Experimental and Analytical Investigation of RC Columns Strengthened Using Fibre Reinforced Cementitious Matrix (FRCM)

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***Abstract*: The deterioration of concrete structures occurs due to various reasons and must be upgraded for its safe working conditions. Various techniques were adopted for strengthening RC structures , namely, steel plates, external post tensioning, externally bonded Fibre-Reinforced Polymer (FRP), and near-surface-mounted FRP systems to increase shear and flexural capacity. The FRP materials are applied to strengthen the beams, columns, and slabs of buildings and bridges. The FRCM is a composite material consisting of one or more layers of cement-based matrix reinforced with fibre fabric.**

The objective of this paper is to investigate the feasibility of Fibre-Reinforced Cementitious-Matrix (FRCM) materials as an alternative external strengthening technique for RC members. Columns in three different geometry were casted for determination of axial loading capacity.Columns were wrapped with GFRP using cementitious matrix and cementitious matrix with partial replacement with metakaolin.The axial load capacities of respective strengthened rc columns were determined. The experimental results are validated using ANSYS software.

***Keywords:*FRCM,Strengthen techniques,RC columns,GFRP**

1.INTRODUCTION

An increasing number of structures have reached the end of their service life either due to deterioration caused by environmental factors or due to an increase in applied loads . These structures may be structurally deficient needs extensive rehabilitation or replacement. Strengthening can be used as the cost-effective alternate to the replacement. The drawbacks of epoxy–FRP has some such as inability to bond to a damp substrate, poor behaviour of the resin at temperatures above the glass-transition temperature,poor fire resistance, low reversibility, and lack of vapor permeability.Because these limitations are mainly related to the use of epoxy, one solution is to replace the organic binder with an inorganic one.Accordingly, a composite made of cement-based matrix reinforced by continuous dry-fibre fabric termed fabric-reinforced cementitious matrix is proposed to address these disadvantages. FRCM is a new development in cementitious composites designed specifically for the structural repair and rehabilitation industry. In this work, the effect of Fibre reinforced cementitious matrix in strengthening of RC columns is done experimentally. Axial load capacities of columns are obtained. This chapter describes about the RC columns strengthened using GFRP using cementitious matrix and cementitious matrix with partial replacement by metakaolin.

II. OBJECTIVES

- To check the performance of columns using M20 grade concrete.
- To check the performance of columns wrapped with GFRP using cementitious matrix
- To check the performance of columns wrapped with GFRP using cementitious matrix with partial replacement by metakaolin
- To compare load-deflection behaviour of columns
- To validate the experimental results using ANSYS

III.SCOPE

The study is limited to

- Rectangular, square and circular columns
- Axial loading
- GFRP using cementitious matrix and with partial replacement by metakaolin.

IV.LITERATURE REVIEW

This chapter gives a brief review of previous studies conducted in field of FRCM.

Zena R. Aljazaeri1 and John J. Myers, F. (2016) submitted a paper on “Fatigue and Flexural Behavior of Reinforced-Concrete Beams Strengthened with Fiber-Reinforced Cementitious Matrix “This system consists of two components: a structural reinforcement mesh and a cementitious matrix. The first aim of this study was to evaluate the fatigue resistance of reinforced concrete beams strengthened with FRCM under fatigue loading and post fatigue flexural strength to failure.

Ida Bagus Rai Widiarsa et al(2016) submitted a paper on “Performance of CFRP jacketed Square Reinforced Concrete Columns Subjected to Eccentric Loading”.They Investigated the performance of square RC columns jacketed with CFRP subjected to eccentric loading. Jacketing the square RC columns under eccentric loading with CFRP enhance their performance by providing higher load carrying capacity and ductility compared to unjacketed RC columns

Tomasz Trapko(2014) published a paper on “Behaviour of fibre reinforced cementitious matrix strengthened concrete columns under eccentric compression loading “This paper discusses FRCM reinforced concrete columns under eccentric compression. Limit load capacity and damage patterns were analysed, and horizontal displacements of the columns were measured, showing elementcapacity for plastic deformation.

Rahul Ravala, Urmil Dave(2013) submitted a paper on "Behavior of GFRP wrapped RC Columns of different shapes" Present experimental investigation mainly emphasises on effectiveness of external GFRP strengthening for RC Columns of circular, square and rectangular shapes having same cross sectional area. 9 columns were control and the rest 6 columns were strengthened with one layer of GFRP wrap having 20mm of corner radius. Stress-strain behaviour revealed that the strength gained from FRP confinement was prominent for circular columns. Square and rectangular-section columns are found to experience lesser increment in strength as compared to that of circular columns.

V.METHODOLOGY

The properties of the constituents in concrete such as cement, fine aggregate, coarse aggregates are determined. The properties should conform to recommendations given in IS codes.Mix design of M20 grade concrete and cement mortar mix is prepared by using the material properties. The properties such as compressive strength, flexural strength, split tensile strength were obtained experimentally.Trial mixes are prepared by different mortar ratios 1:1,1:2,1:3,1:4 and 1:5. Cubes, are to be casted to obtain mechanical properties of concrete such as compressive strength. Obtain the mix which gives maximum strength values. The optimum percentage of metakaolin is also determined.RC column is to be casted with the M20 mix. Rectangular column of dimension 157mm×200mm×1000mm and square column 177mm×177mm×1000mm,circular column of dia 200mm were casted,RC columns are wrapped with GFRP cementitious matrix and cementitious matrix with partial replacement with metakaolin. Load deflection behaviour and ultimate strength of column, ultimate failure load, vertical deformation, axial strain, cracking pattern were measured for the columns is to be investigated. The experimental investigation is to be validated using ANSYS software.

A.Mix Design

Table 1.
Mix proportion for M20 grade concrete

Material	Cement	Fine Aggregate	Coarse Aggregate	Water
Weight (kg/m^3)	383.2	789.27	1004.36	191.6
Ratio	1	1.75	2.62	0.5

VI. RESULTS

Table II
Workability of Fresh Concrete

Mix ID	w/c	Obtained Slump
	0.5	50mm
M1	0.5	52mm
	0.5	50mm

B. Tests on Hardened Concrete

Fig.1 Compressive Strength Test on Cube

Fig.2 Split Tensile Strength Test on Cylinder

Fig.3 Specimen under Flexural Strength Test

Table III
Compressive Strength of Hardened Concrete Cubes

`Mix	Sample No.	7th day Compressive Strength (N/mm²)	14th day Compressive Strength (N/mm²)	28th day Compressive Strength (N/mm²)
M1	1	16.66	21.33	23.88
	2	15.55	22.66	25.33
	3	16.66	21.44	25.88
	average	**16.29**	**21.81**	**24.84**

Table IV
Compressive strength of hardened concrete cylinder

`Mix	Sample No.	7th day compressive strength (N/mm²)	14th day compressive strength (N/mm²)	28th day compressive strength (N/mm²)
M1	1	12.48	16.23	18.45
	2	13.04	17.92	18.45
	3	11.91	15.66	19.02

Table V
Split tensile strength on hardened concrete cylinder

Mix	Specimen No.	Age in days	Breaking Load(kN)	Split Tensile Strength(N/mm²)	Average split tensile strength(N/mm²)
M1	1	28	210	2.87	2.87
	2		210	2.87	
	3		210	2.87	

Table VI
Flexural strength of hardened concrete beam

Mix	Specimen No.	Age in days	Breaking Load(kN)	Flexural Strength(N/mm²)	Average Flexural strength(N/mm²)
M1	1	28	13.0	4.97	4.72
	2		12.5	4.68	
	3		12.2	4.52	

Table VII
Obtained Strength Values of Mix

Properties	Values(N/mm²)
Compressive strength	24.84
Split tensile strength	2.87
Flexural strength	4.72

C. Tests on Hardened Cement mortar cubes

Fig.4 Compressive Strength Test on Cube

Table VIII
Mix proportion by varying cement sand ratios

Cement sand ratio	Cement (g)	Sand (g)	Water (ml)
1:1	200	600	88
1:2	266.67	533.33	88
1:3	200	600	88
1:4	160	640	88
1:5	133.33	666.67	88

Table IX
Compressive Strength Values of mortar Cube

Mix ratio	Sample	3 days compressive strength (N/mm²)	7th day compressive strength (N/mm²)	28th day compressive strength (N/mm²)
1:1	1	20.2	27.6	44.6
	2	20.8	28.4	45.4
	3	19.6	26.8	42.8
	Average	20.2	27.6	44.26
1:2	1	22.8	31.2	49.2
	2	23.6	32.2	51.4
	3	23.2	31.8	50.88
	Average	23.2	31.73	50.49
1:3	1	26.8	37.6	53.4
	2	27.2	36.8	52.6
	3	27.2	37	54.8
	Average	27.09	37.14	53.6
1:4	1	19.8	27.2	43.2
	2	18.4	25.8	41.8
	3	19.8	27.2	43.2
	Average	19.73	26.75	42.37
1:5	1	17.6	24.2	39.8
	2	17.8	23.6	39.8
	3	16.2	24.4	38.2
	Average	17.42	24.06	39.12

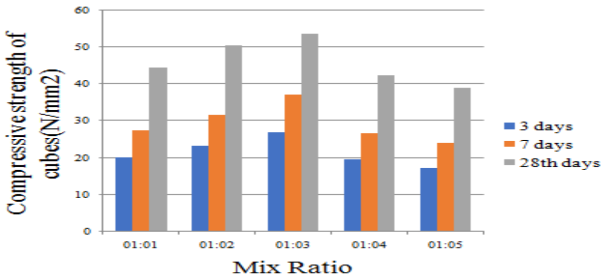

Fig.5 Compressive strength value of cube with different mix ratio

Table X
Mix proportion with varying percentage of metakaolin

% Metakaolin	Cement (g)	Metakaolin (g)	Sand (g)	Water (ml)
5%	190	10	600	96
10%	180	20	600	96
15%	170	30	600	96
20%	160	40	600	96
25%	150	50	600	96

Table XI
Compressive Strength Values of Cube for different % of metakaolin

% of Metakaolin	Sample	3 days compressive strength (N/mm^2)	7th day compressive strength (N/mm^2)	28th day compressive strength (N/mm^2)
5%	1	28.2	32.6	51.4
	2	29.4	31.2	51.2
	3	28.6	32.8	51.4
	Average	28.73	32.2	51.33
10%	1	37.6	44.6	55.2
	2	36.8	43.2	55.6
	3	37.6	43.6	55.2
	Average	37.33	43.8	55.33
15%	1	26.6	30.4	50.2
	2	26.4	30.2	50.6
	3	25.2	30.8	51.4
	Average	26.06	30.46	53.6
20%	1	24.4	28.4	43.2
	2	24.6	28	41.8
	3	24.6	27.2	43.2
	Average	24.53	27.86	42.37
25%	1	20.8	26.2	35.8
	2	20.6	25.4	34.6
	3	19.2	26.4	35.6
	Average	20.2	26	35.33

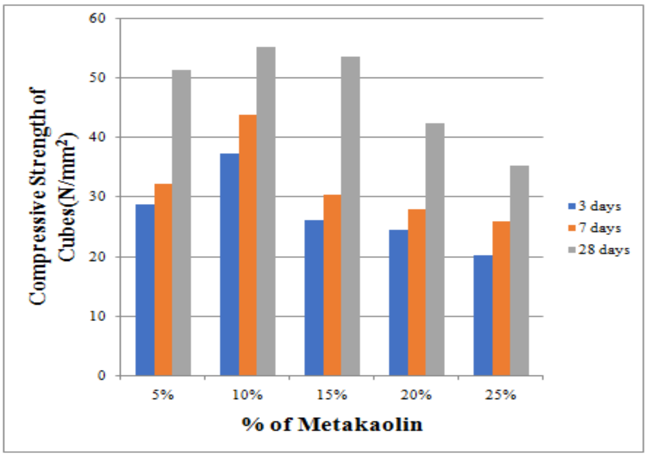

Fig.6 Compressive strength value of cube with different % of metakaolin

VII.CONCLUSIONS

- Preliminary investigation of coarse aggregate, fine aggregate, cement were conducted and the value obtained as per IS specification.
- Strength gained by the cement mortar with 1:3 ratio for three days is 27.09MPa and seven days is 37.14MPa and 28 days is 56MPa which should satisfy the value as per the code IS 12269-1987
- Optimum cement mortar ratio is 1:3
- Optimum value of metakaolin in cement mortar is obtained at 10% repalcement.
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