AN EXPERIMENTAL STUDY ON STRENGTHENING OF RC SQUARE COLUMNS BY CIRCULARIZING AND WRAPPING WITH FRP

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Abstract - ***The present study explores two methods of confining existing reinforced square (sq.) solid segments beneath concentrical loading condition. 3 groups of 9 reinforced sq. sections were comprised of normal quality cement. Reinforcement was kept at minimum, reproducing sections that required retrofitting. Sections of the key group were reference (Group N), though the sides of the second group segments (Group RF) were balanced and wrapped with three layers of carbon-fiber polymers (CFRPs). The sides of the segments of the third (Group CF) were guaranteed with four things of concrete, 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.***

This technique of confining sq. segments with segmental round sections has proved to be success. Test information on stress-strain models, load-deflection, and collapse modes were acquired. The effect of altering the sq. segment to circle by circularizing procedure on the load carrying capacity has been included.

Results from the study demonstrated that each one confining techniques overstated the ability and ductility of sections. Especially, segmental circular solid covers drastically lessened the strain fixation at the corners and incremented confinement efficiency.

Key Words: *Circularizing, Segmental sections, Strengthening, Confinenemt, Fibre Reinforced Polymer.*

1. GENERAL

In recent decades the existing columns are undergoing retrofitting and which has become an indispensable requirement. To strengthen these existing reinforced concrete columns the application of Fiber Reinforced Polymers (FRPs) has been done. The strength, stiffness, and ductility were found to be increased invariably using these FRP, of the strengthened columns. Both the experimental studies and theoretical studies on behavior of concrete confined with FRPs showed the stress-strain behaviors for FRP confined concrete, especially the circular columns under concentric loadings. It was evident based on the theoretical and experimental results, that, the FRP confinement of a circular column was greater than that compared to square column. In case of square columns, the efficiency of FRP confinement was less because, the stresses were concentrated at the corners and the active area of the confined section by FRP was low. Hence, it was noticed that modifying a square column to a circular one will definitely increase the effectiveness of FRP confinement.

Most of the existing columns are square or rectangular in cross sections as these are easy to construct by regular square and rectangular formwork, compared to circular columns. However, early investigations indicated that the FRP confinement for square or rectangular columns with sharp corners provided very little enhancement in their load carrying capacity, while confinement effectiveness increases linearly with an increase in the corner radius. Despite, the curvature of the corners could cause stress concentration. Therefore, modifying a square column to a circular column may minimize the stress concentration became an objective of this study.

Existing structures sometimes requires retrofitting in cases involving change of the use of the structures, change of design codes and construction errors. Since most structures are constructed with normal strength concrete, the experiments of this study imitate that by utilizing normal strength concrete. This study investigates the technique of modifying the cross section by circularizing RC square column to circle.

1.2 Confinement phenomenon

Confinement is generally applied to members in compression, with the aim of enhancing their load carrying capacity or, in cases of seismic up gradation, or to increase their ductility. FRP, as in contrast with steel applies a constant confining pressure after yielding and has an elastic behavior till failure and therefore exerts its passive confining action on member under axial loads in a different way with respect to steel. It has been seen that, at a certain value of concrete strain, the steel starts yielding and from that point it exerts a constant confining pressure, but whereas, the FRP exerts an increasing confining pressure.

Using composite systems as confining reinforcement for concrete, the tensile stresses from concrete are transferred to FRP. The confining system modifies the characteristic stress – strain behavior of concrete applying a confining pressure to concrete. The maximum efficiency of confining systems using FRP materials is achieved in case of columns with circular cross-section because by the fact that the entire section of the column is involved into the confinement effect and the confining pressure is uniformly distributed on the entire cross-section of the element. But in case of columns with noncircular cross-section only a part of it is subjected to the confining effect, and that part is known as the confined area or active area.

In the case of rectangular columns, the confinement can be provided with rectangular-shaped external wrapping, with corners rounded before application. Rectangular confining reinforcement is less efficient as the confinement action is mostly located at the corners and a significant jacket thickness needs to be used between corners to restrain lateral dilation and column bar buckling. Fig 1.1 shows the confinement effect at corners. An alternative approach is to enclose the rectangular column within an externally cast circular or oval shape that provides the appropriate shape for the jacket.

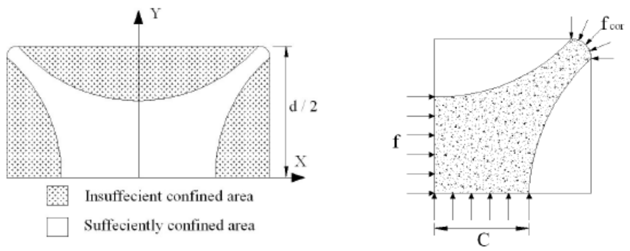

Fig -1.1: Confinement effects at corners

2. EXPERIMENTAL PROGRAM

9 square RC columns casted were classified into 3 groups and tested. The dimensions of the RC square columns were 150 mm × 150 mm in cross section and 750 mm in length. Columns of the first group were reference columns (Group N) with no confinement or any change in the section, while the corners of the second group columns (Group RF) were rounded to 20 mm round corners that were horizontally wrapped with three layers of CFRP. Whereas the sides of the square columns of the third group (Group CF) were bonded with four circular segmental pieces of concrete, thus modifying the cross section of the column from a square shape to a circular shape and then each column was wrapped with three layers of CFRP.

The notation of the specimens is N, RF, and CF states the name of the group to which the specimens belong i.e. normal, round corners with FRP, and circular with FRP.

The average compressive strength of concrete used was 30 MPa. The reinforcement of each of the specimens consists of 4 number of 12 mm diameter bars with 500 MPa yield strength as longitudinal bars and lateral reinforcement was of 6 mm diameter bars of yield strength 250 mm tied at 120 mm spacing. Fig. 1.2 shows the cross sections of the specimens.

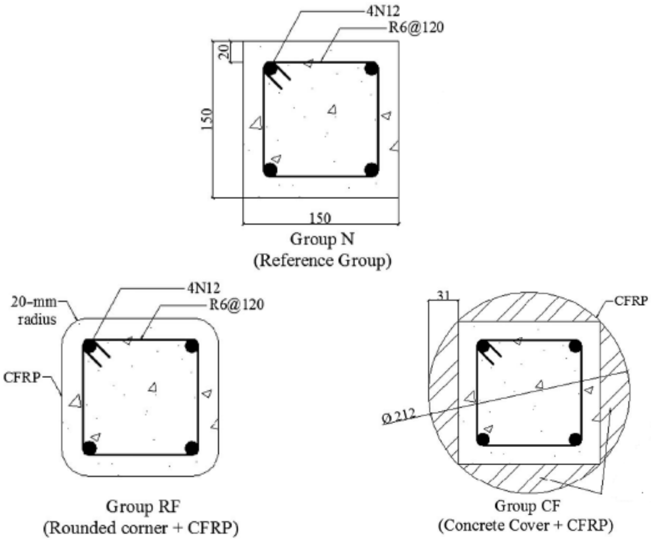

Fig -1.2: Plan view of specimens

2.1 Construction of Segmental Concrete Covers

For the segmental circles concrete used was same as used for construction of square column. M30 grade concrete was used. The formwork was prepared using mild steel sheets which can be bendable to required shape. Wooden frame was constructed to support these sheets. Clamps were provided at regular intervals to maintain the segmental shape. The chord length was 150mm and the arc length was 166.65mm with a sagittal of 31mm. the length was 750mm. whole assembly was kept on vibrating table and concrete was poured into all 4 sheets. Oiling was done at inward surface of the sheets. At the point when the concrete was hardened, they were cured for 28days in curing tank.

Fig 2.1(a)

Fig 2.1(b): Segmental concrete pieces which are to be attached to square columns

These segmental concrete pieces show in Fig 2.1(b) were attached to the each side of square columns. Which led to the change of square cross section to circular.

Each group of specimens were tested in Universal Testing Machine (UTM) of 500T capacity for axial loading and axial deformation. The loading surface was made even and level so that load was applied uniformly over the entire surface. The specimens were placed vertically between the jaws and metal plates were placed above and below the specimen. Whole assembly was digital, deflections and loads were directly recorded in computer. The results were obtained as below

Table 1 Results of Specimens tested under Axial Compression

Groups	Speci mens	Peak load (kN)	Peak Axial Deformation (mm)	Compressive strength (MPa)
Group N	1	725.85	1.33	32.26
	2	734.70	1.47	32.65
	3	718.25	1.26	31.92
Group RF	1	1534.50	22.34	68.20
	2	1564.00	22.76	69.51
	3	1540.65	22.27	68.47
Group CF	1	2907.00	13.35	82.37
	2	2885.40	13.15	81.76
	3	2897.64	13.20	82.10

3. EXPERIMENTAL RESULTS AND DISCUSSION

Each group specimens were tested under axial compression concentric loading. Results were given in Table 1 and the load vs axial deflection curves were compared for each group in Fig 4.1. Some observations were made as below

- ✓ Specimen of group N failing by concrete spalling on the surface and buckling of the longitudinal reinforcement.
- ✓ Specimens of group RF and group CF failing by rupture of CFRP at mid-height of the specimen, as shown in Fig four.5 and Fig four.7.
- ✓ The concrete at mid-height was utterly crushed and was restrained by CFRP.
- ✓ Aggregates of Specimens RF and CF were utterly separated from one another, which were totally different from the concrete of Specimens N.
- ✓ All the Specimens of cluster N, RF and CF illustrated identical behavior throughout the primary stage of the curve, that is, the concrete wasn't crushed.
- ✓ The slopes of the load vs deflection diagrams of Specimens CF was more than that of Specimens N and RF as a result of the world of the cross section of the cluster CF was larger than the cluster N and RF.
- ✓ The loads of the specimens of Group CF and RF gradually increased after the yield load whereas the load decreased after yield load in case of Group N.

The axial strain were calculated by dividing axial deformation by actual length of specimen and the nominal average axial stress of the specimens below concentrical load was calculated by dividing the axial load by the cross-sectional space of the specimens.

The graphs are shown from Fig 4.2

- ✓ The simplest confinement occurred in Specimen CF this is often as a result of the slope of the postpeak curve of Specimen CF is above that of Specimen RF.

In case of Groups CF and CS, no debonding was found between core concrete column and segmental sections, thus they both worked together until failure.

4. CONCLUSIONS

From the experimental results obtained, following conclusions can be made out.

- ✓ The strengthening of columns using segmental circular covers and wrapping with CFRP was possible and worked out be successful.
- ✓ The experiments clearly indicated that no debonding occurred, that is, the whole specimen acted as a whole unit until failure.
- ✓ Each confined specimen showed higher load-carrying capacity compared with unconfined specimens.
- ✓ Among two confined groups, the group CF showed a higher load-carrying capacity followed by group RF. This enhancement was mainly because of the segmental circular covers increasing the cross-section area of specimen.
- ✓ Group CF dominated over the performance of Group RF substantially because decrease in stress-concentration at corners due to segmental circular covers in group CF.

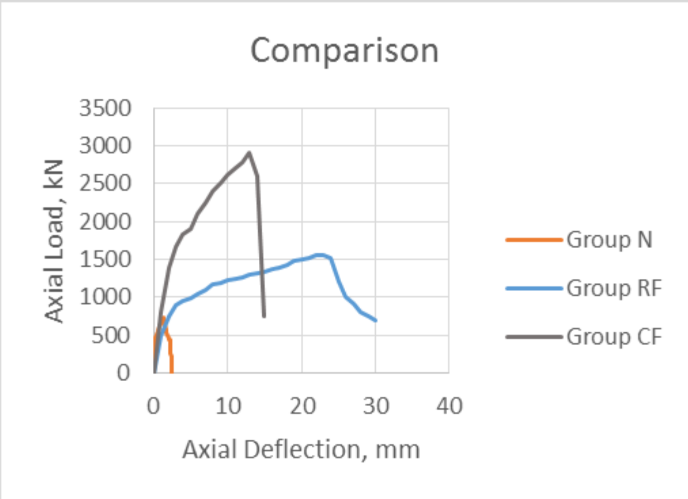

Fig 4.1 Comparison of Load vs Deflection curves

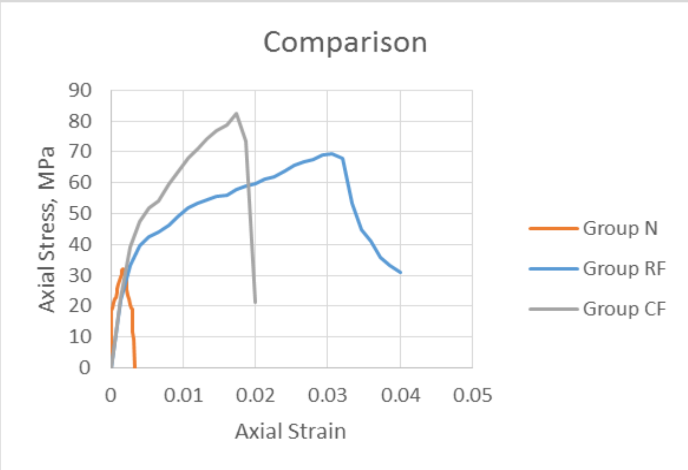

Fig 4.2 Comparison of Stress-Strain curves between Group N, RF and CF

- ✓ The bonding of segmental circular covers significantly increased the confining effect and hence the load-carrying capacity of columns.
- ✓ It was even evident that efficiency of circularized columns was more than the columns with rounded corners.

Finally, the method of modifying a square column to circular section by circularizing process proved to be effective in maximizing the load-carrying capacity of the CFRP confined columns.

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