BEHAVIOUR OF FERROCEMENT ENCASED SQUARE REINFORCED CONCRETE COLUMN UNDER ECCENTRIC LOADING

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Abstract

This paper investigates the behaviour of ferrocement encased square reinforced concrete (RC) columns subjected to monotonically increasing small eccentric load. Three different types of square jacketing techniques have been studied experimentally to find out the effectiveness of ferrocement confinement of RC columns against eccentric loading. Six scaled down ferrocement jacketed specimens (two from each group) and two non jacketed scaled down specimens (square RC columns) were tested for this purpose. The results obtained from this study show that the benchmark specimens (column without ferrocement encasement) fail with non-ductile mode of failure when the load reaches to its peak value. However, in case of jacketed specimens load carrying capacity and ductility performance are obtained to be more than those obtained from benchmark specimen.

Keywords: Column Jacketing, Ferrocement, Restrengthening, Wire Mesh, Eccentric loading.

1. Introduction

In recent years, strengthening of Reinforced Concrete (RC) elements, such as beams, columns, etc., has been given enormous emphasis, as the failure of such elements could catastrophically fail the entire structure. Collapse of building column leads to total failure of a building, as vertical loads are only transferred through this element to the ground (Kaish and Hasan, 2008). In the past few decades, ferrocement has been used as restrengthening/rehabilitating material for its better crack resisting properties. This material has less fabrication cost and does not need any special fire or corrosion protection. Suitability of both prefabrication and self-help construction makes ferrocement an effectively low cost alternative of steel or FRP confinement.

Many researches have been carried out to find out the effectiveness of ferrocement confinement and ferrocement composite plain and reinforced concrete under concentric compressive loading (Singh et al, 1988; Mansur at el, 1990; Walliuidin et el, 1994; Singh et al, 1997; Seshu et al, 1998; Kondraivendhan at el, 2009; Xiong at el, 2011). Shear capacity of ferrocement confined reinforced concrete column also has been carried out extensively to retrofit shear deficient RC columns (Takiguchi at el, 2000; Takiguchi at el, 2001; Abdullah at el, 2001; Kazemi at el, 2005; Rathish Kumar at el, 2007). Since RC columns are not experienced concentric load practically, and are always carried eccentric load. Therefore, RC columns confined with Ferrocement jacketing under the effect of eccentric loads yet need in-depth investigations.

This paper studies the behavior of ferrocement confined reinforced concrete square short columns under small eccentric loading condition experimentally. Different types of square jacketing technique are taken into account to find out an efficient square ferrocement jacketing in retrofitting of existing building columns for developing countries like Bangladesh.

2. Experimental Investigation

In order to investigate the behaviour of ferrocement confined square RC column, eight square columns (six jacketed columns and two non-jacketed columns (NJ)) were tested under small eccentric compression load until failure. Various jacketing techniques such as; (i) Square jacketing with single layer wire mesh (denoted as SL); (ii) Square jacketing with single layer wire mesh and rounded column corners (denoted as RSL); and (iii) Square jacketing with single layer wire mesh and two extra layers mesh at each corner (denoted as SLTL). All jacketing techniques are shown in Figure 1.

2.1 Materials

In this study, fresh Ordinary Portland cement (OPC) of grade 43 confirming Type I of ASTM C-150 was used for preparing test specimens. Local coarse sand named Sylhet sand with Fineness Modulus (F.M.) and specific gravity of 2.70 and 2.61, respectively, was also used for preparing test specimens. The grading of sand is taken in accordance with the guideline of Table

1, adopted by ASTM C 33. Same type of sand was used in making both RC columns and Ferrocement mortars.

Table 1: Guideline of Grading of Sand

Sieve size, U.S. standard square mesh	*Percent passing by weight*
No. 8 (2.36 mm)	*80-100*
No. 16 (1.18 mm)	*50-85*
No. 30 (0.60 mm)	*25-60*
No. 50 (0.30 mm)	*10-30*
No. 100 (0.15 mm)	*2-10*

12 mm downgraded crushed stone and normal water were used in making concrete. Both the longitudinal and lateral reinforcement used in RC columns are of Grade 60 (414 MPa).

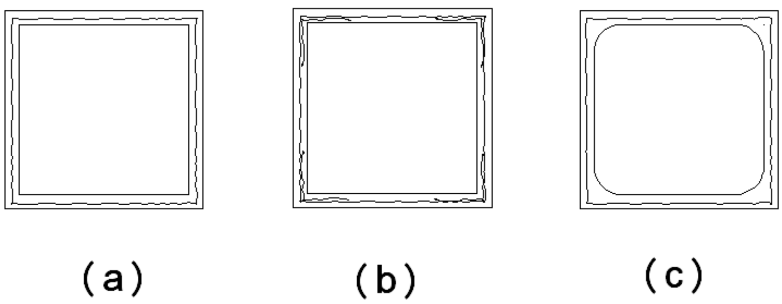

Figure 1: Jacketing schemes, (a) SL, (b) SLTL (c) RSL

2.2 Mixing and Casting of RC columns

In making concrete, mixing ratio was designed for fine to coarse aggregate volume ratio as 0.55, cement content as 360 kg/m^3, air content as 2% and water to binder ratio as 0.45. Both fine and coarse aggregate were taken saturated and surface dry before mixing. Target strength was fixed as 24 MPa, which was confirmed by 28 days cylinder strength test.

The column specimen size was taken as 600 mm long and cross section of 100X100 mm^2 with 4 no. ϕ8mm (dia.) deformed longitudinal reinforcements. ϕ5mm (dia.) seismic tie bar spaced at 100 mm in middle and 50 mm at top-bottom was placed in all column specimens. Two steel plates of 3 mm thick were welded with longitudinal reinforcement at both ends of the specimens. Geometric and material details of both benchmark and jacketed column specimens are shown in Figure 2. Column specimens were cast on steel mould. Concrete was mixed by manually. Cement and aggregates were mixed first thoroughly in dry state, and then water was added and mixed until a uniform mix was obtained. Workability of concrete was checked by slump test. Column specimens were then cast and it was de-moulded after 24 hours of casting. Thereafter, specimens were cured continuously under water for 28 days.

2.3 Ferrocement jacketing of RC columns

Ferrocement encasements of RC columns were done after 7 days of casting. Jacketing thickness was kept 12mm for all specimens, therefore, final size of jacketed specimens was 124mm. Wire mesh used in this study was 20 BWG (British Standard Wire Gauge) woven GI (Galvanized Iron) wire mesh of 12mm square opening. Required size of wire mesh was cut first and then wrapped around the columns with an overlapping of 75 mm in the lateral direction. Thereafter, all the specimens were plastered with rich mix mortar of mixing ratio of 1:2 (cement: sand) by weight. Wire mesh was kept at the middle of jacketed layer with a covering of 6 mm in both exterior and interface surfaces. A gap of 3 mm was kept at both the top and bottom of the specimen to avoid direct compression on the ferrocement jacket.

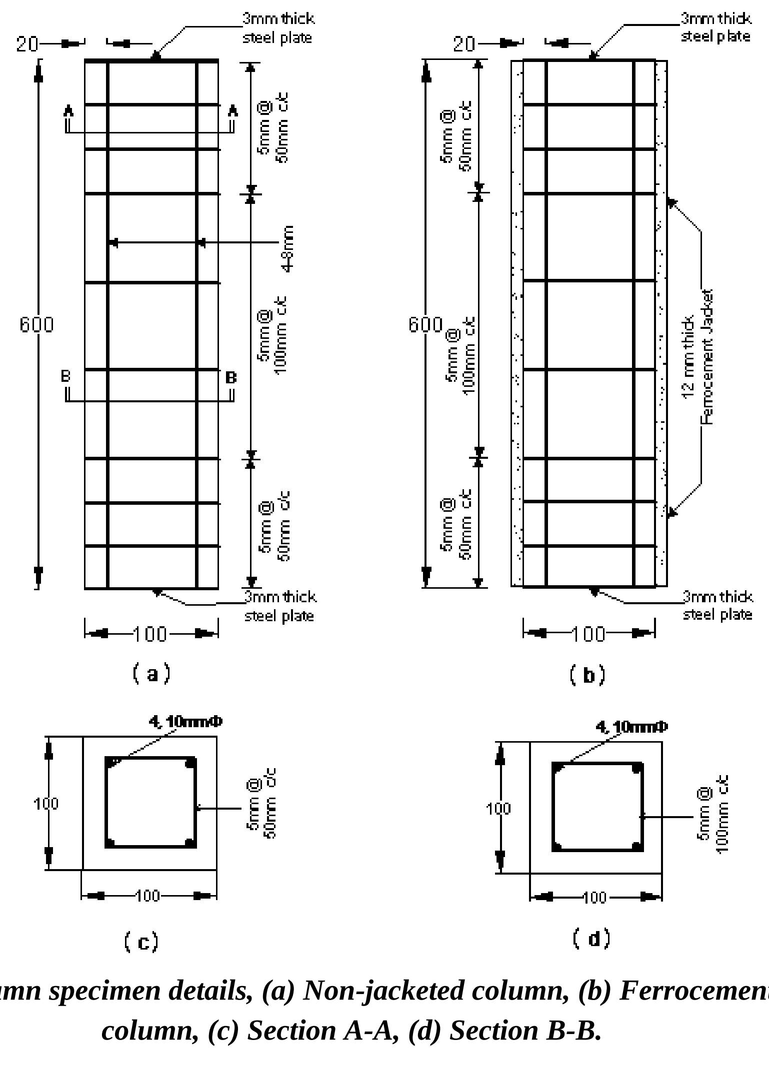

Figure 2: Column specimen details, (a) Non-jacketed column, (b) Ferrocement jacketed column, (c) Section A-A, (d) Section B-B.

After completing ferrocement jacketing, all columns were cured in the water for 28 day from the date of casting.

2.4 Testing procedure and instrumentation

After ending curing period of all cast specimens, specimens were kept in dry place for few hours for attaining surface dry condition. Thereafter, test was carried out in a hydraulic compression testing machine of capacity 2000 kN. All columns are tested under monotonically increasing small eccentric load applied at the top of the specimen until failure. Eccentricity of loading in this study was kept constant for both the benchmark and the jacketed specimens and it was taken as 25mm from the centre point of the specimen. Both axial and lateral deflections were measured using dial gauges within the accuracy of 0.0001 inch (0.00254 mm). Test set up and the positions of dial gauges are shown in Figure 3.

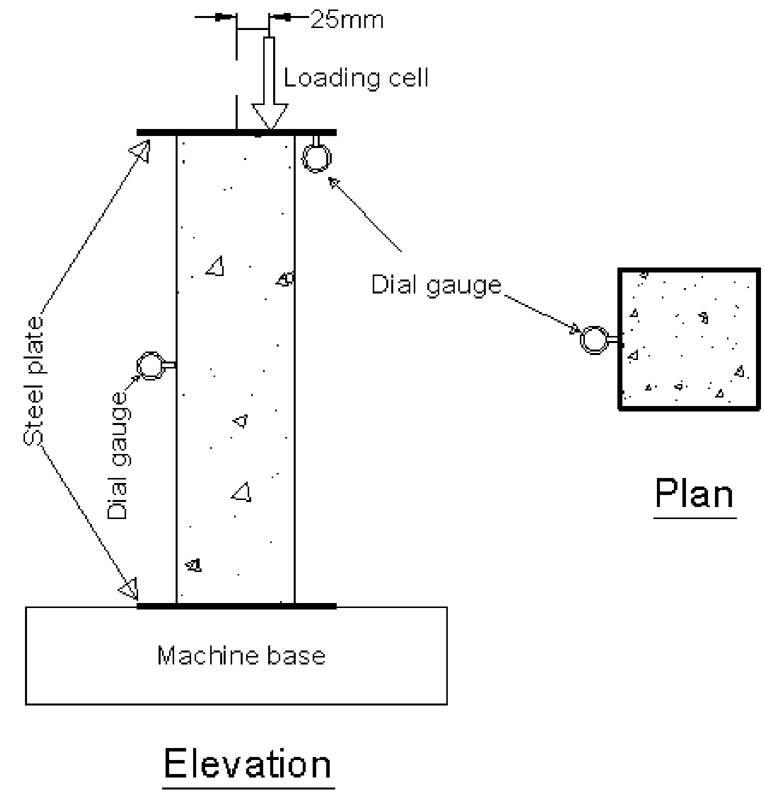

Figure 3: Test setup and Dial gauge position.

3. Experimental Results and discussion

The results obtained from the test carried out on both non-jacketed and jacketed column specimens are discussed in the subsequent sections.

3.1 Effects on ultimate load

The average ultimate load carrying capacities of tested specimens are given in Table 2. It is seen that the load carrying capacity of jacketed specimens is higher than those obtained from benchmark specimens. The increased magnitudes of loading are obtained as 30.91%, 47.76%

and 33.35% for SL, RSL and SLTL type specimens, respectively. Strong crack arresting properties of ferrocement could be the reason for resisting higher load. From Table 2 It is seen that SL and SLTL type specimens fail almost the same load though SLTL type carries two extra layers wire mesh at all corners. RSL type specimen fails in higher load than the SL and SLTL type specimens.

Table 2: Average ultimate load carrying capacity of tested specimens

Sl No.	*Specimen Type*	*Ultimate load of encased specimens (kN)*	*Difference of loading (%)*
1	*NJ*	*246.85*	*0*
2	*SL*	*323.15*	*30.91*
3	*RSL*	*364.75*	*47.76*
4	*SLTL*	*329.17*	*33.35*

3.2 Effects on deflections

Vertical and lateral deflections of both jacketed and non jacketed specimens are given in Table 3. It is seen that the vertical and lateral deflections of SL, RSL, SLTL type specimens are more than those obtained in non jacketing type specimens. The increased magnitudes of vertical and lateral deflections for SL, RSL, SLTL type specimens are obtained as 44.41%, 83.68%, 67.37% and 23.57%, 80.71%, 65.71%, respectively, over NJ type specimen.

Table 3: Average ultimate vertical and lateral deflection of tested specimens

Sl No.	*Specimen Type*	*Ultimate vertical deflection of encased specimens (mm)*	*(%) increment in vertical deflection*	*Ultimate lateral deflection of encased specimens (mm)*	*(%) increment lateral deflection*
1	*NJ*	*3.31*	*0*	*1.40*	*0*
2	*SL*	*4.78*	*44.41*	*1.73*	*23.57*
3	*RSL*	*6.08*	*83.68*	*2.53*	*80.71*
4	*SLTL*	*5.54*	*67.37*	*2.32*	*65.71*

Figure 4 shows typical load-deflection diagram of tested both type of specimens. It is observed from this figure that all the ferrocement encased specimens resist higher ultimate load and ultimate deflection than the Benchmark (non-jacketed) specimen.

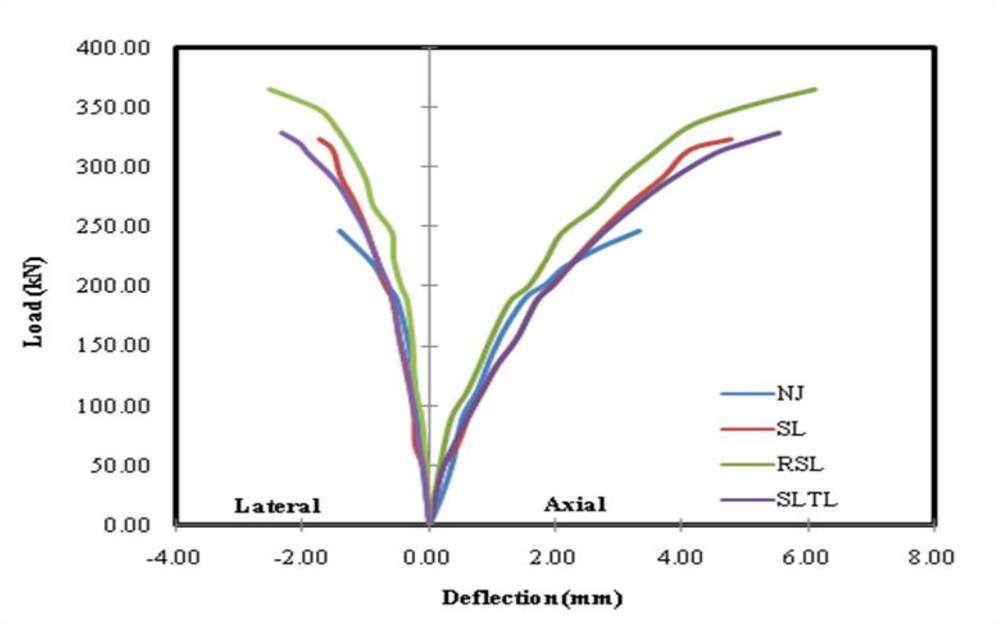

Figure 4: Typical Load-Deflection Curve.

3.3 Effects on Failure Pattern

Figure 5 shows failure patterns of tested jacketed and non jacketed column specimens. It is seen that non-jacketed column starts to fail by crushing of concrete at the point of application of load, whereas jacketed column starts to fail from ferrocement encasement.

Figure 5: Typical failure pattern of tested specimens.

Ferrocement jacket separation was also observed in SL and SLTL type specimens. In case of RSL type specimen, no jacket separation was found. More cracks were appeared in RSL type specimens than SL and SLTL type specimens, which indicate that RSL type jacketing is more ductile than SL and SLTL type specimens.

4. Conclusion

From the experimental observation of ferrocement jacketed RC column under eccentric load, the following concluding remarks could be drawn:

1. Ferrocement jacketing could be used an effective re-strengthening material for column element of building subjected to eccentric loading.

2. Confinement with the ferrocement encasement improves the ultimate load carrying capacity and increases the axial and lateral deflection of RC column.

3. Type SL and type SLTL encasements show almost same ultimate load carrying capacity. However, type SLTL encasement gives higher ultimate deflections than type SL encasement.

4. Type RSL encasement shows higher load carrying capacity as well as ductile properties over all types of jacketing specimens as well as non jacketed specimens.

5. Failure pattern also shows that RSL type encasement is more ductile than other types.

This investigation is based only for few specimens testing. It is noteworthy to mention that more experimental study based on large number of specimen testing is required to justify the practical application of all these types of ferrocement encasements for eccentrically loaded columns.

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