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Capacity optimization of Reinforced Concrete Circular Column

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***Abstract**: The paper is all about pragmatic method of increasing structural performance of reinforced concrete circular column at the same quantity provision of the main bars. Main attention was given to the ring component of the column reinforcement. Materials were collected and treated as it may be demanded in normal design and construction processes. Circular column reinforcement fabrications were carried out as specimens with circular and spiral rings. Different angles of inclination were considered for the spiral rings at equivalent spacing of that of circular, using the same cross sectional size of steel and area of the composite element. Laboratory crushing test was carried out at the required same ages of casting and curing to obtain results. The analysed crushing strength results thus revealed considerable increase in load carrying capacity of the spirally ringed reinforced column above the circular rings at same cost implication.*
***Key words**: Capacity, Circular Column, Lateral ties and Optimization.*

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I. Introduction

1.1 General: Column, structurally, is a vertical and isolated component of a building structure, just like human legs, supporting loads from the head and transfer the same to the ground. Hence, it is an essential compression member. Cross-sectionally, according to BS 8110 (1997): Part 1, Section 3.8.1 and Macginley and Choo (1990), provision apply columns where the greater cross-sectional dimension does not exceed four times the smaller dimension. Stability and strength of a column depends, conventionally on;

- Quality of the materials.
- The slenderness of the column.
- Richness of the concrete mix, in case of concrete type.

According to Morgan, 1964 and Buckle, 1979, if a short column is gradually loaded, failure occurs at ultimate resistance to crushing load. If, however, a long and slender column is considered, failure will occur due to buckling at a lower load than would cause in a short column.

1.2 Effective Height of Columns: Depends on the way in which the top and bottom of a column are held or secured, which normally affects considerably its load carrying capacity. Three conditions are noted in this instance;

i) Column hinged at both ends.
ii) Column with one end fixed and one hinged.
iii) Column with both ends fixed.

Values as applicable to any of the above end conditions are obtained in design tables with permissible stress and corresponding slenderness ratio.

1.3 Material Options: Useful materials of column are timber, steel, steel cased in concrete and reinforced concrete columns. Meanwhile steel and concrete materials are predominantly used in structural works, due to higher load carrying capacity. Reinforced concrete columns have cross-sections significantly larger than corresponding steel columns and failure due to buckling is common because the slenderness ratio is usually low.
1.4 Structural Classification of Columns: Columns are compression members although some may be subjected to bending either due to their slenderness or due to symmetrical bending from beams. In a structure they carry the load from the slab and beam to the foundation. Columns are classified as below.
1.4.1 Classification Based on Reinforcement Types: Reinforced concrete columns are classified into the following three types which are;

(i) Tied Columns: Where the main longitudinal bars are enclosed within closely spaced lateral ties, Fig. 1

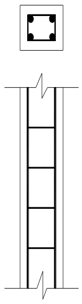

Figure 1: Tied Column

(ii) Spiral Columns: Where the main longitudinal bars are enclosed within closely spaced and continuously wound spiral reinforcement, Fig. 2

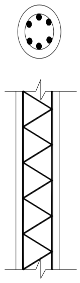

Figure 2: Spiral Column

(iii) **Composite Columns:** Where the reinforcement is in the form of structural steel sections or pipes, with or without longitudinal bar, Fig. 3

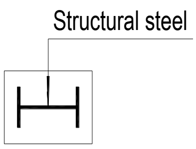

Figure 03: Composite column

This project deals mainly with spiral transverse reinforcement in optimizing reinforced concrete circular column at a varying pitch angle.

1.4.2 Classification Based on Loading Type: Columns may be classified into the following three types:

- ❖ Columns with axial loading (applied concentrically), Fig. 4a
- ❖ Columns with uniaxially eccentrically loading, Fig. 4b
- ❖ Columns with biaxially eccentrically loading, Fig. 4c

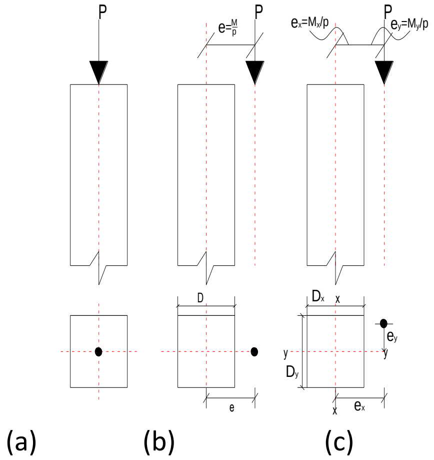

Figure 4: Columns based on loading

The occurrence of 'pure' axial compression in a column (due to concentric loads) is relatively rare. Generally, flexure (and, sometimes shear) accompanies axial compression – due to 'rigid frame' action, lateral loading and/or actual (or even, unintended/accidental) eccentricities in loading. Meanwhile, this text focuses on columns that are loaded axially.

1.4.3 Classification Based On Slenderness Ratio: Columns may be classified into the following two types, depending on whether slenderness effects are considered insignificant or significant:

- Short columns.
- Slender (or long) columns.

Slenderness is a geometrical property of a compression member which is related to the ratio of its effective length to its lateral dimension. This ratio, called slenderness ratio, also provides a measure of the vulnerability to failure of the column by elastic instability (buckling) – in the plane in which the slenderness ratio is computed. Columns with low slenderness ratio, i.e., relatively short and stocky columns, invariably fail under ultimate loads with the material (concrete, steel) reaching its ultimate strength by crushing. On the other hand, columns with very high slenderness ratios are in the danger of buckling (accompanied with large lateral deflection) under relatively low compressive loads. Design codes attempt to preclude such failure by specifying slenderness limit to columns.

There is another important consequence of slenderness of a column subjected to eccentricity compression. When a column is subjected to flexure combined with axial compression, the action of the axial compression in the displaced geometry of the column introduces 'secondary moments'. On the other hand, the secondary moments are negligible in columns with slenderness ratios: such columns are called short columns. Design codes provide guidelines, in terms of slenderness ratios, in drawing line between short columns and slender columns.

According to BS8110 (3.8.1.3), a column may be considered as short when the stiffness in both directions is less than 15 (braced) and 10 (unbraced). It should be otherwise considered as slender column.

1.4.4 Classification Based on Lateral Support: Columns may be classified based on the lateral support, according to Mosley, Bungey and Hulse (2007) as follows:

(i) Braced Columns: If lateral stability to the structure as a whole is provided by walls or bracing or buttressing designed to resist all lateral forces in that plane

(ii) Unbraced Columns: it should be considered otherwise of braced columns.

A set of column may be designed for load bearing, aesthetic purpose or both. Columns designed for load bearing are usually of rectangular sections and may be located internally, edges or corner positions with or without side walls. Aesthetically designed columns are more often of circular section and usually those at close proximity to car parks, strategic locations of building structures in accordance with the architectural concept. The later, are also exposed to danger of accidental external impact forces and severe weather conditions.

Modes of Failure: Generally, column can fail as a result of material failure or due to statical instability. A short column fails by crushing, when the ultimate resistance to axial load is reached, Mosley and Bungey (1990). If a column is long, failure will occur due to buckling at a much lower load than would cause failure in a short column of equal cross-section. This ‘buckling’ failure mode is major of a circular column, Khalifa and Collins (1981). Thus the reason for its focus in respect of capacity optimization.

II. Materials And Method

Materials as needed under normal condition were itemized and collected at market source. The same were brought to the construction laboratory and treated accordingly in line with engineering method as technically required to achieve the desired result.
The materials: Fine and coarse aggregates, cement, water, 8mm & 6mm diameters reinforcing bar, binding wire, planks, metal sheets and consumables.

Method: The approach adopted is as highlighted below;

i) 4Nos column specimen moulds were prepared of planks with inner metal sheet lining, Photo Plate (PP) 01.

PP 01: Specimen Mould

ii) 6Nos Main (longitudinal) bars of 8mm dia. cut to specimen size prepared and spiral transverse reinforcement of Ø6mm wind at angles 15°, 30°, 45° & 60° respectively using binding wire, Photo Plate (PP) 02.

(a)
PP 02: Fabrication of Reinforcement (b)

iii) Reinforcements were properly placed inside the mould and made ready to receive concrete.
iv) Batch mixing of concrete was carried out using mix ratio 1:2:4 and properly placed in the moulds.
v) Each specimen was equally treated as detailed in Table 01 before laboratory test.

Table 01: Specimen Details

Sample Mark	**CT 1**	**CT 2**	**CT 3**	**CT 4**
Angle	15°	30°	45°	60°
Pitch (mm)	46	100	140	240
Bar Ø (mm)	8	8	8	8
Links Ø (mm)	6	6	6	6
Specimen Height (mm)	400	400	400	400
Specimen Dia. (mm)	180	180	180	180
Conc. Mix Ratio	1:2:4	1:2:4	1:2:4	1:2:4
Curing (days)	14	14	14	14

vi) Samples were tested in structures laboratory using universal machine to determine compressive strength at crushing, PP 3.

PP 03: Crushed Specimen

III. Results And Discussion

3.1Results: Having followed the procedural steps, test were carried out, results collected and documented in Tables 02 and 03 below for analysis;

Table 02: Column Specimen with Spiral Ties

Specimen	**15°**	**30°**	**45°**	**60°**
SPS 1 (kN)	295.00	250.00	230.00	210.00
SPS 2 (kN)	292.00	249.00	227.00	203.00
SPS 3 (kN)	289.00	247.00	218.00	205.00
SPS 4 (kN)	285.00	243.00	220.00	209.00
Average (kN)	**290.30**	**247.30**	**223.75**	**206.75**
Crushing Strength (kN/m^2)	**11.41**	**9.72**	**8.79**	**8.12**

Table 03: Column Specimen with Circular Ties

Specimen	**45 (mm)**	**100 (mm)**	**140 (mm)**	**245 (mm)**
CRS 1 (kN)	240.00	218.00	200.00	198.00
CRS 2 (kN)	238.00	215.00	199.00	180.00
Average (kN)	**239.00**	**216.50**	**199.50**	**189.00**
Crushing Strength (kN/m^2)	**9.39**	**8.51**	**7.84**	**7.43**

Table 04: Percentage Optimization of Spiral over Circular Ties

Specimen	45 (mm) / 15°	100 (mm) / 30°	140 (mm) / 45°	245 (mm) / 60°
Circular Ties Crushing Strength (kN/m^2)	9.39	8.51	7.84	7.43
Spiral Ties Crushing Strength (kN/m^2)	11.41	9.72	8.79	8.12
Difference (kN/m^2)	2.02	1.21	0.95	0.69
Optimization (%)	22	14	12	9

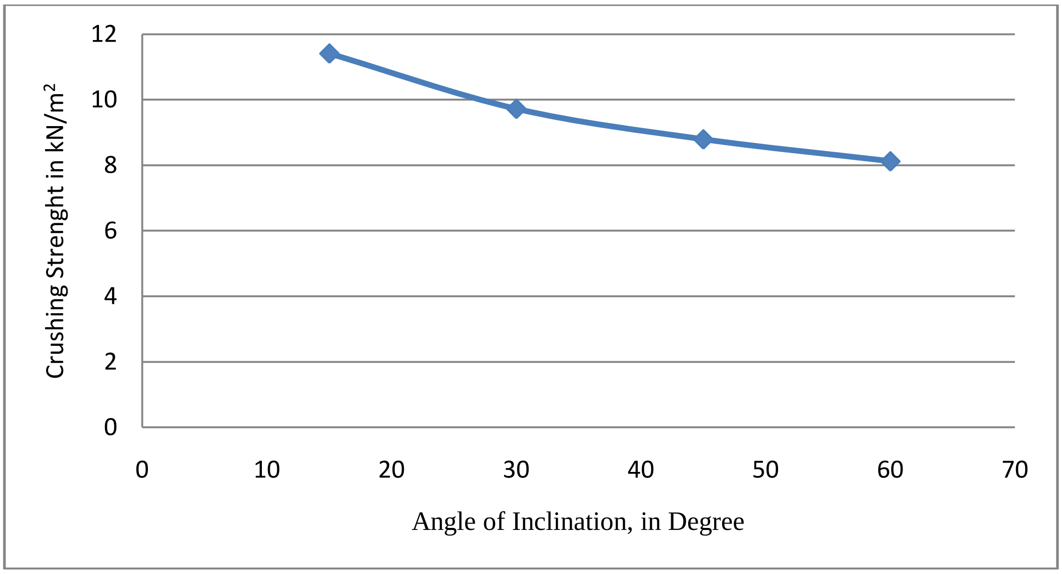

Fig. 5: Crushing Strength for Spiral links

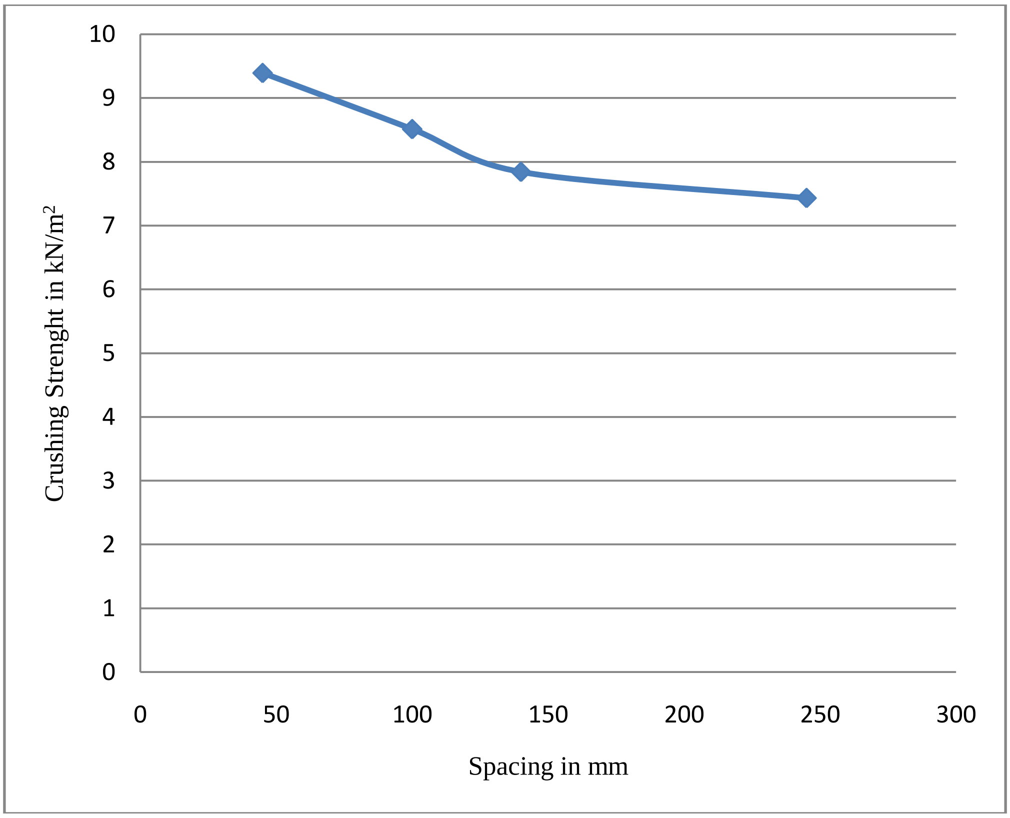

Fig. 6: Crushing Strength for Circular Rings

3.2 Discussion: Normaly, lateral ties are not designed to contribute directly to load carrying capacity of columns because they are usually spaced at about 250mm, Dancygier (1991). From the tables and Fig. 5 and 6 above, generally, load carrying capacity of column reduces as **spiral angles of inclination** and circular **spacings** increases in both cases. However, results of that of spiral rings demonstrated an optimized capacity (strength) of considerable percentage above that of circular rings in all the groups, even at an equivalent pitch (spacing), Tab. 04.

The principle can be compared to the restraining action of steel hoops of a barren filled with soil. The bursting of the barrel due to lateral forces caused by the download is prevented by the steel hoops which are put in tensile stress. Similarly, in a reinforced-concrete column, the downward load tends to make the column shorter and flatter. The binding acts like the steel hoops on a barrel, enabling the column to take more load. Hence, safe load for a spirally bound column is therefore equal to the safe load for the concrete in the core plus the safe load for the longitudinal steel bars, plus the load taken by the binding.

IV. Conclusion

Generally, the strength of all columns is dependent on the strength and elasticity of the materials, the shapes and size of the cross section, the length of the column and the degree of positional restraint of the ends of column. In reinforced concrete, if a compression member is short it is often common to fail by compression failure of the materials by longitudinal splitting and spalling of the concrete. Hence, lateral ties are used to prevent the longitudinal bars from buckling and bursting. These lateral ties also prevent shearing of the concrete on a diagonal plane, Clarke and Birjandi (1993). The same view also buttressed by Kim and Mander (2005). From this work, helical (spiral) ties reveal an increasing percentage of load carrying capacity (optimization) over that of usual circular ties. Thus recommended for circular columns.

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