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# Capacity analysis of reinforced concrete and composite column on a 7 floor building

# Análisis de capacidad de hormigón armado y columna compuesta en edificio de 7 pisos

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***Abstract***

*To design columns with reinforced concrete material is often used in building construction so that reinforced concrete has several advantages, it is the availability of material, but require a large dimension in holding high capacity. To reduce the dimensions of the column structure can be designed with a composite structure. In this study, an analysis will be carried out to determine the difference in dimensions that can be provided by reinforced concrete columns and composite columns holding an equivalent nominal capacity. This analysis was carried out in a case study of the planning of a 7-story lecture building. The initial design of the column applied is a reinforced concrete column which will then be redesigned with a composite structure using a WF steel profile. Based on the results of the research analysis shows that in holding the nominal capacity equivalent, the dimensions of the composite column used are smaller than the reinforced concrete column. In addition, the volume requirement of the material is also lower, this indicates that the composite column is good enough to be applied in building planning.*

***Keywords****: Nominal capacity; reinforced concrete column; composite column*

**Resumen**

Para diseñar columnas con material de hormigón armado se suele utilizar en la construcción de edificios por lo que el hormigón armado tiene varias ventajas, es la disponibilidad de material, pero requieren una gran dimensión en la celebración de gran capacidad. Para reducir las dimensiones de la columna, la estructura se puede diseñar con una estructura compuesta. En este estudio, se realizará un análisis para determinar la diferencia de dimensiones que pueden proporcionar las columnas de hormigón armado y las columnas compuestas con una capacidad nominal equivalente. Este análisis se llevó a cabo en un estudio de caso de la planificación de un edificio de conferencias de 7 pisos. El diseño inicial de la columna aplicada es una columna de hormigón armado que luego se rediseñará con una estructura compuesta utilizando un perfil de acero WF. Con base en los resultados de la investigación, el análisis muestra que al mantener la capacidad nominal equivalente, las dimensiones de la columna compuesta utilizada son más pequeñas que la columna de hormigón armado. Además, el requisito de volumen del material también es menor, esto indica que la columna compuesta es lo suficientemente buena para ser aplicada en la planificación de edificios.

**Palabras clave:** Capacidad nominal; columna de hormigón armado; columna compuesta

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# 1. Introduction

*The buildings that are increasing from year to year require design accurately so that the building can use properly and safely. So, it needs to design a column as a compression member which carries an axial load on the foundation, according to research (Toni et al., 2015). To design column must be designed in such a way that the column does not collapse. Because the collapse of the column can cause the total collapse of the entire building.*

*The capacity of the column to withstand the load is influenced by the components that make up the column, namely concrete which is weak in tension. Therefore, concrete can be combined with steel which has high tensile strength. Either with reinforcing steel as a reinforced concrete column or with the addition of a steel profile into a composite column. (Andreas et al., 2017). Reinforced concrete column structures are more widely used in building construction, this is because reinforced concrete column structures have many advantages, one of which is the flexibility of form and resistance to water and fire, but in holding high-capacity large dimensions are required.*

*The composite column structure in its planning can produce a design of smaller element dimensions than reinforced concrete columns so that it can save the floor area of the building structure. (Alfirdaus et al., 2019). In addition, the use of composite columns also has the advantage that they can increase tensile strength, structural rigidity and can increase resistance to fire hazards. (Maharani and Faimun, 2019). Composite columns that use steel tubes filled with concrete can also increase the compressive strength when filled with high-strength concrete with high-strength steel tubes as well (Guo, 2021). In addition, use of columns can be reinforced with stainless steel spirals or stainless steel is 197% more corrosion resistant than using carbon steel (Wright and Pantelides, 2021).*

*Column tests on elliptical stainless steel filled with concrete were found to be sensitive for both the thickness of the steel tube and the strength of the concrete. A higher tube thickness results in a higher load-carrying capacity, as well as resulting in increased ductility. Higher-strength concrete increases the bearing capacity but reduces ductility (Lam et al., 2010). Increasing the compressive strength of damaged columns can be done by using CFRP. A comparison between poor and medium-quality concrete columns shows that CFRP local coating is more effective in the case of poor-quality concrete (Marta Del Zoppo, 2018). Then in terms of column repair due to cyclic loading, the results showed that the cyclic load and the resulting damage caused a reduction in the axial stiffness of all damaged specimens. Hybrid column repair can restore stiffness and strength due to axial loads (Chellapandian et al., 2019).*

*The next research analyzes the difference in dimensions that can be provided by reinforced concrete columns and composite columns in bearing loads with an equivalent nominal capacity and the types of failure that can occur in reinforced concrete columns and composite columns. The composite column used is a square column with a WF steel profile wrapped in concrete.*

# 2. Methodology

*The methodology used in this research is a literature study, namely the collection of building data and information obtained from the detailed engineering design of the construction of the lecture building of the Faculty of Economics and Business, University of Jember.*

*The study begins with data collection which includes material specifications and dimensions of the building structure, followed by load analysis which includes dead load, live load, and design earthquake load with a design response spectrum. Then carried out structural modeling and analysis of the nominal capacity of reinforced concrete columns. Based on the nominal capacity value of the reinforced concrete column, the calculation of the initial design of the composite column is carried out to determine the dimensions of the column to be used. The case study in this study was carried out on the planning of a 7-story lecture building. The initial design of the columns in this building was redesigned using a composite material with a WF steel profile covered with concrete. The strength of the composite column beyond to support axial loads which are used as a reference based on SNI-1729 2015 is:*

$$P_{no} = \text{Fy} \times \text{As} + \text{Fysr Asr} + 0{,}85\ \text{fc' Ac} \tag{1}$$

a. If $= \frac{P_{no}}{P_e} \leq 2{,}25$

$$\text{Pn} = P_{no}\left[0{,}685^{\frac{P_{no}}{P_e}}\right] \tag{2}$$

b. If $= \frac{P_{no}}{P_e} > 2{,}25$

$$\text{Pn} = 0{,}877\ \text{Pe} \tag{3}$$

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$\phi = 0{,}75$

# 3. Results and Discussion

### *3.1 Structure Model*

*The building structure in this study is a 7-story reinforced concrete structure with a floor height of 27.7 m. the height on floors 1-5 is 4 m and the height on the 6th floor is 5 m. The dimensions of the structure used in this study were adjusted to the existing data. The dimensions of reinforced concrete columns are of three types, namely K1, K2, and K3. The dimensions of each column are 60x60cm, 50x50 cm, and 40x40 cm. Structural modeling with a structural analysis program is as follows:*

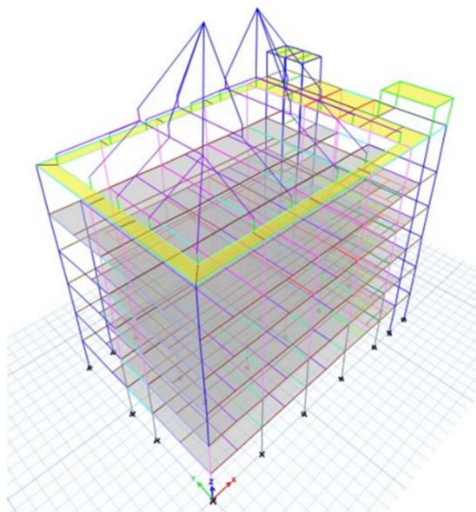

***Figure 1.*** *Structural Model*

*Loading in this study used dead load, live load, and earthquake load. Dead load and live load are adjusted to (SNI-1727, 2013) regarding loading on building structures. Earthquake loads are planned with a design response spectrum based on (SNI-1726, 2019) by determining the type of soil, which includes moderate soil with risk category IV, the location is in Jember, East Java. The design response spectrum diagram is:*

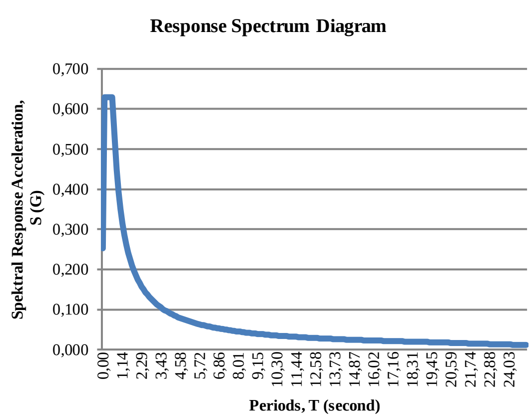


***Figure 2****. Response spectrum design*

*Analysis of reinforced concrete columns refers to (SNI-2847, 2019). Based on the results of structural analysis on reinforced concrete columns, the results of reinforcement are as follows:*

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***Table 1.*** *Column reinforcement details*

| column | size (mm) b x h | Longitudinally reinforcement |
|---|---|---|
| K1 | 600 x 600 | 16 ϴ19 |
| K2 | 500 x 500 | 12 ϴ19 |
| K3 | 400 x 400 | 12 ϴ16 |

*The results of the transverse reinforcement for columns K1, K2, and K3 are as follows:*
*shear reinforcement of end-span: ϴ12–100 mm*
*shear reinforcement of mid-span: ϴ12–150 mm*

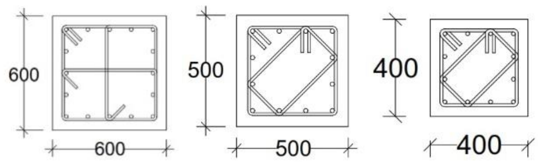

***Figure 3.*** *Type of reinforced concrete columns*

***Table 2***. *Column Capacity*

| Column's type | size(mm) b x h | Pn (kN) |
|---|---|---|
| K1 | 600 x 600 | 6660,5955 |
| K2 | 500 x 500 | 4700,3266 |
| K3 | 400 x 400 | 3078,1334 |

### *3.2 Composite columns Analysis*

*The composite structure used is a square column with a WF steel profile wrapped in concrete. The composite structure is designed to be able to withstand a nominal capacity equivalent to a reinforced concrete column. The dimensions and steel profiles used in the composite column are as follows:*

***Table 3.*** *Composite column details*

| *Column's type* | *size(mm) b x h* | *WF profile* |
|---|---|---|
| *C1* | *500 x 500* | *250x250x14x14* |
| *C2* | *450 x 450* | *200x200x8x12* |
| *C3* | *350 x 350* | *175x175x7,5x11* |

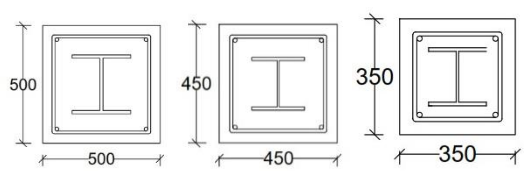

***Figure 4***. *Composite column type*

*Longitudinal reinforcement was used in each composite column, namely, C1 used 4D19, 4D19, and C3 used 4D19. With transverse reinforcement in columns, C1 and C2 D 12-200 with a stirrup spacing of 200 mm and column C3 used D12-150 mm.*

*Based on the results of the analysis, the nominal capacity of the composite column is as follows:*

***Table 4.** Column Capacity*

| *Column's type* | *sizes (mm)* | *Pn (kN)* |
|---|---|---|
| | *b x h* | |
| *K1* | *500 x 500* | *6660,5955* |
| *K2* | *450 x 450* | *4700,3266* |
| *K3* | *350 x 350* | *3078,1334* |

### ***3.3 Composite column and base plate joint***

*The connection to the base plate is designed with a welded joint. 4 anchors with D24 mm were used. The dimensions of the base plate are 25 x 25 cm with a thickness of 30 mm and an anchor length of 500 mm. pedestal dimensions 700 x 700 mm.*

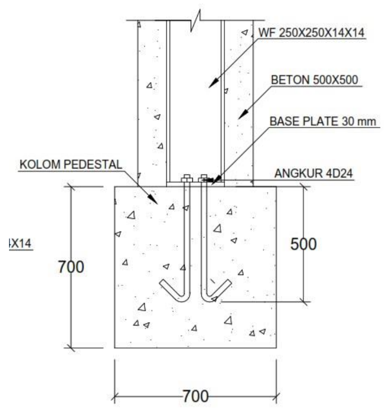


***Figure 1**. Column connection and base plate*

*Comparison of reinforced concrete columns and composite columns in holding equivalent nominal capacity can be seen in (Table 5) the following table:*

***Table 5.** Comparison of dimensions with an equivalent nominal capacity*

| *Column type* | | *size(cm)* | *Area(cm2)* | *Pn (kN)* |
|---|---|---|---|---|
| *Reinforced concrete* | *K1* | *600x600* | *360.000* | *6660,5955* |
| | *K2* | *500x500* | *250.000* | *4700,3266* |
| | *K3* | *400x400* | *160.000* | *3078,1334* |
| *composite* | *C1* | *500x500* | *250.000* | *6852,2072* |
| | *C2* | *450x450* | *202.500* | *4949,1738* |
| | *C3* | *350x350* | *122.500* | *3194,6008* |

*Based on the table above, the comparison chart for the dimensions of reinforced concrete columns and composite columns in holding the nominal capacity of the column is as follows (Figura 6):*

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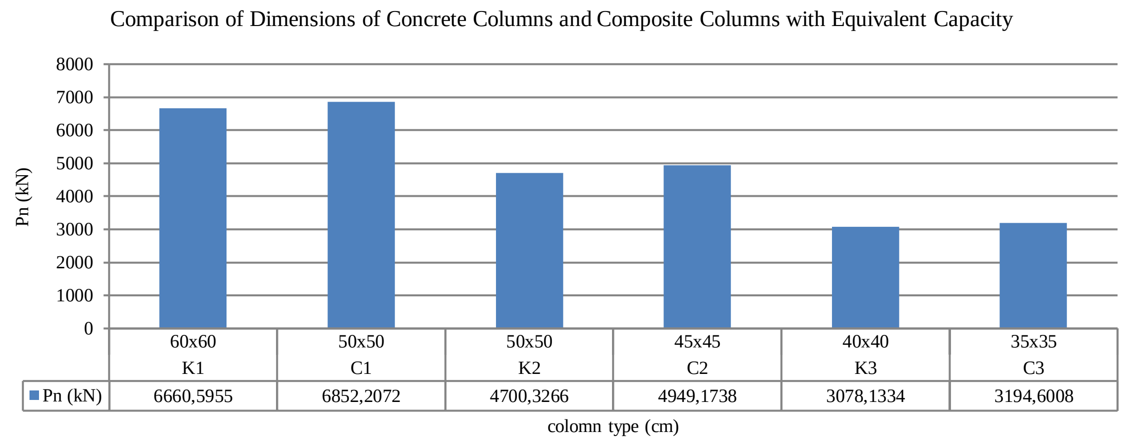


***Figure 6.*** *Comparison graph of column dimensions*

***Table 6.*** *The volume of column material*

| *Column* | *Reinforced concrete* | | *Totally volume($m^3$)* |
|---|---|---|---|
| | *concrete ($m^3$)* | *Steel ($m^3$)* | |
| *K1* | *1,44* | *0,018* | *1,458* |
| *K2* | *1,00* | *0,014* | *1,014* |
| *K3* | *0,64* | *0,010* | *0,650* |
| *C1* | *1,00* | *0,046* | *1,046* |
| *C2* | *0,81* | *0,030* | *0,840* |
| *C3* | *0,49* | *0,024* | *0,514* |

*by combining (Table 5) and (Table 6), the following bar chart is obtained (Figure 7):*

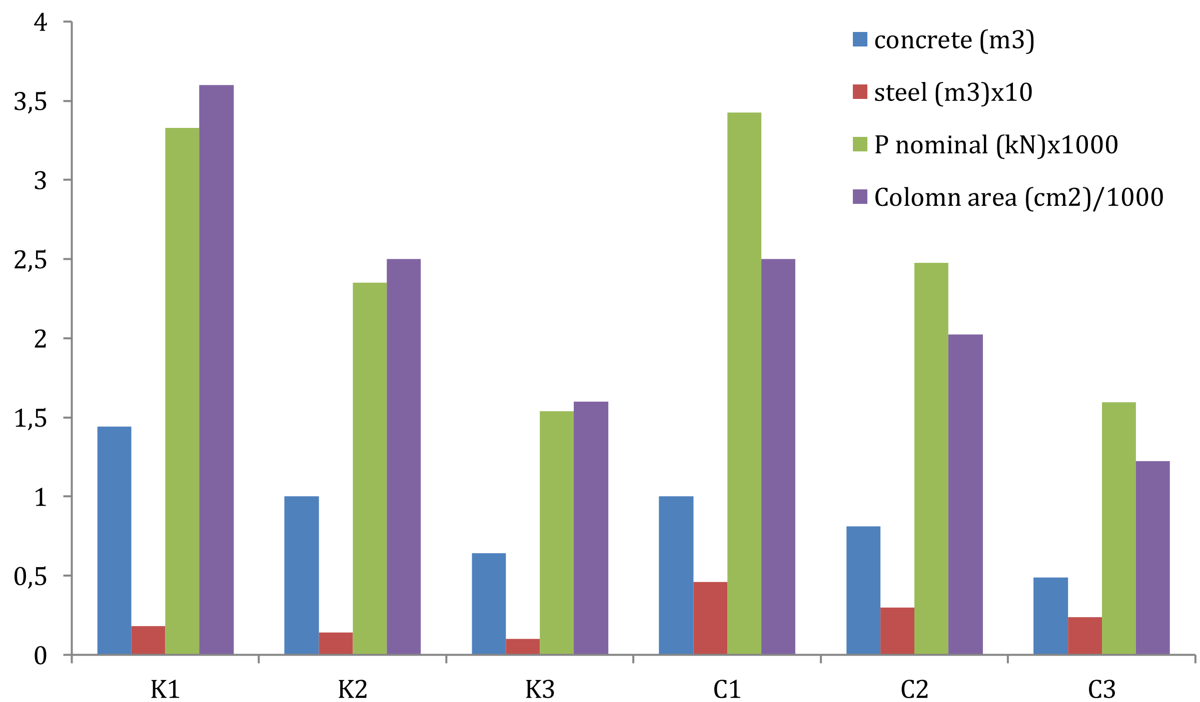


***Figure 7.*** *Comparison graph of material requirements and nominal capacity of columns*

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*From (Figure 7), it can be seen that the composite column can reduce the cross-sectional area of the column with a larger Pn. The profiled steel in the composite column can increase the compressive strength of the column even though the profile steel has greater tensile properties than the compressive strength. So, this explains that the bonding strength between profile steel and concrete has an important role in increasing Pn.*

### *3.4 Failure of reinforced concrete columns Analysis*

*According to research (Sartika et al., 2017), the analysis of the type of collapse in the column is determined based on the interaction diagram. There are 2 types of failure in the column, namely the compression zone and the tension zone. Determination of the type of failure can be determined by comparing the values of the ultimate axial force (Pu) and the axial force in a balanced condition (Pnb). Column interaction diagrams can not only be used in determining the type of failure but can also determine the strength of the column to withstand the load.*
*The diagram of reinforced concrete columns interaction in columns K1, K2, and K3 are obtained as follows:*

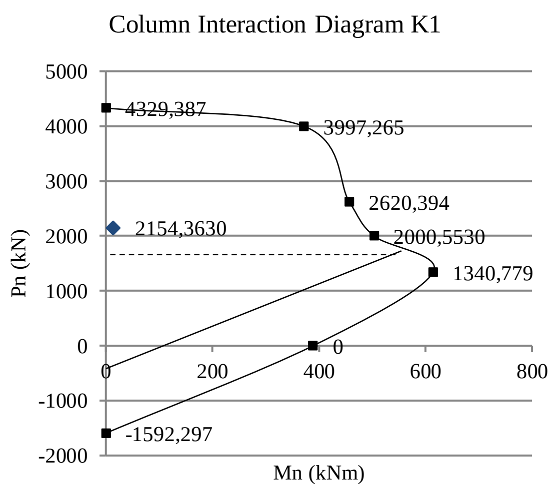


**Figure 8.** Column Interaction Diagram K1

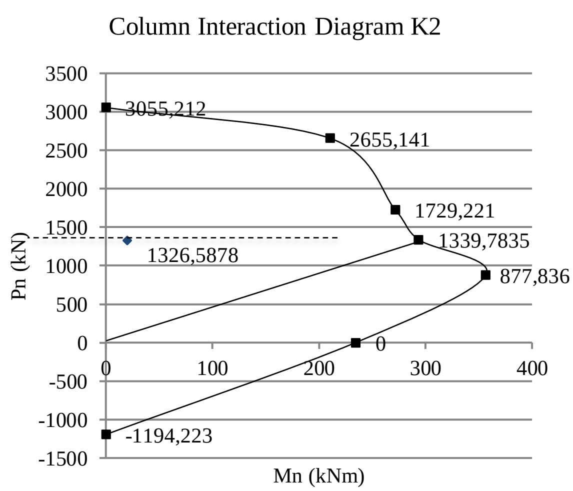


***Figure 9**. Column Interaction Diagram K2*

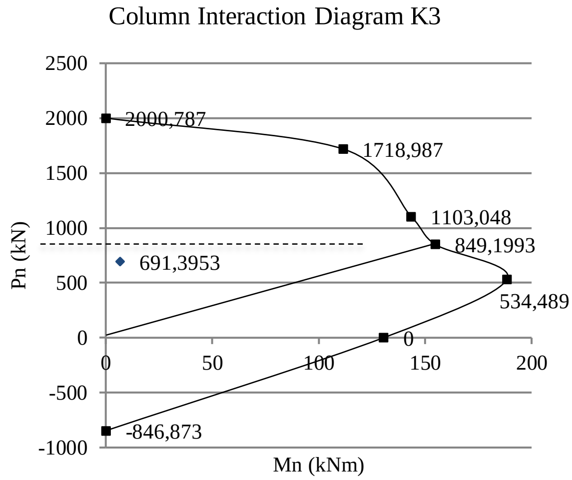


***Figure 10***. *Column interaction diagram K3*

*Based on (Figure 8), (Figure 9), and (Figure 10), it can be seen that the type of failure that occurs in each column is as follows:*

***Table 8.*** *Types of failure of reinforced concrete columns*

| *Column* | *Pu (kN)* | *Pnb (kN)* | *failure* |
|---|---|---|---|
| *K1* | *2154,3630* | *2000,5530* | *Pressure area* |
| *K2* | *1326,5878* | *1339,7835* | *Tensien area* |
| *K3* | *691,3953* | *849,1993* | *Tensien area* |

### *3.5 Composite Column Interaction Diagram*

*According to research (Milanovic and Cvetkovska, 2015), the composite column interaction diagram in determining the type of failure and strength of the C1, C2, and C3 columns is as follows:*

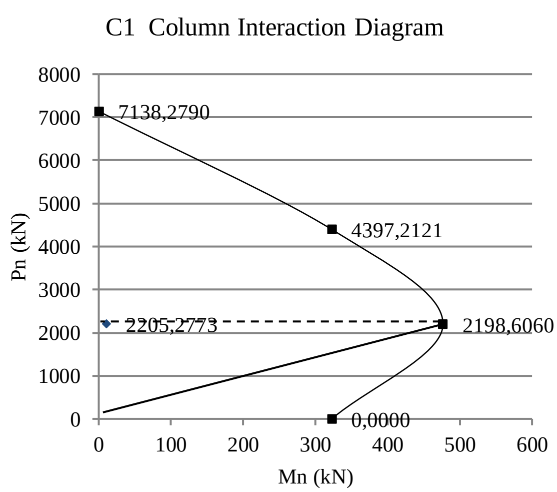


***Figure 11.*** *C1. column interaction diagram*

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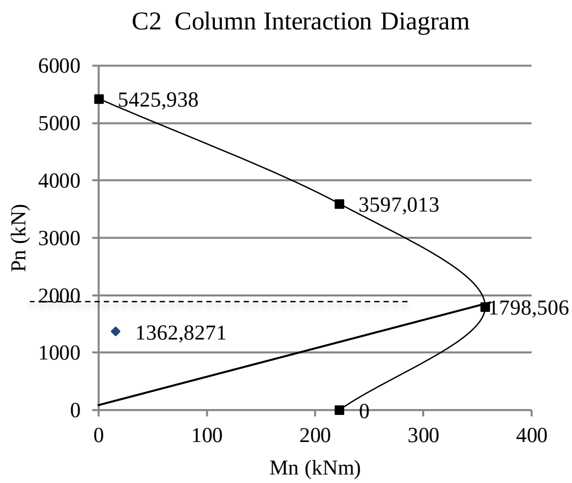


***Figure 12.*** *C2. Column interaction diagram*

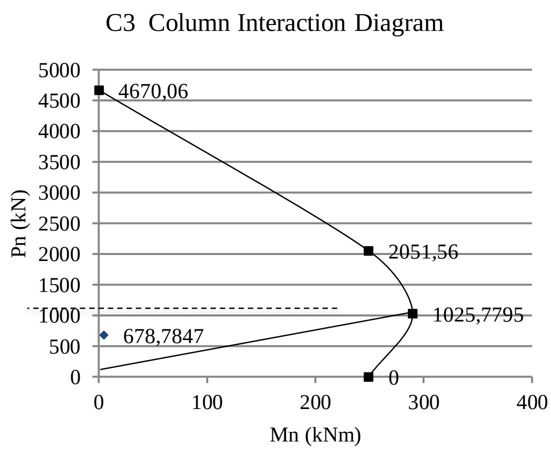


***Figure 13.*** *C3. Column interaction diagram*

*Based on (Figure 11), (Figure 12), and (Figure 13), it can be seen that the type of failure that occurred in each column is as follows:*

***Table 9.*** *Types of composite column collapse*

| *Column* | *Pu (kN)* | *Pnb (kN)* | *Zone failure* |
|---|---|---|---|
| *K1* | *2205,2773* | *2198,6060* | *Pressure* |
| *K2* | *1362,8271* | *1798,5063* | *Tension* |
| *K3* | *678,7847* | *1025,7795* | *Tension* |

# 4. Conclusion

*Based on the results of the discussion in this study, it can be concluded that in holding the nominal capacity equivalent, the dimensions of the composite column used are smaller than those of reinforced concrete columns. In addition, in terms of the total volume of composite column material requirements are also lower than reinforced concrete columns. This shows that composite columns can be a better choice for use in the structure.*

*The results of the analysis based on the type of column failure showed that in the reinforced concrete column and the composite column. There was C1 column collapse due to the compression zone and in the K2, C2, and K3, C3 columns there* *was column collapse due to the tension zone. For further research, analysis can be done in terms of cost and implementation time to know the difference in structural savings*.

# 5. Reference

**Alfirdaus, A. P., Dapas, S. O., and Handono, B. D. (2019).** Technical Evaluation of the Use of Steel-Concrete Composite Columns in Multi-Story Buildings. Civil Static Journal, 7(2), 285–290.

**Andreas, M., Margaretha, M., Yuniarto, R., and Lie, H. A. (2017).** Effect of Steel Configuration and Slenderness Factor on Column Compressive Capacity. Jurnal Karya Teknik Sipil, 6(1), 366–374.

**Chellapandian M, Saumitra Jain, Suriya Prakash S and Akanshu Sharma (2019**). Effect of Cyclic Damage on the Performance of RC Square Columns Strengthened Using Hybrid FRP Composites under Axial Compression. Fibers Journal 7 (10) 90. www.mdpi.com/journal/fibers

**Guo-Chang Li 1, Bo-Wen Chen, Zhi-Jian Yang, Han-bin Ge 2 and Xiao Li. (2021).** Axial Behavior of High-Strength Concrete-Filledhigh-Strength Square Steel Tubular Stub Columns. Advanced Steel Construction – Vol. 17 No. 2 (2021) 158–168

**Wright J.W., Pantelides C.P. (2021)** Axial Compression Capacity of Concrete Columns Reinforced with Corrosion-Resistant Metallic Reinforcement. Wright and Pantelides Journal of Infrastructure Preservation and Resilience (2021) 2:2

**Lam, D., Gardner, L. and Burdett, M. (2010).** Behaviour of axially loaded concrete-filled stainless steel elliptical stub columns. Advances in Structural Engineering. 13(3), 493-500.

**Maharani, P. S., and Faimun, F. (2019).** Modification of the Planning of the Grand Dharmahusada Lagoon Building Using a CFT Concrete Steel Composite Structure with an Eccentric Braced Frame System Type Two-Story-X Braced.Jurnal Teknik ITS, 8(1), 10–17

**Marta Del Zoppo, Marco Di Ludovico, Alberto Balsamo and Andrea Prota (2018)** Comparative Analysis of Existing RC Columns Jacketed with CFRP or FRCC, Polymers 2018, 10, 361; doi:10.3390/polym10040361

**Milanovic, M., and Cvetkovska, M. (2015).** Interaction Diagrams Axial Force-Bending Moment for Fire Exposed Steel-Concrete Composite Sections. Applications of Structural Fire Engineering, (15-16 October), 275–280.

**Sartika, Indra Gunawan, S.T., M. T., and Endang S Hisyam, S.T., M. T. (2017). Structural** Analysis of Reinforced Concrete Building Based on SNI 2847-2002 and SNI 2847-2013 (Case Study: Mother **and** Child Hospital "Rona" **Pangkalpinang** Building). Civil Engineering Journal, 5(1), 57–69

**SNI-1726. (2019).** Earthquake Resistance Design Procedures for Building and Non-Building Structures

**SNI-1727. (2013)**. Minimum Load For the Design of Buildings and Other Structures.

**SNI-2847. (2019).** Structural Concrete Requirements for Buildings and Explanation (ACI 318M-14 dan ACI 318RM-14, MOD).

**Toni, N., Suryanita, R., and Ismeddiyanto. (2015). Prediction** of Collapse Rate of Reinforced Concrete Column Due to Static Loading Using Artificial Neural Networks (ANN). Engineering Journal 2(2), 1-9