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Edge sharpness on axial performance of FRP confined square concrete columns

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ABSTRACT

The investigation focuses on the effectiveness of fiber reinforced polymer (FRP) confinement in upgrading ductility and strength of concrete columns under axial compression. An experimental program is carried out to investigate the influence of the radius of the cross sectional corners on the strength of small scale square column specimens confined with FRP composite laminates. This study was achieved by testing 63 specimens depending on the selected corner radius, the section varied from square to circular. The various parameters such as corner radius, wrap thickness and fiber orientation of 0°, 90°, +45°,-45° and combinations of them were investigated. Smoothening of the edges of square cross-section plays a significant role in delaying the failure of FRP composite at these edges and the efficiency of FRP confinement is directly related to the radius of the cross-section edges.

Introduction

Over the years, engineers have used different methods and techniques to retrofit existing structures by providing external confining stresses. For the past few years, the concept of jacketing has been investigated to provide such forces. Externally applied jackets, have been used as a reinforcement to contain concrete for different reasons. Engineers have used traditional materials such as wood, steel, and concrete to confine and improve the structural behavior of concrete members. Section enlargement is one of the methods used in retrofitting concrete members. This method is as old as the concrete industry itself. Enlargement is the placement of reinforced concrete jacket around the existing structural member to achieve the desired section properties and performance. A reinforcing steel cage is placed on the outside of the existing deficient column, and then new concrete shell is poured to form the reinforced concrete jacket. The main disadvantages of such system are the increase in the column size obtained after the jacket is constructed and the need to construct a new formwork. This could be very critical, especially in commercial buildings, where the goal is usually to maximize the availability of leasable space. Steel jacketing has been proven to be an effective technique to enhance the seismic performance of old bridge columns (Priestley et al.1996). The steel jacket is manufactured in two shell pieces and welded in the field around the column. This type of jacket provides a passive type of confinement that is activated after the concrete starts to dilate and expands laterally in the compression zone as a function of high axial compression strains. However, this method requires difficult welding work and in the long term, the potential problem of corrosion remains unsolved. FRP systems, however, have recently gained world-wide recognition as strengthening measures to increase the ductility and load carrying capacity of existing structural members. As a result, these materials have shown great potential in becoming an attractive alternative to concrete and even steel jackets. (Riad et al., 2008) experimentally studied the square and circular columns strengthened with E-glass fiber reinforced polymer. All the specimens were loaded to failure in axial compression. (Ming et al., 2008) effect of corner radius on the performance of CFRP confined square concrete columns increase the strength of the columns but significant in increasing the ductility of columns. (A.R.Rahai et al., 2008) presents the experimental studies about concrete cylinders confined with high-strength carbon fiber reinforced polymer (CFRP) composites With different wrap thicknesses (1, 2, 3,and 4 layers), fiber orientation. The enhancement of strength and ductility of frp confinement concrete is significant. (bakhshi et al.,2008) studied the various parameters such as concrete strength, number of layers of FRP and fiber orientation. The confinement and ductility effectiveness along with energy absorption capacity are studied based on experimental results. (Green et al., 2006).discuss the technique of FRP strengthening is the wrapping of reinforced concrete columns to increase their axial strength, shear strength, and seismic resistance. In this application, the FRP sheets are generally wrapped around the columns with fibers oriented mainly in the circumferential (hoop) direction. The fibers confine the concrete and increase the axial strength by creating a triaxial stress condition.

(Shamim et al., 2007) studied variables that affect the ductility parameters of a square column include the level of axial load and the amount of confining reinforcement. The proposed procedure relates the confinement design parameters such as the amount of FRP reinforcement and FRP strength to the column's ductile performance.

(Yousef A et al., 2007) presents the experimental and analytical results of various cross section radius of corners on strength of square column confined with CFRP laminates.(Seffo et al., 2012)shows that the experimental and finite element analysis performed in externally bonded CFRP reinforcement is a viable solution towards enhancing the strength and ductility of concrete cylinders subjected to axial load. Parameters considered include the wrap thickness and the wrap configuration, which includes combination of 0 and ±45 ply angles with respect to the circumferential direction and the ply stacking sequence. (Yu-Fe et al., 2010) experimentally studied

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the behavior of axially loaded rectangular column strengthened with CFRP. The various parameters such as aspect ratio and number of layers.(Esfahani et al., 2004) presents the results of a study on the axial compressive strength of columns strengthened with FRP wrap. The application of FRP wrap may not increase the axial strength of square columns. However, if the corners of the square columns are rounded appropriately, the axial strength and ductility of columns increase considerably. (Renato et al.) Demonstrate the concrete confinement capability of FRP laminates consisting of carbon fibers with different fiber orientations including ±45-degree direction and different concrete cross section. The ultimate capacity of ±45-degree FRP laminate strengthened rectangular columns is slightly lower than that of columns strengthened with fibers in the hoop direction.

(Yang,X et al.)Multiple numbers of piles increase the strength of laminates and overall performance. (Yang XB, et al., 2004) conducted test indicated that a smaller corner radius can significally reduce the ultimate strength of FRP laminate sue to stress concentration around the corner area.

The objective of the present work is to experimentally study the influences of the radius of the cross sectional corner radius on the strength of square concrete column with GFRP laminates for increasing the axial strength and ductility of unreinforced concrete columns.

Experimental Programs

Specimen details

The experimental part of the study was achieved by testing a total of 56 column (models) specimens of plain concrete. Nine of the 56 specimens were cylinders and the remaining specimens were short square concrete columns with rounded edges and different in their corner radii. The square columns (150mm X 150mm X 500mm) and circular columns (150mm X 300mm) of sizes were casted. Two different wrap thicknesses and four fiber orientation 0^o, 90 ^{o}, +45 ^{o}, and -45 ^{o} with respect to the hoop direction were investigated.

Table 1 Properties and dimension

Specimen	b (mm)	L (mm)	r (mm)	r/b	No. of specimens
S –r5	150	500	5	0.03	9
S –r15	150	500	15	0.10	9
S –r25	150	500	25	0.17	9
S –r30	150	500	30	0.20	9
S –r38	150	500	38	0.25	9
S –r50	150	500	50	0.33	9
Cylinder	150*	300	75	0.50	9

*For this special case, width of the specimen is equal to diameter of the specimen.

r = the radius of the corner of the square specimen

b = dimension of the square specimen

D = Diameter of the cylinder specimen

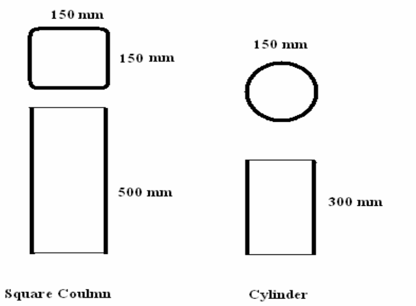

Figure 1 shows the cross-sections and dimensions of the specimens

Material Properties

Concrete

Table 2 Mix Proportion

Cement, Kg/m^3	Sand, Kg/m^3	Coarse Aggregate, Kg/m^3	Water, Kg/m^3	Water/Cement ratio
383.2	546	1188	191.61	0.45

GFRP Laminate:

The glass-fiber sheets used in this study were a unidirectional wrap. The system that was used to bond the glass fabrics over the specimens was an epoxy resin made of two-parts, resin and hardener. The glass-fiber sheets were field laminated using the vinyl ester resin to form a glass fiber reinforced polymer (GFRP) used to strengthen the concrete specimens. The concrete specimens after 28 days of curing were taken out. Voids and deformities on the surface of the specimens were filled using gypsum paste. The two-part system used, consisting of resin and hardener, was thoroughly hand-mixed for at least 5 minutes before use.

Specimen preparation

The square columns with a cross section 150 x 150 x 500 mm with corner radii of 5 mm, 15mm,25 mm,30mm, 38 mm and 50 mm and cylinder 150 x300mm were prepared. After the specimens were cast, compacted and finished, they were covered with a wet burlap cloth, and were left in forms for 1 day. After demoulding, all specimens were cured in the water for 28 days. The control specimens were capped and tested after being air-dried at the age of 28 days. The remaining columns were wrapped with one and two layer of GFRP jacket. Forms for the square column specimens were prepared using 20 mm plywood sheets cut and assembled to provide 90 degrees corners with a plywood formed bottom. The forms were cut and assembled very carefully to ensure accurate vertical sides and 90 degrees corners. In order to round off the corners of the square specimens pvc pipe inserts were glued to the corners of the boxes. Fig 2 shows the completed forms of square specimens. Fig 3 boxes ready for the concrete pour.

Fig 2.

Fig 3

FRP jacketing:

The GFRP laminates are then applied directly onto the surface of the specimens providing both unidirectional and bidirectional lateral confinement. Special attention was taken by the installers to eliminate any voids between the FRP laminates and the concrete surfaces. In the case of square columns a 150 mm overlap was used, while a 100 mm overlap was used in the case of circular specimens to ensure the development of full composite tensile strength.

Test Result and Discussion

Overall behavior

The results show that the confinement of columns with GFRP wraps increase the load carrying capacity of concrete columns. In addition, the greater the number of GFRP layers, the greater the gain in axial load – carrying capacity with respect to unconfined columns.

Square specimen There was a good enhancement in the performance of the entire confined square column. The enhancement was directly related to the corner radius. Thus the column with 50mm corner radius had highest strength improvement but less than that of circular specimen. The failure of all confined square specimen took place at one of the corners within the mid height of the specimen. The failure was gradual and less explosive than the cylinders. The rounding of corner was used to provide a uniform confining stress.

Cylindrical Specimen

The Performance of the cylinder under axial load was consistent. Prior to the failure, cracking noises were heard, indicating the start of stress transfer from the concrete to the GFRP jacket. The jacketed rupture started at the middle portion of the specimen. In case of broken specimen no de-bonding took places at any stage throughout the loading process. Table 3 shows the gain in strength and deflection achieved through confinement concrete.

Effect of fiber orientation

Fiber orientation has significant effect on the fabric stiffness in the hoop direction in a FRP jacket. Influence of confinement on the behaviour of column models are studied by plotting load-displacement curve for various section with different corner radius. The square column with increase corner radius with varying plies(0,1,2) shows the percentage gain in strength for change in plies from 0 to 1 and 0 to 2 as 18.06% , 61.142% respectively.

The fiber orientation included 0°/0°,0°/90°,±45°,90°/90°. These configuration were chosen to study the effects of 0°,90°,45° with respect to the loading direction on the confined behaviour of specimens. The angle orientation with two layers, the percentage gain in strength varies from 28 to 44.In the longtudinal orientation with two layers the percentage gain in strength varies from 75 to 85 .Among these ply configuration 0°/0° provide higher confined strength of 54.4 Mpa for 50mm corner radius than the 0°/90° and ±45° ply configuration. Fig 4 shows compressive strength of various corner radius with different orientation.

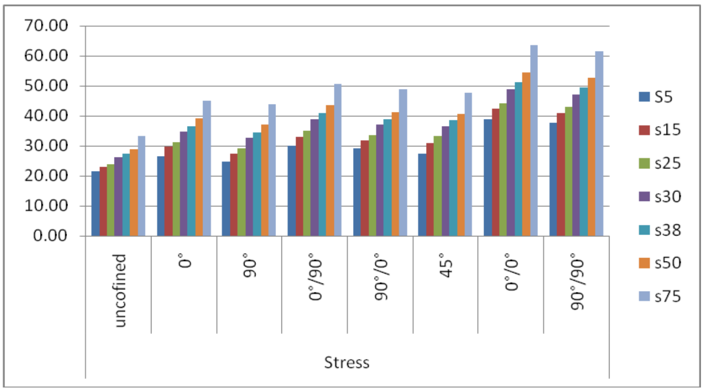

Fig 4 compressive strength for various corner radius

Conclusions

The results have showed the difference in compressive strength for changes in corner radius of the specimen with different fiber orientation. The FRP jacket will increase the axial load capacity. The sample with 0°/0° jacket provided higher confined strength than the jacket with 0°/90°and +45°/-45° ply configuration. The specimens with hoop orientation have bilinear behavior with a nonlinear transition zone. The angle orientation with two layers,the percentage gain in strength varies from 28 to 44 %. In the longtudinal orientation with two layers the percentage gain in strength varies from 75 to 85 .Among these ply configuration 0°/0° provide higher confined strength of 54.4 Mpa for 50mm corner radius than the 0°/90° and ±45° ply configuration. The hoop FRP resists lateral deformations due to the axial loading, resulting in a confining stress to the concrete core, delaying rupture of the concrete and thereby enhancing both the ultimate compressive strength and the ultimate compressive strain of the concrete. The radius of the corner radius in square columns affected the behavior. It determines stress concentration effect. A larger radius can expand the strong constraint zone and diminish the stress concentration. So the reduced confining pressure in a square section due to the concentration of stresses at the corners is solved by using a square section with circular corners.

References

1. Riad benzaid, Nasr eddine Chikh and Habib Mesbah 2008. "Behavior of square concrete column confined with GFRP Composite Warp" Journal of Civil Engineering and Management", 14(2):115-120.

2. Lei-Ming Wang,Yu-Fei Wu, 2008. "Effect of corner radius of FRP confined square concrete columns", Engineering structures, 30, 493-505.

3. A.R.RAhai, P.Sadeghian and M.R.Eshani, 2008. "Experimental Behavior of concrete cylinders confined CFRP Composites",14th world conference on Earthquake Engineering, 12-17, Beijing, china.

4. Mehdi bakshi , Bahareh Abdollahi ,Masoud motavalli, 2008. "The Experimental modeling of GFRP Confined Concrete Cylinders subjected to axial loads" Arabian Journal of Civil Engineering, No. 26,PP. 226-241.

5. Shamim A. Sheikha,_, Yimin Lib, 2007" Design of FRP confinement for square concrete columns" Engineering Structures, 29, 1074–1083

6. Dr.Yousef A, Al-Salloum, 2007. "Effect of the Edge Sharpness on the Compressive Strength of FRP-Confined Square Concrete Columns". King Saud University College of Engineering Research Centre.

7. M. Seffoa*, M. Hamchob, 2012. "Strength of Concrete Cylinder Confined by Composite Materials (CFRP)" Energy Procedia 19, 276 – 285.

8. Riad benzaid, Nasr eddine Chikh and Habib Mesbah, 2008. "Study of the compressive behaviour of short concrete columns confined by fibre reinforced composite". The Arabian Journal for Science and Engineering, Volume 34.

9. Yu-Fei wu , You-Yi Wei, 2010. "Effect of cross sectional aspect ratio on the strength of CFRP confined rectangular concrete columns", Engineering structures 32-45.

10. B. Doran, H.O. Koksal , T. Turgay, 2009. "Nonlinear finite element modeling of rectangular/square concrete columns confined with FRP Materials and Design", 30-3066–3075.

11. Amir Mirmiran, Kenneth Zagers, Wenqing Yuan, 2000. "Nonlinear finite element modeling of concrete confined by fiber composites", Finite Elements in Analysis and Design 35 [79] 96.

12. Renato Parrett, "Axial testing of concrete columns confined with carbon FRP:Effect of fiber orientation", Renato Parretti, Co-Force America, Inc., Rolla, MO, Antonio Nanni, University of Missouri-Rolla, Rolla, MO.

13. Yang,X., Nannni and G.Chen, " Efect of corner radis on performance of Externally Bonded FRP Reinforcement. Nonmetallic Reinforcement for concrete structures", Cambridge, pp-197-204.

14. Yang XB,Wei J,Nanni A,Dharani LR, 2004"Shape effect on the performance of CFRP wraps, Journal of composites for construction", 444-51.

15. ACI Committee 440, 2002. "Guide for the Design and construction of Externally Bonded FRP System for strengthening of concrete structure", ACI 440.2R-02, ACI Farmington Hil, Mich pp.27-28.