrofitting material can be pretty useful because it can be applied quickly to the surface of the damaged element without the requirement of any special bonding material and also it requires less skilled labour, as compared to other retrofitting solutions presently existing. The ferrocement construction has an edge over the conventional reinforced concrete material because of its lighter weight, ease of construction, low self weight, thinner section as compared to RCC & a high tensile strength which makes it a favourable material for prefabrication also. In the present thesis RC beams initially stressed to a prefixed percentage of the safe load are retrofitted using increase the strength of beam in both shear and flexure, the chicken mesh. Place the moulds on the vibrating table and put the wet concrete mix inside the moulds in three layers. Put the button of vibrating table and along with that tamping has to be done using standard tamping rod. Vibration should not be more, otherwise segregation will take place. After filling the moulds with wet concrete, level the surface and give the designation. Demould the specimen after 24 hours, Keep all specimen for curing of 28 days. After curing for 28 days remove all specimen from curing tank then start retrofitting work. Before retrofitting chipping should be done. Then rough layer of motar is applied on the surface of beam Then retrofit all beam with different techniques like HFRC, FRC, SIFCON, SIMCON, Ferrocement. Take slurry infiltrate mat concrete and cover to full beam then mortar will be applied to full beam. Take slurry infiltrated fibre concrete (steel fibre) mixed with mortar and applied over a surface of beams and same process will be done with polypropylene fibre. Hybrid fibre reinforcement concrete method is also same as SIFCON but polypropylene fibre and steel fibre both will mix at same time with different percentage in mortar. In ferrocement retrofitting welded and chicken mesh are used which is cover to beams and then mortar is applied over the surfaces. Keep all beams again for 28 days curing. Then after completion of curing period flexural strength test will be conducted.

Key words: Ferrocement, wire mesh, SIFCON, SIMCON, flexural strengthening, Fiber Reinforced Concrete, Polypropylene Fibers.

I. INTRODUCTION

The cost of civil infrastructure constitutes a major portion of the national wealth. Its rapid deterioration has thus created an urgent need for the development of novel, long - lasting and cost - effective methods for repair and retrofit. In the present days life extension of structures through strengthening is becoming an essential activity. A host of strengthening systems has to be devised and adopted over the years. The choice of the strengthening system depends on the specific performance requirements. As the number of civil infrastructure systems increases worldwide, the number of deteriorated buildings and structures also increases.

A structure when designed properly and constructed requisite standards of workmanship and proper specification adopted and material used are of good quality that is, if all the parameter are related to the construction of the structure are in ideal conditions, its life can be predicated and the load bearing capacity of the structures.

II Materials used:

4.2.1 Cement: Ordinary Portland Cement (OPC) 43 grade conforming to IS: 8112 – 1989 was used. The cement with brand name VIJAYASHAKTHI Super cement was used.

Table 4.1: Properties of cement

Properties	OPC 43(G)
Specific gravity	3.15
Fineness	4.0 %
Normal consistency	32.0 %
Initial setting time	45min
Final setting time	5 hr 45 min

Fig 4.1: OPC 43 grade cement

4.2.2 Coarse aggregate

Locally available crushed aggregates confirming to IS: 383–1970 are used in this project work of size 20 mm below. The specific gravity of coarse aggregate was found to be 2.66. The sieve separation of compound substant data base of fine aggregates used tabulated.

Table 4.2: Properties of coarse aggregate

Property	Results
Particle shape, Size	Angular 20mm Down Size
Fineness Modulus of 20mm aggregate	6.87
Specific Gravity	2.66

Fig 4.2: Locally available crushed aggregates

4.2.3 Fine aggregate

Commonly usable sand confirming zone 2 of IS: 383:1970 is using for the project work. The specific gravity of the fine aggregate was found to be 2.64.

Fig.4.3: Natural river sand

Table 4.3: aggregate properties

IS sieve size	Cumulative percentage passing of fine aggregates (%)	Specifications for Zone II as per IS:383-1970
4.75mm	96.1	90-100
2.36mm	88.2	75-100
1.18mm	76.2	55-90
600 microns	52.5	35-59
300 microns	5.95	8-30
150 microns	0.5	0-10
Pan	0	0
Specific gravity=2.64		

4.2.4 Water: Water used in the concrete mix satisfies the IS norms. The main function of mixing of water in the sand, cement, water freshly take reaction with chemically and produe a pasted form of cement with all ingredient are to be take place.

4.1.6 Fibres

The fibres used in work are steel fibres and polypropylene fibres.

4.1.6.1 Steel fibres

In the present work flat crimped steel fibres of 1mm thickness and 35mm length giving aspect ratio of 35 are used. The density is found to be 7850kg/m3.

Fig 4.4 Steel fibres

4.1.6.2 Polypropylene fibres

Polypropylene fibres are readily available in the market in the standard dimensions. The fibres to be used here are of length 12mm which is prescribed by the manufacturers for the concrete work. The density of PPF is found to be 930kg/m3 .

Figure 4.5 Polypropylene fibres

4.1.5 Meshes

While casting the specimens two types of meshes are used.

4.1.5.1. Welded mesh:

Square welded mesh of opening 12.5mm×12.5mm (1/2inch) is used in the experimentation. The welded mesh have small diameter bars (16 gauges) kept closely in both directions and are spot welded.

Fig 4.8 Welded mesh

4.1.5.2. Chicken mesh:

Chicken mesh having hexagonal opening with 15mm diameter is used.

Fig 4.9 chicken mesh

III.METHODOLOGY

Calculate the material required for 21 beams, 3 bream for without retrofitting, 3 for SIFCON, 3 for SIMCON, 3 for HFRC, 6 for FRC & 3 for Ferrocement specimens using the mix proportion by volume as discussed above and W/C of 0.45.

The following procedure is adapted to cast the specimens.

- Place the moulds on the vibrating table and put the wet concrete mix inside the moulds in three layers.
- Put the button of vibrating table and along with that tamping has to be done using standard tamping rod.
- Vibration should not be more, otherwise segregation will take place.
- After filling the moulds with wet concrete, level the surface and give the designation to it as shown in fig.
- Demould the specimen after 24 hours as shown in figure.
- Keep all specimen for curing of 28 days
- After curing for 28 days remove all specimen from curing tank then start retrofitting work.

- Before retrofitting chipping should be done.
- Then rough layer of motar is applied on the surface of beam
- Then retrofit all beam with different techniques like HFRC, FRC, SIFCON, SIMCON, Ferrocement.
- Take slurry infiltrate mat concrete and cover to full beam then mortar will be applied to full beam.
- Take slurry infiltrated fibre concrete (steel fibre) mixed with mortar and applied over a surface of beams and same process will be done with polypropylene fibre.
- Hybrid fibre reinforcement concrete method is also same as SIFCON but polypropylene fibre and steel fibre both will mix at same time with different percentage in mortar.
- In ferrocement retrofitting welded and chicken mesh are used which is cover to beams and then mortar is applied over the surfaces.
- Keep all beams again for 28 days curing.
- Then after completion of curing period flexural strength test will be conducted.

Flexural strength test

The following procedure is adopted to conduct the flexural strength test.

- Brush the beam clean. Turn the beam on its side, with respect to its position as molded, and place it in the breaking machine. The size of the beam specimen is 100 x 100 x 500 mm.
- Set the bearing plates square with the beam and adjust for distance by means of the guide plates furnished with the machine.
- Place a strip of leather or similar material under the upper bearing plate to assist in distributing the load.
- Bring the plunger of the jack into contact with the ball on the bearing bar by turning the screw in the end of the plunger.
- After contact is made and when only firm finger pressure has been applied, adjust the needle on the dial gauge to "0".
- Here we are applying two point loading on the beam specimen, apply load till it breaks and note that as failure load as shown in figure

Computation of the flexural strength was as follows.

Flexural strength = $\frac{PL}{bd^2}$ **X 1000**

Where,

P = Load in kN

L = Effective length of beam = 400 mm

b = Width of the beam = 100 mm

d = Depth of the beam = 100 mm.

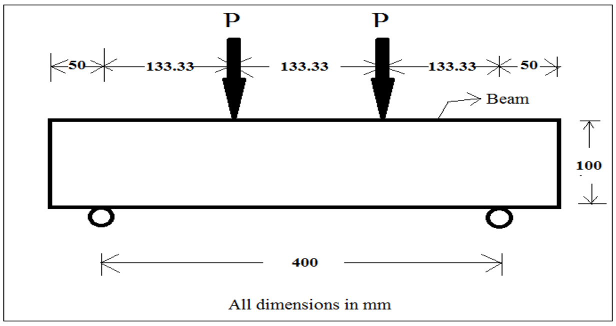

Fig 4.14: Line diagram of flexural test on beams

Fig 4.15: Flexural test on beams

IV.RESULTS AND COMPARISIONS

Flexural strength test results: Following tables gives flexural strength test result for concrete beams without retrofitting and with retrofitting by various techniques.

Table 4.5: Flexural strength of concrete beam without retrofitting

Specimen identification	Failure load (KN)	Flexural strength (MPa)	Average flexural strength (MPa)
	14	5.6	

A1			5.88
A1	15	6	
A1	15	6	

Table 4.6: Flexural strength of concrete beam retrofitted with ferrocement

Specimen identification	Failure load (KN)	Flexural strength (MPa)	Average flexural strength (MPa)
A2	25.5	5.9	11.45
A2	24	5.6	
A2	24	5.6	

Table 4.7: Flexural strength of concrete beam retrofitted with SIFCON

Specimen identification	Failure load (KN)	Flexural strength (MPa)	Average flexural strength (MPa)
A3	24.5	5.7	10.88
A3	22.5	5.2	
A3	21.5	5.0	

Table 4.8: Flexural strength of concrete beam with steel fibre reinforcement concrete

Specimen identification	Failure load (KN)	Flexural strength (MPa)	Average flexural strength (MPa)
A4	22	5.1	10.65
A4	24	5.6	
A4	25.5	5.9	

Table 4.9: Flexural strength of concrete beam retrofitted with hybrid fibre reinforcement concrete (SF+PPF)

Specimen identification	Failure load (KN)	Flexural strength (MPa)	Average flexural strength (MPa)
A1	21	4.9	10.07
A2	22.5	5.2	
A3	21	4.9	

Table 4.10: Flexural strength of concrete beam retrofitted with polypropylene fibre reinforcement concrete

Specimen identification	Failure load (kN)	Flexural strength (MPa)	Average flexural strength (MPa)
A1	20	4.6	8.80
A2	18	4.2	
A3	18	4.2	

Table 4.11: Flexural strength of concrete beam retrofitted with SIMCON

Specimen identification	Failure load (KN)	Flexural strength (MPa)	Average flexural strength (MPa)
A1	14	3.2	6.83
A2	15.5	3.6	
A3	18	4.2	

Overall result of flexural strength

Following table gives the flexural strength test result for concrete beams without retrofitting and with retrofitting by various techniques. Also it gives the percentage increase of flexural strength with respect to the beam without retrofitting. The variation of flexural strength is depicted in the form of graph as shown in the figure.

Table 4.12: Overall result of flexural strength

Retrofitting techniques	Flexural strength (MPa)	Percentage increase of flexural strength with respect to the beam without retrofitting
Beam without retrofitting	5.88	0
Beam retrofitted with Polypropylene FRC	8.80	49.65
Beam retrofitted with Steel FRC	10.65	81.12
Beam retrofitted with Ferrocement	11.46	94.89
Beam retrofitted with SIMCON	6.83	16.15
Beam retrofitted with HFRC (SF+PPF)	10.07	71.25
Beam retrofitted with SIFCON	10.88	85.03

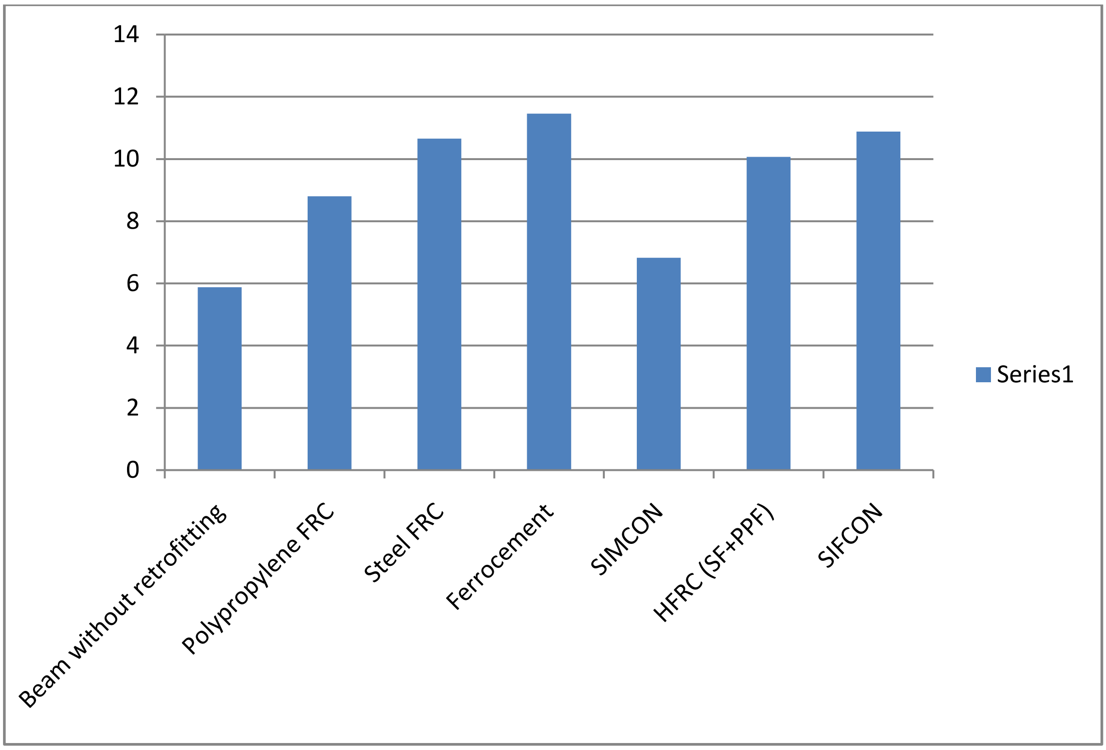

Fig 30: Variation in flexural strength for different retrofitting techniques

V.CONCLUSIONS

Following conclusion may be drawn based on the experimentation conducted on the comparative evaluation of different retrofitting technique for concrete beam.

- Thus it can be concluded that the concrete beam retrofitted with ferrocement yields higher flexural strength and the percentage in the flexural strength as compared to the beam without retrofitting is found to be 94.89%.
- Thus it can be concluded that the concrete beam retrofitted with SIFCON yields higher flexural strength and the percentage in the flexural strength as compared to the beam without retrofitting is found to be 85.03%.
- Thus it can be concluded that the concrete beam retrofitted with steel FRC yields higher flexural strength and the percentage in the flexural strength as compared to the beam without retrofitting is found to be 81.12%.
- Thus it can be concluded that the concrete beam retrofitted with HFRC (SF+PPF) yields higher flexural strength and the percentage in the flexural strength as compared to the beam without retrofitting is found to be 71.25%.
- Thus it can be concluded that the concrete beam retrofitted with FRC polypropylene yields higher flexural strength and the percentage in the flexural strength as compared to the beam without retrofitting is found to be 49.65%.
- Thus it can be concluded that the concrete beam retrofitted with SIMCON yields higher flexural strength and the percentage in the flexural strength as compared to the beam without retrofitting is found to be 16.15%.

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