Effect of Mild Steel Strip Confinement on Ductility Ratio of RC columns

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Abstract: Strength and ductility of reinforced cement concrete columns can be improved by providing proper confinement. This can be accomplished by increasing the number of ties, by increasing the size of ties, by increasing the yield strength of ties, properly arranging main bars around the column periphery, decreasing the spacing between ties and using welded wire fabric etc. In this work strips were employed as confinement. In this paper the test results of two 150x150x600mm RC columns have been discussed. One column was confined with stirrups and other was confined with strips of same cross-section sectional area as for standard round stirrups. The columns were tested under cyclic axial load. Hysterises loops and backbone stress strain curves were drawn. Test results show that ductility ratio of strip confined columns were improved by 52.34% respectively as compared to stirrup confined columns.

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1 Introduction

Improvement in confinement of concrete is significant in preparing earthquake resistant designs of structures in two ways (Sheikh,Uzumeri ,1980). Firstly the concrete with large deformations will help to design efficiently the structures so that they may be able to withstand large deformations that are caused by large earthquake. Secondly, after spalling of concrete cover, the strength and ductility of the member will depend upon the confinement of concrete core. Knowledge of behavior of confined concrete helps in calculating the most suitable quantity of confining steel.

(Saatcioglu, Razvi, 1992) found that, at low deformations, the confinement provided by lateral ties is negligible. (Mander, 1988) found that in order to improve the seismic behavior, plastic hinge region of columns of buildings and bridges should be carefully detailed for ductility. (Rizwan, 2008) highlighted the relative performance of conventional ties and steel strips confined columns under lateral loads and observed relative improvement in strip confined columns. At higher axial loads requirement of confining steel increases so that column may show ductile behavior. Its reason is that at higher loads flexure capacity of columns largely depends upon the concrete compressive strength. There are many parameters that can affect confinement. It has been found that following factors can improve column behavior

1. Size of ties
2. Amount of ties
3. Spacing of ties
4. Strength of Concrete
5. Type of concrete
6. Cross-sectional shape
7. Dimension of cross section
8. Yield strength of lateral reinforcement
9. Heat treatment of lateral reinforcement
10. Rate of loading
11. Eccentric loading
12. Cyclic loading
13. Welded wire fabric
14. Ties with 135 º and 90º hooks.
15. Confinement provided by angles and external strips

In this paper strips were employed as confining steel in RC columns. Strip confined columns and stirrup confined column were tested under cyclic axial load. The Test results of both types of columns were compared in terms of axial capacity and stress strain relations.

2 Description of Tested Columns

Two 150×150×600mm RC square columns were tested under cyclic axial load. Geometry of columns and structural details are illustrated in figures 1 and 2. Strength of concrete used was 34 MPa. Both columns were reinforced with four 6.35mm diameter longitudinal bars. Columns were confined with two types of rings, stirrups and strips.

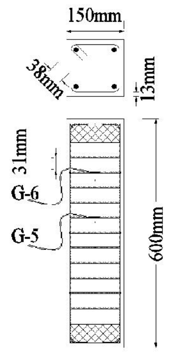

Figure 1. a. Structural detailing of stirrup confined column

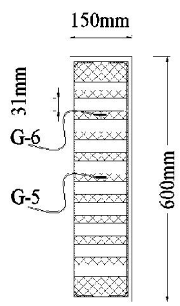

Figure 1. b. structural detailing of strip confined column

Stirrups were made of 6.35mm diameter mild steel deformed bars. Strips were cut from mild steel plates. Width and thickness of strips were selected so that cross-sectional area of strips was equal to that of 6.35mm stirrups. Clear spacing of ties was 31mm which is equal to the “d/4”, where “d” is least dimension of column, 150mm in this case In order to safe guard concrete against crushing under machine jaws 2×38mm collars were fixed at the top as well as at the lower edge of column as shown in figures 1 and 2 above.

Properties of test specimen, type of confinement, and identification number are summarized in Table 1.

Table 1. Cross sectional dimensions of confinement used

Column No	Identification Name	Type of confinement (mm)	Width-Thickness ratio
1	S-B	6.35 mm MS deformed bars	1
2	16-B	1.6×19.77 mm strips	12.4

For the test specimen in identification name, “S” stands for columns with confined with stirrups and “16” stands for 1.6×19.77 strips.

Grade 40 deformed 6.35 mm diameter bars were used as longitudinal bars as well as ties. Tension test of these bars was performed as per ASTM A615 in Universal High Frequency Fatigue Testing machine (UHFFT). For strips tension test was performed on the coupons cut from plates as per Standard Test Methods for Tension Testing of Metallic Materials “E 8M-04”. Tension test on the specimens was performed, in UET Taxila, using MTS 810, Universal High Frequency Fatigue Testing Machine (UHFFT Machine).Yield and ultimate strength of testes coupons was 242 and 365 MPa respectively

3 Fabrication of strip confinement

Strips were cut from mild steel plates in a steel press as shown in Figure 3 and then using chisel and hammer strip edges were cut in two parts to obtain two frayed cuts at each end. Prepared strip sample is shown in Figure 4. Strip ties were then prepared from these strips by bending all four edges with an L-key. Contrary to stirrups, strip ties have four legs as shown in Figure 5. Out of these four legs 2 legs were bent inwards through 135° hooks, whereas remaining two legs were bent 90º in a style shown in the figure 5.

Figure 3. Strip being cut from MS Plate

Figure 4. A frayed cut strip end

Figure 5.Typical strip used as confining steel

3.1 *Application of steel strain gauges*

Axial strain in strip confinement was measured by applying two strain gauges (EA-13-240LZ-120/E) on to the surface of confining steel. One of the gauges was installed on to a strip fixed in middle of the column and other was pasted on strip fixed at upper half portion of the column.

3.2 *Preparation of Samples for Testing*

Sample were cast with concrete and cured for 28 days and allowed to dry for one day before final finishing. Grid lines of 30 mm square were drawn on all faces. Top and bottom face of column was finished and smoothened with a grinder as shown in figure 6.

Figure 6.Typical strip used as confining steel

4 Testing Protocol

Samples were subjected to cycle axial load in compression testing machine, using displacement control criteria. Rate of loading was maintained at 0.14 to 0.34 MPa/Sec. A 200 ton load cell was used to record loading automatically in a data logger. Total five gauges were installed. Location and details of these gauges on four faces of the columns are shown in Figure 7.

Figure 7.view of test set up.

For axial displacement measurement between two points 450 mm apart, two gauges were installed in longitudinal direction on front and rear faces. These gauges were installed using screws tightened into hole drilled on column surface as shown in figures 8 and 9.

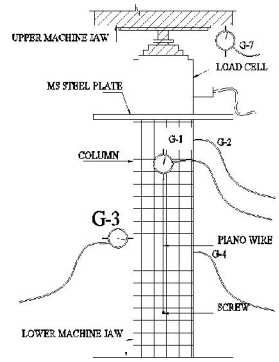

Figure 8.Front view showing instrumentation

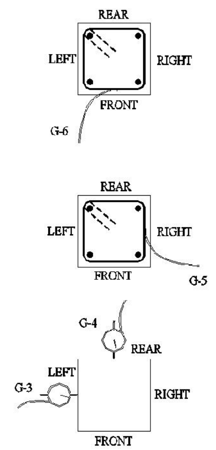

Figure 9.Top view showing instrumentation

Gauges 3, 4 and 7 were applied just to monitor any abnormality during test and improve the quality of experiment. Lateral displacement buckling of columns was measured with gauge numbers 3 and 4 installed at mid points perpendicular to the left and rear face respectively. These gauges were also helpful in monitoring the cover spaling off the surface. Overall movement of upper jaw of UTM was recorded using gauge number 7, attached to the top jaw of compression machine. Strain in confining reinforcement was measured with two electrical resistance strain gauges. These gauges were installed at two locations one on strip/tie situated near mid height of column and other was installed on strip/tie situated in upper half portion. All gauges and load cell were connected to a data logger for automatic recording of load, corresponding displacements and strains. Detail of instruments is shown in Figures 8 and 9. A description of gauges installed is given in table 2.

Table 2. Description of gauges

No	Detail of gauges installed
1	Gauge number 1 to measure axial displacement of column on front face
2	Gauge number 2 to measure axial displacement of column on rear face
3	Gauge number 3 to measure lateral displacement of column on right face and cover spalling.
4	Gauge number 4 to measure lateral displacement of column on right face and cover spalling
5	Gauge number 5 to measure strain in middle strip/stirrup
6	Gauge number 6 to measure strain in strip/stirrup present in upper half of the column
7	Gauge number 7 to measure the over all axial displacement of column
8	Universal testing machine
9	200 Tons capacity Load cell

5 Results and discussions

As in this experiment all other parameters were constant except type of confining steel. Axial capacity, ductility ratio and stress strain relation can be considered to be effected by type of confining steel. Axial capacity was calculated by using the relation 1 adopted by Shamim R Rizwi and Murat Saatcoglu, (1990)

Capacity of the column "P_{calc}" was computed using relation.

$$P_{calc} = \alpha f_c^{'}\left(A_g - A_s\right) + A_s f_y \quad (1)$$

Where α in Equation (1) is the ratio of unconfined concrete strength to the cylindrical strength. In this tested program, value of α was selected as "0.85". Value of α varies between 0.85 and 0.9 for large size samples.

$A_g =$ Gross area of column

$A_s =$ Area of longitudinal steel

$f_y =$ Yield strength of steel

$f_c^{'}$ =Concrete strength in this case it is the strength of cylinder at the time of testing

Summary of test results is presented in table 3 and 4.

Table 3. Axial Strength of columns

Type	P_{test} (KN)	P_{calc} (KN)	P_{test}/P_{cal}
SB	1060.9	690.7	1.54
16-B	945.12	690.7	1.37

Table 4. Ductility ratio of columns

Type of column	ε_{85}	μ_e
S-B	0.0044	1.110
16-B	0.0068	1.690

It was observed that tested capacity of columns 1 and 2 was 54% and 34% higher than the calculated capacity respectively. Axial capacity of stirrup confined column was 12.25 % higher than strip confined columns. Effect of strip confinement on ductility was evaluated by calculating the ductility ratio μ_e defined by Saatcoglu and Razvi (1992) as ratio of core concrete strain to an assumed strain of (0.004):-

$$\mu_e = \varepsilon_{0.85}/0.004 \quad (2)$$

$\varepsilon_{0.85} =$ Core concrete strain corresponding to the stress at $0.85 f_c^{'}$

Ductility ratio of strip confined column was 52.34% above the stirrup confined columns. Stress strain relation for both types of columns is shown in Figure 10.

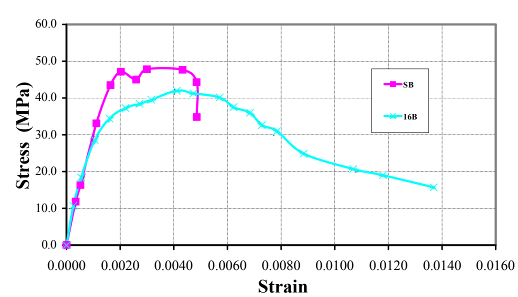

Figure 10.Stress strain relation

Corresponding hysteresis loops for stirrup and strip confined columns are shown in Figures 11 and 12.Maximum displacement level reached by the strip confined column is 6mm whereas it is about 3mm for stirrup confined columns conforming that ductility was enhanced by replacing the strips with stirrups.

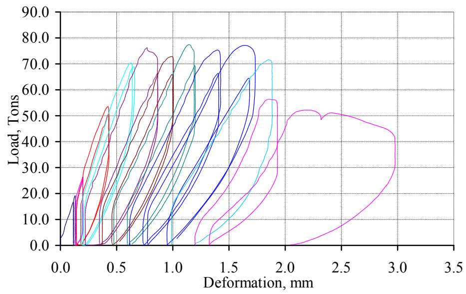

Figure 11.Load deformation hysterises loops for stirrup confined columns (S-B)

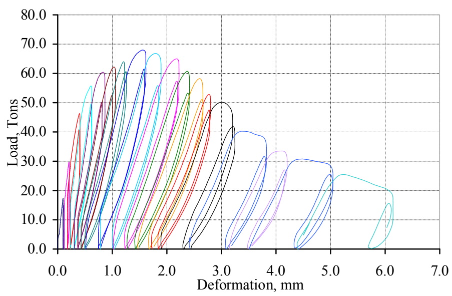

Figure 12. Load deformation hysterises loops for strip confined columns (16-B)

Conclusions

Based on these investigations following conclusions are drawn:-

1- Axial capacity of stirrup confined column was 12.25 % higher than strip confined columns.

2-Ductility ratio of strip confined column was 52.34% above the stirrup confined columns.

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