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Effects of Sections Shape on Performance of RCC Columns Under Concentric and Uniaxial-Eccentric Loading

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ABSTRACT- This project's main goal was to determine which column cross sectional form can hold the highest weight under various loading circumstances. Concentric and eccentric loads with uniaxial bending were applied. The subsequent case employed 50mm and 75mm eccentricity to one of the axes. This project's goal was to determine the greatest load-bearing cross sectional form of a thin column. 18 shaped columns were made for this purpose. Six square columns, six circular columns, and six hexagonal columns. All columns had the same cross section area, length, weight, and reinforcing %. The columns were then tested on a loading frame to see which form would withstand the highest weight under concentric and eccentric loading conditions.

KEYWORDS – RCC columns, Concentric loading, Eccentric loading, Buckling, Beam column.

I. INTRODUCTION

Columns are the most significant structural components of any building and are used in architecture and structural engineering to transmit the weight of the structure above to the other structural elements below by compressing the structure i.e. a column is a compression member[1]. The employment of reinforced concrete columns under eccentric stress are ubiquitous around the world and eccentric loading has been demonstrated to be a frequent concern for the columns. Concrete columns reinforced with steel have shown to be extremely successful under eccentric stress but it has also been noticed that eccentrically loaded reinforced concrete columns have more apparent cracks, spalling of concrete and buckling. Column being a compression member, there are longitudinal and transverse reinforcements in it[2]. Axial load and moment capacity of the column section are sustained by longitudinal reinforcement while transverse reinforcement resists the shear and also gives lateral support to the longitudinal reinforcement. Columns can have varied cross sections, such as round, square or hexagonal with varying kinds of loading shown in Figure 1.

A. *Classification of Columns Based on Type of Loading*

- Columns with axial loading (applied concentrically)
- Columns with uniaxial eccentric loading
- Columns with biaxial eccentricity

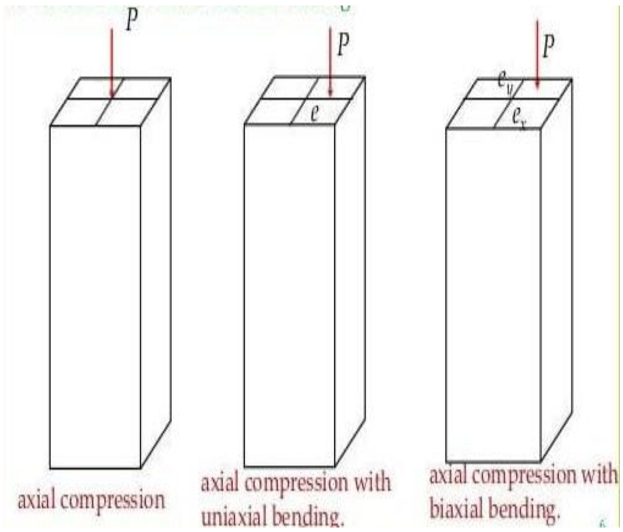

Figure 1: Various column loading

B. *Experimental Setup*

18 columns with varied cross-sectional shapes were cast in this project, six columns had square cross-sections, six had circular cross-sections and six had hexagonal cross-sections. Length of the columns were 1m and were casted as thin columns. The proportion of reinforcement, area of cross-section, weight as well as the lengths were kept similar for all the columns. The columns were then tested on loading frame to discover the maximum resistance under different loading circumstances i.e. concentric and eccentric loading. The reinforcement employed was 10mm thermo mechanically treated steel bars. The compressive strength of concrete utilised was 25 MPa.

C. Description and Details of Various Columns

Table 1: Description and details of various column

S No.	Cross sectional shape	Cross sectional size	Length (mm)	Reinforcement (longitudinal)	Reinforcement (lateral)	No.
1	Square	135mm side	1000	6—10mmØ	8mmØ @ 150mm c-c	6
2	Circular	150mm Dia	1000	6—10mmØ	8mmØ spiral with 250mm helical length	6
3	hexagonal	84mm side	1000	6—10mmØ	8mmØ @150mm c-c	6

Figure 2 shows the Detailing of the square column.
Figure 3 shows the Detailing of circular column
Figure 4 shows the Detailing of hexagonal column

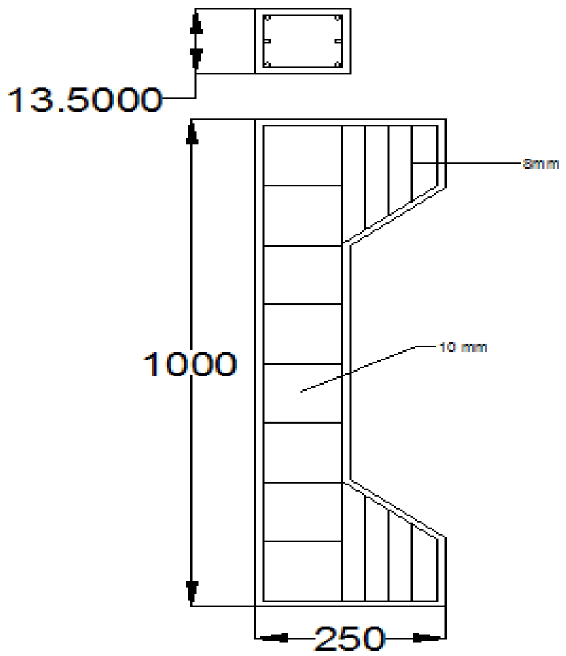

Figure 2: Detailing of square column

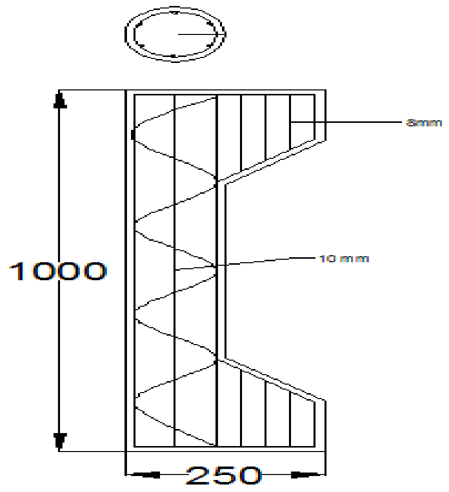

Figure 3: Detailing of circular column

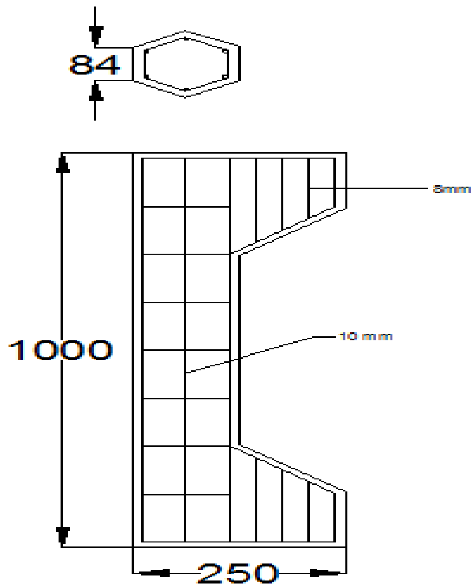

Figure 4: Detailing of hexagonal column

II. PROBLEM STATEMENT

A significant portion of the world's civil engineering reinforced concrete (RC) infrastructure, including bridges, municipal buildings, transportation systems, and parking facilities, is facing problems due to poor design and/or construction practises, changes in space, functionality, or loading, overuse, seismic upgrading, and, of course, insufficient maintenance. Reinforced concrete columns, being a key structural supporting element, may require reinforcement for a variety of reasons.The new millennium's increasing expectations for sustainable and enduring structures, along with limited accessible resources, have awoken the need for novel construction technologies and more efficient use of structural materials. With the increasing number of towering buildings and massive constructions, high performance concrete is becoming increasingly popular. High Performance Concrete (HPC) is described as concrete that fulfils particular performance and uniformity criteria that cannot always be met consistently using ordinary ingredients and standard mixing, putting, and curing techniques.
The following are the study goals:

- To develop an experimental program that will fill the gap in lack of knowledge regarding behaviour of columns.
- To find which shape of column will resist the most weight under different loading conditions i.e. concentric and eccentric loading.

III. LITERATURE REVIEW

Hany A. Kottb In recent decades, high strength concrete (HSC) has been generally approved by designers and builders to be utilised in concrete constructions, especially in high compressive stress sections. The project intends to explore the behaviour of high strength concrete columns under eccentric compression using experimental and analytical techniques. The research is broken into two main components; the first part is an experimental examination for ten square columns tested at the Cairo University Concrete Research Laboratory. The key analysed parameters were eccentricity of the applied load, column slenderness ratio; and ratios of longitudinal and transverse reinforcement. The second part is analytical analysis using nonlinear finite element programme ANSYS11 on nineteen columns (ten tested square columns and nine rectangular section columns) to study the effect of the previous parameters on the column ultimate load, mid-height displacement, and column cracking patterns. The examined columns exhibited a satisfactory agreement with the experimental results with an average difference of 16 percent and 17 percent for column ultimate load and mid-height displacement correspondingly. Results indicated a high agreement for cracking patterns. Predictions of columns capacities using the interaction diagrams based on ACI 318-08 stress block values demonstrated a safe design approach of HSC columns under eccentric compression, with ACI 318-08 being more conservative for mild reinforced HSC columns[3].
Firoz Nadaf This research focuses on Behaviour of slender column subjected to eccentric loading. Six thin, reinforced concrete columns with slenderness ratio equals to 15; the compressive strength of the concrete were ranged from 60 to 100 MPa. Slender column were exposed to eccentric axial load with load-eccentricity: depth ratio of 0.15. Three columns were reinforced with six bars having a nominal strength of 415 MPa and other three were reinforced with same number of bars having strength equals to 500 MPa with longitudinal steel ratio equals to 4 percent. The test results were compared with the values anticipated using IS 456-2000. These test, enabling the provision for thin columns in the code to be evaluated against experimental values, have revealed that IS 456-2000 are extremely safe and uneconomical design document for HPC slender column[4].
Chengshun Xu The size impact of reinforced concrete (RC) members is largely driven by: 1) the heterogeneity and the mechanical nonlinearity of concrete; 2) the complicated mutual interaction between steel rebar and the surrounding concrete. The usage of high-strength concrete (HSC) is growing increasingly widespread as the structural dimension rises, which in turn makes the size impact behaviour more and more visible. Moreover, the bulk of RC members are under complex stress circumstances, which makes the size impact more challenging. Experiments on a total of 16 geometrically equivalent high-strength RC columns with the maximum cross-sectional dimension of 800 mm× 800 mm were done. The mechanical behaviour of the high-strength RC columns exposed to axial monotonic and repetitive cyclic compressive loadings were evaluated and the size influence on axial compressive strengths was analysed[5].
Katelyn E. Shipp The goal of this research was to find out which shape of column is the strongest and will sustain the most weight. It was predicted that the round shaped column would be the strongest and would support the maximum weight. The findings of the experiment validated the theory. The cylindrical shaped column was by far the strongest column and sustained the most weight. The cylindrical shaped column is the strongest is because of corners. The flat surfaces of the forms do not support structural load. Therefore, it is the corners of the forms that give the columns their strength. The triangle has three corners to sustain its load, the square has four, the hexagon has six and the octagon has eight corners. In comparison, the circle may be considered as having 360 corners. Thus, the circle is by far the strongest shaped column[6].
Emad El-Sayed Etman This study covers an extended experimental programme composed of twenty seven specimens to explore the behaviour of reinforced concrete, RC, slender columns with rectangular sections under the impact of eccentric loads. The programme has three group each having 9 specimens. The first group (A) is considered as a control group tested without strengthening and the second group (B) is strengthened using near surface mounted (NSM) longitudinal steel bars while the third group (C) is strengthened using NSM longitudinal steel bars partially wrapped with one ply of carbon fibres reinforced polymers (CFRP) sheets. In addition to the strengthening schemes, the test parameters comprised the investigation on the change in the ratio of the internal longitudinal steel bars as well as the stirrups' volumetric ratio. All specimens are tested eccentric loading with eccentricity-to-section height e/h = 0.25. The investigation found that the strength gain in specimens in group (C) is larger than in group (B) (B). The proposed strengthening

techniques enhanced the ultimate capacity as well as the ductility of the eccentrically laden columns[7].

IV. PROPOSED SYSTEM

A. Tests on Materials

- Determination of initial and final setting time.
- Workability test.
- Fineness test.
- Compressive strength of concrete.
- Compaction factor test.
- Consistency of standard cement paste.

B. Formwork

Formworks for square and hexagonal columns were prepared from ply board sheets of 12mm thickness. Formwork for circular columns was prepared from PVC pipes and the end projections were taken with the help of ply board sheets. The steel used was TMT 415 steel shown in Figure 5 below:

Figure 5: Formworks for various columns

C. Mixing of Materials and Casting

The mixing has been done in a drum by mixing the materials and aggregates for 5 minutes in a mixer before adding water in numerous stages. A homogenous mixture was achieved. The concrete columns were placed and cured with utmost care. To achieve full strength, they were permitted to cure for 28 days after casting. The specimen were then cleaned and removed from the frame work.

D. Instrumentation and Experimental Set Up

All columns were tested on a universal testing machine (500KN) with a hydraulic jack
the specimen's deflection and load carrying ability were measured using an electric resistant Proving ring with 500KN capacity.
Figure 6 shows the Loading frame
Figure 7 shows the Proving ring
Figure 8 shows the Loading jack
Table 2 shows the Results under concentric loading
Table 3 shows the Results for 50mm eccentricity
Table 4 shows the Results for 75 mm eccentricity

Figure 6: Loading frame

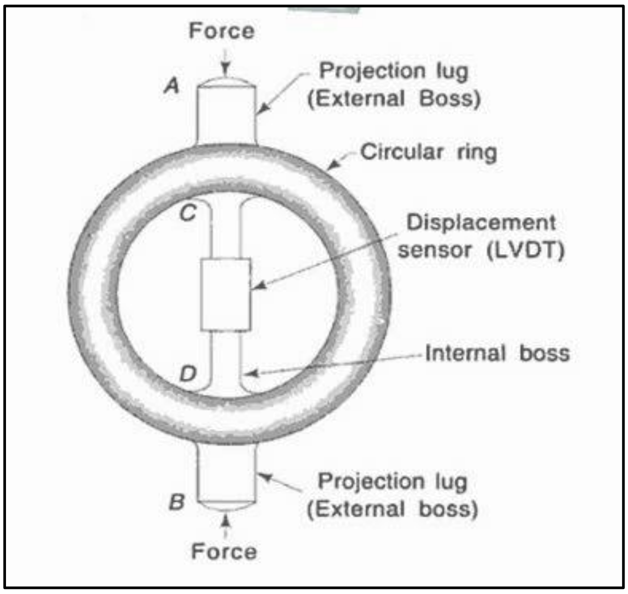

Figure 7: Proving ring

Figure 8: Loading jack

V. RESULT ANALYSIS

A. Columns Under Concentric Loading

Using the loading frame outlined above, columns with square, circular, and hexagonal cross sections were evaluated. Each column received the same amount of stress in the same direction. More reliable findings were obtained by doing the tests on two specimens of each kind.
Result:

Table 2: Results under concentric loading

S No.	Column Type	Avg. ultimate Load(KN)
1	Circular	301
2	Square	285
3	Hexagonal	228

B. Columns Under Eccentric Loading

A loading frame was used to test the columns with varied cross-sectional forms. Initially, the columns were tested with an eccentricity of 50mm and subsequently 75mm.
Results:

Table 3: Results for 50mm eccentricity

S NO.	**COLUMN TYPE**	**Average ultimate load,P_u (KN)**	**Average Moment M_u, (KN-M)**	**Percentage increase in P_u (%)**	**Percentage increase in M_u (%)**
1	Hexagonal	197.15	9.85	-	-
2	square	264.5	13.225	27.7	27.83
3	circular	273.6	13.65	3.32	3.11

Table 4: Results for 75 mm eccentricity

S NO.	**COLUMN TYPE**	**Average ultimate load P_u (KN)**	**Average moment M_u (KN-M)**	**Percentage increase in P_U (%)**	**Percentage increase in M_u (%)**
1	Hexagonal		7.94	-	-
2	Circular	222.6	11.1	28.6	28.4
3	square	240.4	12	7.4	7.5

VI. CONCLUSION

As the eccentricity of the columns develops, the buckling of the columns correspondingly increases, causing the high eccentric overloaded columns buckle more than the low eccentric loaded columns. In compared to low eccentric overloaded columns, the high eccentric loaded columns show larger cracks. More high-eccentrically loaded columns have been observed to display load fluctuations. Under eccentricity, reinforced concrete columns demonstrate effective resistance. Increasing the eccentricity of the columns decreases the maximum load that may be supported. In reinforced concrete columns, the ultimate stress (cracking) increases as the eccentricity develops.

Circular columns are better equipped to sustain concentric loads than the other two. Square column likewise has adequate load bearing capability however the load carrying capacity of hexagonal column is considerably low. Manufacturing the hexagonal column casting more expensive is the difficulties of creating the formwork and other components of the column. The building of a square column is easier than a cylindrical one.

The square column performs better than the other two when subjected to eccentric loading. In respect to the other two, the square column carries higher weight as the eccentricity develops. Square columns, which do not need symmetry of reinforcement along the column axis, should be utilized with known eccentricity direction and reinforced on opposing faces where bending would cause compression and stress. The round column gives equal resistance to loads (lateral) emanating from all directions when the eccentricity direction is unknown.

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