Retrofitting Of Cylindrical R.C. Columns Using Rubber Rebars Along With FRP

Submitted in partial fulfillment of the requirements

Of the degree of

MASTER OF TECHNOLOGY

In

CIVIL ENGINEERING

By

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2017

DECLARATION

I hereby declare that the research project entitled "**Retrofitting of Cylindrical RC Columns using Rubber Rebars along with FRP**" is an authentic record of my own work carried out as requirements of Dessertation-II for the award of degree in Civil Engineering from Lovely Professional University, Phagwara, under the guidance of **Mr. S. Ganesh**, during the period of January to May 2017. All the information furnished in this project report is based on my own intensive work and is genuine.

Date: **PEERZADA JAFAFR ABASS**

Place:

CERTIFICATE

This is to certify that the declaration statement made by the student is correct to the best of my knowledge and belief. He has completed this Project under my guidance and supervision. The present work is the result of his original investigation, effort and study.

No part of the work has ever been submitted for any other degree at any University. The Research Project is fit for the submission and partial fulfilment of the conditions for the award of degree in Civil Engineering from Lovely Professional University, Phagwara.

Mr. S. Ganesh

Assistant professor

Signature of Supervisor

AKNOWLEGEMENT

This report emphasizes all the necessary information as project problem I would like to say that the whole specified course is covered in this project report. The project was entitled ― "Retrofitting of cylindrical Reinforced Concrete Columns With Rubber Rebars along with FRP".Thesis can't be completed individually, so it isn't fair if I don't say a word of thanks to all those who sincerely advise me during this entire report and made the period enlightening and memorable one.

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Finally I am very grateful to my parents who blessed me with their kind love and encouraged me in all stages of the work.

Signature of Student

PEERZADA JAFFAR ABASS

ABSTRACT

This paper presents the results of a research program that evaluated use of rubber rebars in RC columns retrofitted with fiber reinforced polymer (FRP). The jacketing system of columns consists of carbon fiber wound manually onto prototype RC columns. The research attempts to address a key issue involving strengthening of columns by comparing the strength values of pre and post retrofit prototype models. The principle of research study is to explore the feasibility of rubber rebars as reinforcement along with FRP. A total of 18 cylindrical RC columns were tested under varying axial load. Specimens consists of full scale cylindrical columns (150*300mm) reinforced by using steel and rubber rebars. The key parameters of this extensive research work includes thickness of jacket, concrete strength, loading type, amount of reinforcement, and bonding pattern(arrangement) of GFRP sheets. The varying parameter is loading and area cover by FRP over the column viz.mid, extreme ends and whole column retrofitted. It was demonstrated that high axial load has detrimental effect on deformation capacity. Compared with the performance of pre-retrofitted RC columns, test results showed that post-retrofitted columns having rubber re-bars results in increase in ultimate strength than pre-retrofitted ones. The amount of FRP greatly affects the drift capacity of retrofitted RC columns.

The principle of research study is to explore the feasibility of rubber rebars as reinforcement by comparing crushing value on application of loads. The report has three major sections: introduction, a summary of tests, and a discussion of findings the strength of models.

Key words: Reinforced Concrete Columns; Rubber Rebars; Fibre Reinforced Polymer; Seismic Retrofitting; Bonding.

LIST OF ACRONYMS AND ABBREVIATIONS:

FOS	factor of safety
LL	live load
PCC	Portland cement concrete
RC	reinforced concrete
N	Newton
MS	mild steel
mm	millimeter
kg	kilogram
UC	universal column
c/c	Centre to Centre
BM	bending moment
Φ	diameter of column
Cm	centimeter
mm	millimeter
Rc	reinforced concrete
Ast.	Area of reinforcement
Cfrp	carbon fibre reinforced polymer
G	specific gravity
Frp	fibre reinforced polymer
Hss	high strength steel
H	height of column
P	normalized axial load
Ef	elastic modulus of FRP;
P	applied load;

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CHAPTER -1

INTRODUCTION

1.1 GENERAL:

The modification of existing building structures which makes them more resistant to seismic activity or ground motion is known as retrofitting of structures.

Building structures can be

--earthquake damaged

--earthquake vulnerable

To replace buildings retrofitting has proved to be more economic and immediate shelter to problems.

Retrofitting may be;

--retrofitting of RC structures

--retrofitting of masonry structures

1.2 STRATEGIES:

Strategies are the ways following seismic provisions and advanced materials which are available, like FRP, HSS, and FRC etc. retrofit techniques are quite different from retrofit strategies. Retrofit technique use technical methods to obtain the strategy, while retrofit strategies use basic approach to get desired objective, like increase in strength, increase in deformability, reducing demands, etc.

Strategies leads to:

1. Increase in global capacity or strength.
2. Increase in local capacity of building elements.

3. To provide damping by using seismic friction dampers.

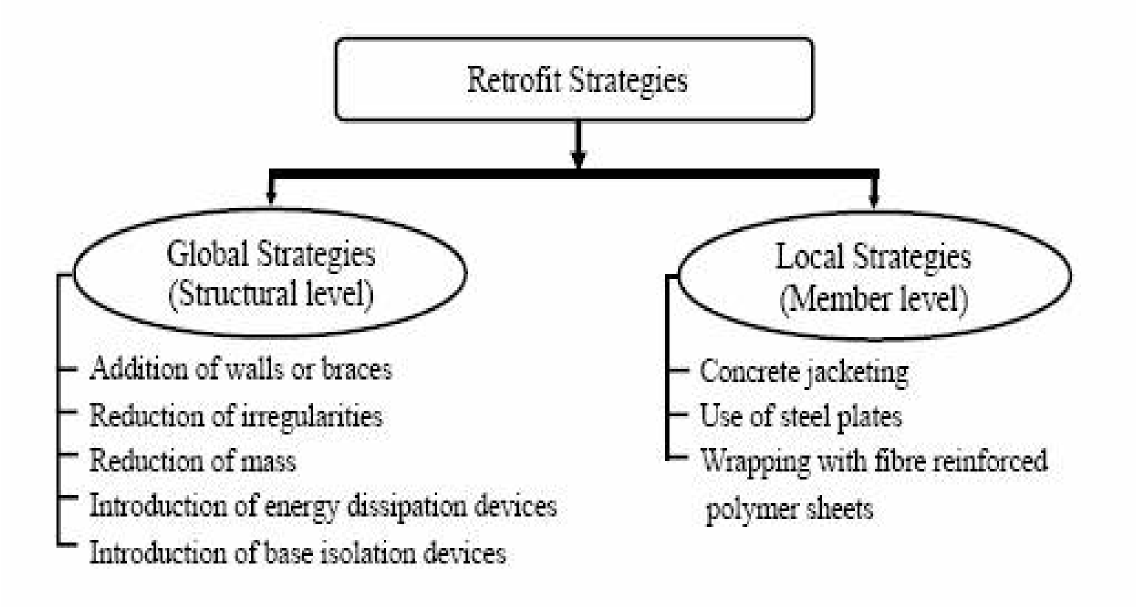


Fig. 1: Types of retrofit strategies.

1.3 OBJECTIVES:-

- To upgrade lateral strength of structure.
- Comparing the strength of parent and retrofitted structure and get to know whether approachable strength is coming or is not feasible.
- To make the structural element more economic (using rubber rebars).
- Structure is light in weight.
- Easy to handle and maintenance cost is low.

The materials used in the whole research are: cement, sand, aggregates, frp, tape, rubber rebars. The properties related to them are mentioned below:

1.4 PROPERTIES OF MATERIALS:

1.4.1 Properties of cement:

1. High compressive strength,
2. More economical than steel,

3. It is corrosion resistant and no any atmospheric effect on it,
4. Its hardening property continues for a long time as it hardens with age. This property gives it a unique place among building materials,
5. Binding nature of cement with steel is rapid, but weak in tension, at suitable places steel reinforcement is placed to take the tensile stresses, often known as reinforced cement concrete.

1.4.2 Properties of aggregates:

1. It possess absorption and porosity.
2. It is permeable in nature.
3. Possesses strength.
4. Possess specific gravity.
5. Possess spaces.
6. Shape of particle.
7. Surface texture.

1.4.3 Properties of FRP:

1. It is impact resistant.
2. Able to carry heavy loads.
3. It is flexible.
4. Having good strength and stiffness.

1.4.4 Properties of steel rebars:

Thermal expansion, Corrosion resistant, &Tensile in nature.

A) Physical properties of steel reinforcement bars:

Serial No.	Test	Unit	Mandatory as per IS: 1786-2008

	Grade		Fe-500-D
1.	Yield stress	N/mm2	500 Min.
2.	Tensile strength	N/mm2	10% more than actual YS but not less than 565
3.	Elongation	%	16 Min.
4.	Uniform Elongation	%	5 Min
5.	Bend test		Up to 20mm-3D
			Over 20mm-4D
6.	Re-bend test		Up to 10mm-4D

Table no.1: Properties of steel rebars.

B) Chemical composition of steel rebars:

Serial No.	**Test**	**Unit**	**Mandatory as per IS: 1786-2008**
1.	Carbon	%	0.25 Max
2.	Sulphur	%	0.04 Max
3.	Phosphorous	%	0.04 Max
4.	S+P	%	0.075 Max
5.	Carbon equivalent	%	0.42 Max

Table no. 2: Chemical composition of steel rebars.

Why KADHENU 500D TMT bars:

1. Highly earthquake resistant.
2. High bonding strength.
3. Non- vulnerable to cracking under extreme hot and cold conditions.

4. High ductility and thermal stability (400-600degrees).

(A) (B)

Fig. no.2: Steel reinforcement bars in spiral form.

Fig. no.3: Arrangement of steel rebars within frame work.

1.4.5 GFRP properties:

FRP possess linear-elastic behavior therefore their properties are interrelated by Hooke’s law.

Physical properties of GFRP

Fiber	Density(g/cm^3)	Tensile strength(GPa)	Young's modulus (GPa)	Elongation (%)	Coefficient of thermal expansion($10^{-7}/^0C$)	Poison's ratio	Refractive index
GFRP	2.58	3.445	72.3	4.8	54	0.2	1.558

Table no.3: Physical and mechanical properties of GFRP

Chemical composition of GFRP

Fiber	SiO_2	Al_2O_3	TiO_2	B_2O_3	CaO	MgO	NaO	K_2O
GFRP	55	14.0	0.2	07	22	1.0	0.5	0.3

Table no.4: Chemical composition of GFRP in weight (%)

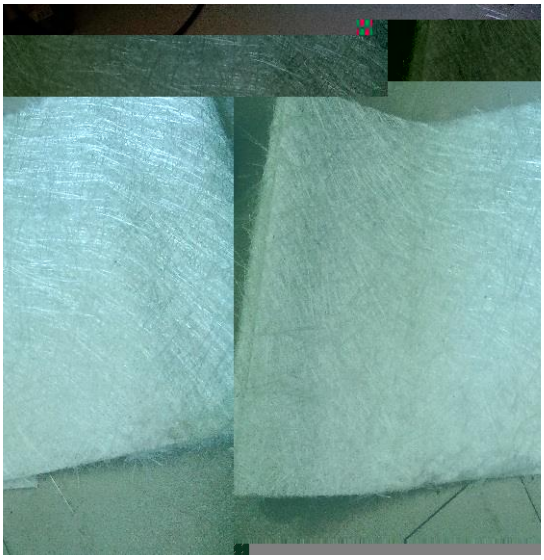


Fig. 4: Glass fiber and the column wrapped with GFRP.

1.4.6 Rubber re-bar properties:

Rubber re-bars are cost effective, having low compression set and good mechanical properties.

1.	Color	Black
2.	Material	Nitrile
3.	Cross section type	Circular
4.	Hardness (shore A)	70
5.	Maximum temperature(^{0}C)	80
6.	Minimum temperature(^{0}C)	-20
7.	Elongation at break (%)	300
8.	Tensile strength(MPa)	12
9.	Compression set (%)	25

Table no. 5: properties of rubber re-bars.

Fig. 5: Rubber re-bars.

1.4.7 Epoxy raisin and its properties:

Epoxies are mainly applicable when two materials are combine for a particular time. Because of its characteristics it possess wide range of applications in both business and individuals. Epoxy's high popularity is because of its high mechanical strength, cheap and quicker than welding. Its performance properties lies as below:

1. Bio-incompatibility
2. Eco-friendly
3. Resistance to chemicals.

Material properties of epoxy raisin:

A. Mechanical properties:

Serial No.	***Property***	***Value***
1	Glass transition temperature(Tg)(^{0}C)	120-130
2	Tensile strength(N/mm^2)	85
3	Tensile modulus(N/mm^2)	10500
4	Elongation at break (%)	0.8
5	Flexural strength (N/mm^2)	112
6	Flexural modulus(N/mm^2)	10000
7	Compressive strength(N/mm^2)	190
8	Co-efficient of linear-thermal expansion.	$34*10^{-6}$

Table 6. Mechanical properties of epoxy raisin.

B. Thermal properties:

Serial No.	***Properties***	***Value***
1.	Thermal shock	2000 cycles
2.	Smoke emission	Low smoke emission
3.	Flammability	Class 0 (current building regulations)
4.	Thermal decomposition	350 ^{0}C

Table 7. Thermal properties of epoxy raisin.

Cost analysis of re-bars:

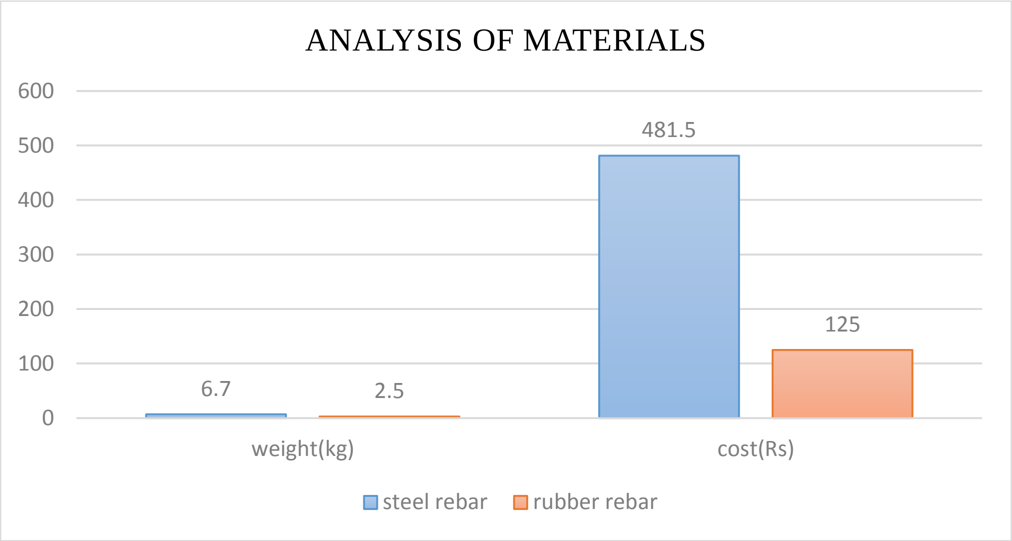


Fig. 6: Chart showing cost analysis of re-bars.

CHAPTER -2

LITERATURE REVIEW

1. **M. S. Saiidi, et al: "experimental study on RC flare bridge columns subjected to earthquakes having shear retrofitting (March 2001)".**

Rc columns having structural flares have advantage over the prismatic columns as hinge (plastic) acts at places away from end connection. Research studies revealed that plastic hinge doesn't act at sections or get started at sections having maximum bending moment when the column is having parabolic structural flares. The position of hinge depends upon the geometry of structural flares and steel details longitudinally or from moment curvature analyses performed at various cross sections.

2. **Dong S. Gu, Gang Wu, Yu-Fei Wu, and Zhi-Shen Wu Yu-Fei Wu: "effectiveness of confining retrofitted circular columns under stimulated seismic load (May 2010)".**

Drift capacity is hghly influenced by axial load and by the aspect ratio for frp retrofitted columns. High load is effective to capacity. To resist high load and attain desired capacity, frp's which are highly confined are required. Aspect ratio is directly proportional to drift capacity as revealed by studies, which means higher aspect ratio increases drift capacity. Energy dissipated from retrofitted columns are influenced by jacket confinement stiffness implies influence is negligible when there is low axial load and when there is high axial load, there is greater stiffness and hence energy is dissipated more.

Research studies have revealed that capacity of columns is greatly affected by confining, that is, low level confinement increases drift capacity. However, there is reduction in deformation capacity when confinement goes beyond the critical value.

3. **P. Lignola, G. Manfredi, A. Prota, et al: "study on the Performance of CFRP retrofitted Hollow Columns (January 2007)".**

In this paper they studied the behaviour of hollow non-circular column subjected to both axial load and bending. Total of 7 specimens have been tested.

Research studies found that composite wrapping enhances the strength of piers under eccentric loading. There was improvement in strength when specimens were loaded with smaller eccentricity but was opposite to ductility which shows improvement in strength loaded to bigger eccentricity. Curvature ductility measures were used for measuring the ductility. For unstrengthened columns, the curvature ductility varies between 1-1.5 while for strengthened columns, the same ranges between 3.02- 8.07.

4. **R. Realfonzo, and et al: "Research study on how FRP retrofitted Columns behave using Steel Devices (October 2009)".**

This paper represents behaviour of columns confined by FRP. Constant load were applied on specimens. Both confined and unconfined frp columns were tested. Research studies found that the increment in ductility was by the confinement of frp. At high loads (v=40%) improvement of strength were seen by frp confinement.

The degradation of stiffness is not dependent on frp confinement system. For strengthened columns, the energy dissipated is more than unstrengthened.

5. **B. Shan and Y. Xiao: "Behaviour of RC Columns Subjected to Simulated Earthquake Loading retrofitted externally by FRP (January 2014)".**

This research paper gives us report about how retrofitted columns behave with stimulated earthquake loading having different degrees. The result show that creep of column increases with increase in damage degree. At high earthquake or high axial load, the life of creep declines and causes rupture of frp. Creep model is prepared and is verified. According to results from creep model, damage index=0.85 for frp retrofitted columns is maximum acceptable damage level.

6. **H. L Coffman, et al: "study of how RC columns react seismically mainly durability is seen (May1993)".**

In this paper performance of 4 columns were studied. The RC columns of period 1950 to mid-1970 era were retrofitted and tested under quasi –static lateral loads. From the research studies, the stiffness of column didn't change with retrofitting. The column strength didn't increase and the energy dissipated get slightly increased. From the studies, details got effected but not substance with the amount of used material.

7. **J. G. Teng, et al: "study on how FRP-Jacketed Columns react when subjected to cyclic load as well as Seismic Load (January 2016)".**

This paper represents behaviour of cyclic & seismic loading of retrofitted RC columns. Numerical model was proposed and being implemented into *opensees* by using beam-column element. The results obtained from analyses were analysed and compared with results of tests. The fixed end rotation has effect on the column and accounts more than 15% of lateral displacement under cyclic loading. The response of retrofitted columns, under the effect of ground motion having both large and small amplitudes can be predicted by same model.

8. **S. W. Park, et al: “under repeated ground motions performance of RC bridge column seismically (June 2001)”.**

In this research paper, the RC column is investigated by experiments using shake table. The model is subjected to simulated ground motion. The same column beard ground motions. It has been found that with increase in damage level of column, the stiffness of column got decreased. The energy dissipated also increased with increase in damage level. On cracking of concrete, the energy dissipated is significant in initial stage of loading. The analyses of frequency of columns vibration at earthquake ground motions shows, with increase in damage level, frequency decreases.

9. **R Sadone, et al: “experimental study on retrofitted columns under seismic loading using FRP”**

In research paper, strengthening configuration were applied on retrofitted columns. Confining frp and flexural reinforcement were seen from the analysis of tests. From the studies, the ductility got enhanced for confined RC columns at the footing- column junction plastic hinge is located and where accumulation of damage zone lies. There was no change in ductility and strength with longitudinal reinforcement.

10. **Alper Ilki, et al**: “**Retrofitting of circular and rectangular RC columns of low and medium strength using FRP (February 2008)”.**

In this research paper, 68 specimens were tested subjected to uniaxial compression retrofitted externally by CFRP. Among 68, 40 specimens were casted as low strength concrete (LSC) and transverse reinforcement as inadequate, whereas 28 moulds were casted as MSC and transverse reinforcement as adequate. The important parameters in the whole research work were thickness of jacketing, strength of concrete, amount of reinforcement, orientation, spacing etc of bonding of cfrp sheets and the type of loading, etc.

From the research studies, it has been found that with increase in confinement of cfrp sheets, the ductility and strength also get increased. The strength was more in circular columns rather than rectangular/square ones. In low strength concrete the retrofitting was more efficient which provides cost effective solutions to existing buildings, being build using concrete having strength low. It has been found that jacketing prevents buckling of bars and spalling of concrete.

11. **Lampros N. Koutas, et al: "Retrofitting of masonry RC infilled frames along with textile reinforced mortar (TRM)" (2015).**

In this paper, 3 storey masonry infilled frames are retrofitted externally by textile reinforced mortar (TRM) along with special anchorage details. Analytical model was prepared to check behaviour of TRM.

Research study revealed that there is global enhancement of both lateral strength and deformation capacity. The TRM layers over the surface are supplemented by fabricated textile based anchors. These layers can accommodate high shear deformations.

12. **M.B.S. Alferjani et al: "Application of CFRP laminates for strengthening RC beams in shear (*February 2013*)".**

In the paper, 10 articles based on strengthening of RC beams by CFRP has been reviewed. It was found that with increase in number of layers of CFRP laminate, strengthening time and cost both increased. The main aim of the research work was to provide versatile and economical solution for the service life of RC structures.

13. **Christos G. Papakonstantinou, et al: "behaviour of retrofitted RC beams with GFRP to fatigue" (2001).**

The main aim of the research work is to check the effects of GFRP sheets on fatigue performance of RC beams. Tests have been conducted with or without GFRP sheets on beams along the tensile surfaces. The transverse reinforcement in RC beams (152*152*1321mm) was enough to resist shear failure.

From the research, it has been found that with the application of externally bonded GFRP sheets, fatigue life of RC beams has also extended. In both strengthened and non-strengthened beams, the failure of steel reinforcement remain same.

14. **C. Desprez, et al: "stress strain model for FRP retrofitted concrete columns under the application of cyclic and seismic loading" (2012).**

In the paper simplified stress-strain model is presented to predict the effect of FRP on RC columns. Inspired by La Borderie's and Eid and Paultre's model, model is prepared. Here La Borderie's model was modified by introducing both internal and external confinement effects. The model was used to reproduce the tests on FRP retrofitted RC column and pier.

15. **M.Kazem Sharbatdar: "behaviour of new FRP retrofitted RC beams under monotonic and cyclic loading (2008)".**

In this paper FRP re-bars were used and the research revealed that diagonal cracks were developed in tension zone along log span beams and rupturing of FRP in compression zone along short span beams. The results also showed linear moment curvature relationship.

CHAPTER -3

RESEARCH METHODOLOGY

3.1. GENERAL:

The entire research comprises of following steps: viz.

1. Casting of prototype models,
2. Finding the crushing load/strength, and
3. Comparing strength values.

The materials required are:

I. cement(pozzolona Portland cement,43 grade),
II. sand,
III. 10mm fine aggregates (40%),
IV. 20mm coarse aggregates (60%),
V. FRP,
VI. Steel and rubber rebars, and
VII. Water

Initially the testing of materials are done, for cement the tests include, fineness, soundness, consistency and initial and final setting time. After performing the corresponding tests the respective values are noted down. Similarly for coarse and fine aggregates the tests are, viz. crushing, abrasion, specific gravity, impact, water absorption test, and sieve analysis. The end values are noted down. These values are then compared to the standard values and is seen whether the material chosen are feasible for research purpose or needs more attention.

Firstly slenderness ratio is seen by length of column (*le*) to least radius of gyration(*r*). To calculate the diameter of prototype model, slenderness ratio is used (l/d=3). The details of the bar like diameter and area are calculated by load assumptions. The prototype model is then prepared with corresponding dimensions (150mm*300mm).

The moulds are casted with materials like cement, sand and aggregates. The design mix used is M20. On an average three moulds are casted. After casting, the moulds are oven dried and are taken for testing purposes. Testing is seen for 7 and 28 days and the crushing or strength values are obtained. Similarly another mould is casted but the little difference is instead if steel reinforcement rubber rebars are used. The same procedure if followed written above and the strength values are obtained.

The same models are retrofitted with FRP and Elastic tape with the pattern like center, on extreme ends and the entire column. Strength values for each column is obtained.

The final step is to compare the strength values of retrofitted with normal columns and the result is drawn whether the strength is comparable or more than former ones.

Fig. 7: Picture showing framework of specimens and concrete mixer.

3.2. TESTING:

A. AGGREGATE TESTS:

1. Aggregate crushing value

Crushing test is performed to know how much aggregates will be crushed.

Apparatus required: Cylinder, plunger, Sieves, Compression testing machine.

Fig. 8. Apparatus for crushing test.

Formula:

Crushing value = B/A* 100%.

2. **Aggregate abrasion value**

To determine the abrasion value of aggregates, abrasion test is performed.

The apparatus required are: Los Angles abrasion testing machine, Abrasive charge – 12 no's (weighing between 390 & 445g), & Sieve of size 1.7mm.

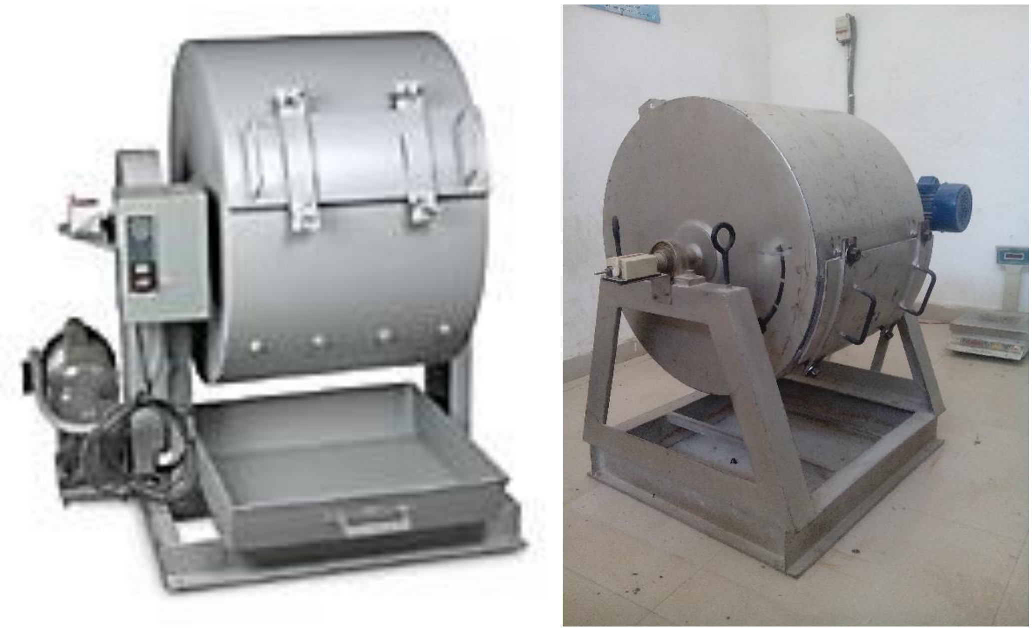


Fig. 9. Apparatus for abrasion

Formula:

Abrasion value = (A-B)/B* 100%.

3. **Impact test:**

To find the impact value of aggregates, impact test is performed.

The apparatus required are: Impact testing machine, Sieves, cylindrical metal, tamping rod rounded at one end.

Fig.10. Apparatus for impact value

Formula used:

Impact value = B/A * 100%

4. **water absorption test:**

To determine how much water is absorbed by coarse aggregates, water absorption test is performed.

The apparatus required are: perforated wire basket, water container, dry and soft cloth.

Formula:

Water absorption = [(A-B)/B]*100%

Result: water absorption = [(500-494)/494]*100 **= 1.1%**

5. **Sieve analysis**

To determine size of the aggregates, sieve analysis is being performed.

Apparatus required: different sieves as per IS standard.

A). Determination of sieve analysis of fine aggregates.

Determination of coarse sand, medium or fine sand is done by sieve analysis.

Serial No.	Fine aggregates	Fineness modulus
1.	Fine sand	2.2-2.6
2.	Medium sand	2.6-2.9
3.	Coarse sand	2.9-3.2

Table no. 8: Types of fine aggregate and their range

Fine aggregates having fineness modulus greater than 3.2 are unsuitable for concrete preparation.

Calculation:

Sample weight (fine aggregate) =1 kg

Serial No.	Sieve size	Weight retained(kg)	%age weight retained	Cum %age weight retained(kg)	%age weight passing(kg)
1.	4.75mm	0.02	2	2	98
2.	2.36mm	0.045	4.5	6.5	93.5
3.	1.18mm	0.092	9.2	15.7	84.4
4.	600 µm	0.177	17.7	33.4	66.5
5.	300 µm	0.492	49.2	82.6	17.4
6.	150 µm	0.161	16.1	98.7	1.3
7.	Pan	0.013	1.3	100	0.1
Total		1kg		X=238.9	

Table no. 9: fineness modulus of fine aggregates.

Result:

The fineness modulus of fine aggregates is X/100=**2.389**

B). Determination of sieve analysis of coarse aggregates.

Calculation:

Weight of coarse aggregate taken =5kg.

Serial no.	Sieve size(mm)	Weight retained(kg)	% weight retained	Cum % weight retained(kg)	Cum % passing
1	80	0	0	0	100
2	40	0	0	0	100
3	20	0.400	8	8	92
4	10	2.850	57	65	35
5	4.75	1.480	29.6	94.6	5.4
6	2.36	0.270	5.4	100	0
Total		5.0		267.6=X	

Table no. 10: Fineness modulus of coarse aggregates.

Fig. 11: Sieves used for sieving coarse aggregates.

Result:

The fineness modulus of coarse aggregates =X/100=267.6/100=**2.676**

6. **Specific gravity:**

Specific gravity is defined as ratio of mass of the solid to the equal volume of water. As the specimen contain voids which are permeable to water, therefore two measures are used:

Apparent specific gravity is defined as mass of aggregates to the volume of aggregates excluding water permeable voids. It is denoted by G_{app}.

Bulk Specific Gravity is calculated on the volume of aggregates including water permeable voids. It is denoted by G_{bulk}.

Specific gravity =W3/ [W-(W1-W2)] =**2.73**

B. CEMENT TESTS:

1. FINENESS

To determine that portion of cement whose grain size is larger than size of mesh, fineness test is performed.

The apparatus required: 90µm IS Sieve, nylon brush, balance.

Figure for sieve is given below and isn't actual 90µm sieve.

Fig. 11. Seives used for calculating fineness of cement.

Calculation:

Sample No.	Weight of dry cement(g)	Weight retained on 90µm IS Sieve(g)	Fineness (%) (x/200)*100
Sample 1.	200	11.5	5.75
Sample 2.	200	10.9	5.45
Sample 3.	200	10.7	5.35

Table no. 11: Results of fineness of cement.

Result: The fineness of cement comes out as **5.5%**

2. **Soundness**:

Soundness of cement is determined by Le-Chatelier test.

The apparatus required: Le-Chatelier test are Balance, Water bath.

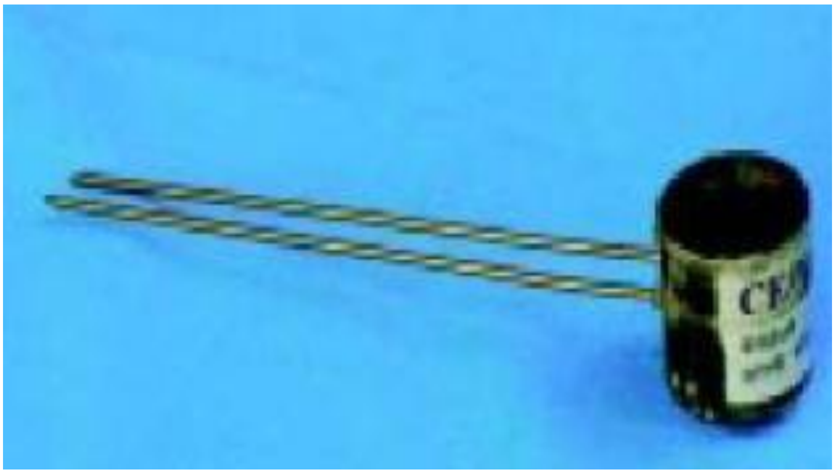


Fig.12. soundness intrument

Calculation :

Sample No.	L1(mm)	L2(mm)	Soundness(mm)
Sample 1.	1.5	1.9	0.4
Sample 2.	1.5	1.85	0.35
Sample 3.	1.5	1.75	0.25

Table no. 12: Results of soundness test of Cement .

L1= Distance separating the two indicator points submerged in water bath at normal temperature for 24 hours.

L2= distance between the two indicator points submerged in water bath at 100 for three hours.

Soundness or expansion = L2-L1

Result: By taking the mean of three samples, soundness came out as **0.33mm**

3. **Consistency**

Consistency test is used to make paste consistent and the water required for making the same, consistency test is being done.

Instruments required – Vicat apparatus, Balance, Gauging trowel

Fig. 13. Vicat apparatus

Calculation:

Serial No.	**Weight of cement (g)**	**Percentage by water of dry cement (%)**	**Penetration(from the bottom of mould) (mm)**
1.	300	25	41
2.	300	27	34
3.	300	29	31
4.	300	30.5	23
5.	300	32.5	11
6.	300	334.5	7

Table no. 13: Results of standard consistency of Cement.

Result: The standard consistency comes out as **34.5%**

4. **Initial and final setting time**

   to find out the setting time of cement the same test is being performed

Apparatus required: Vicat apparatus, Balance, Gauging trowel are needed.

Calculation:

Weight of dry cement is 300gm

Standard consistency is 34.5%

Volume of water added is 0.85P=87.97ml

Sample No.	**T1(min)**	**T2(min)**	**Setting Time (T2-T1)**
Sample 1.	10:15	10:52	37
Sample 2.	11:05	11:39	34
Sample 3.	12:02	12:33	31

Table no. 14: Experimental values of setting time of cement.

Result: By taking the mean of three readings the initial setting time comes out as **34 minutes** and final setting time as **590 minutes**.

5. Specific gravity:

It is the ratio of mass of solid to equal volume of water at a specified temperature. It is denoted by G. its units are kg/m3.

Here, W= weight of cement (50gm)

W1=weight of diesel in the flask (240.35gm).

W2=weight of diesel and cement in the flask (279.352gm).

Result: specific gravity = W/ [W-{W2-W1}*0.85] = **3.15**

CHAPTER -04

OBSERVATION/FINDINGS

The Experimental and BIS values of cement properties are:

Serial no.	Test name	Test value	IS requirement
1.	Fineness	5.5%	!>10%
2.	Soundness	0.33	<10%
3.	Specific gravity	3.15	3.15
4.	Initial setting time	34 minutes	!<30 minutes
	Final setting time	590minutes	!>600 minutes
5.	Consistency	34.5%	-

Table no. 15: BIS values of cement.

Serial no.	Test name	Test value	
		Fine aggregates	**Coarse aggregates**
1.	Crushing test	17.19%	
2.	Impact test	-	20.24%
3.	Water absorption	1.29%	1.895%
4.	Specific gravity	2.73	2.87
5.	Bulk density	1.657gm/cc	1.420gm/cc (for 10mm aggregates). 1.455gm/cc (20mm aggregates).

6.	Flakiness index	9.41%
7.	Elongation index	12.80%

Table no. 16: BIS values of aggregates

Experimental values obtained are given in the following table:

Serial No.	Test Name	Test Value
1	Water absorption	1.1%
2	Fineness modulus of coarse aggregates	2.676
3	Fineness modulus of fine aggregates	2.389
4	Specific gravity(FA)	2.73

Table no. 17: Experimental values of aggregates

IS CODES INVOLVED ARE:

1. IS 1489(Part 1):1991-specification for PPC part 1flyash based.
2. IS 2386(Part 1):1963-method of test for aggregates for concrete: part 1 particle size and shape.
3. IS 2386(Part 3):1963-methods of test for aggregates for concrete: part 3 specific gravity, density, voids, absorption and bulking.
4. IS 2386(Part 4):1963-methods of test for aggregates for concrete: part 4 Mechanical properties.
5. IS 456:2000-code of practice for plain and reinforced concrete.
6. IS 383:1970-specification for coarse and fine aggregates from natural sources for concrete.
7. IS 5513:1996-specification for vicat apparatus.
8. IS 5525:69-recommendations for detailing of reinforcement in RC works.
9. IS 7320:1974-specification for concrete slump test apparatus.
10. IS 9377:1979-specification for apparatus for aggregate impact.
11. IS 10070:1982-specification for machine for abrasion testing of coarse aggregates.

CHAPTER 5

CONCRETE MIX DESIGN

1. Data for mix design

The data required for concrete mix is specified below:

a) Characteristic compressive strength of concrete at 28 days(*fck*),
b) Degree of workability,
c) w/c ratio and minimum cement required to ensure adequate durability(IS: 456-1978),
d) Standard deviation.

Target strength for mix design:

The characteristic strength is given by the following relation:

$$f'_{ck} = f_{ck} + t * s$$

Where,

f'_{ck} = target compressive strength at 28 days,

f_{ck} = characteristic compressive strength at 28 days,

s= standard deviation,

t = a statistic.

Referring IS: 456-1978 and IS: 1343-1980, the target strength came out as;

$$f'_{ck} = 20+1.65*4.6$$
$$= 27.59 N/mm^2$$

2. Selection of w/c ratio:

The preliminary water cement ratio can be selected from the graph in the corresponding IS code by using the target compressive strength. From the graph w/c ratio came out as **0.48**

3. Selection of water content and fine aggregates ratio:

By knowing the nominal size and type of aggregates, the water content and sand content can be easily [table 4. IS: 10262-1982].

Serial No.	Nominal max. aggregate size(mm)	Water content(per cubic meter)	Sand (%age of total aggregate by absolute vol.)
1	10	208	40
2	20	186	35
3	40	165	30

Table no. 18: Approx. sand and water content per cubic meter.

So, for 20mm aggregates, the maximum water content per cubic meter is 186kg while the sand content as 35%. From this data, and using water cement ratio, the estimated cement content is calculated as:

$$w/c = 0.48$$

$$c = w/0.48 = 186/0.48$$

$$c = 387.5 kg/mm^3$$

The cement content so obtained is checked against the minimum cement content for durability requirement. Therefore by using correction factors [enlisted in IS: 10262-1982-table 6], the sand content as (35-3.9=31.1%) and cement content as:

$$\text{Required water content} = 186+186*3/100$$

$$= 191.6\ l/m^3$$

$$\text{Therefore, cement content} = 191.6/0.48=399.16=400 kg/m^3 \text{ (approx.)}$$

4. Determination of fine and coarse aggregates:

By knowing the quantities of water and cement, the aggregate content per unit volume of concrete can be calculated from the given equations:

- **For fine aggregates:**

$$\mathbf{V = [W+C/S_c + 1/\rho * f_a/S_{fa}] * 1/1000}$$

$$0.98*1000 = [191.6 + 400/3.15 + 1/0.311*f_a/2.73]$$

$$980 = 191.6 + 126.98 + 1.177 f_a$$

$$f_a = 561.95 kg/m^3.$$

- **For coarse aggregates:**

$$\mathbf{V = [W + C/S_c + 1/1- \rho * C_a/S_{ca}]*1/1000}$$

$$0.98 * 1000 = [191.6 + 126.98 + 1/0.689*C_a/2.87]$$

$$980 = 191.6 + 126.98 + 0.5057C_a$$

$$C_a = 1812.63 kg/m^3.$$

Where,

V = absolute volume of fresh concrete,

W = mass of water (kg/m^3),

C = mass of cement (kg/m^3),

S_c = specific gravity of cement,

ρ = ratio of fine aggregate to total aggregate by absolute volume,

f_a , C_a = total mass of fine aggregate and coarse aggregate(kg/m^3)

S_{fa} , S_{ca} = specific gravities of saturated dry fine aggregates and coarse aggregates.

5. Calculation of batch masses:

Water	*Cement*	*Fine aggregates*	*Coarse aggregates*
191.6	400	561.95	1812.6
0.48	1	1.40	4.53

Table no. 19: Calculated batch masses.

Total parts by weight = 1 + 1.40 + 4.53

= 6.93

Volume of cylinder = $\pi r^2 h$= 0.00529m^3

Wastage as 3% excess = 1.03 *0.00529*2400

= 13.07kg.

Now the quantities of material required for one cylinder:

1. Cement = 13.07*(1/6.93) = 1.886kg
2. Fine aggregates = 13.07*(1.40/6.93) = 2.64kg
3. Coarse aggregates = 13.07*(4.53/6.93) = 8.54kg
4. Water content = 0.48*1.886=0.905ltr.

5.124(20mm)

3.41(10mm)

Therefore for 18 cylinders the materials required are:

1. Cement = 33.588=34kg(approx.)
2. Fine aggregates = 47.52=48kg(approx.)
3. Coarse aggregates(20mm)= 92.23=93kg(approx.)
4. Coarse aggregates(10mm) = 61.38=62kg(approx.)
5. Water content = 16.29=17ltr(approx.)

Experimental program:

Specimen Details

A total of 18 specimens were tested under the axial load throughout the test. The specimens so tested represents the part of building column or bridge column. All these specimens were divided into two groups according to reinforcement used. The reinforcement of first group was steel while for the 2nd one rubber Rebars were used.

The first group included six specimens and all were tested under "as built" condition. The height of the specimens H measured from bottom to the point of application of load is 300 mm. the aspect ratio *H*/*D* found was 2.0. The specimens were reinforced with 6 of 8mm diameter bars longitudinally, yield stress of 500 MPa. Longitudinal bars were evenly distributed in a circle with a constant clear cover of 15 mm. Lateral reinforcement of two bars (diameter=6 mm) were provided with a spacing of 200 mm. The equivalent cylinder strength was 27.59 which was calculated from the relation

$$f_{ck} = f_{ck} + t * s$$

Where, f_{ck} is the 28 days compressive strength.

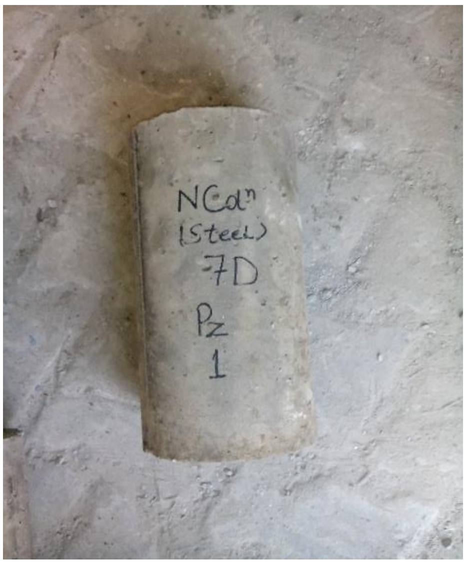
The second group included 12 specimens among which six specimens were tested under "as built" condition, while others were retrofitted using FRP jacketing. Specimen size remains same and same number of bars were used in longitudinal and lateral reinforcement. The details of test specimens are given in the following table:

Serial No.		Specification	Specimen		
			SRC	RRC	RCC
1.	Column section	Column height (H)	300mm	300mm	300mm
		Column dia. (D)	150mm	150mm	151.5mm
		Concrete cover (cc)	15mm	15mm	15mm
		Concrete strength (f'_c)			
		Axial load (Mean) Failure(KN) (P)- 7 Days - 28 Days	228.4 273.3333	87.43333 130.1333	259.1 386.2667
		Ratio of axial load (P/f'_cA_g)			
2.	Longitudinal reinforcement	Bar diameter(d_b)	8mm	8mm	8mm
		Bar area (A_s)			
		Clear cover(cc)	15mm	15mm	15mm
		Spacing(s)	70mm	70mm	70mm
3.	Lateral reinforcement	Bar diameter(d_b)	6mm	6mm	6mm
		Bar area (A_s)			
		Spacing(s)	200mm	200mm	200mm

***A_g= gross sectional area**

Table 20: Details of test specimens

(A)



(B)

(C)

Fig.no. 14: specimens of RC Columns

TESTING AND INSTRUMENTATION

The test set up is shown in fig. 2. The pre-retrofit RC columns were tested using compressive testing machine while the post retrofit ones where tested using universal testing machine. Specimens were subjected to varying axil load with rate of loading as 5.2KN/s. The axial load was controlled by a pressure gauge. An average of three specimens was taken. Both crack value and failure values were noted down. The capacity of CTM was 2000KN which enables easy testing of specimens as the ultimate strength found was 286KN. Inclined cracks were always seen rather than lateral ones.

Fig.15: Test set-up.

Test Observations and Results:

Test observations

The first group of specimens showed greater resistance towards the varying axial load rather than columns possessing rubber re-bars. It was observed that the cracks were developed vertically starting from the upper edge and moving towards the bottom edge. Later increasing the load beyond peak value, column showed no response and the load capacity drops from the maximum, and the lateral cracks appears. The vertical reinforcement showed bent in bars.

These all kinds of failures were prevented by wrapping the glass fiber around the columns. It enables them to bear greater loads and hence increase in strength. All retrofitted RC columns showed same behavior towards axial loading. Subjecting the retrofitted columns under loading, the GFRP sheets broke when load was increased beyond the column bears.



(A) **(B)** **(C)**


(D) **(E)**

(F)

Fig. 16: Views of specimen failures.

Test Results:

Serial no.	Columns	Strength (Days)KN			
1.	Steel reinforced columns	7 days		28 days	
		Crack value	Failure	Crack value	Failure
1.1.	NC1	217	222	262	285
1.2.	NC2	225	237.9	271	286
1.3.	NC3	217	225.3	243	249
2.	Rubber reinforced columns	7 days		28 days	
		Crack value	Failure	Crack value	Failure
2.1.	RC1	70	75.7	112	122.7
2.2.	RC2	79	84.8	119	127.2
2.3.	RC3	93	101.8	133	140.5
3.	Retrofitted columns(confined with GFRP)	7 days		28 days	
		Crack value	Failure	Crack value	Failure
3.1.	R’RC1	239.2	255	371	387.6
3.2.	R’RC2	272	285.2	417	431.2
3.3.	R’RC3	226	237.1	331	340

Table 21: Test values of each specimens.

Graphical analysis of specimens

Analysis of test results

While accessing the performance of FRP confined RC columns, two considerations are used: i) confinement ratio, which is defined as confinement pressure to unconfined concrete strength and, ii) stiffness of confinement which is mainly used for measuring the stiffness of confinement of FRP.

CASE I:

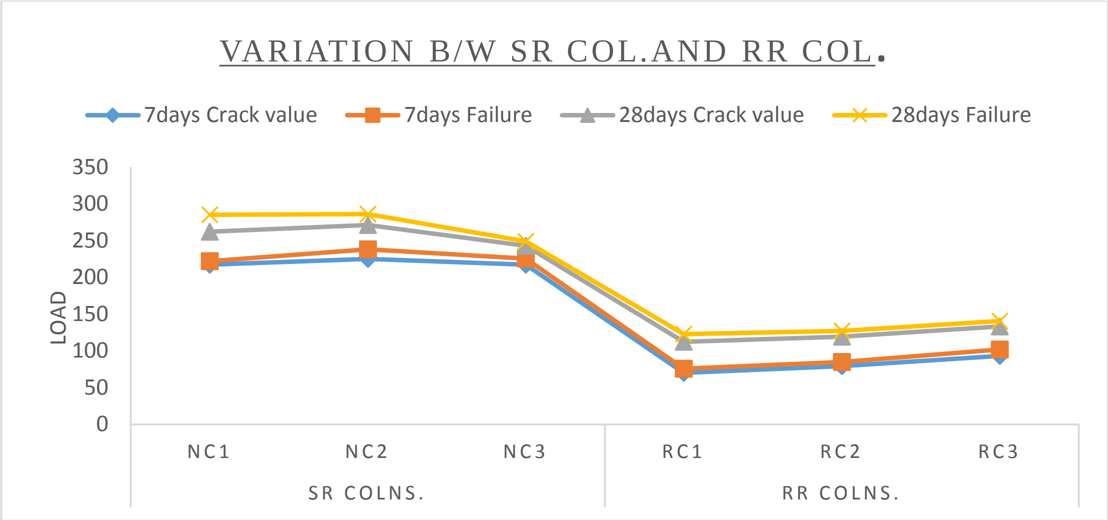


Fig.17: Variation between steel reinforced columns and rubber reinforced columns.

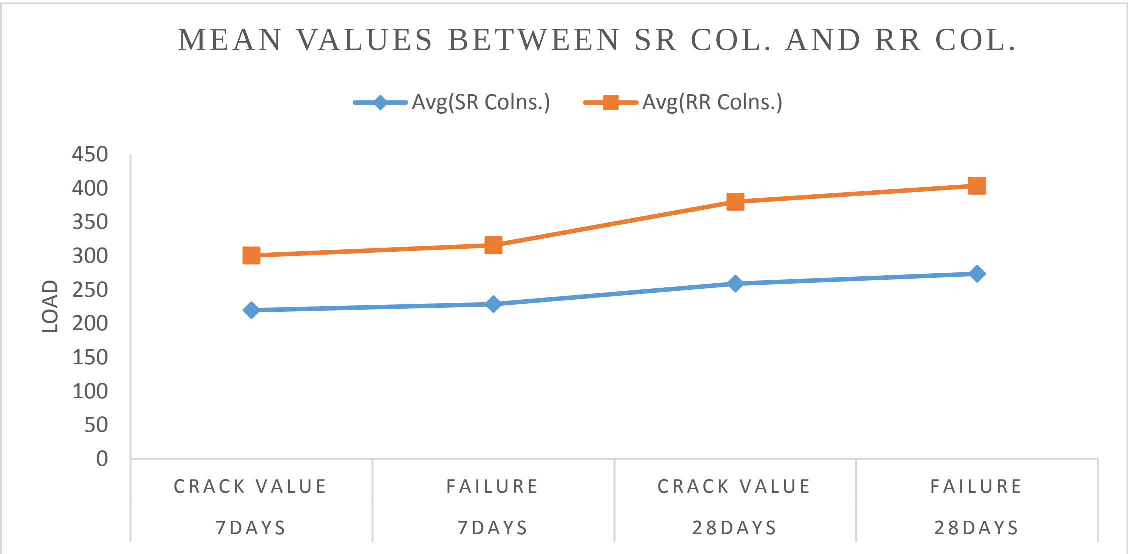


Fig.18: comparison between mean values of steel reinforced columns and rubber reinforced columns.

From the graph it's clearly seen that the steel reinforced columns show greater resistance towards applied load. As it is obvious because of the properties of rubber re-bar. So, the rubber re-bars with such properties can't be used for construction purpose.

CASE II:

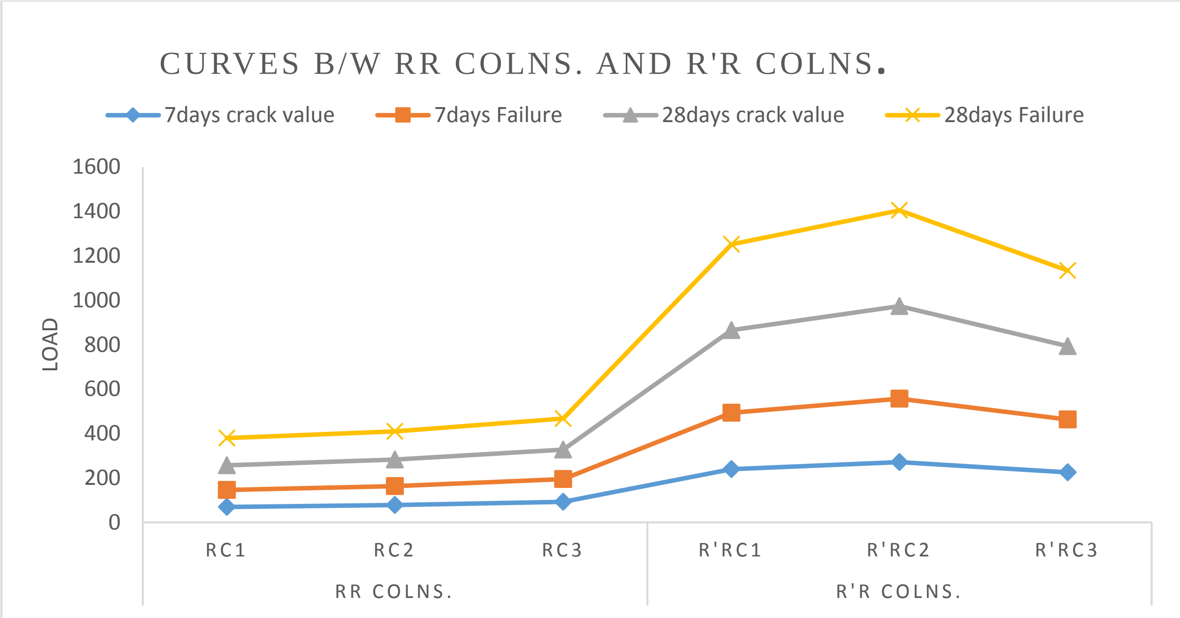


Fig. 19: Variation between rubber reinforced columns and FRP retrofitted columns.

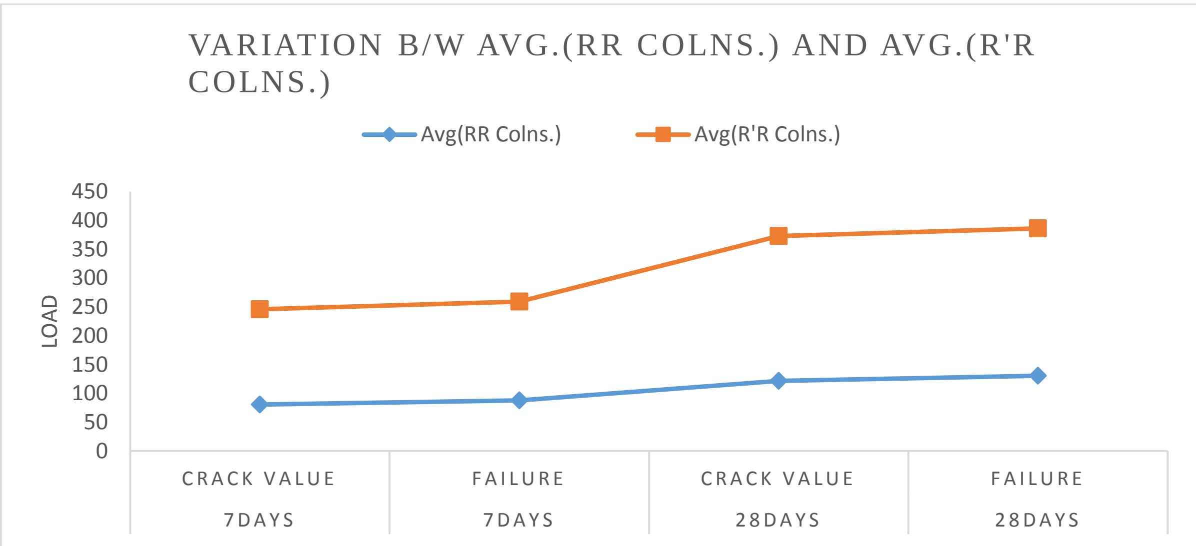


Fig. 20: Variation between mean values of rubber reinforced columns and retrofitted columns.

From the figures given above, it can be directly revealed that wrapping glass fibers increases the strength of a column. The values obtained are enormously effective. Both for 7 and 28 days the curve of retrofitted columns is above the rubber reinforced columns

CASE III:

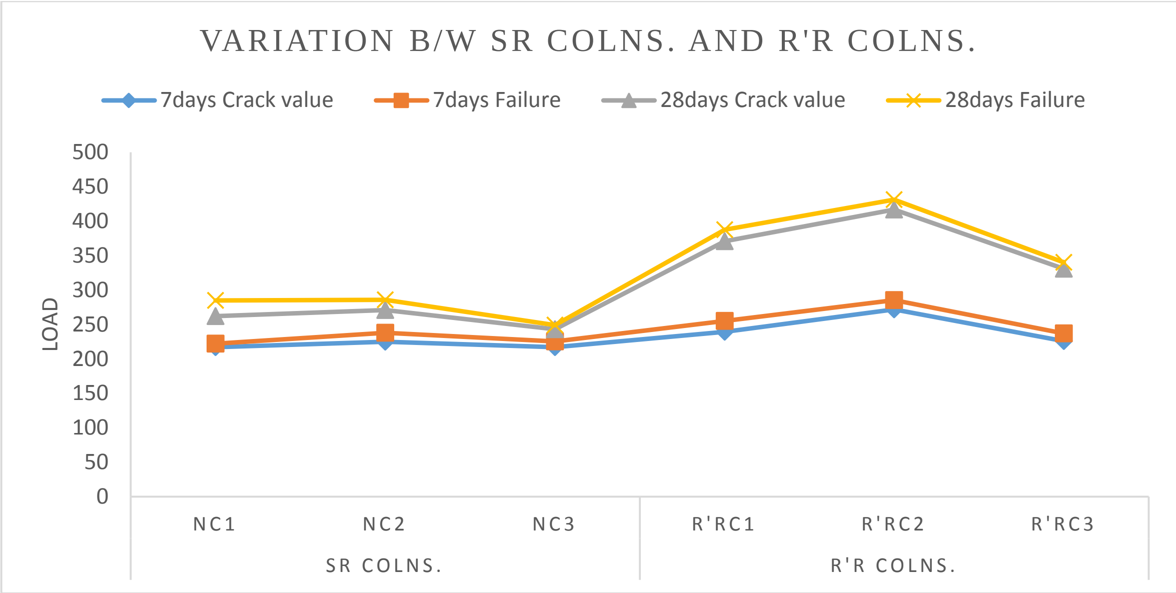


Fig.21: Variation between steel reinforced columns and GFRP retrofitted columns.

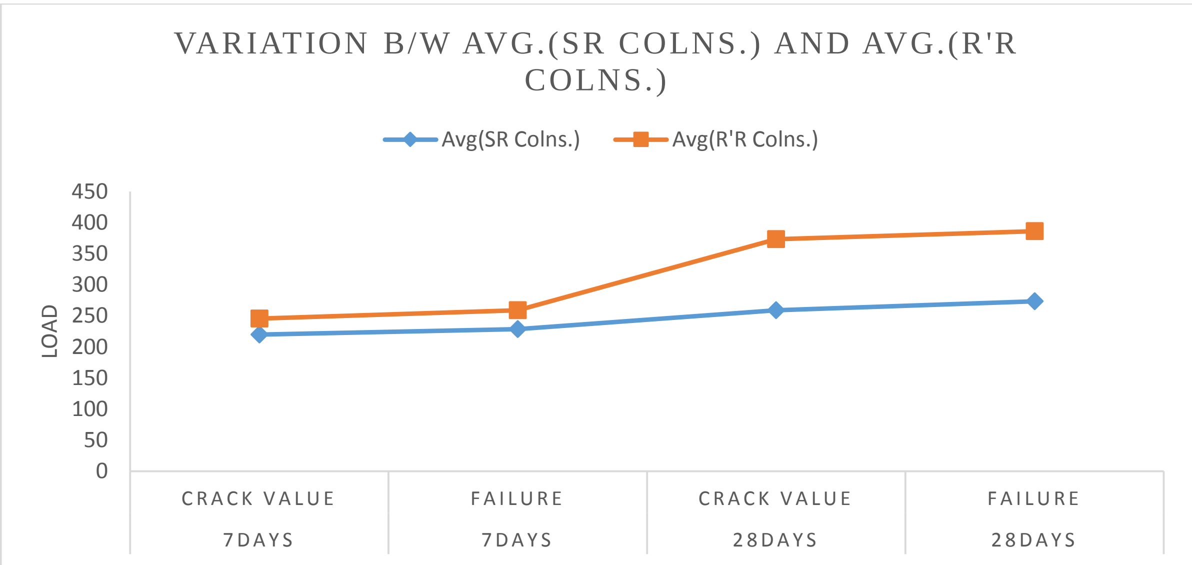


Fig.22: Variation between mean values of steel reinforced columns and GFRP retrofitted columns.

The main comparison was between steel reinforced columns and GFRP retrofitted columns. It can be seen that retrofitted curve is above the steel curve, which enables the material used in construction fields as by attaining the high strengthening values. The 28 days strength values are higher than other cases.

CHAPTER -06

CONCLUSION

1. It has already been widely accepted that high loads have unfavorable effects on deformation capacity. Under different loads, the test results of columns can be used to analyze the effect of axial loads on retrofitted columns. The specimens having aspect ratios are retrofitted hence show more response towards axial load.
2. Aspect ratio has direct effect on drift capacity, as more the aspect ratio higher will be the drift capacity.
3. The amount of FRP affects greatly the deformation capacity. With increase in FRP layers, the deformation capacity shows negative response.
4. Maximum strength of retrofitted RC columns have increased. By taking unretrofitted RC columns as a reference, the failure performance of retrofitted columns rehabilitated from brittle-shear failure to ductile-flexural performance.
5. From the cost analysis and also possessing light nature, the rubber-rebars can be used in construction to improve the performance of RC Columns along with FRP.
6.

CHAPTER -07

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