A Review on Analytical investigations on column confined with FRP sheets &ferrocement

VIJITHA M [1], Dr JAYALEKSHMI R [2]

[1] PG Student, Department of Civil Engineering, NSS College of Engineering, Palakkad, Kerala, India
[2] Professor, Department of Civil Engineering, NSS College of Engineering, Palakkad, Kerala, India

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Abstract - *The aim of providing column confinement is to increasing the load carrying capacity, enhancement of ductility and for seismic up gradation. Ferrocement provides good strength, resistance to impact, resistance to fire, resistance to earthquake and corrosion. The unique properties of FRP composites are high strength, stiffness, large deformation capacity, corrosion resistance. That uniqueness presents an attractive option as an alternative and extremely efficient retrofitting technique. The confinement effectiveness of FRP jackets depends on parameters such as the type of concrete, steel reinforcement, thickness of the FRP jackets and stiffness and loading conditions. This paper presents a review of the technical works done*

***Key Words*: Confinement, Column, Ductility, Ferrocement, Fibre reinforced polymer(FRP), Retrofitting**

1. INTRODUCTION

Civil engineering structures comprises of different structural elements, namely beam, columns, lintel, slab, foundation etc. All elements are equally important in load transfer mechanism. Among this column are the most important structural element in any structure that transfers the entire loads to the foundation. L/D ratio is an important aspect that determines the load carrying capacity of the columns. According to slenderness ratio columns are classified into short and slender (long). The failure of short column is due to crushing where as in long column failure due to combination of crushing as well as buckling. The strengthening of week columns is required to improve the load carrying capacity and ductility. The strengthening can be achieved by external confinement of column. The column confinement can be done by different ways, among this the following strengthening technique are more famous.

1. Confinement with fibre reinforced polymers
2. Confinement with external steel caging techniques
3. Confinement with ferrocement

Both ferrocement and FRP are composite material, its behaviour different from conventional material. The Ferrocement confined columns are useful in the buildings where strengthening of the column is required with enhanced performance. fibre reinforced composite materials consist of fibres of significant strength and stiffness, fibres and matrix maintain their physical and chemical identities, yet their combination performs a function which cannot be be done by each constituent acting singly.

2. LITERATURE REVIEW

Study of column confinement is an emerging field in civil engineering. Many research works are published on column confinement. Some of these main research works are reported in the literature are presented. One of the first major works done in the field of column confinement by **H. Saadatmanesh, M. R. Ehsani, & M. W. Li (1994).** He conducted study on columns in existing structures externally reinforced by means of high-strength fibre composite straps. The straps can be wrapped in a continuous spiral and/or in discontinuous ring. The straps are constructed from high-strength fibres woven to form a flexible fabric like material. The fabrics can be made very thin, resulting in flexibility sufficient for them to be wrapped around circular as well as rectangular columns. For improved structural performance as well as protection against environmental factors, the straps can be impregnated with resin either before or after the wrapping operation. The ends of the straps can be mechanically coupled or they can be epoxy-bonded to the column. From the study it was observed that the strengthening method can be used to increase effectively the strength and ductility of seismically deficient concrete columns.

Katsuki Takiguchi & Abdullah (2000) carried out an experimental study focused on reinforced concrete column strengthened with ferrocement jacket. In five 1:6 scale model square columns were constructed and have been tested under constant axial load while simultaneously being subjected to cyclic lateral load. From the test results its observed that to strengthen reinforced concrete column with inadequate shear resistance ferrocement jacket is effective alternative material.

Abdullah and Katsuki Takiguchi (2003) studied the columns confined with ferrocement and they have used both square and circular columns. Three types of columns have been used for the study under cyclic and compressive loading strengthened with reduced number of layers of wire mesh for the centre portion, was tested to investigate the behaviour and strength of the important practical aspect of strengthening RC column with Ferrocement. Six layers of wire mesh have been used for the confinement with these ferrocement. Three types of failure modes of the strengthened columns have been identified, jacket fractured within plastic hinge region, jacket ruptured due to bearing axial loading after its ends come in contact with the top and bottom stubs, and failure due to fracture of longitudinal reinforcements within the gaps. The important conclusion from this paper is that the Ferrocement column jacketing could be used as an effective strengthening material for column element of building subjected to eccentric loading.

M. Reza Esfahani and M. Reza Kianoush (2005) studied strengthening technique of axially loaded column with FRP wrap. Axial load and displacement of columns were recorded during tests using a displacement control test set up. Test results are compared with the values calculated using CSA (Canadian Standard Association) Code provisions and recent proposed equations. From the result it is inferred that the FRP wrap increases the strength and ductility of circular columns, significantly. According to the test results, the FRP wrap did not increase the strength of square columns with sharp corners. However, the square column with rounded corners exhibited a higher strength and ductility compared to those with sharp corners.

Harajli, M. H. (2006) studied, a comprehensive and yet simple mathematical model developed to produce the stress–strain response of FRP confined concrete column sections and evaluated the effect of FRP confinement on the ultimate axial strength of concrete columns. The developed stress-strain relationship can be employed very efficiently and effectively for analysing the response of FRP confined concrete under different types of load application.

Yousef A. Al-Salloum et al (2007) studied how the radius of the cross-sectional corners (edges) influence the strength of small scale square concrete column specimens confined with FRP composite laminate. The experimental program included testing under pure axial load with two specimens of each group were confined with one layer CFRP, while the other two unconfined were used as control specimens. The results show that smoothening the edges of square cross-section plays an important role in delaying the rupture of the FRP composite at these edges, and radius of the cross-section edges is proportional to confinement efficiency. To predict the strength of FRP-confined square as well as circular sections a modified analytical model is presented.

P. Rathish Kumar et al (2007) conducted an experimental program on RC and Ferrocement jacketed columns subjected to simulated seismic loading by three scale model bridge pier specimens designed as shear deficient specimens, tested under different axial loads, before and after retrofitting with ferrocement jackets. The conclusion of the work is that the external confinement using ferrocement resulted in enhanced stiffness, ductility, and strength and energy dissipation capacity.

Riad Benzaid et al (2008) Studied the behaviour of square concrete column confined with GFRP composite warp. The parameters considered are the number of composite layers and the corner radius for a square shape. From the study it is observed that the number of layers of FRP materials and the corner radius are the major parameters, having a significant influence on the behaviour of specimens. The axial load capacity and ductility of columns is enhanced by Bonding hoop of FRPconfinement. 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.

Venkataraman Nagaradjane et al (2009) proposed a Monte-Carlo simulation based procedure for assessing the reliability of Fibre Reinforced Polymer (FRP) confined reinforced concrete columns. Assessment of reliability provides a quantitative measure of effectiveness of repair. Java based computer program was developed to assess the reliability of circular concrete columns strengthened using FRP composites. The influence of diameter, thickness of wrap, longitudinal steel and elasticity modulus of wrap on reliability was studied. The results indicated that the diameter of column and wrap thickness strongly influenced the reliability of columns. The influence of internal steel reinforcement area and elasticity modulus of Fibre Reinforced Polymer on reliability was very limited. Computationally efficient formulation for estimating reliability was proposed.

Carlos Chastre and Manuel A.G. Silva (2010) conducted experimental study on RC columns confined with CFRP composites, and subjected to axial compression. The influence of several parameters on the mechanical behaviour of the columns is studied by keeping the column height constant and changing other parameters: the type of material (plain or reinforced concrete), the steel ties spacing of the RC columns and the number of CFRP layers and the diameter of the columns. A stress–strain model for CFRP confined concrete is also proposed.

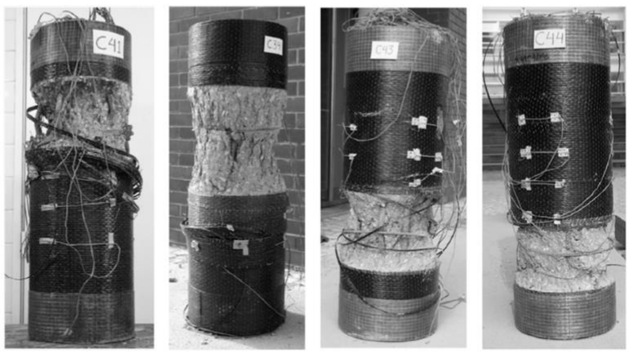

Fig -1 :Rupture aspect of RC columns confined with 1,2,3 and 4 CFRP layers (Carlos Chastre and Manuel A.G. Silva (2010)

Jason Fitzwilliam and Luke A. Bisby (2010) studied the slenderness effect of confined and unconfined column with both axially as well as eccentrically loaded. From the study it is inferred that CFRP wraps increase the strength and deformation capacity of slender columns.by incorporating a FRP confined concrete stress-strain model a theoretical axial flexural interaction diagrams developed using conventional sectional analysis and predicted the effect of slenderness on confined and unconfined columns under eccentric loads.

T. Turgay et al (2010) conducted an experimental study on FRP-confined RC columns under concentric loading and concentrates on the performance of large-scale square/rectangular RC columns wrapped with CFRP. The study reports the results of an experimental research program on the performance of large-scale square RC columns wrapped with carbon fibre reinforced polymer (CFRP) sheets. The study focused on the total effect of longitudinal and transverse reinforcement and FRP jackets on the behaviour of concentrically loaded columns. A stress–strain curves of the columns are predicted by the analytical approach previously proposed for FRP-confined concrete.

Bisby et al (2011) carried out an experimental program to study the effectiveness of FRP confinement for enhancing the strength and axial/lateral stress–strain response of fire-damaged circular concrete columns. Various levels of heat induced damage to the concrete are examined, covering the full range of relevant fire exposure temperatures. The study includes the compressive strength and stress–strain behaviour of both unconfined and FRP confined plain concrete cylinders after being heated to various elevated temperatures for up to four hours and cooled to room temperature. The results show that FRP confinement is highly effective for enhancing the load-carrying capacity of even severely fire-damaged concrete columns. The results show that the mechanics of FRP confinement column of similar composition but with varying compressive strengths. A modified version of a pre-existing confinement model is proposed for use in designing FRP strengthening schemes for fire-damaged concrete columns.

Chaojie Zhou and Huaxin Liu (2011) studied the compression performance of FRP confining concrete square section column under axial loading. For studying the behaviour they experimented on sixteen groups of columns subjected to axial loading. Various design parameters, such as types of FRP, amounts of FRP sheets, width of straps and spacing of straps, have been considered. In this test the strength grade of concrete is C30, sectional dimension is 100mm×100mm, height-to-thick ratio (h/b) is 3. Specimens are divided into sixteen groups; test results take the average of three effective specimens. The conclusion is that all specimens of the axial compressive strength and ductility of concrete prism wrapped by FRP sheets have all increased to a certain degree, the process of destruction of concrete prism wrapped by FRP sheets become slower than common concrete prism. Ferrocement confinement is more effective than FRP confinement due to its increased cross sectional area of wire mesh. The confinement confined specimens showed higher compressive strength, energy absorbing capacity and ductility than BS or FRP strengthened circular columns.

S.M. Mourad and M.J. Shannag (2012) studied the ultimate load capacity of stressed column samples confined with ferrocement, they use welded wire mesh as confing material. The aim of their study was to investigate the overall response of the specimens in terms of load carrying capacity, stress and strain, lateral and axial displacement, and ductility. In case of pre-stressed specimens, the results showed that the confining increased the load carrying capacity to 33%. Ductility of the specimens also increased. In case of stressed samples to a value of 60% and 80% of the ultimate load capacity, the confinement enhanced the ultimate load capacity to 28% and 15% respectively. With the confinement the column specimens failed in a ductile manner as compared to brittle failure of the control specimen.

M. Yaqub et. al (2013) carried out an experimental study to compare the effectiveness of Ferrocement and fibre reinforced polymers (FRPs) jackets for the repair of post-heated square and circular reinforced concrete columns. Glass fibre reinforced polymer (GFRP), carbon fibre reinforced polymer (CFRP) and Ferrocement jackets were used to repair the heated columns. All the columns were tested under axial compression. The test results covering the axial compressive strength, stiffness (secant stiffness), ductility, deformation and energy dissipation for the non-heated and non-repaired, and post-heated and non-repaired columns, were explored and compared with those of the post-heated columns repaired with FRP and Ferrocement jacket. The test results showed that the FRP jackets increased the compressive strength, ductility, deformation ability and energy dissipation capacity of post heated columns but did not increase the stiffness.

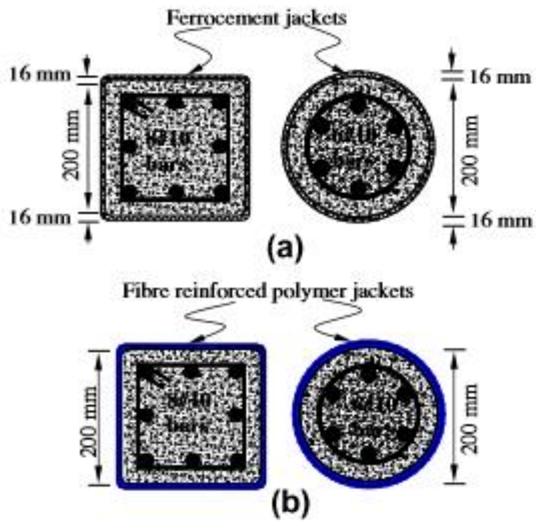

Fig-2. Arrangement of reinforcing bars: (a) ferrocement jacketed columns and (b) FRP jacketed columns (M. Yaqub et. al (2013))

Mohamed A. Tarkhan (2015) conducted an experimental study in which fourteen reinforced concrete (RC) columns were casted, strengthened and tested under concentric loading. The variables considered in this study are the slenderness ratio of column, the pre-loading level of the original column, and the orientation of ferrocement mesh. Initial cracking load, ultimate capacity, and mode of failure were recorded and discussed for different models. It was observed that the ferrocement jacket increases the load capacity and ductility of the columns depending on the parameters.

Md. Mozaffar Masud and Arun Kumar (2016) investigated the effect of confinement using ferrocement as wrapping material on the circular RC columns under concentric loading condition. Based on experimental results it was obtained that one layer of confinement with ferrocement jacket increases load carrying capacity up to 23.8%; while two layers of confinement with ferrocement jacket increases load carrying capacity up to 55.2% with respect to unconfined column specimen.

Hanan Suliman Al-Nimry et al (2017) investigated the effectiveness of using fibre reinforced polymer (FRP) sheets in confining heat-damaged columns. The effects of heating duration, stiffness and thickness of the FRP wrapping sheets were examined. Test results confirmed that elevated temperatures adversely affect the axial load resistance and stiffness of the columns. Full wrapping with FRP sheets increased the axial load capacity and toughness of the damaged columns.

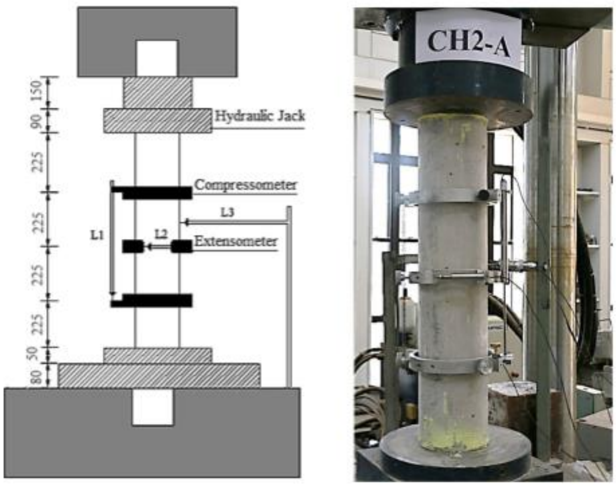

Fig. 3 Test setup (dimensions in mm)(Hanan Suliman Al-Nimry et al (2017))

3. CONCLUSIONS

From the literatures reviewed the following conclusion can be drawn:

- ferrocement confinement Increases strength stiffness, ductility, and energy dissipation capacity
- Externally ferrocement jacketed Columns give better fire resistance, earthquake and corrosion resistance.
- Ferrocement confined columns will have low residual stress concentration, cracking and the durability of the structure can be increased.
- FRP as strengthening and retrofitting material has several advantages over conventional materials. Its thickness is small and hence its application does not add weight to existing structures. It helps to preserve the cultural heritage of monumental structures. It is not corrodible.
- The number of layers of FRP materials and the corner radius are the major parameters, having a significant influence on the behaviour of specimens.
- The FRP jackets increase the ultimate axial compressive strength of post-heated reinforced concrete columns greater compared to the ferrocement jackets but the FRP jackets do not contribute to restoring the stiffness of the post-heated reinforced concrete columns.

From the literatures reviewed, it is understood that not much studies were conducted on the slenderness effect and effectiveness of external confinement The ultimate need of my study is to fill the gap areas noted in the technical papers.

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