A REVIEW ON SHAPE EFFECT OF CFRP CONFINED COLUMN

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ABSTRACT

Numerous kinds of research have been done to find new ways to make structural elements stronger. The use of FRP composite for strengthening is the result of this research. Due to the distinctive properties of carbon fibres and polymer matrix combinations, carbon fibre reinforced polymers are becoming increasingly popular in fibre reinforced composites. A crucial component of concrete technology that aims to improve concrete performance indices during construction and long-term use is the wrapping of concrete structures with fibre polymers. The confinement efficiency of externally bonded FRP jackets can be directly affected by the shape of columns' cross sections. Sections that are circular have a higher benefit of strength than those that are square or rectangular. The radius of the corners is limited by internal steel reinforcement, so rounding the corners of FRP confinement can improve its efficiency. However, the effect is limited, especially for large columns. An experimental investigation into the effect of curvilinearization on a CFRP confined preloaded column is the purpose of this project. Curvilinearized square columns CSC have only been the subject of a very small amount of research, most of which was limited in scope and used small specimens.

Keywords: CFRP, Preload, resin matrix, CFRP confinement, Curvilinearization.

1. Introduction

The complex medium known as fibre-reinforced polymer is made by inserting reinforcing fibres into a polymer matrix. The matrix can be polyester, vinyl ester, or epoxy. It is available in a variety of sizes and shapes. Additionally, hybrids can be developed and used in a variety of settings. In order to deal with changes in usage and general deterioration, civil engineers were urged to take steps to improve and upgrade the existing infrastructure. Years of research and searching for a new way to develop a new strengthening method led to the development of FRP composites for these purposes. One crucial step is selecting the materials for various strengthening systems. Adhesives, resin matrices, and reinforcement are the fundamental components of a FRP strengthening material system. Fibre-reinforced polymers saw a significant increase in demand as structural strengthening became more prevalent. Concerning the dependability of FRP-wrapped columns, several experimental and analytical studies have been conducted. This strengthening technique has greatly improved the ductility property and axial load carrying capacity of the columns. Nevertheless, the performance of columns with a circular cross sectional area has been one of the primary focuses in most of these studies. Despite the fact that the amount of information available with square or rectangular cross sectional columns has developed over time, it is still limited. On FRP-constricted specimens, various investigations were carried out without using preload. In the field, the effect of preload has been ignored. Before the FRP confinement becomes effective, the preload caused initial stress and deformation in concrete, resulting in different stress-strain behaviour than in the absence of preload. If designers do not fully comprehend the consequences of preload, they may be uneasy about their designs, especially if the literature does not provide much information on the topic. As a result, it is necessary to probe the impact of preload on the properties of FRP-wrappped concrete.

2. Literature Review

Wisam A. Aules, et al., (2022) [1] Ferro cement has become more common in RC structures in recent years. Ferro cement has primarily been used to build up the confinement of the regular concrete columns. Furthermore, the effectiveness, particularly when combined with CFRP confinement, is unknown at this time. This research looked into a novel modification method that uses ferro cement to change the cross-sectional area of square shaped columns into curvilinear shaped columns. Full and partial confinements were the two examined forms of solitary confinement. For this research, 15 square shaped plane concrete columns were built to look into the impact of changing the shape of square columns using the ferro cement jacket and CFRP for improved confinement. The most energy was absorbed by columns with curvilinear shape, modified, as well as complete wrapping.

Taraka M.R. Balla et al., (2022) [2] The purpose of this work is to investigate, through experiments and FE analysis, how non-identical sizes affect the performance of hybrid type FRP technology under the action of axial compression. The size effect, one of the study's findings, can be of help to suggest design options for hybrid FRP processes. Two numbers of samples were reinforced using Externally Bonded, Near Surface Mounted, and hybrid Fibre Reinforced Polymer techniques for every aspect ratio. As the aspect ratio increased, the FE results clearly showed that effective pinning reduced the strength and peak stress of the EB-compressed samples. The test and results from FE demonstrated that the variation had no impact on the ultimate strength of the samples braced by the NSM process. Analysis alone indicates that for hybrid specimens with an aspect ratio of 1, strength increases of up to 55% are possible. The strength increase for his HYB for samples with aspect ratio is reduced to 23%.

Francesco Miceli et al., (2021) [3] This study presents the results of experiments in which small concrete cylinders covered with carbon fibre FRP (CFRP) liners were tested under different pre-stressing conditions using pure axial compression. The primary purpose of contrasting the stress-strain curves of unloaded, stressed, and pre-stressed specimens is to determine the influence of pre-stress scale on the performance of the CFRP additive. Five test specimens were forced with CFRP without pre-stressing (labelled "P0"), and five of them corresponded to 20%, 50%, and 80% of the applied compressive strength of specimens. The variation had little effect on the ultimate axial strain until the pre-stress scale was restricted to 50% of the maximum load. The initial axial stiffness in this case appeared to be lower than that of normal concrete. Therefore, axial, and radial stiffness should be considered for high loads.

Wisam A. Aules, Saad M.Raoof (2021) [4] The confinement efficiency of square cross-section concrete members reinforced with CFRP was the subject of experimental investigation. To reduce the uncertainty of the outcomes, in each case, two similar samples were tested.. The compressive strength was significantly improved by adding one more CFRP layer. Stronger samples were more likely to deform axially and laterally than unreinforced samples. Squares with rounded edges had the greatest capacity for both axial and lateral deformation for various reshaping methods.

I.A. Tijani, A.M et.al (2020) [5] The load eccentricity characteristics of glass fiber reinforced prestressed concrete were analyzed. In this study, 72 short concrete cylinders were cast and eccentric compression tests were performed with a wide range of load eccentricities to achieve similar His FRP containment stiffness. From this study, we concluded the mechanical behavior due to eccentric loading of CFRP-encapsulated prestressed specimens. In her research, a new model was developed to efficiently analyze the mechanical effects of eccentrically loaded samples. The model developed is technically suitable for considering the degree of damage. Their model analysis showed that the cross-sectional stress-strain curves exhibited a hardening effect due to unbalanced loading of FRP limiting pre-stress specimens.

Gao Ma et al., (2020) [6]. The purpose of this research is to utilize FRP to correct marred plain concrete columns by not using epoxy injection. Materials like synthetic glass as well as carbon fibre reinforced polymer composite (FRP) have become more common in concrete structures in recent years. The influence of pre-damage over the strength of BFRP modified concrete in repetitive and cyclic compressive loads was investigated in experiments. Based on the most recent test results and information gathered from the literature, a repetitive compressive stress-strain model, a modified model of strength, and an ultimate stress model for BFRP modified concrete were developed. Furthermore, these models took into account the negative effects of previous concrete damage.

J. Y. Zhu et al., (2020) [7]. Cladding and wrapping concrete columns with FRP has become a popular and efficient method of increasing compressive strength and ductility. There were 12 FRP open CSCs and 8 FRP among the 16 small specimens forming a systematic test programme for the axially loaded behaviour of FRP open concrete in CSC. There was an unconstrained CSC and two FRP unconstrained squares of concrete. The size effect of FRP-bonded square concrete columns is also greatly reduced if the square cross-section is curved.SC, the square concrete columns would have had a significant impact on size. SC, on the other hand, was less effective.

Lei-Ming Wang, Yu-Fei Wu et al., (2020) [8] Externally bonded FRP composites have seen increased use in the rebuilding process of structures in recent years. Because of common benefits like high strength-to-weight ratio and very good resistance to corrosion, they are popular. Although the corner radii differ, the grade of concrete and thickness of the shell remain the same. The radii are 0, 15, 30, represents a square (sharp corner) pillar and 75 represents a round pillar. However, for columns with a high ratio of corner radii, increasing the upper limit may not help.

Jun-Jie Zeng et al., (2020) [9] Seawater Sea Sand Concrete (SSC) has become a popular substitute to conventional concrete due to non-renewable resource usage and overexploitation. In this article, we conduct an experimental investigation of the confinement mechanism and axial compression behaviour of square SSC pillars encapsulated in CFRP or PET-FRP jackets. Each column sample had a cross sectional area of 150mm x 150mm with a height of 300mm. The parameters investigated were the layers of the FRP sheath (1, 2, or 3 layers), the various types of FRP composites (PET-FRP and CFRP), and distinct water mixtures used in the SSC construction. Compressive stress-strain curves in prismatic section show softening and strain hardening stages due to high elongation and low elastic modulus of the jacket for PET-FRP wrapped SSC.

Vui Van Cao 2020 [10] A study of the consequence of pre-stress on the FRP properties restrained specimens was carried out. In this study, three samples were cast and compressive strength tests were conducted on samples. They applied preloads of 20%, 30%, and 40% of the average intensity of these samples. All samples were tested under axial compression to failure. Specimens wrapped in FRP have been found to be susceptible to blast damage. From this, we conclude that the elastic stiffness of cylindrical specimens decreases when concrete cylinders are pre-stressed with 20%, 30% and 40% and wrapped with 2 and 3 layers of FRP. It is necessary to suppress the decrease in rigidity by adding up to of FRP layers. This study describes the mechanism of the bias effect. Finally, they corrected the model with preloaded.

Faiz Uddin et al., (2019) [11]. Fibre-reinforced polymer (FRP) is frequently utilized in the construction industry for strengthening and repairing RC structures. This paper presents the findings of a large-scale experiment in which 18 RC square columns were subjected to increasing eccentricities under 3 point bending with pin-pin end conditions, in compression to pure flexure. The 1, 2, and 3 CFRP layers' volumetric ratios are, according to the proposed CFRP volumetric ratio, 0.3, 0.6, and 0.9%, respectively. Except for e = 35 mm, where a minute decrease is noticed, an rising pattern of load carrying capacities is seen with a rise in CFRP volumetric ratios. CFRP volumetric ratios show a steady trend at e = 35 mm and an expanding trend at e = 50 mm. The pattern is decreasing at 25 mm eccentricity.

Anh Duc Mai et al., (2018) [12]. This study investigates the experimental performance of concentric as well as eccentric axial loads, four-point bending loading, and alternating CFRP-wrapped square and round square shaped RC columns. For this study, 12 RC specimens were created and tested, 8 square and 4 circular. The cross sectional area of the square shaped RC specimens was 150 mm x 150 mm with a height of 800 mm. Periodic wrapping with CFRP improved the strength of square-shaped RC specimens under concentric, 15 mm and 25 mm eccentric axial loading. As a result, the ductile property of the square column improved significantly.

Marco Filippo Ferrotto et al., (2017) [13]. The goal of this experimental investigation is to assess the deflection and strength potential of retention in circular specimens exposed to various levels of preload. In two separate FRP strengthening configurations, Type A and B cylinders were reinforced with two as well as three Cfrp laminates, respectively. With short-term pre-stressing forces, the axial load and tensile strength of circular columns reinforced with CFRP plate were investigated. When designing, you must take care of an adequate mechanical restraint ratio so that the stress-strain curves do not soften.

J. Raja Murugadoss, **et al., (2015) [14].** The feasibility and economic benefits of strengthening RC columns with CFRP composite strips were investigated. The parameters used were the total amount of FRP layers and the effective distance between the CFRP strips. After it was installed on the supports, the centre line of the column was carefully aligned with the axis of the machine. The initial crack occurred close by the supports at 50% of the maximum load. As the load increased, the cracks became larger and newly developed compression cracks were visible on the four edges of the column. Finally, cracking of the specimen at the supports indicates that the column has yielded resulting in crushing of the concrete. Moreover, this method of CFRP strip strengthening offers a fix that is 0 percent cheaper compared to fully wrapping the column.

Riad Benzaid and Habib-Abdelhak Mesbah (2013) [15]. In most cases, it is recommended to use a square column with rounded corners to make the FRP barrier work better. The desired free concrete strength range (26, 50 and 62 MPa) was achieved with three concrete mixes. The concrete blocks were cast with mixtures prepared in the laboratory, which, after drying with a mechanical mixer, were covered with CFRP sheets. The value of compressive strength of a closed column rises with the number of CFRP sheets, but more slowly than its deformation capacity. CFRP-enhanced specimens exhibited a typical transition zone and bilinear trend. Typically, the maximum compressive strength along with elongation is unvarying, but their exact values can change depending on how other parameters affect them.

A. Mukherjee et al., (2002) [16]. GRP wrapping is less effective on columns with non-circular cross-sections or columns with off-centre loads. In this paper, we investigate these complex effects on the mechanical behaviour of GRP encapsulation columns. Experiments investigated the outcomes of geometrical along with loading errors on columns of differing shapes. The specimens in this set had rectangular, square, and circular cross-sections. The same amount of clipping was applied to each column for meaningful comparison. The effective length aspect ratio to the minimum radius of rotation served as a guideline in choosing dimensions for struts with different cross-sections. Non-circular columns loaded concentrically will fail at corners. At a corner radius of 15 mm, the hoop stress concentration in FRP is determined to be insignificant.

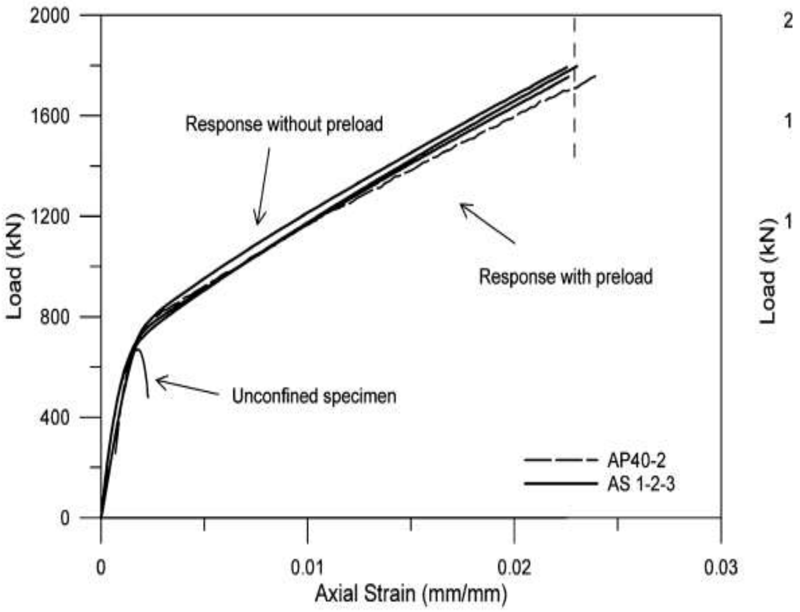
3. Effect of Preload on Capacity to carry axial loads:

An analysis of the related articles demonstrates unequivocally that the obtained outcomes regarding the impact of preload on the stress-strain behavior of Fiber wrapped concrete differ significantly. Some investigators claim that preloading has no influence on stress-strain behavior, while others claim that it has a critical impact on the mechanical strength along with the ultimate strain of FRP-confined concrete. A few investigators have discovered that preloading escalates the axial resistance.

Table 3.1 Preload effect on capacity to carry axial load:

Author	Size Of Specimen	Compressive Strength Of Concrete Fcm (Mpa)	Axial Load(P) Kn	Preloaded	Preload%	Without Preload Fcu (MPA)
Marco Filippo Ferrotto (2017)	150 X 600	38.13	1756..96 1789.95 1641.54	15.252 22.87 30.504	40% 60% 80%	99.42 101.29 92.89
		41.70	1365.62 1433.69 1492.68	22.93 29.19 37.53	55% 70% 90%	77.28 81.29 84.44
Hadi Ziaadiny (2020)	150 X 300	18.5	1500	0 11.09 13.87 16.70	0% 60% 75% 90%	46.10 50.08 53.1 43.79
		17.05	1500	0 10.22 12.78 15.33	0% 60% 75% 90%	61.37 62.21 63.37 57.60
		23.22	1500	0 14.39 17.18	0% 60% 75%	73.718 80.098 80.85

				20.89	90%	79.22



4. Effect of preload by number of layers of CFRP:

The axial loading of the confined sample with preload rises with the amount of layers of CFRP on the samples. Even when the preload value is not applied, the axial compressive load of the sample is raised, when the number of layers of CFRP is raised.

Table 4.1 Comparison of axial load by number of layers:

Author	**Size Of Specimen**	**Compressive Strength Of Concrete Fcm (Mpa)**	**No Of Layers**
Marco Filippo Ferrotto (2017)	150 X 600	38.13	3
		41.70	3

Hadi Ziauddin (2020)	150 X 300	18.5	1
		17.05	2
		23.22	2

5. Effect of preload on stress strain curves

Comparing the stress- strain graphs of samples without preload and samples subjected to preload, it is inferred that the stress-strain values found to be increasing when the preload values of the confined sample increases.

Fig 5.1 Stress-strain curves for with and without preloaded:

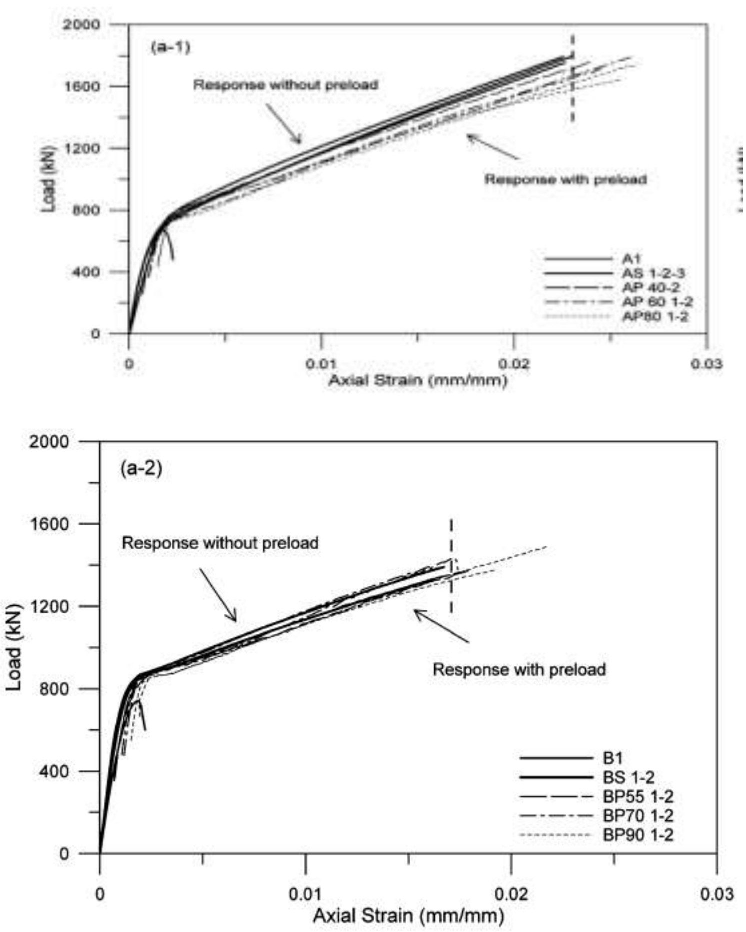
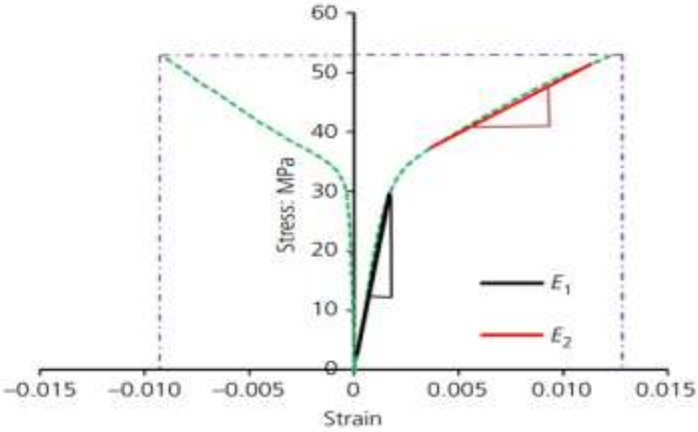


Fig 5.2 Initial slope of non-linear part of the stress–strain curve (E1) and the slope of the linear second portion of the curve (E2)

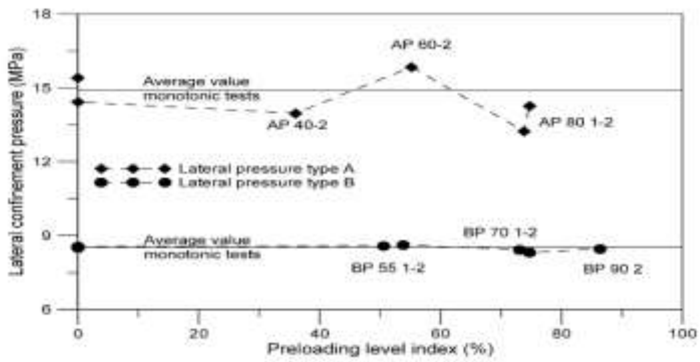


6. Influence of preload on lateral constraining pressure

Depending upon the various research works done on CFRP confinement, it is inferred that when the preload value increases, the lateral confining pressure also increases.

Table 6.1 Preload effect on lateral confining pressure:

AUTHOR	SIZE OF SPECIMEN	LATERAL PRESSURE(MPA)	PRELOAD %
Marco Filippo Ferrotto (2017)	150 X 600	13.962	40%
		15.844	60%
		13.238	80%
		8.578	55%
		8.314	70%
		8.456	90%



7. Conclusions:

After reviewing several researches and studies, it can be concluded that:

• A stress-strain model for preloaded concrete with FRP.

• When compared to unconfined concrete cylinders, the specimens wrapped in FRP materials have significantly higher strain and strength capacities.

• The type of FRPC wraps, the strength of the unwrapped concrete, and the number of reinforcement layers all plays a role in the improvement in stress and strain.

• It is essential to maintain a minimum corner radius for noncircular columns. The minimum required corner radius has been determined through a study using finite elements.

• At the beginning of the strength curve, efficient confinement of columns with sharp corners is inadequate to improve the column strength.

• On the other hand, once the peak load begins, this confinement gets big enough to make the columns more ductile.

• For the CFRP-confined specimen, the lateral confining pressure rises in tandem with the preload value.

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