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STRENGTHENING OF REINFORCED CONCRETE RECTANGULER COLUMNS BY USING FRP SHEETS

D.MAHIMA[1], J. SAIBABA[2]
1* Student, M. Tech structural engineering, Indira institute of technology and science Markapur, AP523320
2* Assistant professor, Indira Institute of Technology and science Markapur, AP- 523320.
Email id: mahimamahi172@gmail.com

ABSTRACT:
Strengthening of columns is needed now a days because of various reasons. Upgrading existing strength of columns, rectifying inadequacies due to poor construction practices or due to degradation or due to environmental effects are may be some reasons for strengthening required for columns especially. In this project the strength behavior of RC short axially loaded columns (100mm x500 mm) strengthened with FRP sheet strips and the effect of edge rounding (sharp edges are made up of round) on load carrying capacity are studied.
The Column is wrapped with strips of different FRP sheets at different spacing of constant FRP sheet material area. Columns are reinforced with 4#10mm diameter steel bars. The columns are designated as CC, SG 83.33, SG50, SB83.33, SB50, SC83.33, SC50, RG83.33, RG50, RB83.33, RB50, RC83.33, RB50. Here CC column is of control column without FRP sheet sticked. S stands for sharp edge columns. R stands for rounded edge columns. G, B and C stands for Glass, Basalt, and Carbon FRP sheets respectively. Here numerical indicates the width of the FRP strips in mm.
The % Age increase in load carrying capacity of FRP strengthened columns compared with control column (CC) For SG83.33 is 20.7%, for SG50 is 49.1%, for SB83.33 is 6.7%, for SB50 is 13.3%, for SC83.33 is 29.49%, for SC50 is 65%, for RG83.33 is 43.1%, for RG50 is 63.33%, for RB83.33 is 24.9% for RB50 is 40.3%, for RC83.33 is 54.85% for RC50 is 67.26%.
Among all strengthened columns, RC50 (rounded edge column with 50mm carbon strip) load carrying capacity is more (701KN) and also the % Age increase in load carrying capacity compared with control column (CC) is 67.26%. The load carrying capacity of columns with 50mm strip is more than the columns with 83.33mm strips. By observing the deflections at maximum load, more ductile failure is observed in case of FRP wrapped columns as all FRP strengthened columns deflections are more than the control column. The load carrying capacity of short axially loaded R.C columns can be increased by wrapping FRP sheet as strip around the column. Further the load carrying capacity is more if the sharp edges are made round.

1.0 INTRODUCTION

The maintenance, rehabilitation and upgrading of structural members, is perhaps one of the most crucial problems in civil engineering applications. 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 lead to the investigation of several processes 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

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structure while addressing limitations such as constructability, building operations, and budget. Structural strengthening may be required due to many different situations.

Fiber reinforced polymers (FRP)

Fiber Reinforced Plastics (FRP) is the generic term for a uniquely versatile family of composites used in everything from chemical plant to luxury power boats. An FRP structure typically consists of UN saturated polyester (UP) resin applied to a mould in combination with reinforcement, most commonly glass fiber, to form a part that is rigid, highly durable and low in weight. FRP provides an unrivalled combination of properties:

- Light weight
- High strength-to-weight ratio (kilo-for-kilo it's stronger than steel)
- Design freedom
- High levels of stiffness
- Chemical resistance
- Good electrical insulating properties

Strengthening using FRP composites

Especially, usage of fiber reinforced polymers (FRP) materials for strengthening has rapidly increased in recent years. Due to their light weight, high strength, resistance to corrosion, speed and ease of application and formed on site into different shapes can be made them preferences. The composite materials (FRP) are used for strengthening of reinforced concrete structures instead of classical method. The benefits of this material externally bonded FRP sheets and strips are currently the most commonly used technique for strengthening in concrete structures.

Advantages FRP Composites

There have been several important advances in materials and techniques for structural rehabilitation, including a new class of structural materials such as fiber-reinforced polymers (FRP). One such technique for strengthening involves adding external reinforcement in the form of sheets made of FRP. Advanced materials offer the designer a new combination of properties not available from other materials and effective rehabilitation systems. Strengthening structural elements using FRP enables the designer to selectively increase their ductility, flexure, and shear capacity in response to the increasing seismic and service load demands. For columns, wrapping with FRP can significantly improve the strength and ductility.

Objective of the study

- By observing the literature available, studies are limited to full wrapping of FRP sheet around the columns. Also, studies using FRP strips are very meager.
- Therefore, it is interesting to study the strength behaviour of short axially loaded columns strengthened with FRP sheet strips, also the effect of edge rounding (sharp edge are made round).

2.0 LITERATURE REVIEW

[1] Athira M. A., Meera C. M., Sreepriya Mohan (2016) In this paper an attempt has made to study the behavior of RC columns wrapped hybrid fibre sheets. Effects of number of layers of individual FRP sheets and effectiveness of using hybrid FRP sheet to confine RC columns are investigated. The entire test specimens loaded to fail in axial compression and the ultimate load carrying capacity, axial deformation and failure or crack patterns, are investigated and the test results are compared with unwrapped specimens.

[2] Yuvaraj rolli, k v mahesh chandra (2015)- “The sides of the square column were rounded with a segmental round structure, and this way changing the cross section of the columns from a square to a circle before every column was wrapped with three layers of CFRP. Results from the study demonstrated that each one confining technique overstated the ability and ductility of sections.
[3] Beryl Shanthapriya A,Sakthieswaran N (2015 -This paper presents an experimental study focuses to find the effect of corner shape modification in square column on FRP properties and to achieve whether the former is suitable for high strength concrete or low strength concrete. Here a study on the behaviour of axially loaded short reinforced concrete columns that have been strengthened with glass
[4] Manish Kumar Tiwari, Rajiv Chandak, R.K. Yadav (2014) In this study specimen of rectangular cross section having length to width ratio of 2.0 and 0.90% longitudinal reinforcement were prepared and tested for 28 days compressive strength. The specimens were wrapped with 0,2,4,6 and 8 layers of GFRP outside the surface of the specimens as confinement
[5] Sultan Erdemli Gunaslan Halim Karasin (2014) this study, literature’s experimental results are compared with American Concrete Institute (ACI440) and Turkish Seismic Design Code 2007(TDY2007) in addition to mechanical properties of FRP material.

3.0 MATERIALS AND METHODS

Ordinary Portland cement of 53 grade (KCP CEMENT) confirming to IS12269:1987 was used in this study. Properties are shown in tabl3 3.1

Table: 3.1 Properties of Portland cement 53 grades

Sl. No	**Type of cement**	**Fineness by air permeability method (m2/kg)**	**Setting time(min)**		**Compressive strength in Mpa**		
			Initial	Final	3 days	7 days	28days
1	OPC 53 grade	225	75	125	32	37.8	53

Fiber reinforced polymer (FRP) Sheet

Continuous Fiber –Reinforced materials with polymer matrix (FRP) can be considered as composite, heterogeneous and anisotropic materials with a prevalent linear elastic behavior up to failure. They are widely used for strengthening of civil structures.
There are many advantages of using FRPs: lightweight, good mechanical properties, corrosion-resistant, etc. Composites for structural strengthening are available in several geometries from laminates used for strengthening of members with regular surface to bi- directional fabrics easily adaptable to the shape of the member to be strengthened.

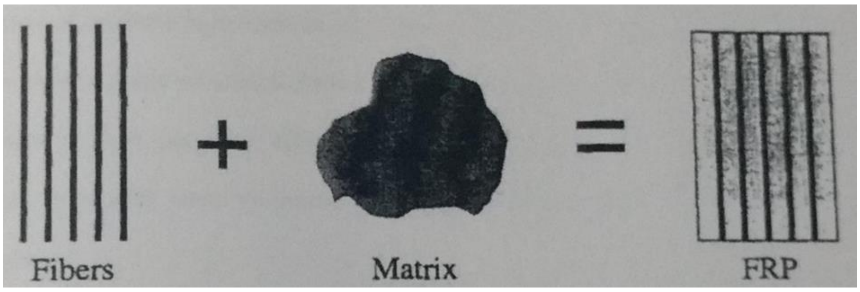

Figure 3.1: FRP materiel composition

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Glass fiber reinforced polymer sheet

Glass Fiber Reinforced Polymers are a proven and successful alternative that have numerous advantages over traditional reinforcement methods, giving structures a longer service life. The GFRP rebar is a structural ribbed reinforcing bar made of high strength and corrosion Resistant glass fibers that are impregnated and bound by an extremely durable polymeric epoxy resin.

Table 3.2: properties of glass fiber

Code	W oven pattern	Thickness (mm)	Tensile Strength (Mpa)
Glass	bi-directional	0.11	2358

Epoxy resin:

Epoxy resins are relatively low molecular weight pre-polymers capable of being processed under a variety of conditions. Two important advantages of these resins are over saturated polyesters resins are: first, they can be partially cured and stored in that state, and Second they exhibit low shrinkage during cure. However, the viscosity of conventional epoxy resins is higher and they are more expensive compared to polyester resins.

Table: 3.3 Concrete mix design

Cement	Fine aggregate	Coarse aggregate		Water
		20 mm	10 mm	
385	614	754.5	503	173.3
1 Kg	1.595Kg	2.123kg	1.145kg	0.45 lt

Figure 3.2: Casting of rectangular columns with sharp edges

Figure 3.3: Casting of columns with round edge

Curing: After casting of columns, casted columns were taken from the moulds and cured in water for 28 days

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Figure 3.4: Casted columns after curing

Testing of columns

- Columns were tested by applying axial load using UTM and failure loads and displacement at failure were noted.
- First control column were tested (control column means column without frp)

Figure 3.5: control column testing under UTM

Control column was tested under UTM and failure load was noted. Then remaining columns sticked with FRP sheets were tested.

FRP sheets were sticked in following ways. The area of FRP strips is kept constant.

- Glass FRP - 83.33mm wide strips were sticked @ 125mm spacing, 50.00mm strips were sticked @ 62.5mm spacing,
- Basalt FRP- 83.33mm wide strips were sticked @ 125mm spacing, 50.00mm strips were sticked @ 62.5mm spacing,
- Carbon FRP- 83.33mm wide strips were sticked @ 125mm spacing 50.00mm strips were sticked @ 62.5mm spacing

4.0 TEST RSULTS

The failure loads and displacements at failure of the columns were noted and tabulated as below.

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Table 4.1: Failure loads and Displacements of Sharp and Rounded Edge columns

Description of Column	Failure load and Displacement of Sharp-edged columns			Failure load and displacement of Rounded edged columns		
	Load (KN)	Displacement (mm)	Designation	Load (KN)	Displacement (mm)	Designation
Control column	419.1	6.8	CC	419.1	6.8	CC
Glass 83.33mm strip	506.1	7.7	SG83.33	599.85	7.1	RG83.33
Glass 50mm strip	625.25	8.1	SG50	684.53	9.7	RG50
Basalt 83.33mm strip	447.2	6.8	SB83.33	523.75	8.3	RB83.33
Basalt 50mm strip	475.2	7.7	SB50	588.2	7.9	RB50
Carbon 83.33mm strip	542.7	8	SC83.33	649.0	7.5	RC83.33
Carbon 50mm strip	691.7	7.4	SC50	701.0	7.5	RC50

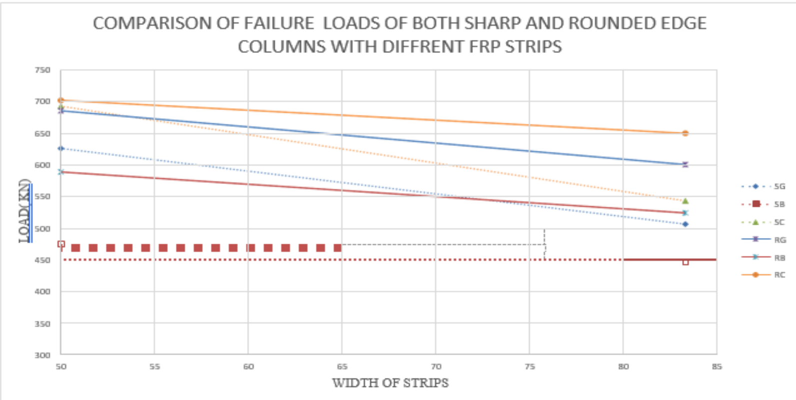

Figure 4.1: Comparison of failure loads of both sharp and rounded edge columns with different FRP strips

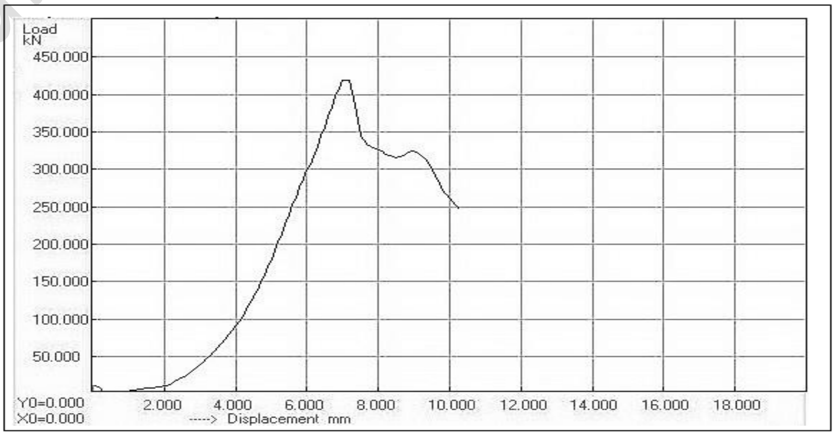

Figure 4.2: load Vs displacement curves for CC

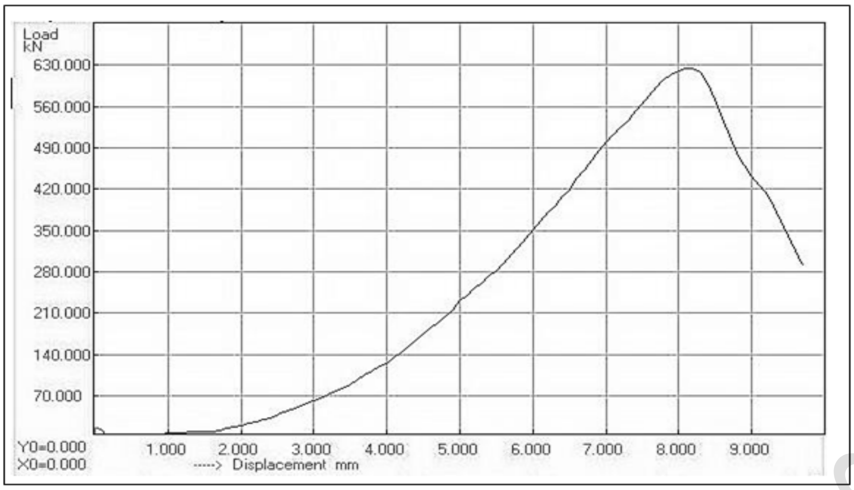

Figure 4.3: load Vs displacement curves for SG50

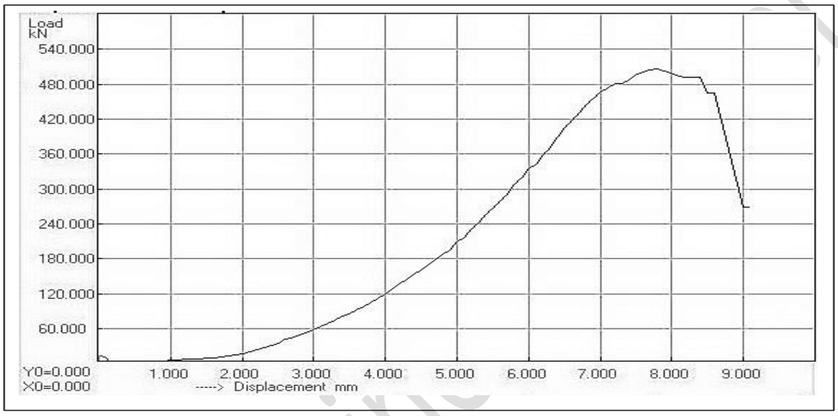

Figure 4.4: load Vs displacement curves for SG83.33

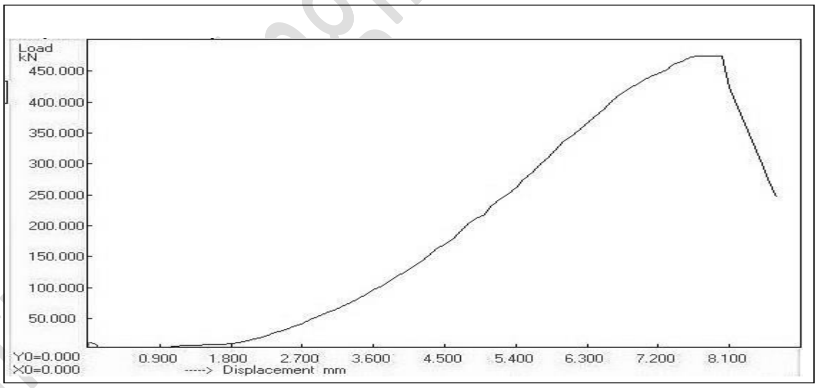

Figure 4.5: load Vs displacement curves for SB50

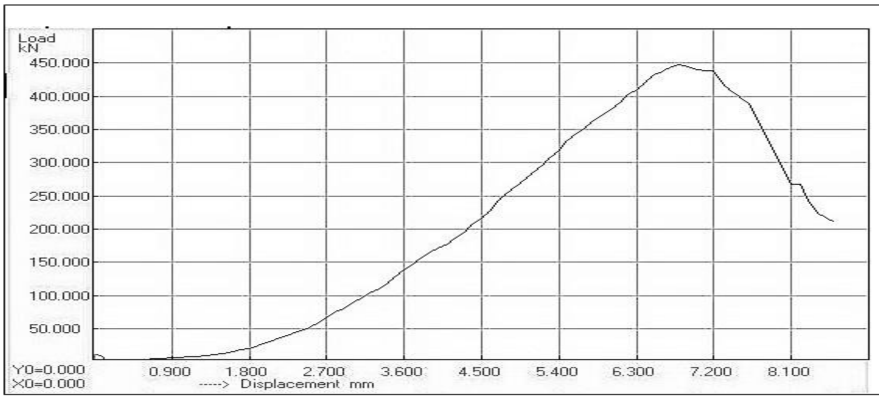

Figure 4.6: load Vs displacement curves for SB83.33

TABLE 4.2: % increase load carrying capacity

Column designation	% Increase in load carrying capacity of Sharp edged columns (%)	% Increase in load carrying capacity of Rounded edged columns (%)
Control column	0	0
Glass 83.33mm STRIP	20.7	43.1
Glass 50mm STRIP	49.1	63.33
Basalt 83.33mm strip	6.7	24.9
Basalt 50mm strip	13.3	40.3
Carbon 83.33mm strip	29.49	54.85
Carbon 50mm strip	65	67.26

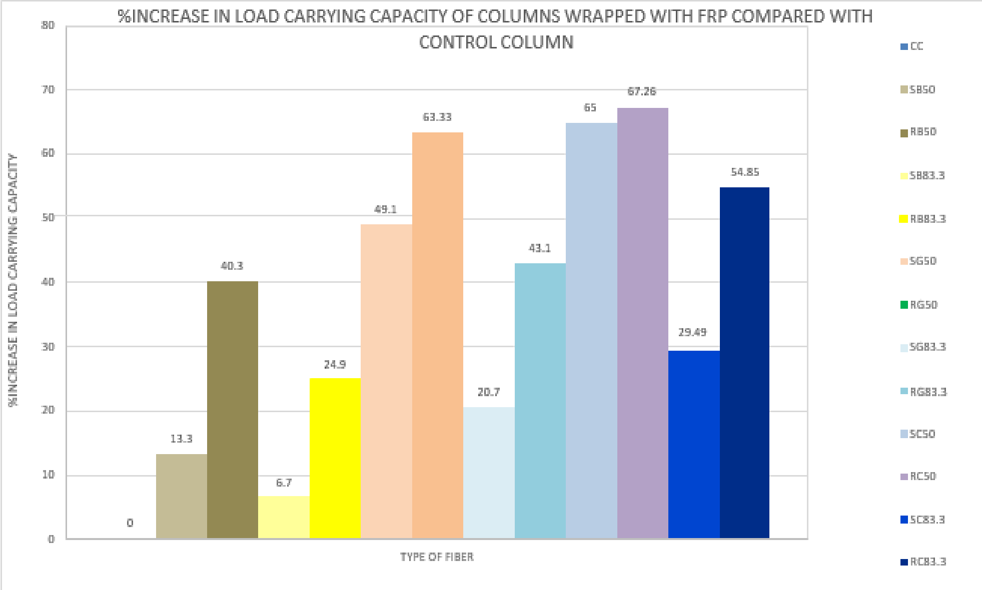

Figure 4.7: % increase in load carrying capacity of columns wrapped with FRP compared with control column

CONCLUSION

- The % age increase in load carrying capacity of FRP strengthened columns compared with control column (CC) for SG83.33 is 20.7%, for SG50 is 49.1% , for SB83.33 is 6.7% , for SB50 is 13.3%, for SC83.33 is 29.49% ,for SC50 is 65% , for RG83.33 is 43.1% , for RG50 is 63.33% ,for RB83.33 is 24.9% ,for RB50 is 40.3%, for RC83.33 is 54.85% ,for RC50 is 67.26% .
- Among all strengthened columns, RC50(rounded edge column with 50mm carbon strip) load carrying capacity is more(701KN) and also the % age increase in load carrying capacity compared with control column (CC) is 67.26% .
- The load carrying capacity of columns with 50mm strip is more than the columns with 83.33mm strips.
- By observing the deflections at maximum load, more ductile failure is observed in case of FRP wrapped columns as all FRP strengthened columns deflections are more than the control column.

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- The load carrying capacity of short axially loaded R.C columns can be increased by wrapping FRP sheet as strip around the column.
- Further the load carrying capacity is more if the sharp edges are made round.

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