RETROFITTING OF REINFORCED CONCRETE BEAMS WITH HPFRCM STRIP COMPARED WITH GFRP

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Abstract*: The maintenance, rehabilitation and upgrading of structural members, is perhaps one of the most crucial problems in civil engineering application. A new retrofitting technique based on a material compatible with concrete is currently under development. It overcomes some of the problems associated with the current techniques based on extremely bonded steel plates and FRP laminates which are due to the mismatch of their tensile strength and stiffness with that of the concrete structure being retrofitted. In order to overcome the limitations of current retrofitting technique an attempt has made to develop a High performance Fiber reinforced cementitous mix in a form of an strip say about 12 to 16 mm thick which is then attached with the controlled beam(which undergoes an 75% Preloading) by means of an strong Epoxy and Hardner mix. By these mean the strip has been placed at various position (i.e. tension face, Tension face and on other vertical sides, tension face and on four rectangular vertical sides.) which is then checked for Flexural, shear and deflection pattern has also be tested using the loading Frame.*

Keywords*: Retrofitting, HPFRCM, Adhesive, Steel Fibers, GFRP.*

1. INTRODUCTION

Existing Concrete structures may, for a variety of reasons, be found to perform unsatisfactorily. This could manifest itself by poor performance under service loading, in the form of excessive deflections and cracking, or there could be inadequate ultimate strength. . Moreover, a large number of structures constructed in the past using the older design codes in different parts of the world are structurally unsafe according to the new design codes. Since replacement of such deficient elements of structures incurs a huge amount of public money and time, strengthening has become the acceptable way of improving their load carrying capacity and extending their service lives. Infrastructure decay caused by premature deterioration of buildings and structures has led to the investigation of several processes for repairing or will be on 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, filing systems, planters, or other items are being added to a structure. Strengthening may be needed to allow the structure to resist loads that were not anticipated in the original design. The main objective is to study and compare the behaviour of RC beams. The majority of structural strengthening involves improving the ability of the structural elements to safely resist one or more internal forces caused by loading such flexural shear etc. Strengthening is accomplished by either reducing the magnitude of these forces. Hence this project aim is to retrofit the RC beams using Glass Fiber reinforced concrete and using High performance fiber reinforced cementitous mix strip, therefore retrofitting of concrete provides economical and technical alternative to traditional techniques in many situations, because of its increased strength, high fatigue resistance easy and rapid installation.

2. HPFRCM

The aim was to achieve a good workable mix with a very low water/ blinder ratio and a high volume fraction of steel fiber, in order that the resulting material, in its hardened state, will be ductile with a relatively high tensile strength. As a result of many trial mixes and testing, the mixes shown in Table 1.

Constituent (kg)	Mix 1	Mix 2
Cement	7.016	7.016
Micro silica	0.701	1.403
Quartz sand	35.04	35.04
Water	0.051	0.051
Fibres	3.744	5.832

Table 1: Mix Proportion for HPFRCC Strip Mix

Since these Mix values are arrived based on the IS specification 92 of mortar Mix in a ratio of 1:6. Where Micro silica for Mix 1 is takes as a 10% of the Quantity of cement and for Mix 2 it is 20% of cement.

Whereas Steel fiber is added as 20% of the dry volume of the Mix 1 and 30% for the Mix 2. Superplasticizer is also added in 7 % of the water cement ratio.

A volume Fraction of `30% (both short and long Fiber) for mix 1 and mix 2 is added. Similarly a volume fraction of 20% is added for Mix proportion 3. The specimen was hot-cured @ 45^0 C for seven days. The strength attained have been found to be equivalent of standard 28-day water curing at 20^{o}C.

3. TEST BEAMS

Three sets of beam were casted for this experimental test program. IN SET I three beams (C1, C2, and C3) were casted using M30 grade of concrete and reinforcing detailing. In SET II four beams (GF1, GF2, GS1, and GS2) out of which two were weak in flexure and two were weak in shear using the same grade of concrete and reinforcing detailing. In SET III eight beams (S1F1, S1F2, S1S1, S1S2, S2F1, S2F2, S2S1, and S2S2) were casted. The dimensions of all the specimens are identical. The cross sectional dimensions of all the three SET of beam is 1000mm by 150mm by 230mm. For SET I 2 beams, 12mm Dia bars are provided as the longitudinal reinforcement both at tension and compression side and 8mm Dia bars as stirrups at a spacing of 150 mm centre to centre. For SET II two beam is provided with shear i.e. with stirrups and two without stirrups. Whereas for SET III four beams is provided with stirrups and four without stirrups as detailed in fig. 1

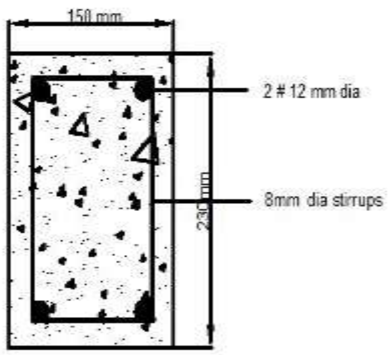


Fig 1: Cross sectional view of the beam weak in Flexure

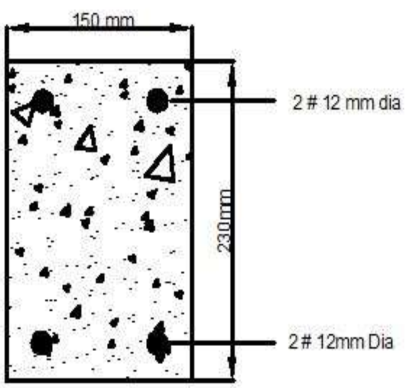


Fig 2: Cross sectional view of the beam weak in Flexure

The detailed description of the beam was listed below in the table 2.

S. NO	Type of Beam	Beam Designation
1	Controlled beam	C1
2	Controlled beam	C2
3	Controlled beam	C3
4	GFRP at the soffit of the beam	F1
5	GFRP up to neutral axis	F2
6	GFRP only on the two vertical side	S1
7	GFRP as U-wrap	S2
8	STRIP at the soffit of the beam Mix 1	F3
9	STRIP up to neutral axis Mix 1	F4
10	STRIP only on the two vertical side Mix 1	S3
11	STRIP as U-wrap Mix 1	S4
12	STRIP at the soffit of the beam Mix 2	F31
13	STRIP up to neutral axis Mix 2	F41
14	STRIP only on the two vertical side Mix 2.	S31
15	STRIP as U-wrap Mix 2.	S41

Table 2: Type of beams casted

Where,

S – Beam weak in shear (without Shear reinforcement).

F –Beam weak in Flexure.

4. CUBE SPECIMENS

Before the beam were casted the test cube were made for M30 grade concrete and the High Performance Fiber reinforced cementitous mix. The mix design calculations were made based on the IS code.

The aggregates used are 12mm and the cement of 53 grade OPC. The cubes are then cured and tested in the CTM after 14days and 28 days as shown in fig 5, 6,7.

Fig 3: Conventional Concrete cube

Fig 4: High Performance Fiber Reinforced Strip

Fig 5: Testing of Cube in CTM

5. FABRICATION OF GFRP

A flat plywood rigid platform was selcted. A thin film of ployvinyl alcohol is applied on the platform as a releasing agent. The Glass Chopped sheet is placed over the plywood platform. Laminating starts with the process of gel coat (Epoxy and Hardner) deposited on the sheet, whose main purpose was to provide a smooth external surface and to protect the fiber from direct exposure to the environment. Layer of sheet is again placed over it and again epoxy and hardner mix is applied over it. A hand roller is used to remove all the air bubbles from the sheet. The sides are cut down for even finish. The process is continued until the required thickness of 3mm is achieved Then, a heavy meal rigid platform was sheet on top of the sheet for the compression purpose. These are left for a minimum of 48 hours before testing as shown in fig 8,9.

Fig 6: Material required for GFRP fabrication

Fig 7: Application of Polyvinyl as releasing agent

Fig 8: Removal of air bubbles using roller

Then the layer of GFRP is tested in INSTRON machine for load carrying capacity as shown in fig 11.

GFRP	*4.9*	*345*	*14020*

Table 3: Load carrying capacity of GFRP

Fig 9: Experimental Setup of INSTRON

Determination of Ultimate load, Ultimate stress and young's modulus

Ultimate Load KN	*Ultimate Stress MPa*	*Young's modulus MPa*

6. Aspect Ratio for steel Fiber

Fiber used: Crimped & Hooked Type

Volume Fraction V_f should be 10 to 30 %

Aspect ratio = Length of fiber/ϕ of fiber

Length & ϕ of fiber: 30 & 0.40 mm

Hence Aspect ratio = 75

For aspect ratio 75,

Relative density = 1.70

Relative Toughness = 10.5

7. CASTING OF STRIPS

The retrofit materials, HP strip Mix 1, Mix 2 were cast in 800mm long and 150 mm wide wooden moulds with a well-oiled base and raised border whose height could be adjusted to give 12mm thick plates. The moulds were rolled on a vibrating table at 50 Hz frequency and smoothed over. To ensure a uniform thickness a glass panel was located on top of the raised border. The strips were left to cure in the moulds for 24 h at 30^{o}c before demoulding. The retrofitted strips were cured for 10 days.

Fig 10: Demoulding of the Strip

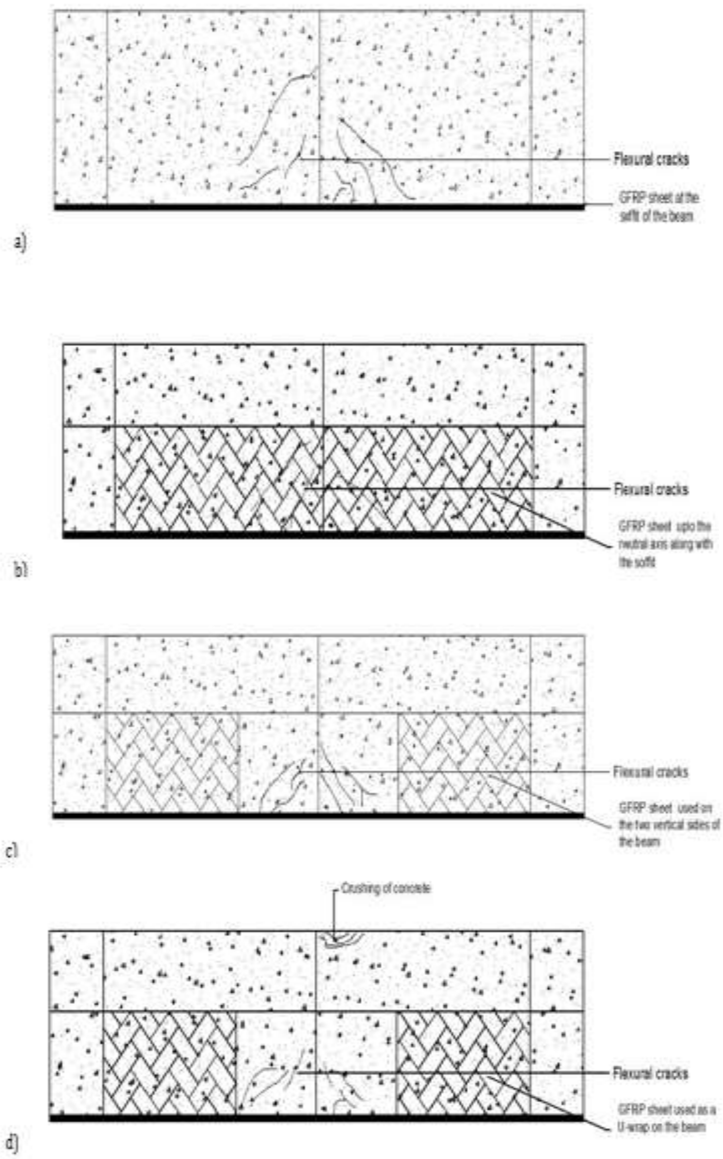


Fig: 11. a) GFRP placed on the soffit of the beam

b) GFRP placed on the neutral axis along with the soffit of the beam

c) GFRP placed on the two vertical sides of the beam

d) GFRP placed in form of U-wrap

Similarly,

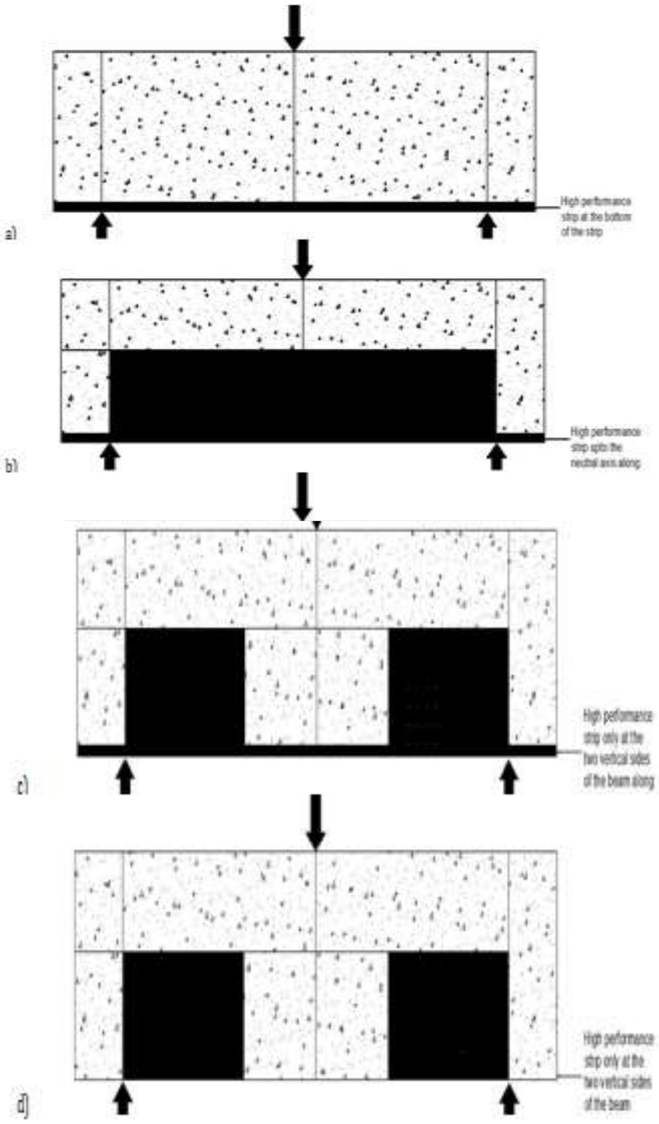


Fig: 12. a) Strip placed on the soffit of the beam

b) Strip placed on the neutral axis along with the soffit of the beam

c) Strip placed on the two vertical sides of the beam

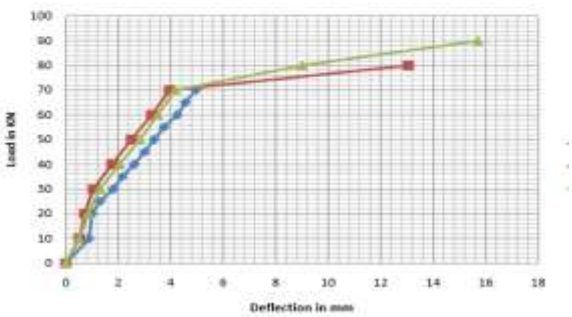
d) Strip placed in form of U-wrap

8. RESULT ANALYSIS

Type of beam	Beam designation	Load at initial crack	Ultimate load	Name of failure
Controlled beam	C1	50	75	Flexure
	C2	53	80	Shear
	C3	65	87	Flexure-Shear
GFRP Weak in Flexure`	F1	76	104	GFRP rupture+ Flexure-shear crack
	F2	76	108	GFRP rupture+ Flexure-shear crack
GFRP Weak in Shear	S1	75	114	Flexural failure + crushing of concrete
	S2	80	112	Flexural failure + crushing of concrete
Mix 1 Weak in Flexure	F3	92	120	Flexure
	F4	94	125	Flexure-shear
Mix 1 Weak in Shear	S3	92	135	Flexure
	S4	95	120	shear
Mix 2 Weak in Flexure	F31	96	130	Flexure
	F41	100	135	Flexure
Mix 2 Weak in Shear	S31	104	132	Flexure-shear
	S41	98	129	Flexure-shear

9. LOAD DEFLECTION HISTORY

The load deflection history was recorded. The mid span deflection of the beam is compared with that of respective control beams. It has been noted that load deflection pattern of the beam wrapped with strip better than that of the beam wrapped with GFRP and the controlled beam. The graph compared the deflection pattern of the controlled, GFRP and HPFRCM strip.



10. CONCLUSION

In this study strengthening of beam with GFRP and HPFRCM strip is studied. In set II the beam is 25 % more than that of controlled beam. Whereas the high performance fiber reinforced strip is 48% more than that of the controlled beam and at the same time 20 % more than that of the GFRP fiber.

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References

I. IS 456 (2000) Plain and reinforced Concrete.

II. IS 800 Practise Of Reinforced Steel

III. IS 10262:2009- Concrete Mix Proportioning.

IV. IS 15388- Specification for Silica Fume

V. IS 1917 part3 – Chemical analysis of Silica Sand.

VI. Abhjith Mukherjee 2016 New Repair and Rehabilitation Technologies for Masonry Buildings. International Journal of engineering and science. Vol.7, Issue 4 ISSN(online): 2319-6734.

VII. Akshayp. Giel et al 2016 from Mahaidol University A Case Study on the Use of Advanced Fiber Wrap Composites for Reinforced Concrete Repair of an Industrial Coker Reinforced Concrete Frame. Journals of Japan concrete institution. Vol.4, Issue 7, pp.142-145.

VIII. Azadehehparvin 2015 from W.T Josep Islamic university Fatigue Strengthening of cracked steel beam with different Configurations and material. International journal of innovative science & technology. pp. 3127

IX. Benson, S.D.P., Karihaloo, B.L.: CARDIFRC — Development and mechanical properties. Part III: Uniaxial tensile response and other mechanical properties. Mag. Concr. Res. 57, 433–443)

X. Bilal S. Hamad et al Bond Studies of High-Strength Concrete Joints Confined with Stirrups, Steel Fibers, or Fiber-Reinforced Polymer Sheets. American Society of Civil Engineering. Vol.4, Issue 6, pp.122-185.

XI. Bing Li et al 2012 Retrofitting Earthquake-Damaged RC Structural Walls with Openings by Externally Bonded FRP Strips and Sheets. American Society of Civil Engineering. ISSN(online): 2319-6734.

XII. Bonneau, O., Poulin, C., Dugat, J., Richard, P., Aitcin, P.: Reactive powder concretes: from theory to practice. Concr. Int. 18, 47–49.

XIII. Chris P. Pantelides et al 2010 Effectiveness of Repair and Strengthening Methods for Reinforced Concrete Columns and Beam-Column Joints International journal of innovative science & technology. Vol.4, Issue 6, pp.122-185.

XIV. Hamdy M. Mohame et al., (2008) Shear strengthening of RC beam with externally Bonded CFRP sheets.

XV. Farshid Jandaghi Alaee et al., (2008) Retrofitting of Reinforced.

XVI. Karihaloo, B.L., Benson, S.D.P., Alaee, F.J.: Cementitious mixtures and a method of production thereof. UK Patent GB2391010 (2007)

XVII. Nicolaides, D., Kanellopoulos, A.D., Karihaloo, B.L.: Fatigue life and self-induced volumetric changes of CARDIFRC. Mag. Concr. Res. 62, 679–683 (2006)

XVIII. Reyes Garci et al 2006 Seismic Strengthening of Severely Damaged Beam-Column RC Joints Using CFRP American Society of Civil Engineering.

XIX. A.S Samer et al 2002 Normal- And High-Strength Fiber-Reinforced Concrete under Compression. International Journal of engineering and science. ISSN(online): 1115-1125

XX. Yang Yang et al 2001 Seismic Repair of Reinforced Concrete Bridge Columns. American Society of Civil Engineering. Vol.6, Issue 5, pp.342-485.

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