Analysis of tranverse reinforcement circular section of reinforced concrete columns as the effect of flexure and axial load

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Abstract. Column is a pressed element that enables to withstand the loads for its structure. The analysis was conducted at the round reinforced column and tied rather than the spherical round reinforced column. The proportion of this column structure was designed in accordance with the function of a building and the zone area of the same earthquake, as well as its loading and dimension of the same space. Furthermore, the researcher also did comparing the ductility’s score of reinforced concrete column of a building from which a model of history building with its width of 20 m, length 30 m and height 40 m had been designed. Based on its proportion of inner force and column ductility and calculation result of ties spiral round space column it was obtained that the inner force of maximum axial (P) = 4356.6 kN, Shear 2-2 (V2) = 132.3 kN, Moments 3-3 (M3) = 142.9 kNm and ductility = 4.59. Meanwhile, the ties rounded-space column was obtained that its axial maximum force was (P) = 4169.8 kN, Shear 2-2 (V2) = 131.3 kN, Moments 3-3 (M3) = 141.4 kNm and ductility 4.11. Based on the analysis above, it was concluded which had ductility score greater than that of rounded-ties space with the same space (Ag).

1. Introduction
In a structural planning of a tall building, safety is one of the most important factors that must be considered. Several factors which affect the strength of a tall building are such as live load, dead load, wind and Earthquake load. In line with this problem, the researcher makes some comparisons of reinforcement to the column structure that is ties concrete column and ties spiral concrete column. These two columns have the same loading functions of a building. Meanwhile, the data of a building have 10 stories (floors) with its width: 20 m, length: 30 m and height: 40 m. Furthermore, the column failure will affect directly on the collapse of the other structural components related to it, or even it became the total collapse limit of a building structure. In general, the failure or collapse of pressed component is not preceded by a clear warning but all of a sudden. Therefore, making a plan of column structure must be considered accurately by providing an extra power or strength than the other structural components. Due to in practical use, column does not only function to support a vertical axial load but it also supports a combination of axial load and flexure moment. In another word, column should be considered as the main material to support the axial load with its a certain eccentricity [6]. Based on the background of a study above, this research was aimed at how the column’s behavior of ties spiral rounded column with istties to the buckling and how its structural ductility comparison of ties spiral concrete column, ties spiral and ties as the effect of flexure and axial load combination. Meanwhile, the limitation of the
problems of this research was dealing with the behavior’s study of reinforced concrete column, such as the column behavior’s study receiving some buckling and ductility. The column used was the ties spiral concrete and we only analized the comparison of ties variation.

2. Method
The column structural designed received the axial and flexure force and from requirement fulfilling of structural safety based on SNI 1727:2013, SNI 1726:2012, and SNI 2847:2013. Column can be restrainted in efforts to increase its axial supporting power. Meanwhile, its nominal capacity of theoretical axial load of non-slender column is as follows:

$$\rho_n = 0.80 \varphi \left[ 0.85 \psi f_{cc}' (A_g - A_{st}) + f_y A_{st} \right]$$ .................................................................(1)

While,

- $A_g$ = width of concrete gross
- $A_{st}$ = reinforcement extent of steel stretching
- $f_y$ = melting tension/stress of longitudinal steel
- $\psi f$ = reduction factor of FRP
- $f'_{cc}$ = stressed force of restrained concrete, psi (MPa)

However, in efforts to increase ductility factor of column transfer, plastic transfer ductility had to be increased, this can be achieved by restraintment. Due to its deflection, curvator and rotation were equivalent with its moment, so that ductility factor was intended for the material can be written as follows:

$$\text{Ductility factor} = \frac{\text{deflection(curvature or rotation) at ultimate}}{\text{deflection(curvature or rotation) at steel yield}}$$ ....................................................(2)

3. Results and Discussion
3.1 Column Dimension Design
As the building design used its own building modeling: length of a building: 28 m, width: 20 m and height: 40 m, so the column dimension design was made the same.

$$W_{total} = W_{floor} + W_{roof} = 2190.8 + 118.08 = 2308.9 \text{ kN}$$

3.2 Earthquake Load
Earthquake load design of a building structure used the equivalent static load.

| Floor | Hi(m) | Fx-y (KN) | 100% Fx (KN) | 30% Fy (KN) |
|-------|-------|-----------|--------------|-------------|
| 10    | 40    | 94.42     | 94.42        | 28.32       |
| 9     | 36    | 84.41     | 84.41        | 25.32       |
| 8     | 32    | 66.70     | 66.70        | 20.01       |
| 7     | 28    | 51.06     | 51.06        | 15.31       |
| 6     | 24    | 37.52     | 37.52        | 11.25       |
| 5     | 20    | 26.05     | 26.05        | 7.81        |
| 4     | 16    | 16.67     | 16.67        | 5.00        |
| 3     | 12    | 9.38      | 9.38         | 2.81        |
| 2     | 8     | 4.17      | 4.17         | 1.25        |
| 1     | 4     | 1.04      | 1.04         | 0.31        |

Source: Data of Research Result

3.3 Column Design
Based on the initial design, the design data used in the calculation are:
3.3.1 Determination of Round Column Dimension

Structure calculation using round column (ties) was carried out by re-calculation of the structure of a building by changing the square columns as it was used previously into ties. The calculation itself was based on the ratio between square column and ties sectional area (Ag). It should be noted that both of the accounted cross-sectional area (Ag) are the same. The ties dimension calculation could be seen as the following calculation:

a. Dimension of Square column 56.5
   \[ Ag = 250591 \text{ mm}^2 \]
   From the graph of the column diagram can be obtained:
   \[ r = 1.85 \% \]
   \[ \rho = r \cdot \beta = 0.018 \times 1 = 0.018 \]
   \[ Ast = \rho \cdot Ag = 0.018 \times 250591 = 4510.6 \text{ mm}^2 \]

b. Calculation of Round Column Capacity (Ties)
   According to SNI 2847: 2013 Article 10.3.6.2, the axial load capacity of the column should not be less than the axial load of the factored structure analysis.
   \[ Ag = 250591 \text{ mm}^2 \]
   \[ Ast = 4559.3 \text{ mm}^2 \]
   \[ \varphi \cdot P_{n(max)} = 0.8 \times \varphi \times \left[ 0.85 \times f'c \times \left(A_g - A_{st}\right) + fy \times A_{st}\right] \]
   \[ = 0.8 \times 0.65 \times [0.85 \times 35 \times (250591 - 4559.3) + 240 \times 45593] = 43751.111.1 \text{ N} \]
   \[ = 4375.1 \text{ kN} > P_{u} = 4164.49 \text{ kN} \quad \ldots \quad \ldots \text{OK} \]

c. Calculation of Transversal Reinforcement Column
   To equate column transversal reinforcement (ties) with ties spiral by (SNI 2847 – 2013 article 9.10) ties spiral net distance should not exceed 75 mm and not less than 25 mm. Then the distance of the ties used for the rounded column is ties \( \Phi \) 10 – 75.

3.3.2 Ductility Calculation of Round Column (Ties)

From the curvature moment diagram of a ties rounded column D56.5, the column’s ductility obtained was 4.111.

3.4 The Concept of Strong Column Weak Beam

In accordance with the philosophy of capacity design, SNI 2847-2013 Article 21.6.2 requires that:

\[ \sum M_{nc} \geq (1.2) \sum M_{nb} \]

In order to find the value of Mg, the followings are the data needed for its calculation:

a. Beam drag reinforcement 5D19 (\( A_{s1} = 2416.9 \text{ mm}^2 \))

b. Beam tap reinforcement 3 D19 (\( As = 850.2 \text{ mm}^2 \))

c. Sengkang (Ties) diameter 8 mm

d. Concrete cover taken 30 mm

e. \( d = 350 - 30 - 8 - 0.5 \times 19 = 292.5 \text{ mm} \)

The value of \( M_{nb} \) was obtained by adding up \( M_{nb}^{+} \) and \( M_{nb}^{-} \) of the beams which were integrated with the column. In this case, the equation is as the following:

\[ M_{nb} = As \cdot fy \left( d - \frac{a}{2}\right) \cdot 0.8 \]
On the upside (tap reinforcement):

\[ a = \frac{A_s \cdot (1.25 \cdot f_y)}{0.85 \cdot f'c \cdot b} = \frac{2416.9 \times (1.25 \times 240)}{0.85 \times 35 \times 200} = 121.8 \text{ mm} \]

Thus:

\[ M_{nb^-} = 2416.9 \times 240 \left(292.5 - \frac{121.8}{2} \right) \times 0.8 \]

\[ = 107458737.3 \text{ Nmm} = 107.4 \text{ kNm} \]

On the upside (axial reinforcement):

\[ a = \frac{A_s \cdot (1.25 \cdot f_y)}{0.85 \cdot f'c \cdot b} = \frac{850.2 \times (1.25 \times 240)}{0.85 \times 35 \times 200} = 42.8 \text{ mm} \]

Thus:

\[ M_{nb^+} = 850.2 \times 240 \left(292.5 - \frac{42.8}{2} \right) \times 0.8 \]

\[ = 44248443.2 \text{ Nmm} = 44.2 \text{ kNm} \]

Therefore:

\[ \sum M_b = M_{nb^-} + M_{nb^+} \]

\[ = 107.4 + 44.2 = 151.6 \text{ kNm} \]

\[ \sum M_{nc} \text{ value obtained from the column interaction diagram using PCAcolumnn is } \Sigma M_{nc} = 305 \text{ kNm} \]

Requirements of Strong Column Weak Beam (SNI 2847 – 2013 Article 21.6.2)

\[ 305 \text{ kNm} \geq 1.2 \times (151.6) = 181.9 \text{ ……….. OK} \]

3.5 Calculation of Statistical Analysis Using SAP2000

Based on the calculation result of inner force resulted from D56.5, spherical ties round column is as follows:

| Table 2. Inner Force Result analyzed and Round Column D56.5 Analysis |
|---------------------------------------------------------------|
| Column | Pu (kN) | V2 (kN) | M3 (kNm) |
| Round (Tied) | 4169.9 | 131.3 | 141.4 |
| Round (Spiral) | 4239.8 | 132.8 | 142.8 |

Source: Research Data

3.6 The Comparison of Column Capacity

The comparison between round (ties) column capacity and round (spiral) column capacity could be seen in Table 3 below:

| Table 3. The Comparison Between Axial Load Capacity (Pn), MomentLoad(Mn), and Column Ductility Value (D56.5) |
|---------------------------------------------------------------|
| Column | Dimension (cm) | Axial Load (Pn) (kN) | MomentLoad (Mn) (kN) | Ductility |
| Ties | D56.5 | 4805 | 338 | 4.111 |
| Spiral | D56.5 | 5449 | 346 | 4.592 |

Source: Data of Research Result

4. Conclusion

Having finished the loading calculation, it was found that the column behavior as the effect of the combination between axial and flexure loads and to find its column ductility, it could be concluded as follows:
1. From the calculation result of rounded columns' ties spiral, it had a relatively greater force behavior compared with the rounded column ties from which it was obtained that its maximum axial force \((P) = 4169.8 \text{ kN}\), shear 2-2 \((V2) = 131.3 \text{ kN}\), shear 3-3 \((V3) = 40.7 \text{ kN}\), moment 2-2 \((M2) = 88.7 \text{ kNm}\), and moment 3-3 \((M3) = 141.4 \text{ kNm}\);

2. Regarding with the reinforcement design of transversal column in accordance with SNI 2847:2013, that was the round ties spiral column, it was found that the clear distance between ties spiral should not either more than 75 mm or less than 25 mm. Then it was obtained that the comparison of column ductility the rounded column ties spiral ductility was 4.592 and the rounded column ties ductility was 4.111.

3. Finally, based on the analysis result, it could be concluded that transversal reinforcement affected to the strength of column’s structure. Therefore, the distance between the ties reinforcement of reinforced concrete column, the greater strength that column structure was. Thus, the round ties spiral concrete column had a greater ductility value compared with the ties one.

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6. **References**

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