Review Paper on Experimental Study of Concrete Columns Wrapped with Fiber Reinforced Polymer

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Abstract: **This paper provides a review of some of the progress in the area of fiber reinforced polymers (FRP)-strengthening of columns. The addition of FRP materials to upgrade deficiencies or to strengthen structural components can save lives by preventing collapse, reduce the damage to infrastructure, and the need for their costly replacement. The retrofit with FRP materials with desirable properties provides an excellent replacement for traditional materials, such as steel jacket, to strengthen the reinforced concrete structural members. Existing studies have shown that the use of FRP materials restore or improve the column original design strength for possible axial, shear, or flexure and in some cases allow the structure to carry more load than it was designed for.**

Index Terms **– Fiber reinforced polymer, columns, different cross section of column, various testing.**

I INTRODUCTION:

With structures becoming old and the increasing bar corrosion, old buildings have started to demand additional retrofits to increase their durability and life. To meet up the requirements new innovative materials and technologies in construction industry has started to make its way. Engineers throughout the world have used Fiber Reinforced Polymer (FRP) to solve their structural problems in an efficient and economical manner. In the field of civil engineering, most of the use of FRP is confined to repairing and strengthening of structures. Use of FRP for confinement has proved to be effective retrofitting and strengthening application. The confinement in seismically active regions has proved to be one of the early applications of FRP materials in infrastructure applications. Confinement may be beneficial in non-seismic zones too, where, for instance, survivability of explosive attacks is required or the axial load capacity of a column needs to be increased due to higher vertical loads. Hence, FRP composites are finding ways to prove effective. Like other materials, FRP also has its limitations. There are several situations in which a civil structure would require strengthening or rehabilitation due to lack of strength, stiffness, ductility and durability. Some common situations where a structure needs strengthening during its lifespan are:

- Seismic retrofit according to current code requirements.
- Upgraded loading requirements; damage by accidents and environmental conditions.
- Initial design flaw.
- Change of usage.

Depending on the desired properties, usage and level of damage in structural members, these can be repaired and strengthened by several widely used methods.

In this review paper, review of an experimental study will be carried out different authors for finding the increase in strength of RCC columns with FRP wrapping.

II. LITERATURE REVIEW

J. G. Teng et al. (2002) have studied an experimental study on FRP-confined concrete in elliptical columns. In this study, experiments were conducted on short elliptical plain concrete columns confined with carbon FRP. A total of 20 model concrete column specimens in five series were prepared from five batches of concrete. Each series consisted of a circular specimen and three elliptical specimens prepared from the same batch of concrete. The circular column was approximately 152 mm in diameter and 608 mm in height. The cross-sectional area and height of the three elliptical specimens were almost the same as those of the circular specimen, with the nominal a/b ratios being 5/4, 5/3, and 5/2, respectively. Two of the five series of specimens were tested without FRP confinement as control series, while the remaining three series were wrapped with CFRP.

Strain gauges were installed on the model column specimens to measure both axial and hoop strains during tests. For concrete specimens without FRP wrapping, eight strain gauges of 60 mm gauge length were installed at the middle height of each specimen, one in the axial and one in the hoop direction, at each of the four vertices of the elliptical section. For CFRP-wrapped specimens, four three-element strain rosettes of 20 mm gauge length were installed on the surface of the CFRP jacket at the four vertices, respectively, at 50 mm above the middle height. The specimens were axially loaded in a universal testing machine of 2,750 kN capacity.

Based on the experimental results, the following conclusions can be made.

1. The confining FRP becomes increasingly less effective as the section becomes more elliptical but substantial strength gains from FRP confinement can still be achieved even for strongly elliptical sections.

2. The axial compressive strength of FRP-confined concrete in elliptical specimens can be predicted using the common form of strength models for FRP-confined concrete in circular specimens with the replacement of the confining pressure by an effective confining pressure.
3. specimens tested in the present study, those with the effective confinement ratio equal to or less than 0.11 showed a descending branch in the stress–strain curve, while the other specimens showed a monotonically increasing bilinear stress–strain curve. For the latter specimens, an increase in the effective confinement ratio results in an increase in the ultimate strain.

Gebran Karam et al. (2005) have studied that Confinement Effectiveness in Rectangular Concrete Columns with Fiber Reinforced Polymer Wraps. The extension to rectangular sections of the pulley model is an innovative mechanistic based method for passive confinement efficiency estimation. A refined finite element method was created using a nonlinear concrete constitutive law in order to analyze stresses in columns passively confined with fiber reinforced polymer wraps. Rectangular as well as square cross sections of variable corner radii were investigated with respect to a circular cross section. A rigorous numerical method for calculating geometric confinement efficiency factors is proposed and typical factors are calculated and compared with the predictions of the simple pulley model showing good agreement. Results indicates an increase in corner stresses with sharper corner radii, a localization of failure at the corners, and a decrease in confinement effectiveness with an increase in the rectangularity of the cross section or an increase in corner sharpness.

In addition following can be noted:

1 the cross-section shape factor and the corner sharpness factor and confinement stiffness factor are the parameters controlling the geometric confinement efficiency.
2 The reduction in effectiveness, and cause localized failure are caused because of the stress concentration that develop at the corners of passively confined rectangular cross sections.
3 The confinement effectiveness decreases linearly with the increase in corner sharpness factor.
4 The confinement effectiveness decreases with the decrease in the cross-section shape factor or the increase in the rectangularity of the cross section.
5 The proposed method for the calculation of the confinement effectiveness offers a mechanistically rigorous alternative to
the arbitrary geometric factors typically used in research and design, and allows a more elaborate interpretation of observed and published experimental results.

Yu-Fei Wu et al. (2003) have studied Unified Strength Model Based on Hoek-Brown Failure Criterion for Circular and Square Concrete Columns Confined by FRP. This paper presents a new model based on the Hoek-Brown failure criterion which was developed for rock materials is proposed because most existing models for evaluating the strength of fiber-reinforced polymer FRP-confined concrete columns are based in an early work of Richart et al.(1928). The existing strength models for FRP-confined circular and square concrete columns are reviewed, evaluated, and compared with the proposed model. An updated database that includes a large number of test data are then used to evaluate the models. The models and test results are then compared and then it indicates the accuracy of the proposed model. Apart from this improved accuracy, the proposed model also has a unified form for both circular and square columns, and can be used to predict the strength of columns that have existing damage or cracks. Test data for FRP-repaired concrete columns are collected from the literature and used to evaluate and demonstrate the performance of the proposed model in predicting the strength of FRP-confined deficient columns.
The proposed model has two important advantages compared with existing models:
1. it has a unified form for both circular and square columns and
2. it is applicable to concrete columns with existing damage. A comprehensive, updated database has been used to evaluate the performance of the proposed and existing models, demonstrating the advantages and enhanced accuracy of the proposed model.

Pedram Sadeghian et al. (2010) have conducted experimental work on Study of Rectangular RC Columns Strengthened with CFRP Composites under Eccentric Loading. This paper presents the results of experimental studies on reinforced concrete columns strengthened with carbon fiber reinforced polymer (CFRP) composites under the combination of axial load and bending moment.

A total of seven RC specimens were designed with a rectangular section (200 mm x300 mm). The test portion of each specimen had a height of 1,500 mm and each haunched head had a height of 600 mm. The specimens were tested under compression eccentric loading up to failure. Three different FRP thicknesses of 1.8, 2.7, and 4.5 mm (two, three, and five layers); four fiber orientations of 0°, 90°, +45°, and 45° with respect to an axis perpendicular to the column axis; and two eccentricities of 200 and 300 mm were investigated. Two columns were unstrengthen; two were strengthened with two longitudinal layers and one transverse layer of CFRP ; two others were strengthened with four longitudinal layers and one transverse layer of CFRP ; and the last column was strengthened with two diagonal layers of CFRP. One specimen of each group was tested under an eccentricity of 200 mm, and another was tested under an eccentricity of 300 mm. The specimen DD` was tested under an eccentricity of 300 mm only.

All specimens were reinforced with 4ϕ 12 mm longitudinal ribbed bars (fy=465 Mpa) symmetrically placed. Transverse reinforcement was provided with rectangular ties ϕ 6.5@200 mm made of smooth bars (fy=325 Mpa). A hydraulic actuator was used to apply the axial load to the columns. A total of six linear variable displacement transducers (LVDTs) and 26 strain gauges were used for every specimen. The specimens were tested using a 600 kN capacity compression actuator under displacement control and the data were monitored using an automatic data collecting system. Displacements and strains were monitored by a digital data logger system. The tests were performed up to failure of the specimens. Force, displacements, and strains were obtained during the test and were filed by computer software.
The following conclusions are drawn:

1. The strengthened specimens had similar bilinear load displacement curves as the unstrengthened specimens. The first part of all curves was approximately linear up to the yield point, when the tension steel bars yielded. The axial secant stiffness and yield strength were improved with increasing axial stiffness of the FRP. After the yielding point, the FRPs were effectively activated, so the plastic region of all curves had limited stiffness degradation. The axial tangent stiffness was improved with increasing longitudinal stiffness of the FRP. The maximum load carrying capacity of each specimen was reached at the FRP failure point, when the longitudinal fibers of the FRP failed in tension.
2. The moment-curvature behavior showed that longitudinal layers improved the bending stiffness and moment capacity of the specimens, but curvature capacities were not generally improved. The behavior of the specimen with angle orientation was a little different. In this case, not only the bending stiffness and moment capacity were enhanced, but also the curvature capacity was improved.
3. When the strengthened columns fail in tension-controlled failure, the transverse layers could not make any improvement on the confinement of the compression side of the section. In this region the concrete behavior is similar to the unconfined concrete.
4. The sine-shaped model for second order deformation is in a good agreement with experimental data for different levels of deformation from the linear region up to the failure point on the prismatic part of the specimens. The model can be used for design calculation of RC columns strengthened with CFRP composites.

Zhenyu Wang et al. (2011) have studied a cyclic axial stress-strain model for CFRP-confined RC square columns. The seismic design of fiber reinforcement polymer (CFRP) confined reinforced concrete (RC) columns, requires the development of an accurate axial stress-strain model that considers cyclic compression. The model is informed from physical observations and CFRP confined square unreinforced and reinforced concrete column of large size under varying cyclic compression patterns were tested and from that test measurements obtained.in this research paper the presented stress – strain model is consists of three main components.
A a monotonic stress-strain model to explain the envelope curve.
B a polynomial expression for the unloading path.
C a straight line for the reloading path.

In this research paper the effect of internal longitudinal and hoop steel reinforcement is is also considered , in addition to their influence on the ultimate stress- strain. The accuracy of the model is finally validated with an experimental database compiled of tests reported in the companion paper and other relevant tests extracted from the open literature.

Conclusion:
1. Results show that with an increase of cross section size confinement effectiveness of CFRP decreases.
2. Tests have shown the stress-strain responses of square RC square columns of larger size, which are confined with CFRP wraps, to exhibit a post peak-softening behavior followed by a plateau stage.
3. This paper shows the capability and accuracy of the model for predicting the stress-strain relationship of CFRP confined square RC columns under cyclic axial compression from the Comparisons between the predictions of the proposed model and test result.

Khaled Abdelrahman et al. (2011) have conducted experimental work. This paper, the behavior of non reinforced and reinforced large-scale columns (300 × 1200 mm) wrapped with CFRP and SFRP sheets is examined and compared with that of unwrapped columns. A total of six large-scale concrete columns 300 mm in diameter and 1200 mm in height were fabricated and tested to failure. The specimens were divided into two groups: Group I consisted of nonreinforced concrete columns and was composed of a control column (NR-CT), a CFRP-wrapped column (NR-CFRP), and an SFRP wrapped column (NR-SFRP). Group II consisted of reinforced concrete columns and was composed of a control column (R-CT), a CFRP-wrapped column (R-CFRP), and a SFRP-wrapped column (R-SFRP). All columns in Group II were longitudinally reinforced with six 20 M steel bars and laterally reinforced with 10 M spiral steel reinforcement, spaced at 50 mm center-to-center along the entire height of the columns. All columns were wrapped with fibers in the hoop direction. All columns were instrumented with conventional foil strain gauges, which had a resistance of 120 Ω and a gauge length of 6.54 mm. Horizontal and vertical strain gauges were installed at midheight of the columns located 180° from each other to measure hoop and axial strains, respectively. All columns were loaded in uniaxial compression at a loading rate of 200 kN⁄ min until failure.

Conclusion:
Based on the experimental results, the following conclusions can be made:
1. Wrapping of SFRP sheets was very effective in increasing the axial strength and deformability of the concrete columns. Columns wrapped with SFRP sheets showed superior performance compared to columns wrapped with CFRP sheets in terms of the stress-strain behavior, axial strength, axial strain, and hoop strain.
2. The dilation response of the columns wrapped with the SFRP sheets showed behavior similar to that of the columns wrapped with CFRP sheets. Wrapping the columns with one layer of CFRP and SFRP sheets was not sufficient enough to curtail the dilatation tendency of the concrete.
3. The SFRP sheets provided a higher percentage contribution toward the total ductility of the columns than the CFRP sheets. Thus, the columns wrapped with SFRP sheets showed a higher percentage increase in the total ductility of the columns compared to the CFRP-wrapped columns.

Muhammad N. S. Hadi et al. (2012) have conducted an experimental study on the performance of carbon-fiber-reinforced-polymer (CFRP) wrapped square reinforced concrete (RC) columns under eccentric loading.

The experimental program consisted in testing a total of 16 RC specimens, of which 12 were tested under compression loading and four under flexural loading. The specimens had four N12 (12 mm diameter deformed bars) as longitudinal steel reinforcement and R8 (8 mm diameter plain bars) spaced at 100 mm as transverse steel reinforcement (ties). The R8 ties spaced at 50 mm were applied at both ends of the specimens to prevent premature failure at the locations. The specimens were divided into four groups: unwrapped, wrapped with one layer of CFRP, wrapped with three layers of CFRP, and wrapped with one layer of vertical (along specimen axis) CFRP straps and two layers of horizontal (transverse) CFRP. Each group consisted of four specimens; one specimen was tested concentrically, one was tested under a 25 mm eccentric load, one was tested under 50 mm eccentric load, and the final one was tested under flexural load.

Two different monitoring systems were used to measure the displacement of the columns. For concentric loading, one LVDT was connected directly to the testing machine to measure the axial displacement of the column during the test. Data read from this LVDT were recorded at the same time as load data were recorded by the testing machine. A second LVDT, a laser LVDT, was also used in addition to the first one for eccentric load to measure the lateral deflection (δ) of the column. The second LVDT was placed horizontally near the mid-height of the column. When the specimen and the instrumentation were placed in position and initial calibration was done, the compression testing then started. The column was tested under displacement control with a loading rate of 0.5 mm/min, and the end point position was set at 50 mm. As mentioned previously, four specimens were tested as beams under flexural loading with a span of 700 mm. Pure bending was applied to the specimens by means of a four-point loading to determine the flexural capacity of the specimens without axial load. The testing machine recorded the applied load simultaneously during the test. A laser LVDT to measure the mid span deflection of the beam during the test. The beam was tested under displacement control, the end point position was set at 50 mm, and the loading rate was set at 0.3 mm/min.

Conclusions**:** Based on the experimental work carried out in this study, the following conclusions were drawn:

1. CFRP wrapping had a more significant effect on the maximum load of eccentrically loaded columns compared to concentrically loaded columns.
2. No significant increase in maximum load was obtained when the columns were wrapped with one layer of CFRP.
3. Increasing the number of the CFRP layers resulted in an increase in the load and the performance of the columns.
4. The CFRP wrapping enhanced the performance of the columns by postponing the rupture of the concrete and reinforcement, which means it increased the column ductility. Similar results were obtained in beams tested in flexure.
5. In columns with a large eccentricity, which means with a large bending moment, the presence of CFRP straps produced higher ductility than in columns wrapped horizontally with a similar number of CFRP layers.
6. Using an existing strength model to estimate the capacity of CFRP column yielded strength magnitudes that were lower than the experimental ones. This observation shows that the model yields good predictions of the strength of CFRP wrapped columns.
7. The theoretical axial load-bending moment interaction diagram shows values that are close to those of the experimental result, except at the point under concentric load. Finally, the use of longitudinal FRP layers can be recommended in combination with FRP wrapped circumferentially to enhance the performance of columns loaded eccentrically.

Ahmed Shaban Abdel-Hay et al. (2014) have conducted experimental work.This study represent overall behavior of R.C square columns with poor concrete at upper part, strengthened with CFRP. Ten square columns of height 2000 mm and cross section of 200 x 200 mm are tested. One of them is controlled specimen and the other nine specimens are divided into three groups. All specimens had the same longitudinal reinforcement and stirrups.

A high strength carbon fiber fabric, SIKA WRAP 300 C, was used for jacketing the tested columns. The CFRP materials had a nominal thickness of 0.167 mm. surface of concrete column is Prepared by using a hammer and blower to remove the weak element on the concrete cover. The column was chamfered by radius of 20 mm. Then epoxy paste is applied on the column surface to fill the uneven surface of concrete. SIKA DUR 41 CF was used to bond the CFRP with column, then rolling the CFRP laminates by special laminating- roller to ensure that the CFRP is saturated with epoxy resin and there are no air voids between the fibers and concrete surface.

All columns were loaded with 500 ton hydraulic machine in the material laboratory. The applied load was read out on the load cell scale. LVDTs were placed at upper and lower part of column to measure the longitudinal strains, and electrical strain gages of 20 mm gage length were used to measure the fiber strain.

Conclusions: The following conclusions are drawn from this work.

1) Partial strengthening of square columns with poor concrete at upper part can be used. It is significant to wrap the poor part only using one layer of CFRP.
2) Increasing the jacket height will provide a higher ductility for wrapped columns without significant increase in ultimate load of columns.
3) Confined part must be provided with corner radius to increase concrete strength as the upper part is quite weak.
4) The ultimate load of wrapped column increases as the concrete strength of upper part increases, while the ductility decreases.
5) Increasing the top concrete height causes an increase in ductility, but the failure load decreases.
6) Ductile failure mode achieved in specimens of top concrete height of 500 mm, while in case of 350 mm top concrete height, the failure mode was brittle.

Garyfalia g. triantafyllou et al. (2014) have conducted experimental work on Axially Loaded Reinforced Concrete Columns with a Square Section Partially Confined by Light GFRP Straps. The study presents the experimental behavior of reinforced concrete columns strengthened externally by transverse glass fiber reinforced polymer (GFRP) sheets. The columns had a square section and very low concrete strength.

The experiments involve 16 specimens of square sections with 150-mm sides, 25-mm corner radius, and 750-mm height (side to height ratio equal to 5). Two plain concrete prismatic columns were tested as a reference. Four prismatic plain concrete columns were confined by glass fiber-reinforced polymer (GFRP) in four different confinement levels. One prismatic reinforced concrete column had slender longitudinal smooth bars (and sparse stirrups) of low yield strength and another four identical columns were confined by identical levels of GFRP. Finally, another corresponding set of five columns had slender ribbed bars of high-yield strength. The columns were subjected to monotonic axial loading up to failure. Four different configurations of FRP confinement were applied in the plain concrete columns, in the reinforced concrete columns with S220 bars, or in the columns with B500C bars. Three specimens were fully wrapped by GFRP sheets of a single layer. The remaining nine specimens were partially wrapped with GFRP straps in order to develop comparable levels of external light confinement. The straps were placed in between the steel stirrups with 100-mm spacing at centers. The three remaining specimens were wrapped with two layers of 40-mm wide straps.

Two linear variable displacement transducers (LVDTs) were used to measure the axial deformation of the columns (between the loading platens). A special wire meter was supported on the bottom and top metallic collars to measure their relative distance. This device provided an additional measurement of the axial deformation of the main area of the investigation. Two additional LVDTs measured the lateral deformation of the columns at the midheight. The same instruments were placed on the concrete surface in between straps in cases of partial wrapping. A laser meter was used to measure the relative horizontal distance between two targets on the FRP jacket (or on the midheight strap for partial wrapping). In the same position, a strain gauge was glued to provide the strain of the GFRP. The specimens were subjected to axial compressive load under a displacement control mode with a constant rate of 3×10^{-5} mm/mm/s until their failure.

Conclusion:

1. The plain or reinforced concrete columns with one layer of 65-mm wide strap revealed relatively inferior behavior to the corresponding columns with two layers of 40-mm wide strap, while having equivalent effective confinement ratio.
2. The columns with internal steel reinforcement presented higher FRP wrapping efficiency than their plain concrete counterparts. Even in the cases of partially wrapped columns with 40- or 50-mm wide straps, the dual confining action of the steel and FRP reinforcement altered the behavior from softening to hardening, despite the inadequate steel reinforcement detailing.
3. The lower bound combined confinement ratio of steel and FRP confinement ranged among 0.051 and 0.125. Further research is necessary to accurately address the dual effects of steel and partial FRP confinement with regard to confinement efficiency along column axis. It is concluded that the 0.08 limit could safely ensure ascending stress-strain response for both plain and reinforced concrete columns of low concrete strength with partial FRP confinement and similar characteristics.
4. The concrete axial strain performance of columns with S220 slender bars was inferior to the one of their counterparts with B500C slender bars. Thus, fully or partially FRP wrapped columns with S220 slender bars require relatively higher FRP strengthening to achieve similar ultimate strains.

Yang Yang et al. (2015) have studied experimental work on Emergency repair of an RC bridge column with fractured bars using externally bonded prefabricated thin CFRP laminates and CFRP strips.

This paper represents an experimental study of an emergency repair technique for a reinforced concrete (RC) bridge column that had buckled and fractured longitudinal bars was developed. The repair technique involved removing loose concrete, casting grout, cutting a trench around the base of the column in the footing. After that embedding carbon fiber reinforced polymer (CFRP) strips for flexural reinforcement, building a jacket from a prefabricated thin CFRP laminate, lowering the jacket into the trench bonding the CFRP composites to the column and the footing with pressurized epoxy, and restoring the strength of footing with externally bonded CFRP sheets. The repaired column then tested to failure under constant axial load and cyclic lateral load resulting in combined flexure, shear, and torsional moment loading.

In this paper, the original column is referred to as Calt-3.The column had an oval-shaped cross section of (610 mm x 915 mm), and the clear concrete cover to the spiral reinforcement was 1 in. (25 mm). The total height of the specimen was 166 in. (4.2 m) with an effective height of 132 in. Spiral reinforcement of dia 12.7 mm provided with a pitch of 70 mm. Then column was subjected to axial compression load of 979 KN. The objective of repairing Calt-3 was to restore the flexural, shear, and torsional strength of the column; thus the method was considered an emergency repair rather than a permanent repair that aims to restore the deformation capacity as well. After rehabilitation and confinement of column then the column is ready for actual test. The repaired column was subjected to the same cyclic lateral loading protocol and constant axial loading as applied to the original column. Two load cells were integrated within the two actuators that measured force during testing. Load cells were also installed under the hydraulic jack on the top of column to record the variation of axial load. Two integrated direct current-linear voltage displacement transducers (DC-LVDTs) within the two actuators recorded the displacement during testing. Strain gages were installed on the surface of the CFRP jacket to measure both the longitudinal and transverse strains. Five levels of strain gages were also installed onto four of the CFRP strips before they were installed onto the column. Four strain gages were installed on the CFRP straps on each side of the footing to measure the surface strains of the CFRP. Then repaired column then tested to failure.

Conclusion:

1. The repair method gains the torsional strength but resulted in a lower torsional stiffness and ductility compared to that of the original column.
2. Energy dissipation per cycle as well as cumulative energy dissipation of the repaired column were lower than that of the original column.
3. The design method for the transverse CFRP in this study was adequate and precluded damage to the transverse carbon fibers in the jacket.
4. The footing repair was successful and effective with no observed debonding of CFRP from the footing.
5. Since stiffness and energy dissipation of the repaired column were different from that of the original column, more work is needed to investigate the influence of the repair method on the response of the bridge structure.

Thamer Kubat et al. (2016) have studied CFRP confinement of circular concrete columns affected by alkali-aggregate reaction Alkali-aggregate reaction (AAR) causes expansion as well as cracking in concrete, which directly affect the mechanical properties of concrete, leading to a decrease in the service life of structures. Wrapping damaged components with epoxy-bonded carbon fiber reinforced polymer (CFRP) is a method of rehabilitation. This paper describes the level of expansion in concrete caused by AAR and its effects on the mechanical properties of concrete during a period of one year.

The first part of this research deals with the effect of concrete expansion levels of 0.01, 0.37, 0.76, 1.24, and 1.57%, which were achieved at ages of 7, 28, 90, 180 and 360 days, respectively. on the mechanical properties of AAR-affected concrete. The second part deals with the effect of confinement with different numbers of CFRP layers on the behavior of circular concrete columns damaged by AAR as well as undamaged columns. Two types of concrete were cast: non–expansive normal concrete (Nc) and reactive concrete (Rc). The mix proportions followed the ASTM C1293-08 [47]. The same concrete mix was used throughout the research and had a water-cement ratio of 0.42: 1 (cement): 1.7 (fine aggregate): 2.54 (coarse aggregate). Fused silica of 0–1 mm particle size was used at a dosage rate of 7.5% by mass of total aggregate. General Purpose cement was used for the mix. The alkali content of this cement was 0.5% expressed as sodium oxide equivalent (Na2Oequ). Sodium hydroxide was added to the mix water of both Rc and Nc to increase the level of alkalinity in both concretes to 1.25% by cement mass expressed as Na2Oequ as required by ASTM C 1293. All samples were stored under the conditions specified by ASTM C1293 from remolding until the time of testing. To evaluate the effectiveness of CFRP confinement, twenty-six circular concrete columns were fabricated from both concretes (Nc and Rc). The columns were 200 mm in diameter and 500 mm in height and two types of columns were prepared; plain (P) and reinforced (R). All columns were tested under compression.

Conclusion:

1.CFRP confinement enhanced the strength and strain capacities.

2.The confinement efficiency with one or two CFRP layers was approximately the same for both plain and reinforced columns with normal concrete.

3. CFRP confinement was more effective for columns with reactive concrete than columns with normal concrete. The confinement efficiency reached 462% and 593% when reactive plain concrete was wrapped with one layer and two layers of CFRP, respectively. The confinement efficiencies of one, two and three CFRP layers for reactive reinforced columns were 282%, 402% and 498%, respectively.

Mohammed T. Jameel et al. (2017) have carried experimental work on Behavior of circularized and FRP wrapped hollow concrete specimens under axial compressive load. This paper investigates the suitability of the circularization technique for strengthening square hollow concrete specimens. A total of eight specimens made from normal strength concrete. The specimens were divided into two groups: solid and hollow specimens. All the specimens were 300 mm in height and 106 mm 106 mm in cross-section. The hollow specimens had a central square hole of 35 mm sides. Each group consisted of four specimens. The first specimen in each group was the reference specimen. The second specimen constructed with 20 mm round corners and was wrapped with two layers of CFRP, which simulates the conventional strengthening method. The third specimen was circularized with full length plain concrete segments and wrapped with two layers of CFRP. The fourth specimen was circularized with concrete segments which were 20 mm shorter than the length of the specimen and wrapped with two layers of CFRP. All specimens were tested under axial compression loading.

For testing T0he universal Denison compressive testing machine with a maximum load capacity of 5000 kN is used. Transducer (LVDT) was used. For the circularized specimens, the LVDT was mounted onto a frame of two circular rings. For square specimens, a square test setup was designed. The travel linear variable differential transformer (LVDT) was mounted onto two box frames that were fixed at the top and bottom of the specimen by steel bolts. All specimens were tested under a displacement controlled axial load at the rate of 0.5 mm/min. The data were recorded at every two seconds.

Conclusion:

1. Circularization proved to be an effective method in strengthening CFRP confined square hollow concrete specimens similar to CFRP confined solid concrete specimens.

2. The experimental investigations carried out in this paper demonstrated that the specimens circularized with full length concrete segments confined with CFRP achieved higher ultimate axial load than the specimens circularized with short concrete segments confined with CFRP.

3. When the effect of circularization is compared with rounding the corners of the CFRP confined specimens, after excluding the contribution from section enlargement, the circularization technique contributed less to the yield stress of the hollow specimens than to the yield stress of the solid specimens.

XIV. Future work:

In summary, a comprehensive literature review was performed in order to gain a better insight into the key issues relevant to behavior R.C.C. columns of various cross sectional areas wrapped with different fiber reinforced polymers. Many guidelines are reviewed regarding this topic. All the researchers discussed the effect of R.C.C. columns of various cross sectional areas wrapped with different fiber reinforced polymers. All these topic require further research and it is essential for improving effect of fiber reinforced polymer wrapped R.C.C. columns with square cross section.

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