Design Of Reinforced Concrete Slender Columns In a 3-Story Residential Building

Angga Fandam Wahyu N[1*], Baehaki[2], Soelarso[3], Zulmahdi Darwis[4]
[1,2,3,4]Department of Civil Engineering, Sultan Ageng Tirtayasa University, Indonesia

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ABSTRACT

In some building designs that carry a high aesthetic or architectural value, the use of flat columns brings a number of significant advantages. Their slender design provides more flexibility in interior layout and adds to the aesthetic value of the building. This study was conducted to determine the reinforcement requirements and behavior of flat columns as well as checking the displacement in accordance with SNI 1726:2019. The results show that column I and column L are categorized as swaying and long columns, while column T and column Plus are included in the category of non-swaying and short columns. The required reinforcement requirements are as follows: For column I with dimension 130 x 800, 10D16 main reinforcement is required with D10-100 mm stirrups inside the plastic joint area and D10-150 mm outside the plastic joint area. Column L of dimension 130 x 500 requires 16D16 main reinforcement with D10-100 mm stirrups both inside and outside the plastic joint area. T columns of dimension 130 x 500 require 10D16 main reinforcement with D10-100 mm stirrups inside and outside the plastic joint area. Plus columns of dimension 130 x 400 require 12D16 main reinforcement with D10-100 mm stirrups inside and outside the plastic joint area. The maximum defelction that occurs is still within the permissible tolerance limits of 15.32 mm in the X direction and 11.15 mm in the Y direction so that the building structure is declared safe and stable against the loads received in accordance with SNI 1726: 2019.

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Corresponding Author:

Angga Fandam Wahyu Nugroho,
Department of Civil Engineering,
Sultan Ageng Tirtayasa University,
Jl. Jendral Soedirman Km 3, Banten, 42435, Indonesia.
Email: 3336200082@untirta.ac.id

1. INTRODUCTION

In building designs that emphasize aesthetics and high-quality architecture, flat columns offer significant advantages. Their slender design increases the flexibility of interior layout and space planning, and adds to the aesthetic value of the building. Therefore, flat columns are an optimal solution to increase flexibility and architectural value without compromising structural strength [26]. Columns are vertical elements that transmit axial compressive forces, with or without moments, from the floor slab to the foundation [6]. Columns can also be defined as elements of a frame structure subjected to compression and bending [17]. Four flat columns with different shapes and dimensions consisting of rectangular, L, T, and Plus were analyzed.

1.2 Literature Review

Flat columns are applied by considering the width of the wall, providing aesthetic value and creating the impression of a wider room [7]. A flat column can also be defined as a column whose load capacity at ultimate conditions is determined not only by the strength of the material and the dimensions of the section, but also by its degree of slenderness, which causes additional bending moments due to lateral deformation [23]. In low-rise buildings, conventional columns with rectangular or round cross-sections can be used, as well as non-conventional columns such as flat columns [12].

Previous research conducted by Shanti Wahyuni Megasari, et al (2020) The use of flat columns meets architectural needs by changing the building from 1 floor to 2 floors for sleeping areas, and replacing existing columns with I, L, and T-shaped flat columns [14]. Previous research comparing the planning of flat columns with conventional columns, namely conducted by Abdullah Indra Pratama, et al (2021) resulted in the same column reinforcement but with different blanket thicknesses, where the flat column blanket is only 30 mm while the conventional column is 40 mm [5]. Research conducted by Servie O. Dapas, et al (2016) resulted in column buckling length, stiffness value, and moment magnification. The results show that the column types include long or slender columns in a swaying and buckling state. [9]. The use of flat columns in buildings has a significant effect on conventional columns such as research conducted by Teddy, et al (2024) with a two-story building resulting in a moment ratio of 11.5% [19].

Research conducted by Richard, et al (2013) examining the capacity of flat columns using interaction diagrams shows that flat columns can withstand the forces and moments that occur. The maximum axial force and moment for condition I are (65.7250; 726.79), while for condition II are (65.581; 726.79) [13]. Research conducted by Iona, et al (2023) on flat columns under the influence of gravity loads showed that the columns can be used in structural planning by considering the slenderness ratio [16]. Bob, et al (2023) compared conventional columns with plus columns to obtain a comparison of reinforcement ratio values [20]. Flat columns are also susceptible to buckling, such as research conducted by Hongwei, et al (2017) that flat columns can buckle due to the slenderness factor in the column [21]. Vinayagam, et al (2021) also conducted flat column research on column failure in the form of buckling which resulted in flat columns being susceptible to buckling and deformation [22].

In analyzing flat columns, you can also use the second order analysis method such as the matrix method carried out by Ludovit, et al (2017) examining the normal force acting with eccentricity using the Transfer Matrix Method [24]. In addition, Rangesh, et al (2023) conducted a special-shaped column research by analyzing the finite element method with the help of CSICOL software to check the capacity of the column [25].

In addition to analyzing the behavior of the column, the displacement of the column also needs to be reviewed in accordance with SNI 1726-2019. Research conducted by Youfrie (2016) shows that the displacement of a flat column reaches 28.93 mm in the X and Y directions [11]. The purpose of using flat columns is to overcome the reduction in planned space area. Flat columns, which are special shaped columns with symmetrical cross-sections, are an alternative solution to the problem. These special shaped columns include L, T, and Plus shapes [5].

According to SNI 2847-2019, columns are categorized into two types, namely short columns and long columns (slender columns). This difference is determined by the column slenderness ratio, which is the ratio between the column length and its lateral dimension [3].

McGregor (2012) explains to determine whether a column is swaying or not with the following constraints [15].

$$Q = \frac{\Sigma Pu \text{ x } \Delta 0}{Vu \text{ x } Lu} \tag{1}$$

Description:
Q : Column Stability Index
Σpu : Accumulated axial force from the level above
Vu : Total factorized shear force in the level under review.
Δ0 : Relative horizontal deflection between the two floors under review
Lu : Column height

SNI 2847-2019 provides the following limitation requirements for columns:

a. For columns subject to swaying (article 6.2.5a)

$$\frac{k \text{ x } lu}{r} \leq 22 \tag{2}$$

b. For columns that cannot be swayed (article 6.2.5b)

$$\frac{k \text{ x } lu}{r} \leq 34 \pm 22 \, (M_1/M_2) \leq 40 \tag{3}$$

Where M1/M2 (kNm) is positive if the deflection in the column is classified as a single deflection, and is negative if it is classified as double deflection [30].

Description:
k : column effective length factor
lu : column net length, m
r : radius of gyration or radius of inertia of the column cross-section, m

The effect of slenderness must be taken into account in designing structural elements subjected to compression [8].

The column effective length factor (k) is strongly influenced by the level of resistance at both ends of the column (Ψ) (article 6.2.5.1) [3].

$$\Psi = \frac{\sum \frac{EI}{lc}}{\sum \frac{EI}{lb}} \tag{4}$$

Description:

Ψ : degree of resistance at the end of the column
E : elastic modulus of concrete = 4700 √f'c,
I : moment of inertia, mm4
lc : column clear length, mm
lb : beam clear length, mm

The value of k is divided into two types, namely for column types that cannot sway and column types that can sway (article 6.2.5.1) [3].

a. Columns cannot sway (article 6.2.5.1)

The effective length factor (k) can be taken from the smallest value of:

$$k = 0{,}7 + 0{,}05 \, (\psi A + \psi B) \leq 1{,}0 \tag{5}$$

$$k = 0{,}85 + 0{,}05 \, \psi min \leq 1{,}0 \tag{6}$$

b. Columns subject to swaying (article 6.2.5.1)

$$k = \frac{20 \text{ x } \Psi m}{20} \text{ x } \sqrt{1+\Psi m} \tag{7}$$

$$k = 0{,}9 \text{ x } \sqrt{1+\Psi m} \tag{8}$$

With ψA being the degree of resistance at the top column end and ψB being the degree of resistance at the end of the lower column, ψm is the average value of the degree of resistance. According to SNI 2847-2019 to prevent the risk of bending in slender columns or long columns, longitudinal reinforcement planning must be carried out by increasing the column's plan moment [3].

a. For portals that do not sway (article 6.6.4.5)

$$M_c = \delta_{ns} \text{ x } M_{2b} \tag{9}$$

$$M_c = \delta_{ns} \text{ x } Pu \text{ x } (1,5 + 0,03h) \quad (10)$$

b. For swaying portals (article 6.6.4.7)

$$M1_c = M1_{ns} + \delta_s \text{ x } M1_s \quad (11)$$

$$M2_c = M2_{ns} + \delta_s \text{ x } M2_s \quad (12)$$

Description:

M_c : magnified factored moment

δns : moment magnification factor for frames that are resistant to lateral sway, or moment magnification factor for frames that cannot sway.

δ_s : moment magnification factor for frames that are not restrained against lateral sway, or moment magnification factor for frames that can sway.

M_{2b} : a large moment at one end of the column that does not cause swaying.

M_{1s}/M_{2s} : small and large moments at one end of the column that cause sway.

According to SNI 2847-2019, the moment magnification factor can be calculated using the following formula:

a. For non-swaying columns (article 6.6.4.6.2)

$$\delta_b = \frac{C_m}{1-\frac{P_u}{0,75 \text{ x } P_c}} \geq 1 \quad (13)$$

If there is a transverse load between the supports, $C_m = 1$

without transverse load, $C_m = (0,6 + 0,4 \text{ x } \frac{M1_b}{M2_b}) \geq 0,4$

b. For sway columns

$$\delta_s = \frac{1}{1-\frac{\sum P_u}{0,75 \text{ x } \sum P_c}} \geq 1 \quad (14)$$

Where,

$$P_c = \frac{\pi^2 \text{ x EI}}{(\text{ k x lu})^2} \quad (15)$$

Description:

P_u : Factored axial force, taken as positive for compressive and negative

P_c : Critical buckling load

C_m : Factor relating the actual moment diagram to the equivalent uniform moment diagram.

δns : moment magnification factor for frames that are resistant to lateral sway, or moment magnification factor for frames that cannot sway.

k : column effective length factor

a. Column cross-section under centric load condition

The cross-section of the column with a centric load, the load acts on the longitudinal axis of the column so that the concrete and reinforcement withstand the compressive load [28].

$$P_o = 0,85 \text{ x fc' x } (Ag – Ast) + Ast \text{ x fy} \quad (16)$$

$$\Phi P_o = 0,65 \text{ x } P_o \quad (17)$$

$$P_{n, max} = 0,8 \text{ x } P_o \quad (18)$$

$$\Phi Pn \text{ max} = 0,65 \text{ x } P_{n, max} \quad (19)$$

Description:

P_o : Centric axial load or axial load on the column axis

ΦP_o : Reduction of centric axial load or axial load on column axis

$P_{n, max}$: Maximum column nominal axial load

ΦPn max : Maximum column nominal axial load reduction

Ag : Gross cross-sectional area of the column

Ast : Total area of reinforcement in the column

f_y : Tensile strength of reinforcing steel

b. The cross-section of the column in the compressive condition determines

If the load Pn at the time of the centric load condition is shifted to the right, the left column section begins to bear the tensile load, while the right one bears the compressive load [1].

$$C > C_b \qquad (20)$$

C is the distance between the neutral line and the edge of the compressive concrete and Cb is the distance between the neutral line and the edge of the inert concrete fiber under the condition of balanced cross-sectional strain [1].

c. Cross-section of column at balanced condition

In a column cross-section with a balanced condition, the tensile reinforcement reaches yield and the compressive concrete strain has reached the ultimate limit [27].

$$Cb = (\mathcal{E}c \text{ x } Es) \text{ x } d \,/\, (\mathcal{E}c \text{ x } Es) + fy \qquad (21)$$

Description:

Cb : The distance between the neutral line and the edge of the inlaid concrete fibers under balanced cross-sectional strain conditions.
Es : Modulus of elasticity of steel
Ɛc : Concrete compressive strain
d : Effective height of column
fy : Tensile strength of reinforcing steel

d. The cross-section of the column in the tensile condition determines

If the axial load Pn has reached a balanced cross-section condition and then shifted to the right, the cross-sectional area of the compressive concrete will be smaller. This causes the compressive strain of the concrete to decrease, so the c value also decreases [1].

$$C < C_b \qquad (22)$$

C is the distance between the neutral line and the edge of the compressive concrete and Cb is the distance between the neutral line and the edge of the inert concrete fiber under the condition of balanced cross-sectional strain [1].

e. Column cross section at load condition $P_n = 0$

For a column section with axial load Pn=0, it means that the column only resists bending moment. Since it only resists bending moment, the column is analyzed/calculated like a normal beam [29].

$$P = (600 \text{ x } As' - As \text{ x } fy)/(1{,}7 \text{ x } fc' \text{ x } b) \qquad (23)$$

$$q = (600 \text{ x } \beta 1 \text{ x } As' \text{ x } ds')/(0{,}85 \text{ x } fc' \text{ x } b) \qquad (24)$$

$$a = \sqrt{P^2 + q} - P \qquad (25)$$

$$fs' = 600 \text{ x } ((a - \beta 1 \text{ x } ds')/a) \qquad (26)$$

$$M_{nc} = 0{,}85 \text{ x } fc' \text{ x } a \text{ x } b \text{ x } (d - a/2) \qquad (27)$$

$$M_{ns} = As' \text{ x } fs' \text{ x } (d - ds') \qquad (28)$$

$$M_n = M_{nc} + M_{ns} \qquad (29)$$

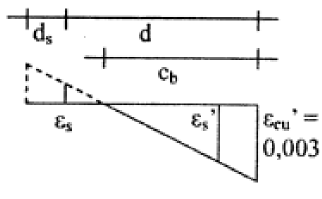

Figure 1. Strain Distribution at Balanced Cross-Section Condition [1]

Column cross-section analysis basically utilizes the compatibility properties of the working strain. Since there are restrictions on the compressive and tensile strength values of reinforcing steel, theresulting equations are complex, so manual calculations must be performed in stages [18]. Inspection of the interaction diagrams can be done manually or with the help of SPColumn software so that the analysis results obtained are accurate [10].

According to SNI 2847:2019 article 18.7.6.1.1 explains that the design shear force Ve must be determined from a review of the maximum forces that can occur at the joint faces at each end of the column [3].

$$V_c = 0{,}17 \text{ x } \left(1 + \frac{N_u}{1{,}4 \text{ x } A_g}\right) \text{ x } \lambda \text{ x } \sqrt{f_c} \text{ x bw x} \quad (30)$$

$$V_s = \frac{A_v \text{ x } f_y \text{ x } d}{s} \quad (31)$$

Description:

V_c : Nominal shear force in concrete
V_s : Nominal shear force in stirrup/seal
A_v : Area of stirrup reinforcement
A_g : Cross-sectional area of the column
bw : Cross-sectional width at column
d : Effective height at column
f_c : Concrete compressive strength
f_y : Tensile strength of reinforcing steel
N_u : Factored axial force
λ : Concrete modification factor 1.0 (normal concrete)
s : Spacing of stirrup reinforcement

The determination of the design inter-level displacement (Δ) should be calculated based on the difference in the displacement at the center of mass above and below the level being analyzed. According to SNI 1726-2019 the displacement of the center of mass at level x(δx) (mm) should be determined according to the following equation: [2]

$$(\delta X) = \delta e \times \frac{C_d}{I_e} \quad (32)$$

Description:
Cd : deflection amplification factor
δxe : deflection at this required location determined by elastic analysis
Ie : specified seismicity factor

2. METHODS

2.1 Research Data

This research was conducted on a residential building located in Jakarta. The structure is a 3-story reinforced concrete building. The main function of the building is residential. The objects to be reviewed are four types of columns namely I, L, T, and Plus.

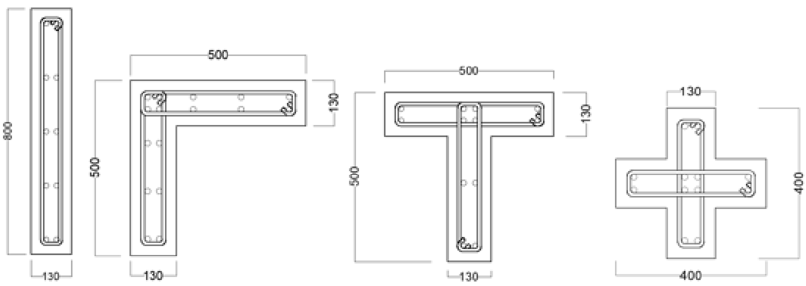

Figure 2. Cross-section of Slender Columns

The four columns are flat columns with different dimensions, namely Column I with dimensions of 130 mm x 800 mm, Column T with dimensions of 130 mm x 500 mm, Column L with dimensions of 130 mm x 500 mm, and Column Plus with dimensions of 130 mm x 400 mm.

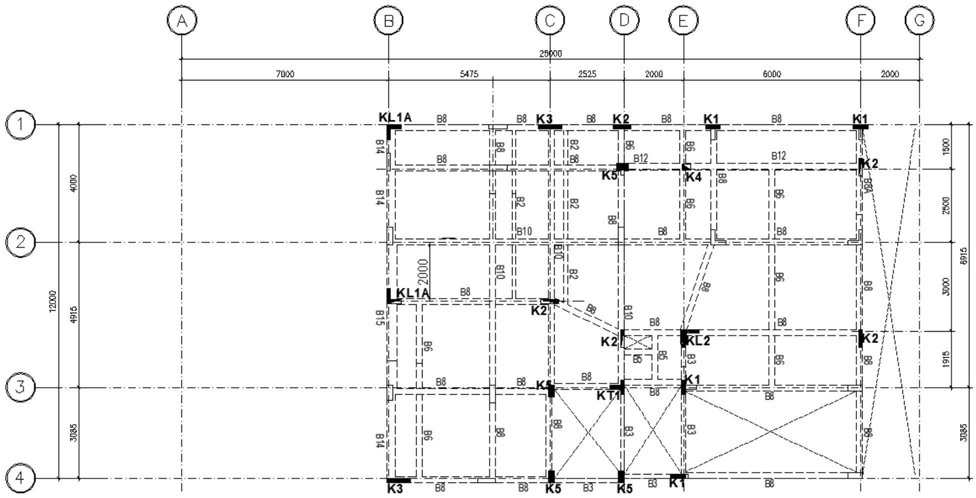

Figure 3. Floor Plan

The concrete quality (f'c) used is 24.9 MPa, the quality of reinforcing steel diameter ≤ 12 uses BJTP 28, fy = 280 Mpa, diameter ≥ 12 uses BJTD 42, fy = 420 Mpa. The regulations used for loading refer to SNI 1727-2019 concerning Minimum Design Loads and Related Criteria for Buildings and Other Structures [4].

2.2 Research Procedur

Broadly speaking, there are two stages of research that are carried out analytically, namely structural modeling and flat column calculation. The research procedure can be illustrated in Figure 4.

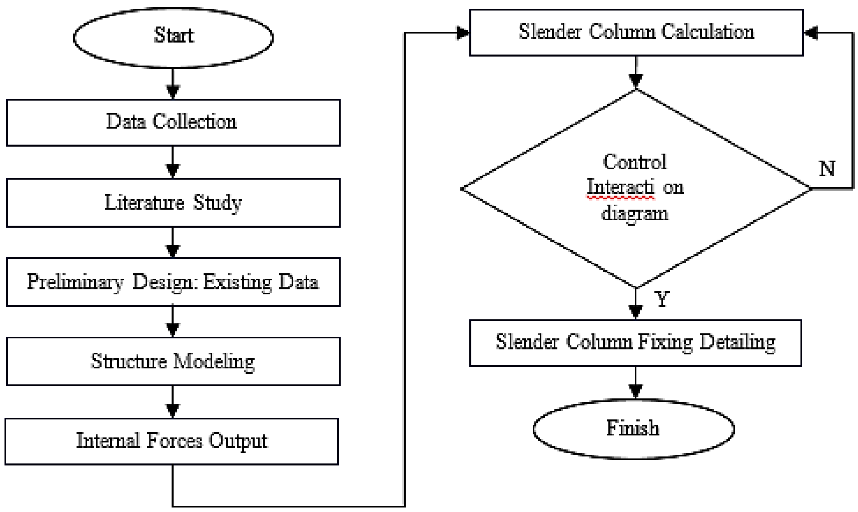

Figure 4. Research Flow Chart

a. Structure Modeling

In the initial stage of the research, a structural model was created based on the plan drawings using the ETABS program. Materials and initial dimensions of structural elements such as plates, beams, and columns were defined based on existing project data. Gravity loads, including live loads, dead loads, and additional dead loads, were inputted in accordance with SNI 1727:2020 through the load pattern and load case features. Next, the loading combination is determined using the load combination feature. After the structural model is completed and all data is inputted, the analysis is run, and the moment output from this analysis will be used for the next study.

b. Slender Column Calculation

In the second stage, the four flat columns were analyzed based on the output generated from the modeling. At this stage, the behavior of the columns, the amount of reinforcement required, and an examination of the interaction diagrams were calculated.

3. RESULTS AND DISCUSSION

3.1 Displacement Analysis of Slender Columns

Table 1. X-Direction Displacement

Story	*Displacement*		*Elastic Drift*		*h*	*inelastic Drift*		*Drift Limit*	*Cek*
	δe_X	δe_Y	δe_X	δe_Y		ΔX	ΔY		
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	
ROOF 2	5,6307	1,8012	0,2	0,1	3000	1,10	0,47	60,000	OK
ROOF 1	5,8497	1,7069	1,6	0,4	3400	8,23	1,92	68,000	OK
ABOVE	4,2029	1,3234	3,1	0,8	4000	15,32	4,23	80,000	OK
BASE	1,1383	0,4765	1,1	0,5	3500	5,69	2,38	70,000	OK

Table 2. Y-Direction Displacement

Story	*Displacement*		*Elastic Drift*		*h*	*inelastic Drift*		*Drift Limit*	*Cek*
	δe_X	δe_Y	δe_X	δe_Y		ΔX	ΔY		
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	
ROOF 2	1,4333	4,7566	0,1	0,2	3000	0,28	0,79	60,000	OK
ROOF 1	1,4891	4,5981	0,4	1,1	3400	2,02	5,46	68,000	OK
ABOVE	1,0847	3,5062	0,8	2,2	4000	3,95	11,15	80,000	OK
BASE	0,2952	1,2771	0,3	1,3	3500	1,48	6,39	70,000	OK

From the results of the analysis, the maximum displacement value that occurs in residential buildings with flat columns is 15.32 mm for the X direction while for the Y direction the maximum displacement value is 11.15 mm.

3.2 Analysis Result of Slender Column Cross Section

The following are the results of the cross-sectional property analysis of the four flat columns.

Table 3. Analisis Properti Penampang

Column Type	b (mm)	h (mm)	A (mm^2)
Column I	130	800	104000
Column L	130	500	113100
Column T	130	500	113100
Plus Column	130	400	87100

3.3 Column Behavior Analysis

Table 4. Analysis of Stability Index and Column Slenderness Factor

Column Type	Q	Q Limit	Description	Result	Slenderness Factor
Column I	0,06	0,05	Sway	36,847	Slenders Column
Column L	0,06	0,05	Sway	37,257	Slenders Column
Column T	0,02	0,05	No Sway	38,479	Short Column
Plus Column	0,01	0,05	No Sway	40,2479	Short Column

It is obtained for the slenderness factor and stability index values for four types of columns, namely for I and L columns including long and swaying columns. For T and Plus column types, they are short columns and do not sway with a limitation of 5% stability index value.

3.4 Column Moment Magnification Analysis

Table 5. Results of Moment Magnification Analysis

CONDITION	Before Enlargement Column I			After Column I Enlargement		
	Pu (kN)	M22 (kNm)	M33 (kNm)	Pu (kNm)	M22 (kNm)	M33 (kNm)
Pu max	352,08	10,243	-36,193	358,98	-24,22	-59,48
M22 max	316,23	11,951	11,44	348,5	-25,77	-39,89
M33 max	351,38	8,979	-41,143	351,38	-22,87	-64,68
CONDITION	**Before Column Enlargement L**			**After Column Enlargement L**		
	Pu (kN)	**M22 (kNm)**	**M33 (kNm)**	**Pu (kN)**	**M22 (kNm)**	**M33 (kNm)**
Pu max	530,93	38,087	-25,857	516,24	-117,49	-96,82
M22 max	500,85	-135,02	14,88	500,85	44,085	-105,18
M33 max	513,67	24,797	-38,54	513,67	-103,19	-95,92
CONDITION	**Before Column Enlargement T**			**After Column Enlargement T**		
	Pu (kN)	**M22 (kNm)**	**M33 (kNm)**	**Pu (kN)**	**M22 (kNm)**	**M33 (kNm)**
Pu max	353,25	-45,41	21,45	-	-	-
M22 max	346,48	-59,596	15,672	-	-	-
M33 max	331,18	-38,676	36,064	-	-	-
CONDITION	**Before Column Enlargement Plus**			**After Column Enlargement Plus**		
	Pu (kN)	**M22 (kNm)**	**M33 (kNm)**	**Pu (kN)**	**M22 (kNm)**	**M33 (kNm)**
Pu max	561,86	-0,872	0,488	-	-	-
M22 max	328,22	8,602	-2,415	-	-	-
M33 max	527,93	-3,295	9,016	-	-	-

From the results, it is obtained that column I and column L experience moment magnification because the column is included in the slim column, while column T and column Plus do not experience moment magnification due to the column being included in the short column.

3.5 Column Interaction Diagram Analysis

For the analysis of the column interaction diagram, five conditions that occur in the column must be considered.

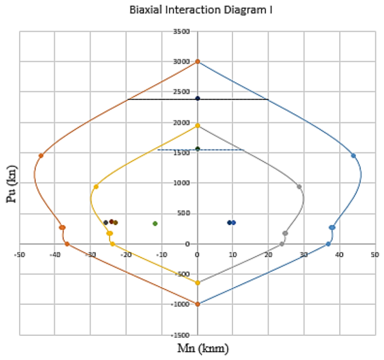

Figure 5. Column Interaction Diagram I

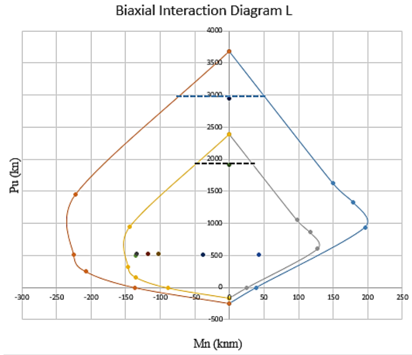

Figure 6. Column Intercation Diagram L

he results of the interaction diagrams in Figures 5 and 6 are obtained for each column can withstand axial and also working moments both before experiencing moment magnification and after experiencing moment magnification.

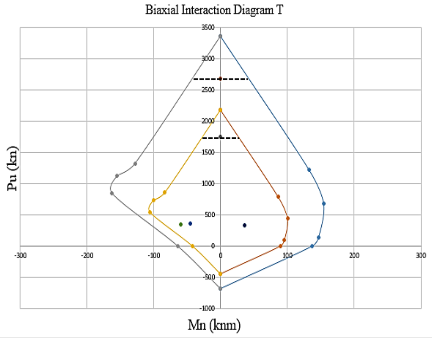

Figure 7. Column Intercation Diagram T

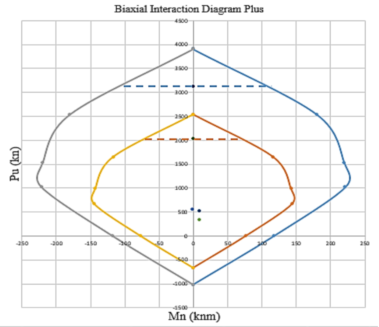

Figure 8. Column Intercation Diagram Plus

The results of the interaction diagrams in Figures 7 and 8 are obtained for each column can withstand axial as well as working moments.

3.6 Shear Reinforcement in Flat Columns

The calculation of shear reinforcement refers to SNI 2847:2019 article 22.5.6.1 and only uses column I as an example of calculation.

$$V_{e\text{-}k} = \frac{M_{prt} + M_{prb}}{l_u} = \frac{369357678{,}5 + 369357678{,}5}{4000} = 184678{,}8392 \text{ N}$$

$$V_{e\text{-}b} = \frac{(M_{prt} \text{ x } DF_t) + (M_{prb} \text{ x } DF_b)}{l_u} = \frac{(242874910{,}5 \text{ x } 0{,}5) + (242874910{,}5 \text{ x} 0{,}5)}{4000} = 60718{,}72763 \text{ N}$$

$V_u = 14070$ N

Since the value of Ve-b < 1/2 x Ve-k, the value Vc ≠ 0, Vc value must be calculated.

$$V_c = 0{,}17 \text{ x } \left(1 + \frac{352080}{1{,}4 \text{ x } 104000}\right) \text{ x } 1 \text{ x } \sqrt{24{,}9} \text{ x } 130 \text{ x } 752 = 283464{,}4503 \text{ N}$$

The shear reinforcement plan is D10-100 mm.

$$V_s = \frac{A_v \text{ x } f_y \text{ x } d}{s} = \frac{314 \text{ x } 420 \text{ x } 752}{100} = 991737{,}6 \text{ N}$$

$ØV_n = 0{,}75 \text{ x } (283464{,}4503 + 991737{,}6) = 956401{,}5378 \text{ N} > V_{e\text{-}b}$ **(OK)**

For the area outside the plastic joint, plan D10-150 mm

$$V_s = \frac{A_v \text{ x } f_y \text{ x } d}{s} = \frac{314 \text{ x } 420 \text{ x } 752}{150} = 661158{,}4 \text{ N2}$$

$ØV_n = 0{,}75 \text{ x } (283464{,}4503 + 661158{,}4) = 708467{,}1378 \text{ N} > V_u$ **(OK)**

Control Shear reinforcement

V_s = 708467,1378 N > 0,33 x $\sqrt{24,9}$ x 130 x 752 = 708467,1378 N > 160981,0687 N...**(OK)**
So, D10-100 mm stirrups are used in the plastic joint area and D10-150 mm in the area outside the plastic joint.

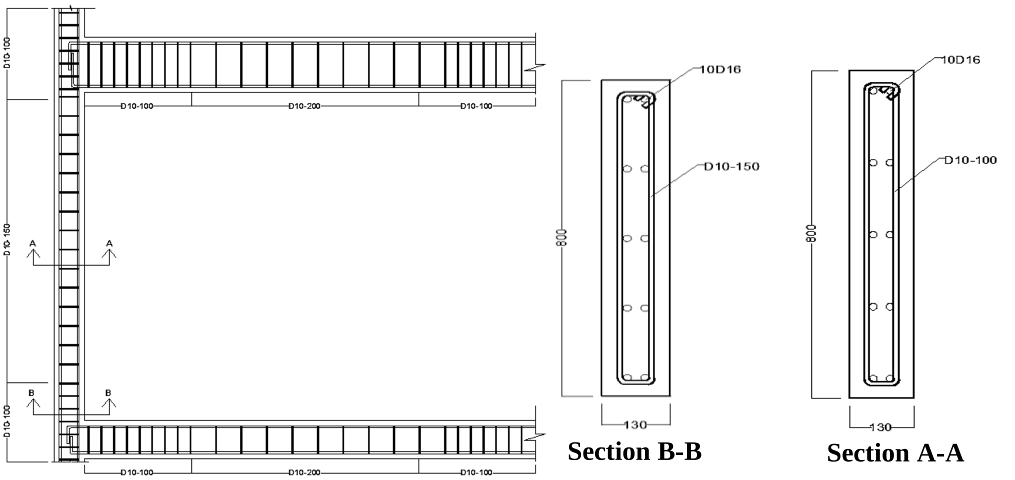

Figure 9. Detailing of Column Reinforcement

4. CONCLUSION

Based on the results of the study, it can be concluded that column I and column L are categorized as swaying and long columns, while column T and column Plus are included in the category of non swaying and short columns. The required reinforcement requirements are as follows: to column I with dimension 130 x 800, requires 10D16 main reinforcement with D10-100 mm stirrups inside the plastic joint area and D10-150 mm outside the plastic joint area. Column L of dimension 130 x 500 requires 16D16 main reinforcement with D10-100 mm stirrups both inside and outside the plastic joint area. T columns of dimension 130 x 500 require 10D16 main reinforcement with D10-100 mm stirrups inside and outside the plastic joint area. Plus columns of dimension 130 x 400 require 12D16 main reinforcement with D10-100 mm stirrups inside and outside the plastic joint area. The maximum displacement that occurs is still within the permissible tolerance limits of 15.32 mm in the X direction and 11.15 mm in the Y direction so that the building structure is declared safe and stable against the loads received in accordance with SNI 1726: 2019.

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