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Experimental Investigation on Effectiveness of Ferrocement Jacketing for Retrofitting RC Square Columns

Altrin R¹, Dr.D.Shoba Rajkumar²

P.G Student, Department of Civil Engineering, Government College of Engineering, Salem, Tamilnadu, India¹

Professor and Head, Department of Civil Engineering, Government College of Engineering, Salem, Tamilnadu, India²

ABSTRACT: Repair and strengthening of weak/damaged columns using various jacketing methods is attracting much attention. Due to its efficient cost-performance ratio, ferrocement jacketing is becoming an attractive option of retrofitting. In this study an experimental investigation on the effectiveness of ferrocement jacketing for rehabilitation of RC square columns preloaded with a fraction of its ultimate load carrying capacity has been carried out. The primary variables considered were number of layers of weld mesh. The study was carried out on RC square columns. Total of 3 columns were tested one as control column to find its ultimate load carrying capacity and other two were 85% stressed columns. Columns except control specimens were preloaded to 85% of its ultimate load then wrapped with one and two layers of weld mesh and then retrofitted using ferrocement. It was observed that, the confinement effectiveness and hence load carrying capacity of columns improved with number of layers of weld mesh wrapping and its load deformation behaviour is improved with increase in axial stiffness of retrofitted specimens.

KEYWORDS: Square column, Axially loaded column, Preloading, Retrofitting, Ferrocement jacketing.

I. INTRODUCTION

The column is one of the most important structural elements designed to carry compressive loads and transfer load to the foundation. The behaviour of reinforced concrete column and their failure modes have been extensively studied in structural engineering. Failure of the most important structural element, such as beams and columns, generally leads to a total collapse of the structure. This necessitates the retrofitting of existing structures to meet safety requirements in seismic areas and where the load carrying capacity has to be enhanced. Research works have proved that the strength and deformation of RC columns can be increased through confinement of concrete core by jacketing techniques. There are many alternative techniques to be used in strengthening RC column. But ferrocement jacketing has recently gained attention as an attractive strengthening method, mainly because of its ability to provide desired confinement at reasonable cost. Retrofitting with ferrocement confinement is the oldest and cost effective technique used to strengthen the concrete structures. The unique properties of ferrocement such as fire resistance, durability, low self-weight, waterproof and crack resistant makes it an ideal material for wider applications. Abdullah and Takiguchi [1], investigated an experimental test to study the efficiency of ferrocement confinement for repairing both circular and square R.C. columns under combined axial and lateral loading. Test results proved that applying external wrapped of ferrocement improves the ductility and strength of columns. Kaish et al [2] studied the influence of using ferrocement laminate in wrapping cylindrical plain concrete specimens, subjected to concentric loads. Kaish et al [3], Mourad, and Shannag [4], and Xiong et al [5] reported that confinement R.C columns by ferrocement overlays lead to a significant enhancement in failure loads and improve ductility. El-Kholy and Dahish [6] proposed a method to be used expanded metal mesh as confinement configuration in addition to regular tie reinforcement. Kazemi and Morshed [7] studied experimentally the behaviour of shear deficient of short concrete columns wrapped by ferrocement. The results demonstrated that ferrocement encasement increases both shear strength and ductility capacity. Mini Soman [8], A.B.M.A.kaish[9], and Veena M [10] preloaded and retrofitted using ferrocement shows higher ultimate load carrying capacity. Belal et al [11] and Tarabia and Albakry [12] carried out laboratory programs and numerical analysis to investigate the behaviour of R.C columns strengthened by steel jacket technique. Irshidat [13] studied the effectiveness of utilizing carbon fiber/epoxy composites in strengthening (RC) columns under axial loads. Punurai et al [14] carried out an experimental and numerical investigation on CFRP wrapped RC slender columns under both of axial load and biaxial bending. In the present study a comparison was made between non jacketed and jacketed column in terms of ultimate load carrying capacity, axial stiffness and its result was discussed.

II. OBJECTIVE

The main objective of the present work herein is to evaluate the effectiveness of using ferrocement overlays in strengthening axially loaded RC column.

III. EXPERIMENTAL PROGRAMME

The experimental work was carried out on 3 columns designed to have equal load carrying capacity. Out of three columns one was control column to find its ultimate load carrying capacity and other two columns each with 85% preloading, these 85% preloaded columns were finally retrofitted using ferrocement with single and double layer of weld mesh. The area of cross section, length and area of steel reinforcement were the same for all the columns. The parameters studied were number of weld mesh layers. Preloaded specimens were wrapped with one and two layers of weld mesh and then retrofitted using ferrocement.

3.1. Materials

Fresh Ordinary Portland Cement (OPC) was used for both casting of specimens and for ferrocement mortar. Manufactured sand passing through 4.75 mm sieve and conforming to zone II of IS 383[15] was used as fine aggregate. Specific gravity and fineness modulus of sand was found to be 2.7 and 3.21 respectively. Same type of sand was used for preparing mortar for ferrocement jacketing. 12.5 mm down crushed stones were used as coarse aggregates. Specific gravity and fineness modulus of coarse aggregates were found to be 2.80 and 6.48 respectively. The properties of fine and coarse aggregate conformed to IS 383. Thermo mechanically treated (TMT) steel bars of 8 mm and 6 mm diameters having yield strength of 470 MPa and 445 MPa respectively were used as reinforcement. Longitudinal reinforcement was provided using 8 mm bars and transverse ties using 6 mm bars. Weld mesh with 1.54 mm diameter wires of yield strength 385 N/mm² and opening size 12.5 mm was used as reinforcement for ferrocement jacket.

3.2. Preparation of specimens

Columns were designed for an axial compressive load of 150 KN as per IS 456[16]. The dimension and reinforcement details are shown in Fig - 4. Square columns of 100 mm x 100 mm x 1000 mm were cast with a clear cover of 15 mm with concrete mix of cube compressive strength 30 N/mm². The mix proportion of the design mix was 1: 1.58: 2.79 with water-cement ratio 0.45. Four 8 mm diameter bars were used as longitudinal reinforcement and 6 mm diameter ties at 100 mm spacing was provided as lateral reinforcement. The top and bottom of the longitudinal bars were bent at 90 degree and spacing of lateral ties were reduced at top and bottom ends to enhance confinement pressure and thus prevent early crushing of the ends. Specimens were de-moulded after 24 h of casting and subjected to water curing for 28 days. Details of specimens are given in Table -1.



Fig-1
Column with single layer of
Weld mesh



Fig-2
Column with double layer of
weld mesh



Fig-3
Retrofitted column specimen

3.3. Preloading of column

The columns except control columns were preloaded 85% of its ultimate load carrying capacity which was obtained by testing of control columns up to its failure. 85% preloading was adopted for the study to simulate the real situations where structures are loaded under service conditions and those damaged by catastrophies.

COLUMN ID	AMOUNT OF PRELOADING	NO OF MESH LAYERS
C-1	-	-
C-2	85%	1
C-3	85%	2

Table – 1 Details of RC Square columnSpecimens

3.4. Jacketing of columns

The column specimens were jacketed with ferrocement after 28days of curing and subsequent preloading. The specimens were sand blasted to roughen their surfaces and tightly wrapped with weld mesh having an opening size of 12.5 mm and wire diameter 1.54mm. A thin layer of Epoxy say Bond Tite was applied to ensure proper bond between concrete surface and weld mesh. After three to four hours of application of epoxy resin. A thin layer of cement grout is applied over the weld mesh for effective transfer of stresses between weld mesh and cement mortar, columns were retrofitted using 1:2 mortar of thickness 20mm all around the periphery of the column. The jacketed specimens were again cured for 28 days. Full height jacketing was provided for all the specimens to ensure proper confinement effectiveness.

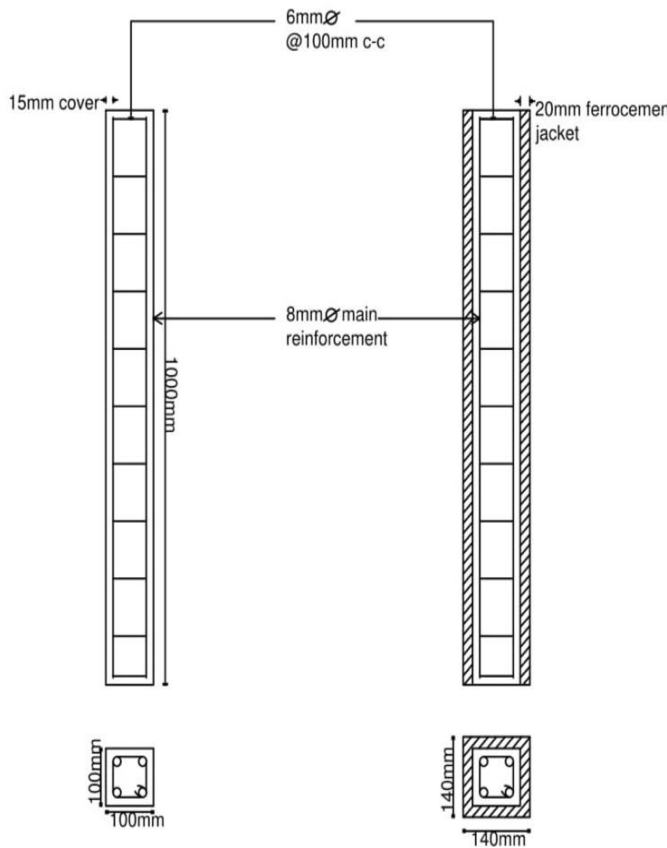


Fig-4 Reinforcement Details

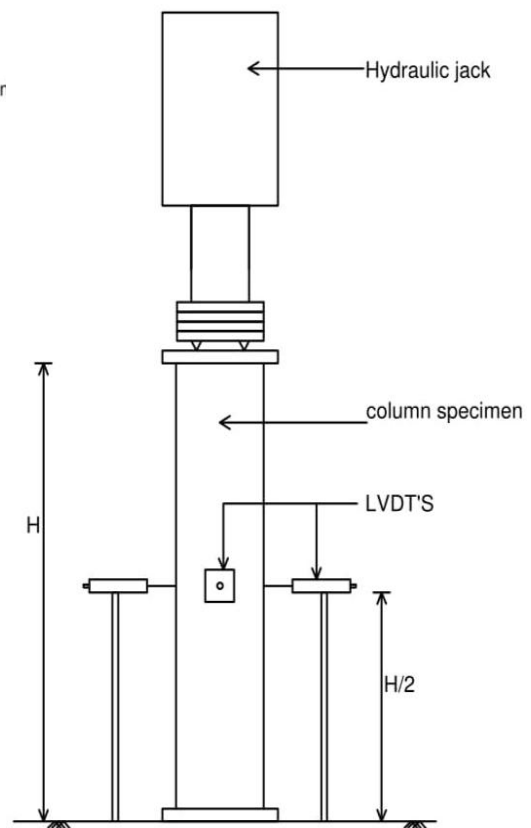


Fig-5 Ferrocement Jacketed of column

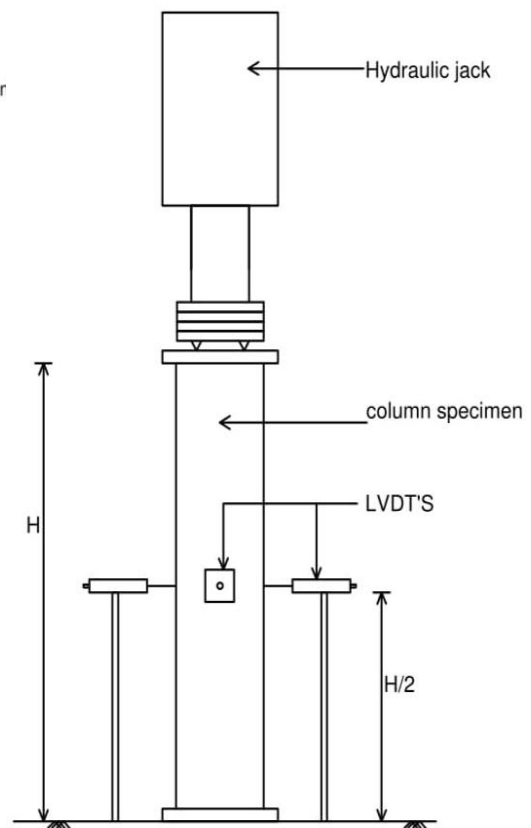


Fig-6 Test setup Column

3.5. Testing of specimens

Control and jacketed columns were tested under axial compressive loading in a 30T hydraulic Actuator. The test set-up is shown in Fig – 6 and 7. Verticality of the column was ensured during the test to obtain a central loading on the column. A thin layer of sand was applied at top and bottom of column. A steel Plates was placed at the top of specimen and initial seating pressure was applied to prevent relative displacement. The load was applied gradually using actuator. The axial displacements were noted using Actuator and four LVDT’s were used to measure deformation / buckling on four sides of the column. Ultimate load, axial deformation and failure modes of specimens were observed.



Fig-7 Test setup and loading condition

IV. RESULTS AND DISCUSSION

The results of the study in terms of ultimate load carrying capacity, axial deformation behaviour, failure patterns and its detailed discussions are given in the following sections.

8.1 Ultimate load carrying capacity

The ultimate load carrying capacity of columns tested is shown in Tables 2. It can be observed that ultimate load of the confined columns increases with number of layers. Square columns jacketed with single layers of weld mesh subjected to 85% preloading gained 13% increase in ultimate load carrying capacity. Whereas square columns subjected to 85% preloading with two layers of meshing improved its load carrying capacity by 20% respectively. Hence it is interesting to note that confinement action increases with number of weld mesh layers during jacketing. So, with increase in no of weld mesh layers around the column ultimate load carrying capacity of the column is improved considerably.

Specimen ID	Amount of preloading	No of mesh layers	Ultimate load (KN)	% Increase in ultimate load
C-1	-	-	160	-
C-2	85%	1	180	13
C-3	85%	2	192	20

Table – 2 Ultimate load of RC Square columns.

8.2 Axial deformation behaviour

Typical load deformation curve for the control and retrofitted specimens are shown in Fig-8. An examination of the load deformation curve shows that retrofitted square columns has reported significant increase in load carrying capacity and has maintained axial stiffness. From the load-deflection curve it can be seen that, the jacketed specimens have higher slope during the initial phases of loading which signifies better axial stiffness for the same. The increase in axial stiffness is a crucial factor which helps in lowering the deflection at yield which in turn has direct effect on the ductile behaviour of the specimens. Thus it can be summarized that the load-displacement response of preloaded columns rehabilitated with ferrocement jacketing, shows better performance than the control column in terms of ultimate load carrying capacity and axial stiffness.

Specimen ID	Amount of preloading	No of mesh layers	Axial Stiffness (KN/mm)	% Increase in Stiffness
C-1	-	-	21.43	-
C-2	85%	1	28.57	33.31
C-3	85%	2	30.24	41.11

Table – 3 Axial Stiffness of RC Square columns.

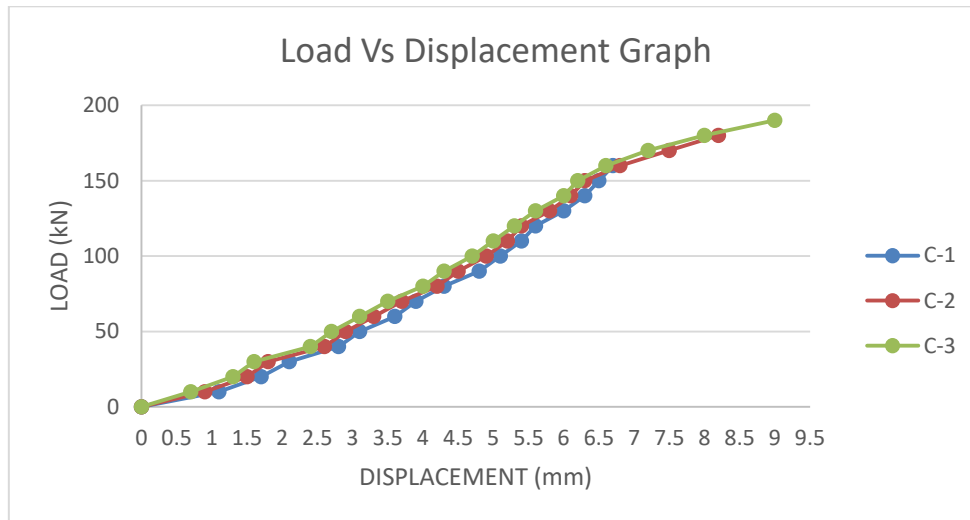


Fig-8 Load vs Displacement graph for column C-1,C-2,C-3

8.3 Failure modes

Samples of specimens after testing are shown in Fig-9. The control specimens without any jacketing showed a sudden failure by bursting of concrete. Longitudinal cracks were developed at top and bottom end of columns before failure in control columns. For jacketed specimens, a ductile failure was observed. In jacketed specimen cracks started from top of the retrofitted column. Crack formation occurs at corners and eventually the mortar cover in that region fell off followed by breakage of weld mesh.



Fig-9 Crack and failure pattern of retrofitted specimen

V. CONCLUSION

From the experimental investigation of small scale ferrocement jacketed RC column under concentric load, the following concluding remarks could be made.

1. Ferrocement jacketing improves the ultimate load carrying capacity and decreases the axial deflection of columns at service load.
2. Confinement effectiveness of ferrocement jacketing is increased with increase in number of mesh layers.
3. Axial stiffness of retrofitted column is improved with increase in number of weld mesh layers.
4. Retrofitted column performed better than control column in terms of ultimate load carrying capacity and axial stiffness.
5. Square columns jacketed with single layers of weld mesh gained 13% increase in ultimate load carrying capacity.
6. Square columns jacketed with double layers of weld mesh gained 20% increase in ultimate load carrying capacity.
7. Retrofitted columns shows a ductile failure where as control column failed in a brittle fashion.

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