REVIEW ON STRENGTHENING OF RC SQUARE COLUMNS USING FRP SHEET WITH DIFFERENT CONFIGURATIONS

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Abstract* — This paper presents a literature review related to role of Fibre reinforced polymer (FRP) reinforcement in RC Square Columns. Several investigators carried out experimental and theoretical investigations on concrete columns retrofitted with various fibre reinforced polymer (CFRP, GFRP, etc.) composites in order to study their effectiveness. Many practical applications worldwide now confirm that the technique of bonding FRP laminates or fabric to external surfaces is a technically sound and practically efficient method of strengthening and upgrading of reinforced concrete load-bearing members that are structurally inadequate, damaged or deteriorated. This paper reviews some articles on strengthening and rehabilitation of reinforced concrete (RC) columns using FRP plates or sheet. This paper reviews the different properties of Carbon Fiber Reinforced Polymer (CFRP) and Glass fiber reinforced polymer (GFRP) composites and epoxy resin, effect of sizes of columns and loading rate beginning failure. This paper presents review on effect of different parameter such as different configuration, number of layers of FRP sheet, dimension of structure, type of FRP sheet, etc. on the manners of RC column. The paper suggests an improved retrofitting or strengthening technique for compression members.

***Keywords* — CFRP, Column strengthening, RC Column, Retrofit methods, FRP strengthening.**

I. INTRODUCTION

FRP composite materials are comprised of high strength continuous fibers, such as glass, carbon, or steel wires, embedded in a polymer matrix. The fibers provide the main reinforcing elements while the polymer matrix (epoxy resins) acts as a binder, protects the fibers, and transfers loads to and between the fibers. A key factor driving the increased applications of composites over the recent years is the development of new advanced forms of FRP materials. Due to these advantageous characteristics, FRP composites have been included in new construction and rehabilitation of structures through its use as reinforcement in concrete, bridge decks, modular structures, formwork, and external reinforcement for strengthening and seismic upgrade.

The main advantages of FRP fabrics, sheets are their high strength to weight ratio and high corrosion resistance. The former property leads to great ease in site handling, reducing labor cost and interruptions to existing services, while latter ensures durable performance. FRP plates are normally at least twice but can be over 10 times as strong as steel plates, while their weight is only 20% of that of steel. FRP composites used in aerospace industry for many years and their superior properties are well known. The limited use of FRP in civil engineering applications is due to their high cost. However, their prices are coming down rapidly, enabling their wider use in civil engineering. For application in the strengthening of structures, the material cost is only one aspect and may be a small portion of the total cost involved including labor cost, loss due to interruptions to services. FRP composites often provide the most cost effective overall solution to civil engineering applications.

FRP systems have been successfully used to strengthen buildings, bridges (piers and abutment), silos, tunnels, underground pipes and tank. The higher cost of FRP materials is offset by reduced costs of labour, use of equipment, and downtime during installation, making them more cost-effective than traditional strengthening techniques. There are different types of FRPs are available in industry amongst which mainly using in strengthening are Glass Fiber(GFRP), Kevlar Fiber (KFRP), Carbon Fiber(CFRP) and Aramid Fiber(AFRP).

II. LITERATURE REVIEW

M.N.S. Hadi et al. (2007) [1] experimented on the behavior of FRP strengthened concrete columns under eccentric compression loading. Columns externally wrapped with two types of materials with eccentrically loaded. All cylindrical plain columns were casted and tested. 3 cylindrical columns were wrapped with GFRP and the other half with CFRP. All columns were tested by applying an axial load at 50 mm eccentricity. All specimens were horizontally wrapped with three Layers of material (GFRP or CFRP). To serve as a reference column a steel reinforced column was also casted and tested. Result showed that Considerable gain in strength and ductility were obtained when reinforcing the columns with CFRP wrapped. The CFRP columns performed better than both the GFRP and the steel reinforced columns. GFRP wrapped columns performed better than the reference columns.

Hossam Z El-Karmoty et al. (2012) [2] experimented on the behaviour of cylindrical concrete specimens reinforced by external wrappings made of unidirectional CFRP and bidirectional GFRP layers. The column specimens were subjected to a new uni-axial compression technique, consisting in sequential loading of the same sample, with the first load step terminated prior to failure of the column. They examined four types of jacketed specimens by glass fiber (GFRP), and one by carbon fiber (CFRP) composites. They concluded that CFRP reinforced columns obtains a significant increase in ultimate compression stress compared to the GFRP reinforced columns. Compressive strength and ductility were increased in FRP wrapped concrete cylinders. The failure in the GFRP reinforced samples were ductile, opposite of the brittle one showed by CFRP.They also concluded use of E glass fabric provides a significant enhancement both in terms of radial deformation and compressive strength, with an interesting cost benefit compared to classical applications.

M. Yaqub et al. (2011) [3] experimented the performance on the of post-heated reinforced concrete square columns repaired with unidirectional fiber reinforced polymers (FRP). Specimens were divided into three groups: post-heated columns, unheated columns, and post-heated columns wrapped with a single layer of unidirectional glass or carbon fiber reinforced polymer jackets. All columns were tested under axial compression. Result showed that the ultimate strength, ductility and the ultimate strain were enhanced by a single layer of glass or carbon fiber reinforced polymer. Strength and ductility of the post-heated square concrete columns under axial loading were increased by the glass and carbon fiber reinforced polymer jackets. The stiffness of post-heated columns not improves by using a single layer of GFRP or CFRP jacket. They found that the strength of the square and circular columns was reduced by 44% and 42% respectively after heating to a uniform temperature of 500 C.

C.G. Bailey (2012) et al. [4] experimented on the seismic performance of post-heated circular reinforced concrete columns wrapped with glass or carbon fiber reinforced polymer jackets. Total shear critical reinforced circular columns were tested in three groups, post-heated, unheated, and post-heated repaired with either glass fiber reinforced polymer or carbon fiber reinforced polymer. As a Result, Shear capacity, ductility and energy dissipation of the post-heated damaged columns were increased significantly using GFRP or CFRP jackets. Stiffness of the post-heated damaged columns was not increased by GFRP or CFRP. The mode of failure of posted-heated columns repaired with GFRP or CFRP was successfully shifted from a shear to a ductile flexural failure. They found that the axial load carrying capacity of square columns after exposure to 500C was reduced by up to 44% and glass and carbon fiber jackets failed at the corners of the square cross-section of post-heated columns, due to the stress concentration in these regions.

K. Galal (2005) et al. [5] found on the performance enhancement of short reinforced concrete column with high and low transverse steel content when retrofitted using fiber reinforced composites. K.galal designed using current as well as old codes and tested 7 reinforced concrete short columns constant axial load and under lateral cyclic loading . Short columns were strengthened by Carbon or glass fiber-reinforced polymers. They concluded that Short columns suffered brittle shear failures even ones designed according to current codes. Shear force and energy dissipation capacities were increased of short column subjected to lateral cyclic displacements. They showed result, Strains in both the transverse steel ties and fiber materials decreased with increasing the number of FRP layers in short column. Shear force and the energy dissipating capacity of RC short columns were increased Using anchored carbon fiber (CFRP) sheets rather than anchored glass fiber (GFRP) sheets for strengthening. They found that increasing the number of FRP layers in short column strengthening decreases the strains in both the transverse steel ties and fiber materials.

M. Yaqub, C.G. Bailey (2011) et al. [6] experimented on the cross sectional shape on the strength and ductility of post-heated reinforced concrete columns wrapped with unidirectional fiber reinforced polymer (FRP). Total columns under axial compression. Cross sectional shape of the columns, the presence of heat damage and the type of FRP used for repair were the main variables of investigation. Three groups of columns were defined as post-heated columns, columns without being subjected to heat and post heated and repaired columns. They found, Column's original cross sectional shape significantly affected the load carrying capacity of post-heated FRP wrapped columns. After heating to a uniform temperature of 500˚ C the strength of the square and circular columns was reduced by 44% and 42% respectively. Maximum strength and ductility of both post-heated square and circular columns was increased significantly by wrapping with a single layer of GFRP or CFRP jackets. They found that axial strength and ductility were increased more efficiently in the post-heated circular cross section wrapped with GFRP or CFRP jackets then square cross section. The compressive strength of fire damaged square and circular columns was improved effectively with The GFRP or CFRP wraps.

Abdeldjelil Belarbi (2006) et al. [7] experimented on the effects of various environmental conditions on the long-term behaviour of reinforced concrete (RC) columns strengthened with CFRP and GFRP sheets. Total 33 RC columns were casted in the laboratory and conditioned under accelerated environmental cycling and accelerated Corrosion process of reinforcing bars. To evaluate the change of mechanical properties of the test columns due to the environmental effects uni-axial compressive failure tests were conducted. They found that Due to the environmental conditioning and the corrosion of steel reinforcement the mechanical properties of RC column system were altered. In the plastic region of the test columns the freeze–thaw cycles could slightly increase the failure load and axial stiffness. CFRP wrapped RC columns did not show any significant effects of the combined environmental cycles used in this test, whereas GFRP wrapped RC columns were affected. Even after corrosion source was removed it was continued in CFRP wrapped RC columns.

A. Bourouz et al. [8] experimented on the axially loaded short and slender high strength concrete columns confined with carbon fiber-reinforced polymer (CFRP) sheets. They tested total of 48 specimens were loaded to failure in axial compression and investigated in both axial and transverse directions. They showed that the failure of all CFRP wrapped specimens occurred in a sudden and explosive way preceded by typical creeping sounds. Regarding confined square columns, failure initiated at or near a corner, because of the high stress concentration at these locations. Increasing the amount of CFRP sheets produce an increase in the compressive strength of the confined column but with a rate lower compared to that of the deformation capacity. The efficiency of the CFRP confinement is higher for circular than for square sections, as the composite wrap was greatly affected by its premature damage at the sharp column corner. The effect of increasing the strengthened columns slenderness ratio results on overall in small effect on its load carring and deformation capacities.

Marc Quiertant et al. [9] experimented on the performance of eccentrically loaded columns externally strengthened with different carbon fiber-reinforced polymer (CFRP) systems. They Results showed that, when the transverse jacketing had strong enough, it increases the axial stiffness and enhances the compressive capacity of concrete through confinement action. Moreover, he had evidented that the lateral pressure exerted by the straps also provides additional support against buckling of longitudinal rebars. Experimented results presented in this paper showed that a significant improvement of the strength capacity, deformation capacity and ductility of columns could resulted of the CFRP application, but the observed gains strongly depend on the reinforcement systems.

Mohd Zuwairi Samsuddin et al. [10] experimented on the Carbon fiber reinforced polymer (CFRP) had been proven to be effective in increasing the axial strength of concrete columns. However, very limited data on the effects of high humidity on the performance of CFRP strengthened columns. In addition, humidity had direct impact on the strength of concrete material. They found results of an experimented short concrete column strengthened with transverse CFRP wrapping, under various humid conditions. A large series of concrete cylinder to stimulate as concrete column were strengthened and tested at 60%, 70%, 80%, and 90% relative humidity. Specimens were stored for at least three weeks at every specified constant humidity level, then tested under pure axial loads. The axial load and longitudinal deformations of each specimen were measured during the test. Test results suggest that an increase in humidity would lead to a reduction in the axial strength of CFRP strengthened concrete columns. he found number of CFRP layer act as important role in reducing the axial strength when exposed to the humidity where thicker CFRP layer contribute more to strength reduction.

III. CONCLUSIONS FROM LITERATURES

1. With increasing numbers of layers of CFRP sheets, there was increment in strength and ductility.
2. Shear capacity, ductility and energy dissipation of the post-heated damaged columns were increased significantly using GFRP or CFRP jackets.

3. CFRP wrapping increases the axial load carrying capacity by providing addition confinement to the concrete without increasing the original column size.
4. Axial load carrying capacity of confined RC columns increases from rectangular to square to circular shape.
5. The significant increase in the axial strength and ductility can be achieved by wrapping CFRP sheets to RC columns.
6. Short column suffered brittle shear failure even designed according to current codes.
7. Use of CFRP in concrete compression members, produces an increase in strength, but this phenomenon is strongly influenced by the aspect ratio of the cross-section.
8. Maximum strength and ductility of both post-heated square and circular columns was increased significantly by wrapping with a single layer of GFRP or CFRP jackets.
9. The load carrying capacity of the column decreased, with increase in aspect ratio of the cross-section.
10. CFRP confinement was a very good alternative for strengthening of circular and square RC columns.
11. The strength of the square and circular columns was reduced by 44% and 42% respectively after heating to a uniform temperature of 500 C.
12. Increasing the number of FRP layers in short column strengthening decreases the strains in both the transverse steel ties and fiber materials.

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