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EFFECT OF SHAPE AND SIZE PARAMETERS ON STRENGTH OF FRP CONFINED CONCRETE COLUMN

SHITALKUMAR C. CHAUDHARI

Assit. Prof. Department of Civil Engineering, Jawaharlal Darda Institute of Engineering and Technology, Yavatmal

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Abstract: *In recent years, fiber reinforced polymer (FRP) has become increasingly more popular as a confining effective material for concrete columns, both in the retrofitting of existing reinforced concrete columns with an FRP jacket and in the use of concrete-filled FRP tubes as structural members in new construction. As a result of FRP confinement, both the compressive strength and the ultimate axial compressive strain of concrete can be significantly enhanced. In this paper behaviour of FRP confined concrete column under axial load have been studied by developing an analytical programme to calculate confined stress and confined strain for circular and square columns on the basis of guidelines provided by ACI-440.2R-08 code.*

Keywords: FRP confined, Column, Circular Column, Square Column, Confinement, Confined strength

Corresponding Author: MR. SHITALKUMAR C. CHAUDHARI

Co Author:

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INTRODUCTION

The most popular construction material in infrastructure industry is reinforced cement concrete. But major flaw in using this material is susceptibility to environmental attack can severely reduce the strength and life of these structures. So the need arise to rehabilitate these structures with new innovative materials which will prove more efficient.

In Civil Engineering industry new technologies and innovative materials has started to make its way to meet up the requirements of advance infrastructure. In recent years, advanced composite materials in the form of fiber-reinforced plastics (FRPs) have found extensive use in retrofitting and rehabilitation of structures. Advanced composites, (FRP) earlier limited to aerospace structures, are gaining acceptance in civil engineering applications also. Fiber reinforced polymer (FRP) composites were first introduced in civil infrastructure applications in the early 1950s as alternative measures for reinforcing concrete. Composites are primarily attractive because of their high strength-to-weight, and stiffness-to-weight ratios, and better durability characteristics. In recent years, fiber reinforced polymer (FRP) has become increasingly more popular as a confining effective material for concrete columns, both in the retrofitting of existing reinforced concrete columns with an FRP jacket and in the use of concrete-filled FRP tubes as structural members in new construction. As a result of FRP confinement, both the compressive strength and the ultimate axial compressive strain of concrete can be significantly enhanced. Thus rehabilitation of structures with FRP composites has proved to be cost effective method of enhancing the service life of structures. As a result, FRP materials have shown great potential in becoming an attractive alternative to concrete and even steel jackets for confining structural members.

Reinforced Concrete (RC) columns as vertical structural members which transmit axial compressive loads with or without moments are of extreme importance for the performance and the safety of structures. These days, it is commonly seen that, there is a need of strengthening and/or rehabilitating these members due to different reasons such as higher load capacity requirement because of design/construction errors, change in the facility use, or revisions of codal provisions.

Confinement of concrete is one of the most efficient methods used to increase the load carrying capacity and/or ductility of a column. It induces the lateral pressure in the concrete as a tri-axial state of stresses and consequently an increment of compressive strength and ultimate axial strain.

FRP confinement is accomplished by providing the fibers mainly transverse to the longitudinal axis of the column which provides passive confinement to column, which is activated once the concrete core starts dilating as a result of Poisson’s effect and internal cracking.

The confinement of non-circular columns is widely accepted to be less efficient than the confinement of circular columns, since in the latter case, the jacket provides circumferentially uniform confining pressure to the radial expansion of the concrete. In non-circular columns, the confinement is concentrated at the corners rather than over the entire perimeter.

2. TECHNOLOGY BEHIND FRP :

A Fiber Reinforced Polymer (FRP) composite is defined as a polymer (plastic) matrix, either thermoset or thermoplastic, that is reinforced (combined) with a fibre or other reinforcing material with a sufficient aspect ratio (length to thickness) to provide a discernable reinforcing function in one or multiple directions. FRP composites are not similar to the regular construction materials such as steel or aluminum. FRP composites are anisotropic (properties apparent in the direction of the applied load) whereas steel or aluminum is isotropic (uniform properties in all directions, independent of applied load). Therefore, FRP composite properties are directional, meaning that the best mechanical properties are in the direction of the fiber placement.

2.1 Constituents of FRP composites:

- Epoxy - The basic functions of the resin are to transfer stress between the reinforcing fibers, act as a binding agent to hold the fibers together, and to provide protection of fibers from mechanical and environmental damage.
- Reinforcements - The primary function of fibers or reinforcements is to carry load along the length of the fiber to provide strength and stiffness in one direction. Reinforcements can be oriented to provide tailored properties in the direction of the loads imparted on the end product.
- Fillers - Fillers are used to improve performance and reduce the cost of a composite by lowering compound cost of the significantly more expensive resin and imparting benefits as shrinkage control, surface smoothness, and crack resistance.
- Additives - Additives and modifier ingredients expand the usefulness of polymers, enhance their processability or extend product durability

Advantages:

1. Corrosion proof.
2. Easy in transportation, can be easily rolled.
3. Higher UTS and young's modulus
4. High fatigue resistance
5. Light weight. Hence, very high strength to weight ratio.
6. Joints can be easily avoided as they are available in desired length.

Disadvantages:

1. Low ductility value and fickly plastic behaviour.
2. Susceptible to local unevenness.
3. High cost.

3. THE CONCEPT OF CONFINEMENT:

The concept of confinement involves RC columns are wrapped by low weight high strength fibre wraps which provides passive confinement to column, which leads to increase in both strength and ductility of column. Wrapping FRP sheets around the columns is accomplished by orienting fibers perpendicular to the longitudinal axis of column, and fibers are fixed to the column using epoxy resin. Epoxy resin is used to fix fiber to column as a binder. The wrap not only increases the concrete strength and provides passive confinement but also provides significant shear strength.

Confinement effectiveness of externally bonded FRP jackets depends on different parameters as;

- Type of concrete,
- Steel reinforcement,
- FRP jacket stiffness (type of FRP, number of plies and design of wrap),
- Shape of cross section,
- Radius of corners, for non-circular sections, and loading conditions.

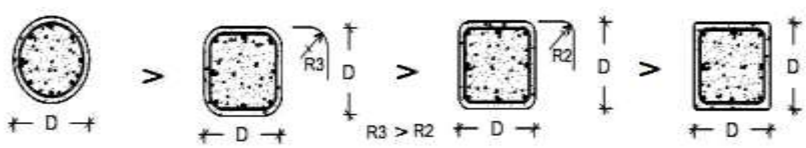

Fig1. Fibre wraps effectiveness with curvature in the cross-sectional area.

4. METHODOLOGY OF WORK:

To study behaviour of FRP confined concrete column under axial load; an analytical programme has been developed to calculate confined stress and confined strain for circular and square column on the basis of guidelines provided by ACI-440.2R-08 as shown in following Table1 & Table2.

To inevestigate the effect of column parameters on confined axial strength of column, square column of size 150mm x150mm and circular column of diameter 150 mm have been considered. The column is filament wound of unidirectional E-glass fibres with polyster resin as matrix. Table 3 shows mechanical properties of fibres and resin.

Table 1 ACI Design Guideline Models for Circular Cross-Section

Guideline	Effective Confinement Pressure f_l (MPa)	Confined Concrete Compressive Strength for Purpose of Design f'_{cc} (MPa)	Ultimate Axial Compressive Strain of Confined Concrete ε_{ccu}
ACI	$f_1 = \frac{k_s \rho_f \varepsilon_{fe} E_f}{2}$; $k_s = 1$ ε_{fe} = lesser of 0.004 and $0.75\varepsilon_{fu}$	$f'_{cc} = f'_c\left[2.25\sqrt{1+7.9\frac{f_1}{f'_c}} - 2\frac{f_1}{f'_c} - 1.25\right]$	$\varepsilon_{cc} = \frac{1.71(5f'_{cc} - 4f'_c)}{E_c}$

Table 2. ACI Design Guideline Models for Square Cross-Section

Guideline	Effective Confinement Pressure f_l (MPa)	Confined Concrete Compressive Strength for Purpose of Design f'_{cc} (MPa)	Ultimate Axial Compressive Strain of Confined Concrete ε_{ccu}
ACI	$f_1 = \frac{k_s \rho_f \varepsilon_{fe} E_f}{2}$; ε_{fe} = lesser of 0.004 and $0.75\varepsilon_{fu}$ $k_s = 1 - \frac{(b-2r)^2 + (h-2r)^2}{3bh(1-\rho_1)}$	$f'_{cc} = f'_c\left[2.25\sqrt{1+7.9\frac{f_1}{f'_c}} - 2\frac{f_1}{f'_c} - 1.25\right]$	Not Provided

Table 3 Mechanical Properties of Glass fibres and Polyster Resin

Property	E-Glass	Polyster resin
Specific Gravity	2.58	1.41
Tensile Strength (MPa)	2.186	72
Tensile Modulus (MPa)	69640	4344
Shear Modulus (MPa)	30130	1600
Poisson's Ratio	0.22	0.36

5. RESULTS AND DISCUSSION:

5.1 Analytical Results of FRP Confined Concrete Column:

Table. 3. Comparison of results of Confined Compressive Strength (Mpa) for FRP confined concrete column

Cross Section	Charecterstic Concrete Strength	Thickness of Wrap	Confined Compressive Strength
	Mpa	mm	Mpa
Circle (Dia. 150mm)	30	1.5	57.5
		2.25	66.93
		3	74.74
	25	1.5	55.92
		2.25	65.15
		3	72.75
	35	1.5	58.83
		2.25	68.42
		3	76.39
Square (150 X150mm)	40	1.5	54.11
		2.25	59.58
		3	64.2

Table 4. Comparison of results of Confined Strain for FRP confined concrete column

Cross Section	Charecterstic Concrete Strength	Thickness of Wrap	Confined Strain
	Mpa	mm	
Circle (152.4 X 305mm)	30	1.5	0.009
		2.25	0.011
		3	0.013
	25	1.5	0.009
		2.25	0.011
		3	0.014
	35	1.5	0.009
		2.25	0.011
		3	0.013

5.2 Effect of Shape Shape of Column:

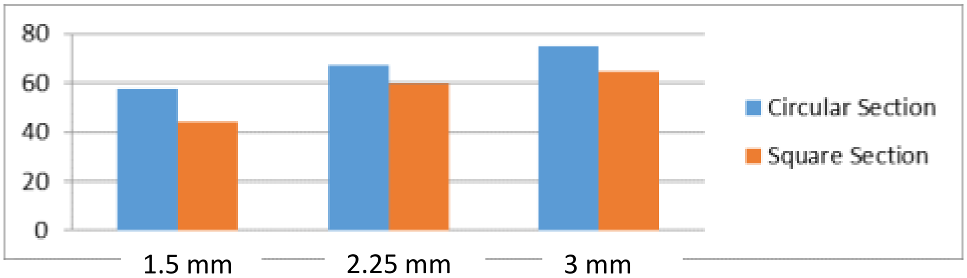

Fig.5. Comparision of confined compressive strength for circular and square column section .

Confined compressive strength of circular concrete column is more than square concrete column by 15-30%. So circular concrete column proves to be most efficient column section for FRP confined column.

5.2 Effect of Wrap Thickness:

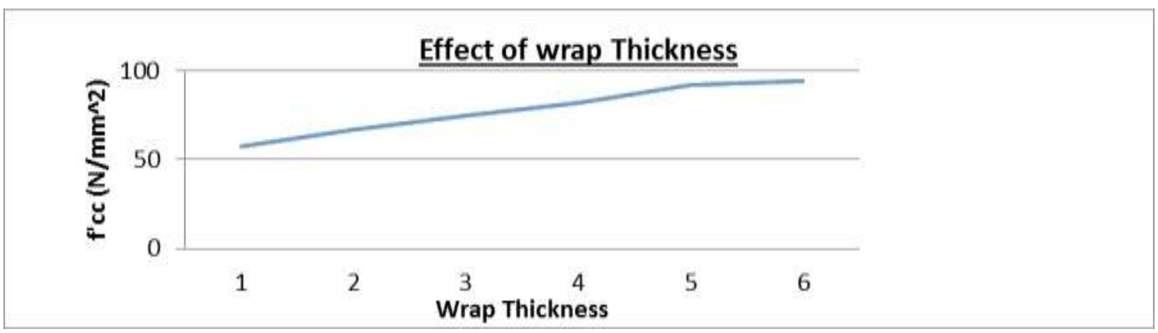

Fig.6. Effect of wrap Thickness

The graph of wrap thikness vs. confined compressive strength of circular column shows linear behaviour. Initially confined compressive strength increases with increase in thickness of wrap. For higher thicknesses of wrap rate of increase of confined compressive strength of circular column shows reducing behaviour.

5.3 Effect of Grade of Concrete:

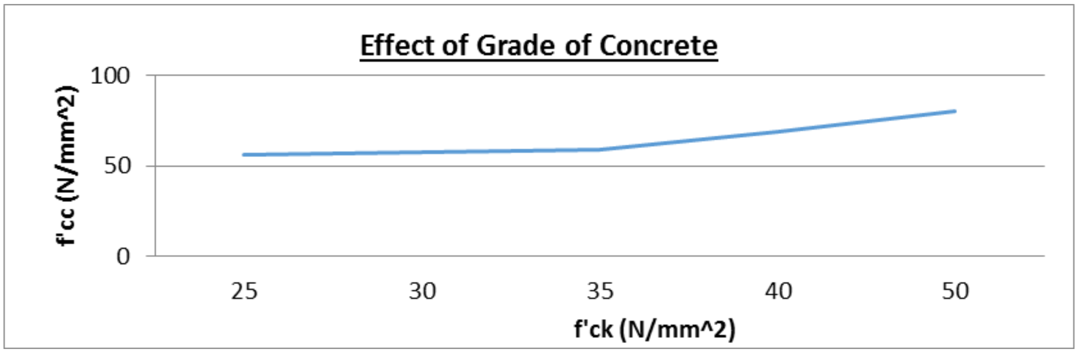

Fig. 7. Effect of Grade of Concrete

Confined compressive strength of circular concrete column increases with increase in characteristic compressive strength of concrete. Rate of increase of Confined compressive strength of circular concrete column is less for lower grade of concrete and comparatively more for higher grade of concrete.

5.4 Effect of Diameter of Circular Concrete Column:

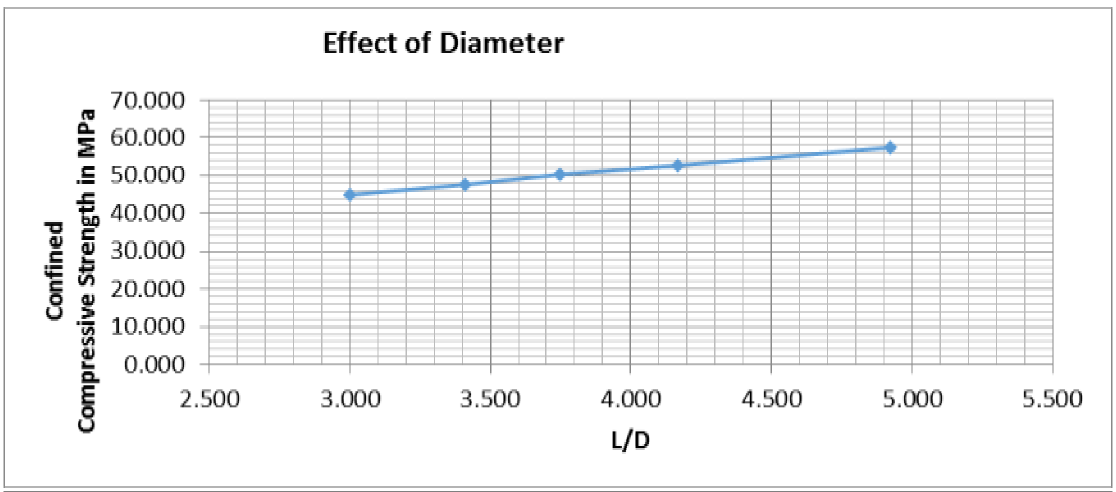

Fig.8. Effect of Diameter

Confined compressive strength of circular concrete column increases with increase in length to diameter (L/D) ratio of column. As diameter of column increases; there is reduction in confined compressive strength of circular concrete column for same length and same wrap thickness. From graph it is observed that economical L/D ratio to be 3.75.

5.5 Effect of Corner Radius for Square Column Section:

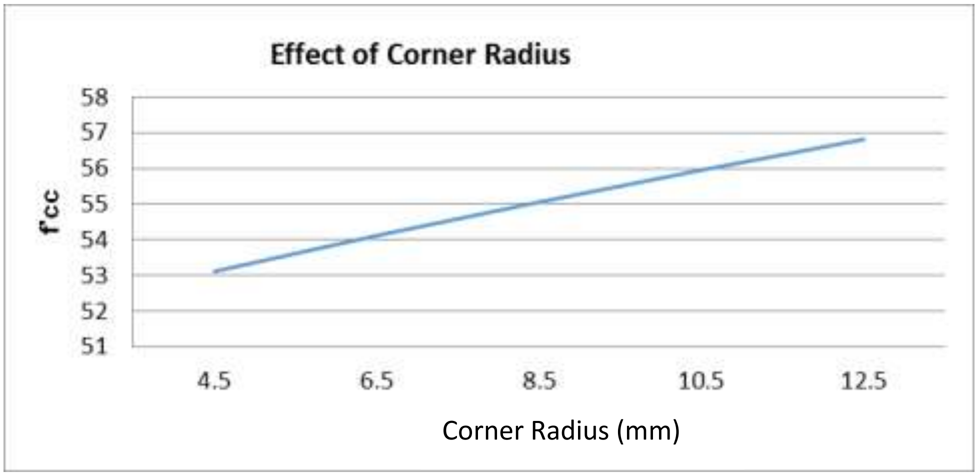

Fig. 9. Effect of Corner Radius

Confined compressive strength of square concrete column increases with increase in corner radius of square concrete column section. So corner radius is important parameter for improving the confined compressive strength of square concrete column section.

6. CONCLUSIONS:

1) Confined compressive strength of circular concrete column is more than square concrete column by 15-30%. So circular concrete column proves to be most efficient column section for FRP confined column.
2) Confined compressive strength of FRP confined circular concrete column increases with increase in thickness of wrap. For higher thicknesses of wrap rate of increase of confined compressive strength of circular column shows reducing behaviour.
3) Confined compressive strength of FRP confined circular concrete column increases with increase in characteristic compressive strength of concrete. Rate of increase of Confined compressive strength of circular concrete column is less for lower grade of concrete and comparatively more for higher grade of concrete.
4) Confined compressive strength of circular concrete column increases with increase in length to diameter (L/D) ratio of column
5) As diameter of column increases; there is reduction in confined compressive strength of circular concrete column for same length and same wrap thickness. It is observed that economical L/D ratio to be 3.75 for FRP confined circular concrete column
6) Confined compressive strength of square concrete column increases with increase in corner radius of square concrete column section. So corner radius is important parameter to improve the confined compressive strength of square concrete column section.

7. REFERENCES:

1. Abhijeet Mukharjee, Mangesh Joshi, "Recent Advances in Repair and Rehabilation of RCC Structures with Nonmetalic Fibres".

2. Amir Miemiran Mohsen Shahawy et al, "Effect of Column Parameters on FRP Confine concrete", Journal of Composites of construction, Vol. 2, No.4, November 1998.

3. A.P. Michael, H.R. Hamilton III, and M.H. Ansley, "Concrete Confinement Using Carbon Fiber Reinforced Polymer Grid", SP-230—56.

4. Dr. Abhay Bambole, Kedar Joshi," Effect of Shape and Size on Fiber Reinforced Polymer Composite Wrapped Concrete Columns"

5. Dr Gopal Rai," New and emerging technologies for retrofitting and repairs"

6. Feng Yu1 and Ditao Niu," Stress-strain model of PVC-FRP confined concrete column subjected to axial compression", International Journal of the Physical Sciences Vol. 5(15), pp. 2304-2309, 2010

7. Riad Benzaid, Nasr eddine Chikh, Habib Mesbah," Study of The Compressive Behavior of Short Concrete Columns Confined by Fiber reinforced Composite", The Arabian Journal for Science and Engineering, Volume 34, Number 1B, 2009

8. Toutanji, H., (1999). Stress-strain characteristics of concrete columns externally confined with advanced fiber composite sheets. ACI Materials Journal, 96(3), 397-404.

9. Xiao, Y., and Wu, H., (2000). Compressive behavior of concrete confined by carbon fiber composite jackets, Journal of Materials in Civil Engineering, 12(2), 139-146.

10. Y.L. Wong , T. Yu , J.G. Teng , S.L. Dong, "Behavior of FRP-confined concrete in annular section columns", Composites: Part B 39 (2008), pp. 451–466

11. American Concrete Institute, ACI 440.2R-08. (2008). Guide for the Design and Construction of Externally Bond