Comparative Analysis of Superpanel Plates and Conventional Plates on the effect of Story Drift and Reinforcement of Column and Beam

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ABSTRACT

Building and non-building construction generally uses reinforced concrete using conventional methods. Over time, this method has evolved and given rise to other approaches such as precast and prestressed methods. However, these methods still have some drawbacks, such as the relatively high density of the material and its impact on other aspects of the structure. New innovations are emerging to solve these problems, such as super lightweight panels with a material density of around 650 kg/m3. This study aims to examine other structural components, namely beam and column structures by comparing the reinforcement requirements and deviation of two buildings with different types of floor plates. The tests were conducted using an analytical approach using ETABS software. The results showed that the average ratio of beam reinforcement between superpanel plate and conventional plate was 77% and column was 94%. The average ratio of X-direction deviation between superpanel plate and conventional plate is 94% and Y is 88%.

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1. INTRODUCTION

1.1 Background

Construction in its implementation is divided into two methods, namely conventional construction method and precast construction method [1]. The conventional construction method, also known as "cast in situ", is a building construction system where the casting of structural elements is carried out directly at the location where these elements will be positioned. On the other hand, the precast construction method involves fabricating structural elements in a factory or workshop, allowing time for curing and strengthening before they are ultimately installed at the designated location. This research is conducted to compare the results of reinforcement requirements using different types of slabs (conventional and superpanel) in accordance with SNI 2847:2019 [2], and to determine the deflection that occurs due to earthquake loads as per SNI 1726:2019 [3].

This study examines the comparison of plates used in a 2-storey office building model regarding the need for beam and column reinforcement. The type of building structure uses a intermediate moment frame [13], with the analysis aimed at reviewing the calculation of reinforced concrete structures according to SNI 2847: 2019 concerning structural concrete requirements for buildings, SNI 1726:

2019 concerning earthquake resistance planning procedures for buildings and non-buildings, and SNI 1727: 2020[4] regarding minimum loads and related criteria for buildings and other structures.

1.2 Problem Formulation

Based on the problems described in the background section, several problem formulations are taken, which are:

1. How do the story drift results compare between the conventional system and the superpanel system?
2. How does the beam reinforcement requirement compare between the conventional system and the superpanel system?
3. How does the column reinforcement requirement compare between the conventional system and the superpanel system?

1.3 Literature Review

To strengthen the study being discussed, the researcher tries to identify various literatures and previous studies that are still relevant to the problem that is the subject of the current research, including:

1. Precast

   "Comparative Analysis of Costs Between Portal Systems Using Conventional Floors and Prefabricated Floors in Shophouses" researched by Andrian Tanjaya. et al (2018) from Petra Christian University. This study aims to determine the difference in cost between the conventional floor portal system and the precast floor portal system in a home office. The method used is a structural modelling study using SAP2000 software. The result of this study is that the total cost of the upper structure of the conventional floor office is always more expensive than the office with precast floors [5].

2. Story Drift

   "Comparative Study of Two-Way Ribbed Plates (Waffle Slab) and Conventional Plates" researched by Eka Susanti. et al (2016) from Adhi Tama Institute of Technology Surabaya. This study aims to compare the waffle slab floor structure system to the conventional system in terms of stiffness, plate thickness, distance between columns and the use of concrete and reinforcement materials. The method used is a structural modelling study using SAP2000 software. The results of this study are the volume of concrete in the waffle slab system is 27.63% more wasteful and the use of steel reinforcement in the waffle slab system is 66.99% more wasteful than the conventional plate system [6].

   "Comparative Analysis of Flat Slab and Conventional Plates on the Effect of Stiffness of the Jogja Apartel Building Structure" researched by Khairul, A. (2021) from the Islamic University of Indonesia. This study aims to compare the structural period, deviation and magnitude of base shear to the influence of the two floor plate systems. The method used in this research is modelling and further structural analysis using SAP2000 software. The results of this study are the results of the structural vibration period and displacement which states that the structure in model 2 (conventional) has a higher level of stiffness than the structure in model 1 (flat slab) [7].

3. Section Moment

   "Comparison of the Use of Concrete Floor Plates and Red Brick Walls Against Aerated Lightweight Concrete Floor Plates and Walls" researched by Undin, N., et al (2017) from Pakuan University. This study aims to determine the weight of the building and the extent of the effect of the comparison of the use of materials that make up the floor and wall plates on the beam and column reinforcement requirements of each model. The method used in this research is the planning of reinforced concrete portal structures in buildings consisting of 4 floors using ETABS software. The results of this study are the largest building weight is model 1 with a weight of

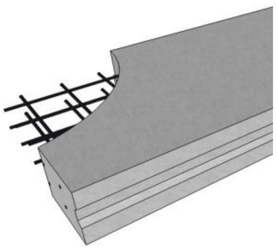
34,159.469 kN and with a percentage of reinforcement requirements of 5.855% and the smallest building weight is model 4 with a weight of 19,275.727 kN and with a percentage of reinforcement requirements of 2.04% of the column cross-sectional area [8].

"Comparative Study of Flat Slab and Flat Plate Analysis" researched by Fransisca N.C. et al (2019) from Sam Ratulangi University Manado. This study aims to determine the comparison of calculation and moment analysis on flat slab and flat plate. The method used in this research is the equivalent frame and direct design method. The results of this study are that the flat plate floor system has a greater field moment than the flat slab, because the flat slab system with thickening and column heads makes the support more rigid and stronger to withstand the existing forces [9].

1.4 Superpanel

Superpanel is a product manufactured from cement, sand, lime, and expansion agents cured under high temperature pressure and autoclave drying for more than 14 hours. Superpanel is extremely strong and produces millions of calcium silicate hydrate crystals that have high stability and durability yet are lightweight [10]. Here are the specifications of the floor superpanel.

Compressive strength = 6 N/mm^2
Fire resistance = > 4 Hours
Planning weight = 750 kg/m^3
Dry specific gravity = 650 kg/m^3
Imposed load = 405 kg/m^2



LANTAI

PANJANG (mm)	LEBAR (mm)	TEBAL(mm)	BERAT (kg/pcs)	M^2/pcs
3000	600	125	168	1,8

Figure 1. Specification and dimension of Superpanel Plate

1.5 Stress-Strain Diagram

A stress-strain diagram is a graph that illustrates the relationship between the stress acting on a material and the strain experienced by the material.

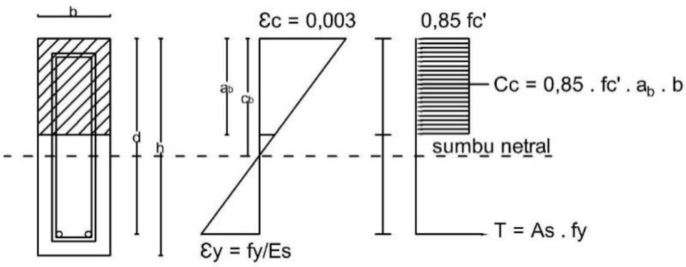


Figure 2. Stress-Strain Diagram [14]

Based on **Figure 2**, using triangular comparison will be obtained:

$$\frac{cb}{d} = \frac{\varepsilon c}{\varepsilon c + fy / Es} \quad (1)$$

Using the force equilibrium equation, it can be written:

$$C = (0{,}85.f'c)b.a \quad (2)$$

$$T = As.fy \quad (3)$$

$$C = T$$

$$0{,}85 \times f'c \times a \times b = A_s \times f_y \quad (4)$$

Obtained an a_b value:

$$a = \frac{As \times fy}{0{,}85 \times f'c \times b} \quad (5)$$

$$c_b = \frac{a}{\beta_1} \quad (6)$$

β1 value for equivalent square concrete stress distribution $17 \leq fc' \leq 28$, $\beta_1 = 0{,}85$ [12].

1.6 Column Interaction Diagram

A column interaction diagram is a graph that illustrates the relationship between the axial force acting on a column and the moment experienced by the column.

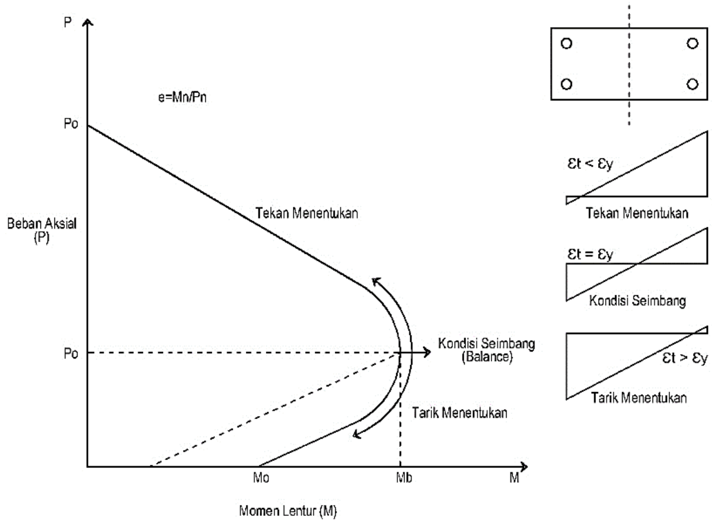


Figure 3. Column Interaction Diagram [11]

Based on **Figure 2**, in making a column interaction diagram, several things are needed, namely:

a. Calculating centric load review
b. Calculating compressive concrete review determines ($c > c_b$)
c. Calculating review at balanced state (c_b)
d. Calculating tensile concrete review determines ($c < c_b$)
e. Calculating the review of the load state $P_n = 0$

1.7 Story Drift

The determination of story drift design should be calculated as the difference in deflection at the center of mass at the top and bottom levels under review [13], here is the story drift formula:

$$\Delta_x = \frac{(\delta 2 - \delta 1) x C_d}{I} \quad (7)$$

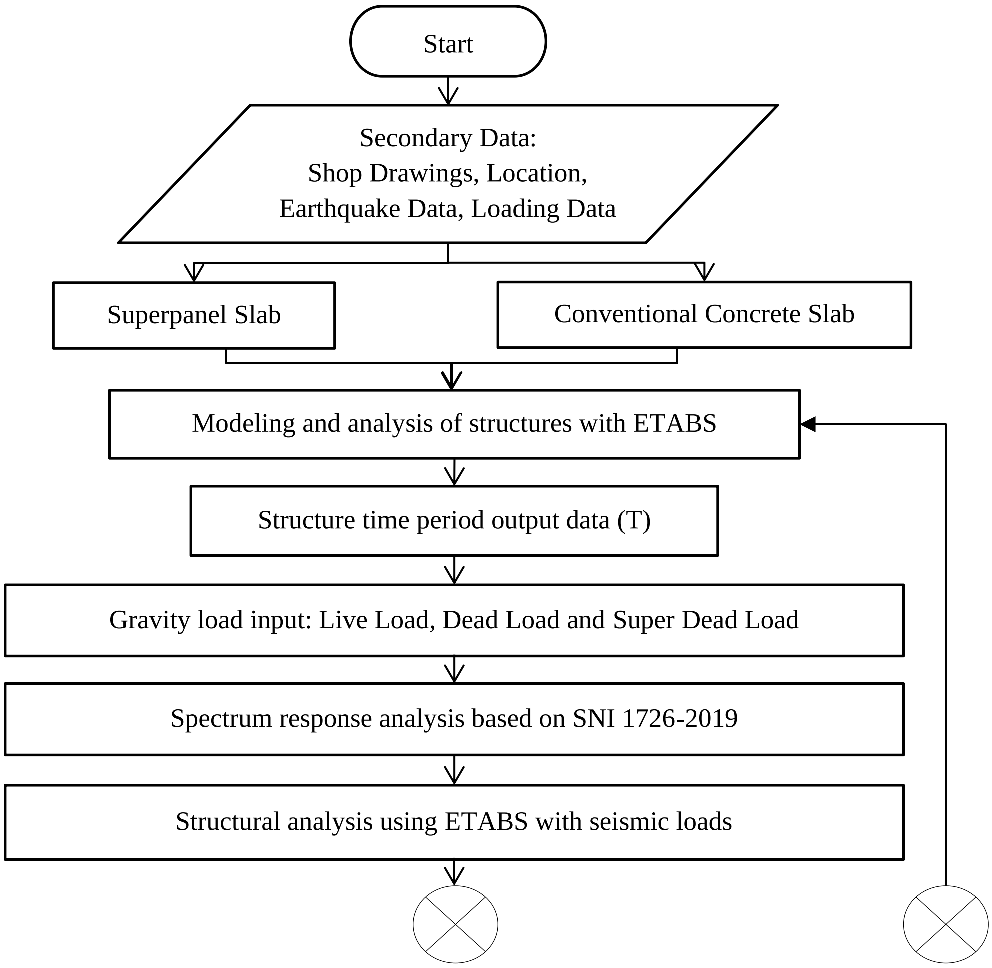
Drift limits for a building in seismic: [15]

$$\Delta_a = 0{,}0025\ h_{sx} \quad (8)$$

2. METHODS

This research was conducted in various stages, namely collecting data needed in the research such as building specifications and material specifications. The stage is continued by modeling with ETABS. The analysis model is divided into 2 types, namely model 1 and model 2. Model 1 is a structural model with conventional plates and model 2 is a structural model with superpanel plates. Modeling is continued by finding the value of the fundamental period (T) [15]. Next, load input is carried out by entering building loads such as live load, dead load, and additional dead load. For the input of earthquake loads, a spectrum response analysis was carried out using earthquake location data contained in the puskim.co.id website. Modeling in ETABS uses adjustments to SNI 1726:2019 which includes the Period of Structure, Story Drift, P-Delta Effect, and Torsional Irregularity. After completing the analysis, a discussion is made regarding the comparison between the 2 slab models which includes aspects of Story Drift, Reinforcement Requirements for Beams and Columns. The description of the building model is described below:

a. Building function : Residential Shophouse
b. Location : Cilegon
c. Building risk category : II
d. Seismic design category : C
e. Structural system : Intermediate moment bearing frame structure
f. Material Quality
   Quality of concrete and reinforcing steel materials.
   1) Concrete
      f'c = K-250 or 20,75 MPa for slabs, columns and beams (density 2400 kg/m^3)
   2) Reinforcing Steel
      Plain reinforcement BJTP 24, Fy = 240 MPa
      Threaded reinforcement BJTD 40, Fy = 400 MPa
g. The soil condition at the research site is medium soil.



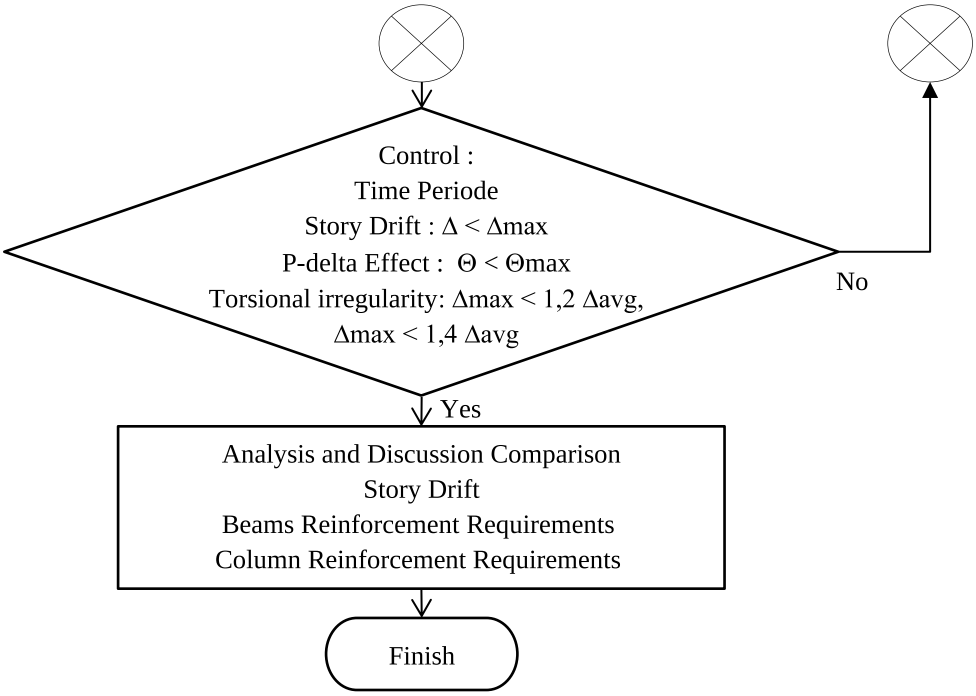


Figure 4. Research Flowchart

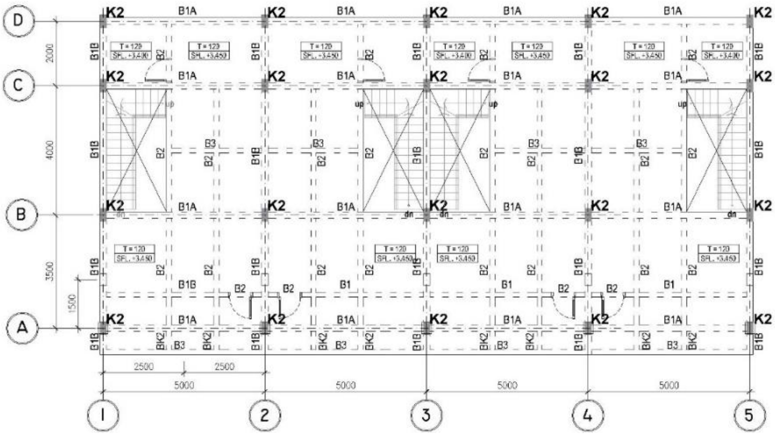


Figure 5. Floor plan of Model 1 Story 1

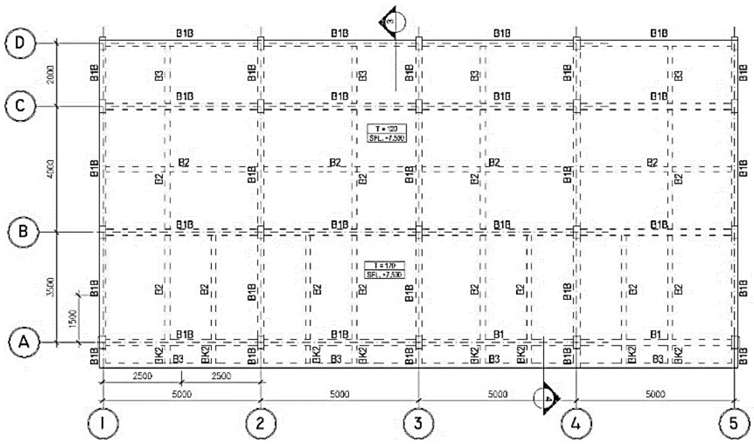


Figure 6. Floor plan of Model 1 Story 2

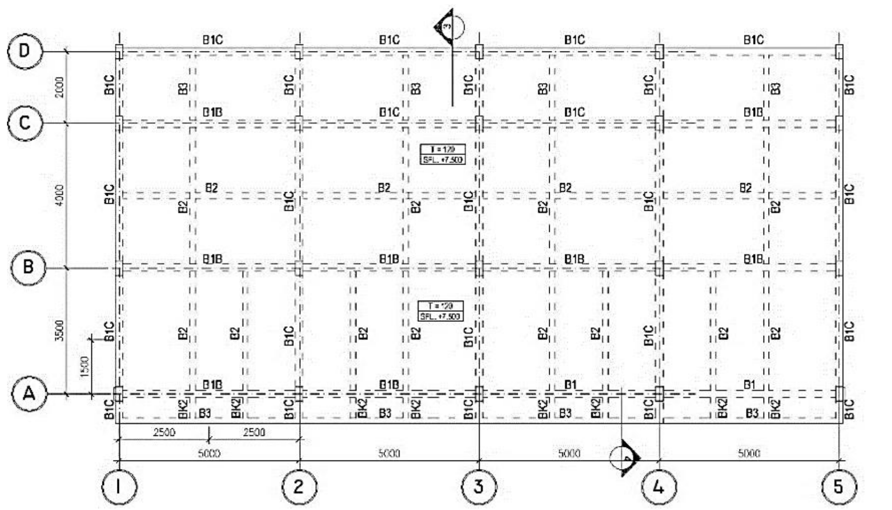


Figure 7. Floor plan of Model 2 Story 2

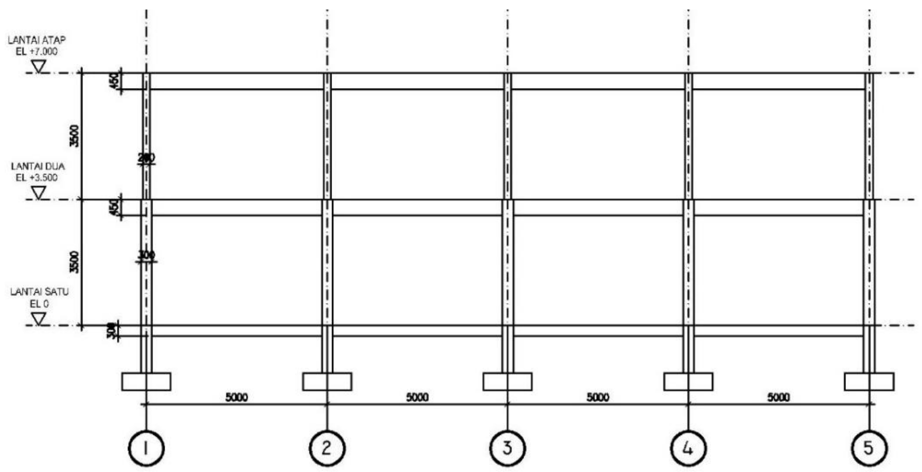


Figure 8. 1st – 5th Portal

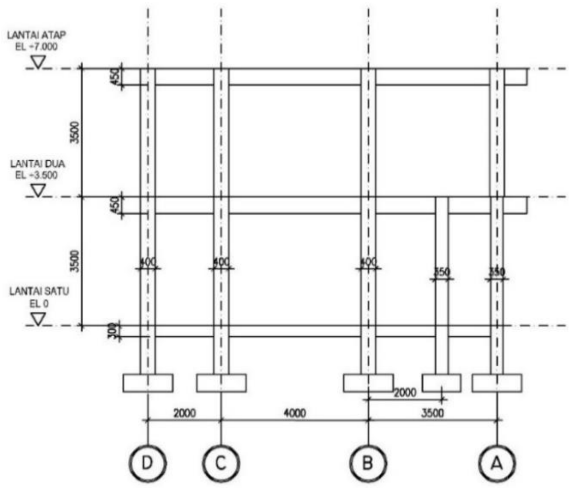


Figure 9. A-D Portal

Figure 5, **Figure 6**, **Figure 7**, **Figure 8** and **Figure 9** are the drawings used as the main reference in conducting the analysis. Each plan and portal drawing provides details that are important in understanding the structure and elements to be analyzed.

3. RESULTS AND DISCUSSION

3.1 Comparison of Deflection Analysis Results of Modelling Conventional Plate System and Superpanel Plate System

Table 1. Comparison of X-Direction Interfloor Story Drift Values of Model 1 and Model 2

Story	Story Height. Hsx (mm)	Displacement δxe (mm)	Total Displacement δx (mm)	Story Drift, Δ (mm)	Maximum Inter-Storey Deviation, Δa/ρ	Desc.
Model 1						
1	3500	2.073	9.331	9.331	87.500	OKE
2	7000	7.562	34.030	24.700	175.000	OKE
Model 2						
1	3500	1.991	8.958	8.959	87.500	OKE
2	7000	7.161	32.224	23.266	175.000	OKE

Table 2. Comparison of Y-Direction Interfloor Story Drift Values of Model 1 and Model 2

Story	Story Height. Hsx (mm)	Displacement δxe (mm)	Total Displacement δx (mm)	Story Drift, Δ (mm)	Maximum Inter-Storey Deviation, Δa/ρ	Desc.
Model 1						
1	3500	11.134	50.103	50.103	87.500	OKE
2	7000	29.363	132.134	82.031	175.000	OKE
Model 2						
1	3500	11.637	52.366	52.366	87.500	OKE
2	7000	27.711	123.698	72.332	175.000	OKE

According to **Table 1** and **Table 2**, the results of the analysis between model 1 and model 2 show a difference in the deviation value of each model. The ratio of maximum story drift in X direction between superpanel plate and conventional plate is 94% and Y is 88%. These results show a decrease in the story drift value caused by the relatively lighter weight/mass of superpanels than conventional plates, so it can be concluded that the use of superpanels can be more efficient in reducing story drift due to earthquake lateral loads..

3.2 Comparison of Analysis Results of Beam Forming Ratio of Structures Modelled with Conventional Plate System and Superpanel Plate System

Table 3. Comparison of Principal Reinforcement and Stirrup Requirements of Model 1 and Model 2 Beams

Beam Code	Support Reinforcement	Field Reinforcement	ϕMn Support	ϕMn Field	Stirrup Support	Stirrup Field
Model 1						
B1A 15x45	6D13	2D13	94,481	36,835	D8-100	D8-200
	3D13	4D13	53,814	68,328		
B1B 15x45	4D13	2D13	68,328	36,835	D8-175	D8-200
	2D13	3D13	36,835	53,814		
B2 15x40	2D13	2D13	32,056	32,056	D8-175	D8-175
	2D13	2D13	32,056	32,056		
B3 15x30	2D13	2D13	22,500	22,500	D8-125	D8-125
	2D13	2D13	22,500	22,500		
Model 2						
B1A 15x45	5D13	2D13	81,884	36,835	D8-100	D8-200

	3D13	3D13	53,814	53,814		

Table 4. Comparison of Principal Reinforcement and Stirrup Requirements of Model 1 and Model 2 Beams (Continued)

Beam Code	Support Reinforcement	Field Reinforcement	ϕMn Support	ϕMn Field	Stirrup Support	Stirrup Field
B1B 15x45	2D13	2D13	81,884	36,835	D8-100	D8-200
	2D13	3D13	53,814	53,814		
B1C 15x45	3D13	2D13	53,814	36,835	D8-200	D8-200
	2D13	2D13	36,835	36,835		
B2 15x40	2D13	2D13	32,056	32,056	D8-175	D8-175
	2D13	2D13	32,056	32,056		
B3 15x30	2D13	2D13	22,500	22,500	D8-125	D8-125
	2D13	2D13	22,500	22,500		

According to **Table 3** and **Table 4**, the comparison between model 1 and model 2 shows a difference. The average ratio of beam reinforcement between superpanel plates and conventional plates is 77%. This result is due to the relatively lighter weight/mass of the superpanel than the conventional plate that is charged to the beam structure, so it can be concluded that the use of superpanels can be more efficient in reducing the need for beam reinforcement.

3.3 Comparison of Analysis Results of Column Fixing Ratio of Structures Modelling Conventional Plate System and Superpanel Plate System

Table 5. Comparison of Principal Reinforcement and Stirrup Requirements of Model 1 and Model 2 Columns

Column Code	Reinforcement	Area	Stirrup Requirement
Model 1			
K1 40X20	12D13	1591,980	d8-175
K2 35X30	8D13	1061,858	d8-175
K3 35X20	6D13	796,394	d8-175
Model 2			
K1 40X20	10D13	1327.323	d8-175
K2 35X30	8D13	1061,858	d8-175
K3 35X20	6D13	796,394	d8-175

According to **Table 5**, the comparison between model 1 and model 2 shows a difference. The average ratio of column reinforcement between superpanel plates and conventional plates is 94%. This result is due to the relatively lighter weight/mass of the superpanel than the conventional plate charged to the column structure, so it can be concluded that the use of superpanel can be more efficient in reducing the need for column reinforcement.

4. CONCLUSION

From the results of the analysis and discussion that has been carried out, it can be concluded that the average ratio of beam reinforcement requirements between superpanel plates and conventional plates is 77% and columns is 94%. The average ratio of X direction story drift between superpanel plate and conventional plate is 94% and Y is 88%. These results show that model 2 (superpanel plate) produces less reinforcement requirements than model 2 (conventional plate) and the resulting story drift is smaller than the story drift value in model 2 (conventional plate).

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