Available online at www.elixirpublishers.com (Elixir International Journal)

Civil Engineering

Elixir Civil Engg. 157 (2021) 55585-55588

ISSN: 2229-712X

Impact of the Shape of Inner Tie on the Performance of Double Layered High Strength Concrete Column Under Compression

Mahesh Kumar[1], Syed Kaleem Afrough Zaidi[2], Murali Krishna Venkata Shiva Kapuganti[3] and Satish Chandra Jain[4]

[1]Department of Civil Engineering, Mangalayatan University, Aligarh, India,
[2]Civil Engineering Section, Aligarh Muslim University, Aligarh, India,
[3]Institute of Business Management, Mangalayatan University, Aligarh, India,
[4]Department of Mechanical Engineering, Indian Institute of Technology, Mandi, H.P. India

ARTICLE INFO

Article history:
Received: 29 June 2021;
Received in revised form:
17 August 2021;
Accepted: 29 August 2021;

Keywords
Axial Compression,
Peak Stress,
Peak Strain,
Confined Concrete Column,
Shape Factor,
Proximity Distance Ratio.

ABSTRACT

Concrete columns confined by single layered stirrup are commonly used for increasing the strength and ductility in seismic areas. Recent experiments have developed hope in the use of double stirrup confinement technique in enhancing the strength and ductility of the columns. In the present study, 12 numbers of double confined concrete square column specimens of high strength concrete, of size 150x150x450 (mm), were cast and tested under uni-axial compression. The columns were reinforced with 6 mm and 10 mm diameter of 500 MPa grade as transverse and longitudinal reinforcements respectively. Varied shapes of inner transverse reinforcement such as square, diamond, circular and spiral with square shaped outer layer stirrup, have been studied. The findings reveal that variation in shapes, contributed to greater compressive strength and better ductility of double layered stirrup confined concrete columns.

1. Introduction

Columns are considered supercritical members of a moment resisting structural system. In seismically active regions it is indispensable to ameliorate the ductility contortion capacity of columns. The desired capability in columns is normally attained through proper confinement of core concrete. The outcomes of a number of key parameters with regard to confinement over the strength and ductility of single layered confined concrete are well referenced [Sheikh, S. A., et. al. (1980), Mander, J. B., et. al. (1988), Saatcioglu, M., et. al. (1992), Razvi, et. al. (1994), Sharma, U. K.,et. al. (2005), Zaidi, K. A., et. al. (2011), D. H. Jing, et. al. (2016)]. It is emphatically accepted across the globe that strength and deformability of concrete improve the seismic performance of reinforced concrete columns. It has also been established that confinement in concrete is attained by appropriate emplacement of transverse reinforcement. Transverse reinforcement in colligation with longitudinal reinforcement restrains the lateral expansion of concrete.

Some recent researchers, such as, Sun, L., et. al. (2016), Wu, D., et al. (2016), D. H. Jing, et. al. (2016), Yang, F., et. al. (2015), Hui-Ding, Jie Chen and Li, Song (2015) and Lin Zhu Sun, et. al. (2011) conducted experimentations on double layered confined concrete columns and explored the behavior of confined concrete by characterizing the increase in strength and ductility of columns. Still, there has been an inescapable need to explore that by what amount the various parameters viz., addition of inner reinforcement, longitudinal bars, variedness in the shape and forms of transverse reinforcement provided as inner layer of reinforcement, varying number and amount of longitudinal reinforcement forming the outer layers, varying the amount and spacing of transverse reinforcement, proximity distance ratio and grades of concrete (normal strength concrete and high strength concrete) of confinement affects the behavior of a double layered stirrups reinforced columns. Drawn by this imperative, this study is being carried out to evaluate the contribution of shape of inner layer corresponding to varied shapes of inner transverse reinforcement, viz., square, diamond, circular and spiral, with square shaped outer layer of 'double layered high strength concrete column' under compression.

2. Experimental Program

Test specimens

A total number of 12 reinforced concrete double layered confined concrete short column prism specimens of size 150x150x450 (mm) were cast and tested in triplicate in order to get the average of three results thus making independent cases of 4 double layered confined concrete columns as shown in Figure 1. Specimens DCCCH1 to DCCCH4, were taken to study the impact of shape of inner transverse reinforcement on the stress-strain behavior and confinement effectiveness of the test specimens. The first four letters in the abbreviations DCCC denote that it is doubly confine

Tele:
E-mail address: vc@mangalayatan.edu.in

concrete column, and the last letter speaks of the type of concrete mix, i.e., high- grade concrete mix (H).

Attributes such as strength of concrete and reinforcement, spacing of lateral stirrups, amount of longitudinal reinforcement were kept same for the specimens, as shown in Figure 1, comprising of specimens DCCCH1 to DCCCH4. Only the shape of the inner transverse reinforcement, in terms of square, diamond, circular and spiral, has been varied.

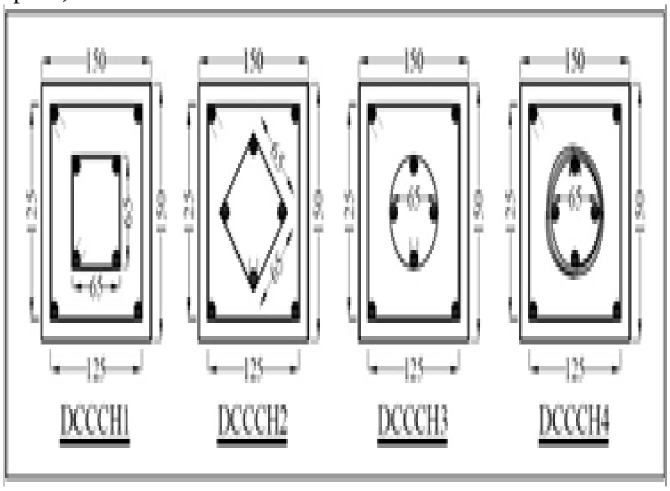

Figure 1. Column x-sections showing various shapes of inner transverse reinforcement for high strength concrete specimens (All dimensions are in mm)

Material properties

The concrete mix was designed following specifications vide IS-12620-2009, using Pozzolanic Portland Cement, natural river sand, crushed aggregate of lime stone of 12.5 mm nominal size and tap water. The mix proportion of concrete has been shown in Table 1. The grade of concrete was taken as M60 and its compressive cube strength after 28 days was 61.10 MPa. Reinforcing bars of 6 mm and 10 mm diameter of Grade Fe500D (SD) have been used as transverse and longitudinal reinforcement respectively.

2.3 Test setup and instrumentation

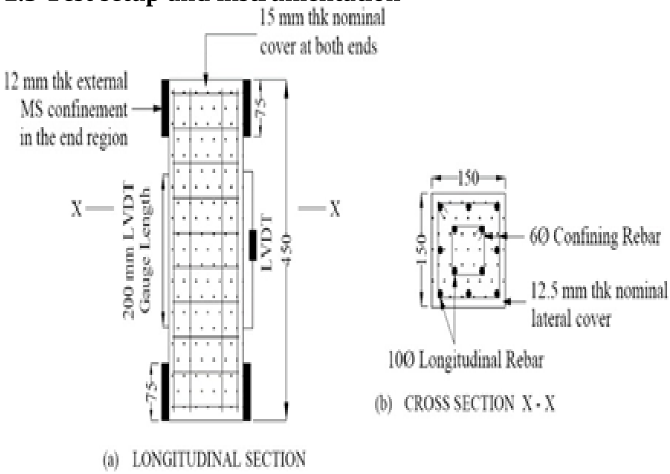

Figure 2 (a-b). Column specimen detail (All dimensions are in mm)

Before processing the specimens for mechanical testing, a failure test region was forced into the middle 300 mm length of the specimens by providing external confinement in the 75 mm end-regions. The external confinement obtained by fastening the end-regions of the test specimens using 12 mm thick steel collars prevented an undesirable and premature end failure of test specimens to happen.

The test specimens were loaded onto a 3000 kN capacity Universal Testing Machine (UTM) blessed with displacement -controlled capabilities, stiff enough to obtain a stable descending branch of the load-deformation curves.

The monotonic concentric compression was applied at a very slow rate to capture clear and complete post peak behavior of the load-deformation curve. The axial shortening of the prism specimens was monitored by a linear variable displacement transducer (LVDT) attached with the test specimen laterally. The mean axial deformation of the 200 mm gage length in the central zone was measured and converted into an average strain. An in-built load cell in the UTM was used to record the loads. A data acquisition system

Table 1. Mix proportions of concrete specimens.

Mix/ Specimen	Cement (Kg/m^3)	Water (l/ m^3)	F A (Kg/m^3)	C A (Kg/m^3)	Silica Fume (Kg/m^3)	Superplasticizer (Kg/m^3)	Cube Characteristic Compressive Strength (MPa)	
							fck (28 days)	fck (90 days)
DCCCH	580.00	185.60	638.00	1044.00	46.40	11.60	61.10	67.30

Table 2. Properties of Square Test Specimens.

Specimen No.			DCCCH1	DCCCH2	DCCCH3	DCCCH4
f_{co} (MPa) = Concrete strength obtained from standard cube test			67.3	67.3	67.3	67.3
f'_{co} (MPa) = Modified concrete strength taken as = 0.85 f_{co}			57.21	57.21	57.21	57.21
Proximity Distance			3φ	3φ	3φ	3φ
Outer	Longitudinal Bar	Number	4	4	4	4
		Ø (mm)	10	10	10	10
	Transverse Bar	Number of stirrups	10	10	10	10
		Ø (mm)	6	6	6	6
		S (mm)	45	45	45	45
		Shape	Square	Square	Square	Square
Inner	Longitudinal Bar	Number	4	4	4	4
		Ø (mm)	10	10	10	10
	Transverse Bar	Number of stirrups	6	6	6	6
		Ø (mm)	6	6	6	6
		S (mm)	81	81	81	81
		Shape	Square	Diamond	Circular	Spiral

Table 3. Specimens Experimental Results

Specimen ID	DCCCH1	DCCCH2	DCCCH3	DCCCH4
Shape of inner transverse reinforcement	Square	Diamond	Circular	Spiral
Experiment Peak Stress σ(Exp) (MPa)	73.82	74.75	78.40	79.78
Theoretical Peak Stress σ (Theo) (MPa)	43.68	43.68	43.68	43.68
Experimental Peak Strain ε(Exp)	0.00499	0.00631	0.00660	0.00694
Theoretical Peak Strain ε(Theo)	0.00215	0.00215	0.00215	0.00215
Strain [Load drops to 85% of Peak Confined Load] ϵ_{c85c}	0.0057	0.0092	0.0087	0.0074
Strain [Load drops to 50% of Peak Confined Load] ϵ_{c50c}	0.0085	0.0200	0.0220	0.0134
Area under the curve [Load drops to 85% of Peak Confined Load (ϵ_{c85c})] A_{c85c}	0.0050	0.0087	0.0097	0.0064
Area under the curve [Load drops to 50% of Peak Confined Load (ϵ_{c50c})] A_{c50c}	0.0069	0.0186	0.0189	0.0130
Area under the curve of Confined Concrete (Accc)	0.0204	0.0248	0.0290	0.0233

was employed to feed and store the recorded data of the LVDT and the load cell into the computer. Pictorial representation is shown in Figure 2 (a-b).

3. Results and Discussion

This experimental study details the results of the tests conducted on square shaped specimens. Various shapes of the inner transverse reinforcing stirrups with High Strength Concrete have been investigated. Experimental results in terms of numeric values, for each of the specimen, obtained after analyzing the shape parameters shown in Table 2 are detailed in Table 3. Bar graphs shown in Figures 3 to 5 affirm, substantial wallop on strength and deformation characteristics of the test specimens owing to varied shapes of inner stirrups. It could be learnt from the Table 3, that σ(Exp)/ σ(Theo), ε(Exp)/ ε(Theo), ϵ_{c85c}, ϵ_{c50c}, A_{c85c}, A_{c50c} and Accc values were found to be in the ambit of [1.69 - 1.83], [2.32 – 3.23], [1.00 – 1.52], [1.00 – 2.59], [1.00 – 1.94], [1.00 –2.74] and [1.00 – 1.42] respectively.

Effect of shape on peak confined concrete load

On comparing the results derived from tests conducted on the specimens with varied shapes of inner transverse reinforcing stirrup, it has been observed that the peak confined concrete load values ranged between 1248 kN to 1539 kN.

The specimen with spiral shaped inner transverse reinforcement showed better performance when compared with its other shapes as shown in Figure 3. The variation between spiral and square shapes has been 9.69%, whereas between square and circular as well as between circular and diamond was 6.9% and 5.12% respectively.

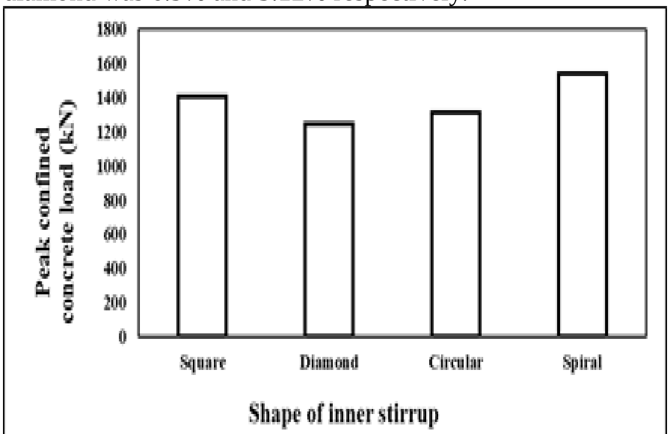

Figure 3. Peak confined concrete load (kN) v/s shape of inner stirrup

Effect of shape on axial strain at peak confined concrete load

It is evident from the Figure 4, that the specimen with diamond shaped inner transverse reinforcement exhibited optimal performance when compared with its other shapes. The specimen with circular shaped inner stirrup showed minimum strain value of 0.0052, whereas the maximum value of 0.0079 was demonstrated by diamond shaped inner stirrup column.

From the present study, it is evident that there has been an increment of 51.9% in strain values that has emerged, only from the change of shape from circular to diamond. The increment in strain values between spiral and diamond shapes inner stirrup columns has been 16.17%, whereas between square and spiral as well as between circular and square was 19.29% and 9.61% respectively.

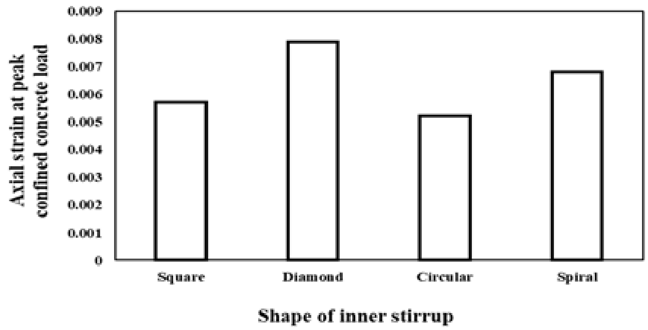

Figure 4. Axial strain at peak confined concrete load v/s shape of inner stirrup

Effect of shape on peak axial stress

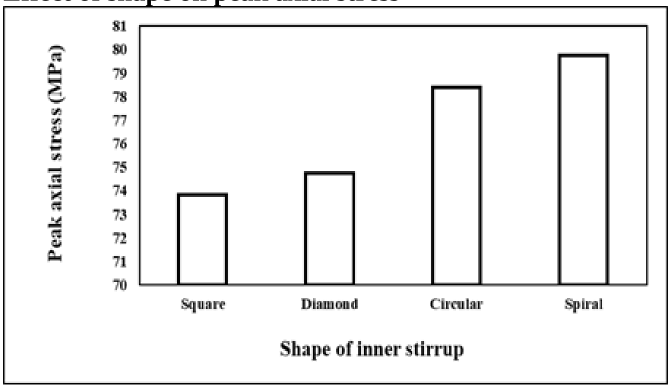

Figure 5. Peak axial stress (MPa) v/s shape of inner stirrup

Figure 5, illustrates the effects of the shapes of inner stirrup over peak axial stress of the test specimens. 8.00%, 6.71% and 1.74% increase in the stress capability have been observed when spiral shaped test specimen has been compared with square, diamond and circular shaped inner stirrup columns. These results indicate that spiral shaped inner stirrup column performed the best, followed by circular, diamond and square shaped inner cores, in that order. The stress values were found in the range of 73.82 MPa to 79.77 MPa.

3.4 Effect of shape on confined stress

The axial strain v/s confined stress curves for specimens DCCCH1 to DCCCH4 have been compared as shown in Figure 6, to examine the effect of shape of the double layered stirrups. The abscissa represents axial strain, whereas the ordinate represents confined stress in MPa.

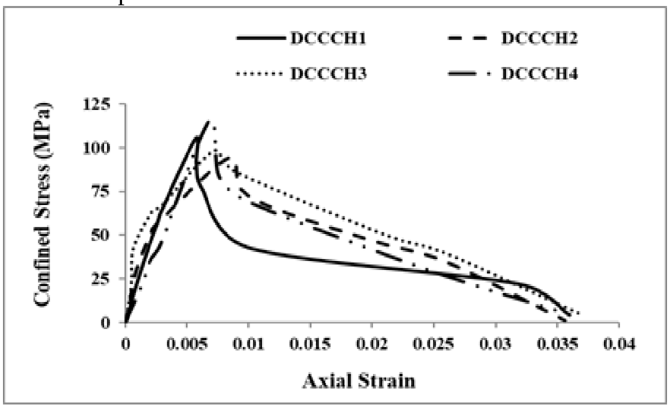

Figure 6. Confined stress v/s axial strain of double layered HSC column

4. Conclusions

This study speaks of an experimental work conducted on ‘double layered concrete columns’ to examine the contribution of shape of inner stirrup to its strength and ductility. Based on the results of this investigation, following conclusions could be drawn:

1. It can be ascertained that specimen with spiral shaped inner transverse reinforcement exhibited better performance when compared with its other shapes viz., square, diamond and circular, in terms of strength. This observation may be by virtue of the substantial contribution of the concrete, inside the circular spiral of double layered concrete specimen.
2. The deformation potentiality in diamond shape was found superior to other shapes such as square, circular and spiral.
3. The stress-strain potentiality of specimens for the spiral shaped inner core was found to be the best followed by circular, diamond and square shaped inner cores, in that order, under compression.
4. Both inner and outer layers have considerable wallop on the demeanour of the specimens.
5. More studies are required to be accomplished so as to further verify the existing outcomes of the present cogitation.

References

1. Bureau of Indian Standards, Recommended Guidelines for Concrete Mix Design. IS-10262, New Delhi, 2009, pp. 21

2. Bureau of Indian Standards, Plain and reinforced concrete code of practice (Fourth Revision IS-456: 2000, New Delhi, pp. 50

3. Ding, H., Chen, J. and Song, L. (2015) ‘Proceedings of the International Conference on Mechanics and Mechatronics, Changsha, Hunan, China

4. Jing, D. H., Yu, T., and Liu, X. D. (2016) New configuration of transverse reinforcement for improved seismic resistance of rectangular Reinforced Concrete columns: Concept and axial compressive behaviour, Engineering Structures 111, pp. 383 - 393

5. Kumar, M., Zaidi, S.K.A., Jain, S.C. and Krishna, K.V.S.M. (2018) “Confinement Techniques to Resist Static as well as Dynamic Compression of Concrete Columns: A Review Paper”, International Journal of Technical Innovations in Modern Engineering & Science, Volume 04, Issue 12, December 2018, pp. 759-770

6. Kumar, M., Zaidi, S.K.A., Jain, S.C. and Krishna, K.V.S.M. (2019). “Strength and Ductility Behaviour of Concrete Columns under Compression with Double Layered Stirrups: An Experimental Study”, International Journal of Civil Engineering and Technology, Volume 10, Issue 01, pp. 1081-1096

7. Kumar, M., Zaidi, S.K.A., Jain, S.C. and Krishna, K.V.S.M. (2019). “Reliability of Non-Destructive Testing Methods in the Assessment of the Strength of Concrete Columns Reinforced with Two Layers of Transverse Confining Stirrups: Empirical Evidence”, International Journal of Recent Technology and Engineering (IJRTE), Volume 8, Issue 2, July 2019, pp. 3450-3459

8. Linzhu Sun, Fang Y, Yagang Z. and Ziling, X. (2011) Study on Load Bearing Characteristics of Double Layered Stirrups Confined Concrete Square Columns. Advances Material Research. 243-249: pp. 1466-1476

9. Mander, J. B., Priestly, M. J. N. and Park, R. (1988) Observed stress-strain behavior of confined concrete. Journal of Structural Engineering ASCE, 114(8): pp. 1804-1826

10. Razvi, S. and Saaticioglu, M. (1994) Strength and deformability of confined high strength concrete columns. ACI Structural Journal, 91(6): pp. 678-687

11. Sheikh, S. A. and Uzumeri, S. M. (1980) Strength and ductility of tied concrete columns. Journal of Structural Division ASCE, 106(5): pp. 1079- 1102

12. Saatcioglu, M. and Razvi, S. R. (1992) Strength and ductility of confined concrete. Journal of Structural Engineering, ASCE, 118(6): pp. 1590-1607

13. Sharma, U. K. Bhargava, Singh, S. P. and Kaushik, S. K. (2005) Behaviour of confined high strength concrete columns under axial compression. International Journal of Advanced Concrete Technology, Japan, 3(2): pp. 267-281

14. Sun, L. Z., Wu, D. Y., Zhao, J. L., Yang, F., and Li, W. (2016) Behaviour of Circular RC columns with two layers of Spirals. KSCE Journal of Civil Engineering Structural Engineering: pp. 1-9

15. Wu, D. Y., Sun, L. Z., Yang, F., Zhao, J. L., and Li, W. (2016) ‘Axial compressive behaviour of square R. C. columns confined using two layers of stirrups’, Advances in Structural Engineering: pp. 1-12

16. Yang, F., Sun, L. Z., Zhao, J. L., Wu, D. Y., and Li, W. (2015) ‘Behaviour of a novel circular HSC column with double high strength spirals’, Advances in Structural Engineering.18(9): pp. 1371-1382

17. Zaidi, K. A., Sharma, U. K. and Bhandari, N. M. (2011) Effect of temperature on uni-axial compressive behaviour of confined concrete. Fire Safety Journal, 48 pp. 58-68