© 2016 IJSRSET | Volume 2 | Issue 5 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

Flexural Strengthening of RC beam using Fabric Reinforced Cementitious Matrix (FRCM)

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ABSTRACT

The advancement of alternative materials and methods for structural rehabilitation is of critical importance to the safety and preservation of the world's habitable heritage. Infrastructure decay caused by premature deterioration of buildings and structures has led to the investigation of several process for repairing or strengthening purposes. 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. For strengthening RC elements, use of FRP system has become a common technique. But FRP strengthening technique has some limitations and which are related to the epoxy matrix used to embed and bond the fibres. Thus substituting epoxy matrix with cementitious matrix appeared to be the most reasonable solution to improve the overall performance. This new generation of composite system is known as 'FRCM' (Fabric Reinforced Cementitious Matrix), which consist of a dry fabric in a cementitious matrix. Due to their superior performance at high temperature, better compatibility with the substrate and improved durability, FRCM systems are a good alternative to FRP system. To present the previous efforts made to develop FRCM as an effective method for strengthening of structures, various journals have been reviewed. This report deals with the study of flexural strengthening of concrete and RC members with the help of various journal reference. It also includes the effectiveness of FRCM with respect to number of confining layer and tensile strength of cementitious matrix. Thus FRCM system are a viable option for flexural and shear strengthening of concrete and RC members.
Keywords: Rehabilitation, deterioration, FRCM, dry fabric.

I. INTRODUCTION

Composite materials are the result of combining basic materials into new material systems that have improved properties over the constituent materials. For that reason research of novel composite materials results in advances in the engineer's ability to deliver improved product designs. Fabric-reinforced cementitious matrix (FRCM) composite systems differentiate themselves for fiber reinforced polymer (FRP) composite systems in that the matrix is brittle, thus exhibiting a more complex mechanical behavior. FRCM is a new development in cementitious composites designed specifically for the structural repair and rehabilitation industry. FRCM systems are currently being introduced in the structural repair and rehabilitation industry as a new effective strengthening technology. Due to their superior performance at high temperature, better compatibility with the substrate, and improved durability FRCM systems are a good alternative to FRP systems.

II. METHODS AND MATERIAL

1. Material Properties and Mix Design

A. Mix Design

Mix proportions for M70 grade concrete was designed. In general, there are number of methods like Indian Standard method, ACI method etc are available for designing normal strength concrete mixes. For designing High Strength Concrete(HSC) mixes, there were no specific literature methods available. In view of considerable variation in the properties of aggregate , it is generally recommended that trial mixes with suitable adjustments in grading and proportioning to achieve desired results.

With the advent of concrete chemicals, concrete of very high strength can be achieved by suitable proportioning and adding more fine cementitious material like Micro Silica. Such mixes are called High Strength Concrete (HSC), which are in frequent use. The Design Mix was obtained after the various trials as shown in Table 1

Table - 1 Mix Design of M70 concrete

Sl. No.	Grade of Concrete	Mix Proportions C:F:C.A (By Wt. of Cement)	W/b Ratio	Micro silica By Wt. Of Cement	Super Plasticizer By Wt.of Cement
1.	M 70	1:0.87:2.03	0.25	5%	1.5%

B. Compressive Strength of Cube

Three numbers of 150mm cube were cast and cube strength of concrete was found out.

Figure 1. Testing of Compressive strength of Concrete

Table - 2 Test result of Concrete Specimen

Grade of concrete	Sl.No.	Compressive strength 7 days(N/mm^2)
M70	Sample 1	49
	Sample 2	52
	Sample 3	51

C. Glass Fabric Mesh

It is one of the most effective reinforcing elements for inside and outside plastering work including technologies of warmth-keeping. Facade mesh fabric effectively perceives deformation stresses arising in stucco layer and ensures long-termprotection against cracks.

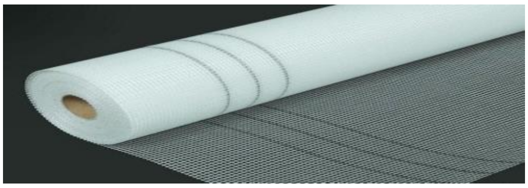

Figure 2. Glass Fabric

D. Cementitious Matrix

The cement based matrixes typically made of Portland cement, silicafume and fly ash as the binder. The function of the matrix is to encapsulate and protect the fibers and transfer stresses from the concrete or masonry substrate to the fibers. The composition of the cementitious matrix is very crucial for the performance of the FRCM system.

Figure 3. Cementitious Matrix

2. Experimental Program

A. Test Programme

Five beams were tested for experimental investigation. The test matrix consisted of five 2155-mm long RC beams having rectangular cross-sectional dimensions of 355 mm and 150 mm with a clear span of 1855 mm. Two 16 mm diameter steel bars were used as the longitudinal tensile reinforcement. Double leg steel stirrups with diameter of 8 mm spaced at 150 mm centre to centre were used for shear reinforcement. All the five were cast with high strength concrete (M70). The RC beams were externally retrofitted by applying Glass fabric on three sides. Two beams were un-strengthened; two beams were strengthened with 1-ply and one beam with 3-ply FRCM. Layout of the test specimen is shown in figure 4.

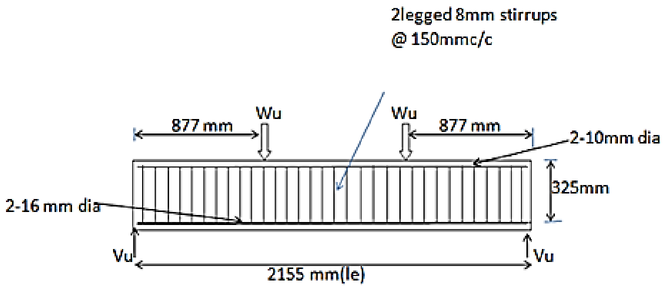

Figure 4. Test Specimen Layout

A. Test Setup

All beams were tested in two point loading . Each specimen was loaded by means of a hydraulic actuator. Applied load was measured using the internal force transducer in the actuator and verified by one load cell placed at one of the supports. Vertical deflections at the mid-span was recorded using linear variable differential transducers (LVDTs).

B. Testing of Control beam

Among the five reinforced concrete specimens, two are considered as the control beams(C1 and C2) and are subjected to two point loading until it fails to take any further load. All the two beams were tested under simply supported end conditions. The specimen were placed on a pinned support on one end and a roller support on the other. The beams are stressed upto a level until it stopped taking any further load. Load versus Deflection graph is plotted for the two beams and the average values are taken.

Figure 3. Testing of Control beam

C. Strengthening with FRCM(1 ply and 3 ply)

The installation procedure is simple. Mixing and application of cementitious matrix is similar to conventional hand-applied repair motors used in concrete repairs. First a thin layer of mortar ie cementitious matrix is applied to the surface of the beams to be strengthened manually with a trowel, then the glass fabric mesh is applied with the primary fabric orientation in the direction of the load and lastly a finishing layer of the mortar is applied to the last fabric layer, completing the composite. The FRCM composite hardens within a few hours and achieve full strength at 28 days.

The second and third layer is applied in the same procedure. The cementitious matrix in the first mesh layer doesnot need to be fully cured in order to apply subsequent layers.

Figure 4. Installation of FRCM

Figure 5. Beams wrapped with 1ply FRCM

D. Testing of FRCM strengthened beams(1ply and 3ply)

The strengthened beams are tested upto failure in simply supported end condition with two point loading. The test set up was same as that of the control beam. First cracking load and corresponding crack width (Brinell microscope) are measured.

Figure 6. Testing of 1ply FRCM beam

Figure 7. Testing of 3ply FRCM beam

III. RESULTS AND DISCUSSION

Experimental results in terms of maximum applied load, average maximum load, and failure mode for three sets of high strength concrete cases are summarized in Table **5.2**. The average ultimate load at failure for the control set was 126.75 kN. Failure of all control beams resulted from concrete crushing in the compression zone after yielding of the longitudinal steel. For beams strengthened with 1-ply FRCM, the average peak load was 149.75 kN about 1.2 times that of the control set and 1-ply FRCM beams failed due to fabric slippage within the matrix. 3-ply beams experienced the highest peak load with an average of 224.625 kN and about 1.5 times that of the 1-ply set. 3-ply beams failed by FRCM delamination from the concrete substrate.

Table - 3 Experimental Test Results

Specimen ID	Max. Load (KN)	Avg. Max Load (KN)	Cracking load (KN)	Failure mode
Control-1 Control-2	125 128.5	126.75	100 105.5	Concrete crushing after steel yielding
H-1 ply(1) H-1ply(2)	149.5 150	149.75	120 125.5	FRCM slippage
H-3ply	180	224.625	140	FRCM delamination

IV. CONCLUSION

An experimental study was conducted on flexural behaviour of High Strength reinforced concrete beams(M70) strengthened with FRCM(1 ply and 3 ply) in this report. The conclusion of this study can summarised as follows:

1. FRCM effectiveness for flexural capacity enhancement varies by 13% (1-ply) and 73% (3-ply) for high strength concrete compared to the control beams.
2. Flexural strength of High Strength RC beams was significantly increased when strengthening with FRCM
3. Strength enhancement of 1-ply beam is 1.18 times than that of control beams
4. Strength enhancement of 3-ply beam is 1.78 times than that of control beams
5. Strength enhancement is proportional to the number of reinforcement layers.
6. First crack occurs at 101 KN in case of control beam whereas in 1- ply and 3-ply FRCM beams it occurs at 120 KN & 140 KN respectively.
7. FRCM RC beams exhibited the following failure modes, depending on the FRCM reinforcement amount
   - Fabric slippage within the matrix(1-ply)
   - FRCM delamination from the substrate(3-ply)

V. REFERENCES

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