Effect of Concrete Strength on Behavior of Strip Confined Columns

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Abstract-This study presents the cyclic axial test results of ten 150×150×600mm RCC columns confined with standard stirrups and mild steel strips of size 2×15mm (Strip-14), 1.6×19.77mm (Strip-16) and 1.28×18.8mm (Strip-18) . Columns were divided in two groups. In group "A" columns concrete strength was 27MPa and in group B columns it was 34 MPa. Strength of concrete used in group "B" column was 26% higher than group "A" columns. Test results revealed that by 26% increasing concrete strength, resulting increase in axial capacity of group B columns confined with stirrups, strip-14, 16 and 18 was respectively 22, 27, 21 and 43 %.

Keywords-columns, confinement, axial strength, stirrups, strips

I. INTRODUCTION

Factors that can improve confinement include [1]-[6], the following:-

1- Spacing of confining steel
2- Additional overlapping hoops and ties.
3- Even distribution of main column bars around perimeter.
4- Increasing the ratio of volumes of transverse reinforcement to volume of concrete core.
5- Improving grade of confining steel
6- Providing spirals, circular ties or strips instead of rectangular ties and cross hoops

Confinement can also be improved by increasing the diameter of wires and decreasing spacing of spirals [6]. Additional parameters that can improve performance of confining steel include proper detailing of confining reinforcement, concrete compressive strength and type of aggregate [6]. Researchers [1], [2], [7] discovered that strength and ductility can be improved by distributing the longitudinal steel around the core. They also found that by supporting each longitudinal bar with cross ties and hoops confinement can be increased. References [8] and [9] reached at the same conclusion. Welded wire fabric can also increases the strength by 40 [10], however improvement in ductility can be achieved only if it is used with ties at d/2 spacing. Reference [8] investigated in detail the affect of following parameters:-

1. Arrangement of main bars in columns
2. Quantity of confining steel and main bars
3. Arrangement of ties.
4. Spacing of ties
5. Properties of lateral steel

It was also discovered that ties if properly placed in column also worked well up till their final fracture. Reference [11] studied the behavior of columns confined with prestressed metal strips in terms of stress strain relation. It was found that active confinement in addition to improvement in strength and ductility can result in stiffer pre-peak response of concrete specimen. Stress-strain curves of specimen are important because these give an overview that whether confinement has increased the ductility and strength [6]. Researchers have found that diameter and yield strengths of confining steel, volumetric ratio of confining reinforcement to concrete core and arrangement of confining steel as well as longitudinal steel significantly affect stress strain relation of columns.

It was also found that both strength and ductility can be improved by replacing stirrups with strips [12]. However when width thickness ratio of strips increases by 12% the improvement in strength is less as compared to ductility. Refrence [6] found that performance stirrup confinement can be improved by concrete compressive strength. This paper investigates the effect of concrete strength on the behavior of strip confined RCC columns.

II. TEST PROGRAM

Columns were tested in two groups, A and B containing five columns in each group. In each group one column was provided with four 6.35mm diameter longitudinal bars and it was confined with 6.35mm diameter standard stirrups. Remaining three columns were confined with mild steel strips of three different width thickness ratios of 7.5, 12.4 and 18.8. It is important to mention here that width and thickness of each strip was selected to achieve cross-sectional area equivalent to 6.35mm diameter deformed bars. Fifth column was cast without any reinforcement. Identification numbers and cross sectional properties of strips are presented in Table I.

TABLE I
CROSS-SECTIONAL PROPERTIES AND IDENTIFICATION NUMBER OF STRIPS

S. No.	Identification number	Thickness (mm)	Width (mm)	Width thickness ratio of strips
1	14	2.00	15	7.5
2	16	1.6	19.77	12.4
3	18	1.28	25	18.8

In group-B columns concrete strength was 34MPa instead of 27MPa rest all parameters were same. Identification name of each column of these two groups and corresponding types of confinement used are shown in group.

Table II. In column 3 of table first letter represents that type of confining steel used and second letter corresponds to the name of group.

TABLE II
SPECIFICATION OF SPECIMEN COLUMNS

Column No. (1)	Group (2)	Identification name of column (3)	Concrete Strength (Mpa) (4)	Type of confinement (mm) (5)
1	Group A	P-A	27	-
2		S-A	27	6.35mm ties
3		14-A	27	15mm strips
4		16-A	27	19.77mm strips
5		18-A	27	25mm strips
6	Group B	P-B	34	-
7		S-B	34	6.35mm ties
8		14-B	34	15mm strips
9		16-B	34	19.77mm strips
10		18-B	34	25mm strips

III. MATERIAL PROPERTIES

In this experimental program three types of materials were used, 6.35mm diameter deformed rebars, strips of different thicknesses and concrete. Tension test on strip material was performed on the coupons cut from plates as per Standard Test Methods for Tension Testing of Metallic Materials “E 8M-04” using MTS 810, Universal High Frequency Fatigue Testing Machine (UHFFT Machine). Fig. 1. presents the stress strain relationship of each test specimen. Yield and ultimate strength of testes coupons is shown in Table III.

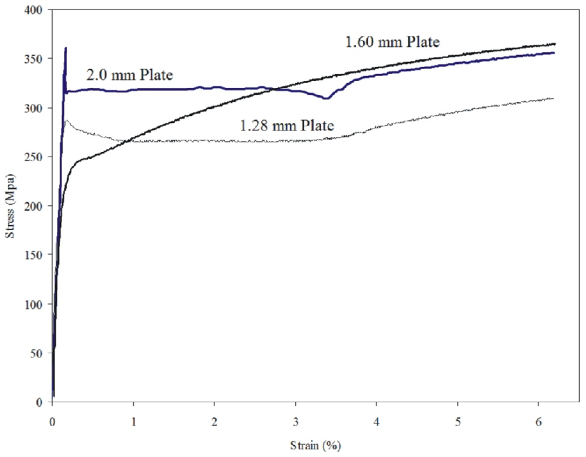

Fig. 1. Stress strain relationship strip material

TABLE III
PHYSICAL PROPERTIES STRIP MATERIAL

S. No.	Strip Identification number	Yield strength (Mpa)	Ultimate strength (Mpa)
1	14	355	361
2	16	242	365
3	18	286	309

IV. STRUCTURAL DETAILING OF SPECIMEN

Structural detailing of columns is shown in Fig. 2-5. In strip and stirrup confined columns clear spacing of stirrup/strip ties were kept equal to 31mm. Clear cover to main bars was 13mm. this resulted in “d” for each column equal to 137 mm. In order to prevent damage of column due to accumulation of stresses near upper and lower machine jaws and avoid misleading results a 2×38mm mild steel collar was externally applied at the top as well as at the bottom of each column.

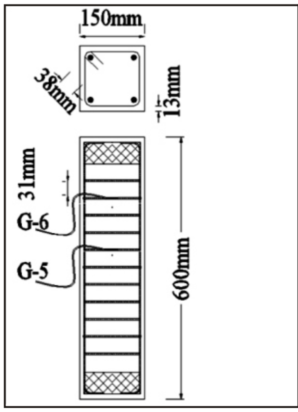

Fig. 2. Standard stirrup confinement

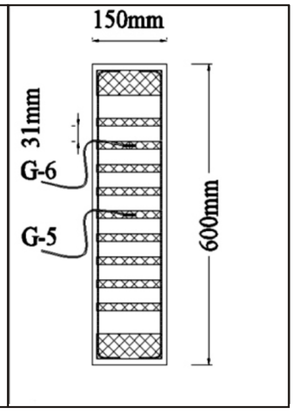

Fig. 3. 15mm strip confinement

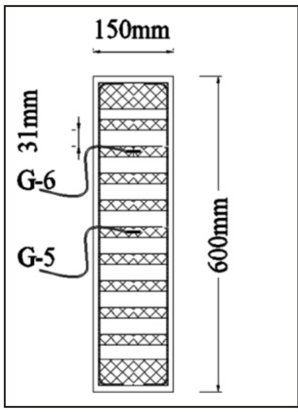

Fig. 4. 19.77mm strip confinement

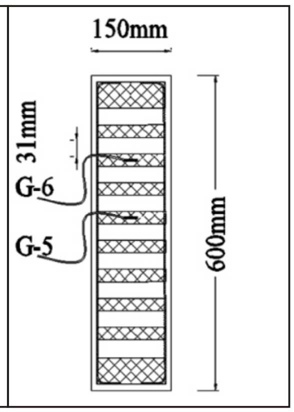

Fig. 5. 25mm strip confinement

V. INSTRUMENTATIONS

Axial deformation in column was measured by two gauges gauge-1 and gauge-2 as shown in Fig. 6. Value of axial force at desired time intervals was measured by 200 ton load cell which was connected to data acquisition system.

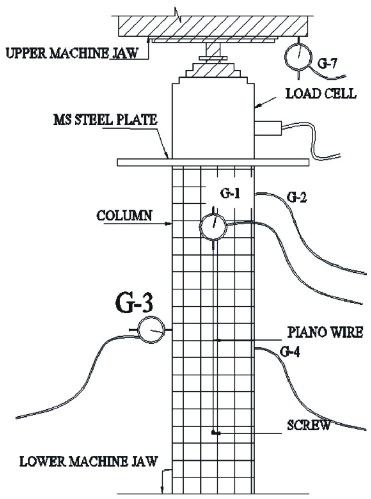

Fig. 6. Diagram showing instrument set up

Gauges 3. and 4. were installed to monitor any abnormal column response during testing. These were installed at mid points perpendicular to the left and rear face respectively. These gauges were also helpful in monitoring the cover spall off. Gauges and load cell were connected to a data logger in which displacement and load data was recorded automatically.

VI. TESTING METHODOLOGY

Specimen were tested in UTM and cyclic axial load was applied during testing .Detail of load cycles applied is shown in Fig. 7. A view of the test lab during experimentation is shown in Fig. 8. All tests were displacement control type and loading rate and strains were controlled manually. During testing axial force was applied at 0.14 to 0.34 MPa/sec, as recommended by ASTM standard.

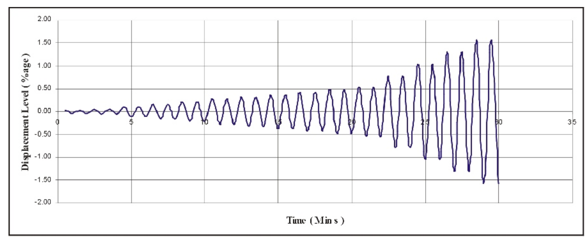

Fig. 7. Graphical representation of load cycles

Fig. 8. Test in progress in laboratory

VII. ANALYSIS OF RESULTS

Stress strain behavior of both groups of columns was drawn up to 0.3% strain and is shown in Fig. 9. Stress strain curves of group A column are drawn in full line and that of group B column is shown in dashed lines.

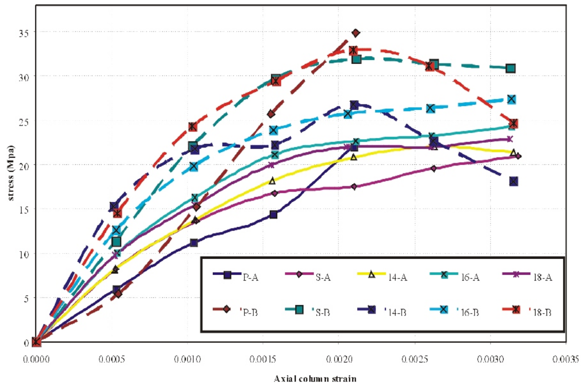

Fig. 9. Stress strain relation

It was observed that irrespective of concrete strength axial capacity of columns increased by increasing the strip widths. However it was reverse for columns confined with wider strips of lesser stiffness. As already mentioned in present study three different types of strip confinement were employed. Increase in widths to thickness ratio of strips has an affect on the stiffness of strips which reduces by decreasing the thickness and increasing the strip width. The resulting decreased stiffness is responsible for reduced confining effects as capacity of strips to resist lateral pressure exerted by lateral expansion of plain concrete reduces. This results in reduction of axial capacity of column with greater width to thickness ratios. It is obvious in figure 10 that axial capacity of column 18-A is 5% less than column 16-A.

Table IV compares the calculated and tested strength of columns in group A and B. In this table calculated axial capacity of column (P_{cal}) is calculated by using following relation:

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

TABLE IV
COMPARISON OF TESTED AND CALCULATED STRENGTHS

Column No.	Type	P_{test} (KN)	(P_{calc}) (KN)	P_{test}/P_{cal}
1	-	-	-	-
2	S-A	607.5	596.7	1.02
3	14-A	495.0	596.7	0.83
4	16-A	540.0	596.7	0.90
5	18-A	517.5	596.7	0.87
6	-	-	-	-
7	S-B	742.5	658.7	1.13
8	14-B	630	658.7	0.96
9	16-B	652.5	658.7	0.99
10	18-B	742.5	658.7	1.13

In above equation α is the ratio of unconfined concrete strength of plain concrete columns to the cylindrical strength. Value of α varies between 0.85 and 0.90 for large size samples [13-14]. In the present study, value of α was "0.93" and "0.82" for group A and B columns respectively.

A_g=Gross area of column

A_s=Area of longitudinal steel

f_y=Yield strength of steel

f_c=Strength of concrete cylinder at the time of testing

Just like group A, columns in group B also showed an increasing trend of axial strength with the increase of strip width. However P_{test}/P_{cal} ratio in columns confined with strip 18 and stirrups was same. Same trend was observed in columns of group A. It was found that axial capacity of columns increased by increasing concrete strength. In the present study the difference in concrete strength of group A and B column is 26% and resulting increase in axial strength of columns is 22, 27, 21 and 43% respectively for columns confined with stirrups, strip-14, 16 and 18 respectively. In addition to above the observed Increase in axial strength for columns confined with strip 18 is maximum, showing 20% strength increase as compare to an average increase in axial strengths of column confined with stirrups, strip-14, 16 and 18. It can be concluded from this research that by increasing column concrete strength increase in axial strength of columns is higher when wider strips are used.

VIII. CONCLUSIONS AND RECOMMENDATIONS

In this research it is found that strips improve both strength and ductility. Area of concrete core of column specimen was kept constant throughout this investigation however it is important to mention here that being less in thickness strip confinement covers more area of concrete core as compared to conventional stirrups. From experiments performed in present study following can be concluded:-

1. In the present study strength of concrete used in group "A" column was 26% higher than group B columns. Resulting increase in axial capacity of columns confined with stirrups, strip-14, 16 and 18 was 22, 27, 21 and 43 % respectively.
2. By 26 % increasing concrete compressive strength, axial strength of columns confined with strip-18 improved by 43 % as compared to an average increase of 23% when stirrups, strip14 and 16 are used.

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APPENDIX-A

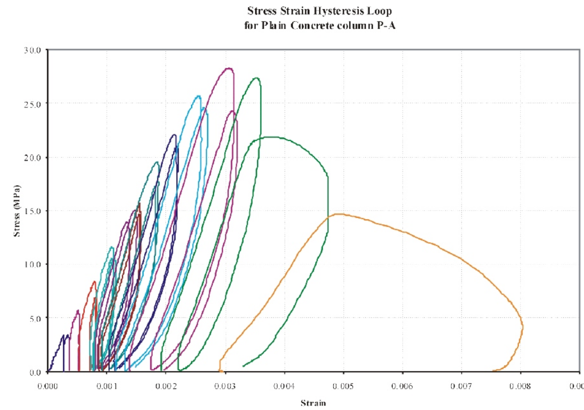

Fig. A1. Stress Strain Hysterisis Loops for column P-A

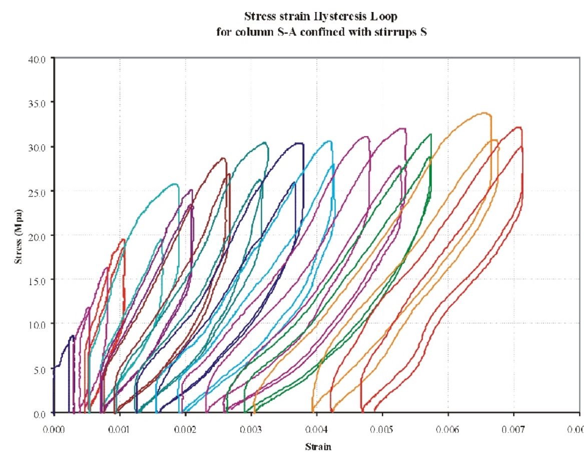

Fig. A2. Stress Strain Hysterisis Loops for column S-A

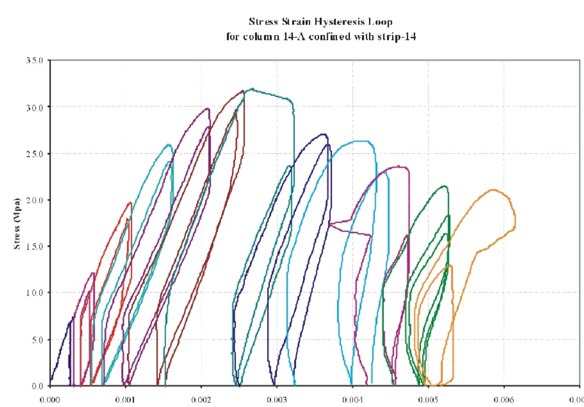

Fig. A3. Stress Strain Hysterisis Loops for column 14A

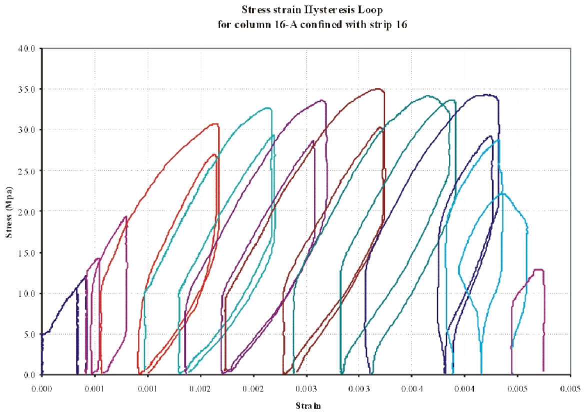

Fig. A4. Stress Strain Hysterisis Loops for column 16-A

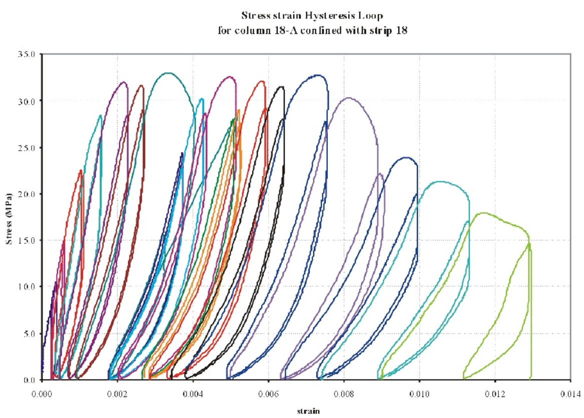

Fig. A5. Stress Strain Hysterisis Loops for column 18-A

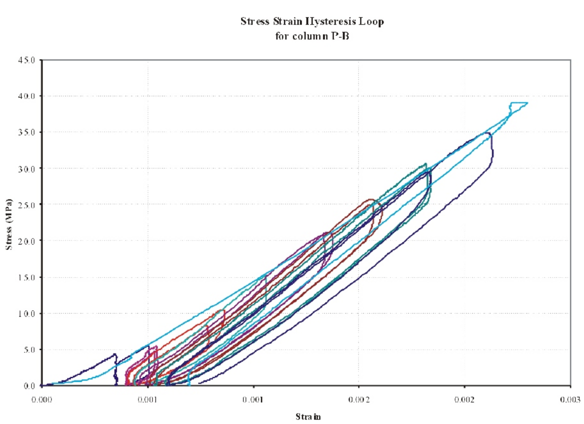

Fig. B1. Stress Strain Hysterisis Loops for column P-B

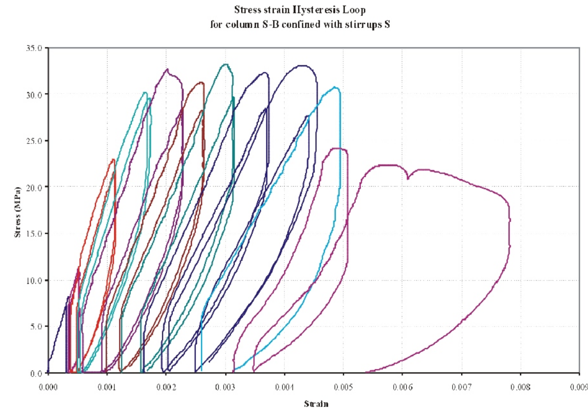

Fig. B2. Stress Strain Hysterisis Loops for column S-B

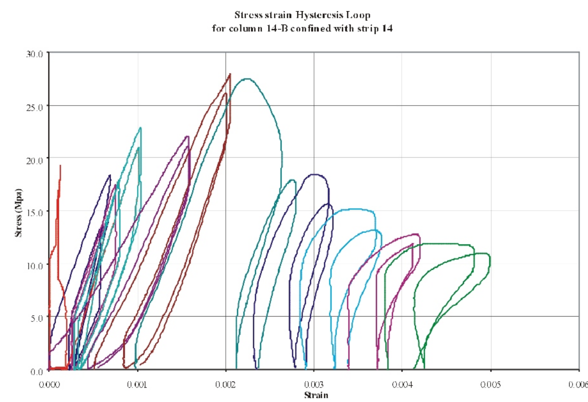

Fig. B3. Stress Strain Hysterisis Loops for column 14-B

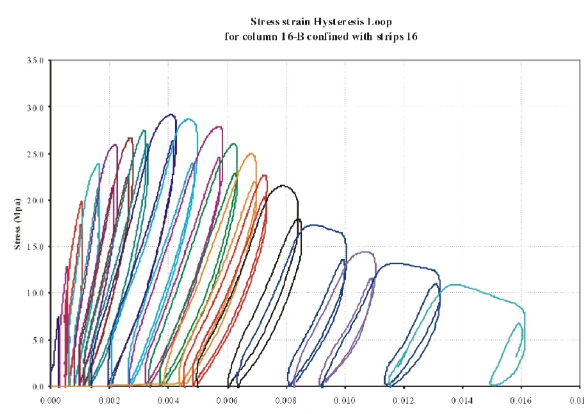

Fig. B4. Stress Strain Hysterisis Loops for column 16-B

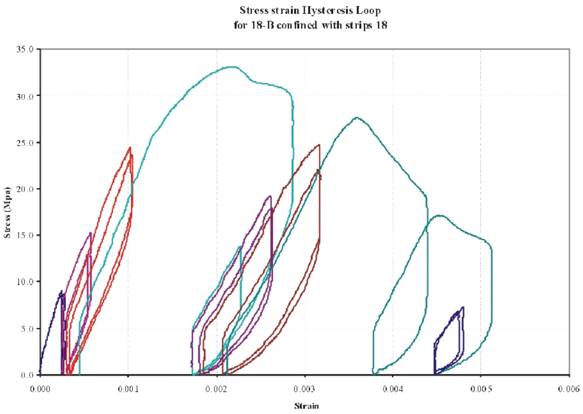

Fig. B5. Stress Strain Hysterisis Loops for column 18-B