

COUPLING BEAM DESIGN WITH SPECIAL MOMENT FRAME AND SPECIAL REINFORCED CONCRETE SHEAR WALLS

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ABSTRACT

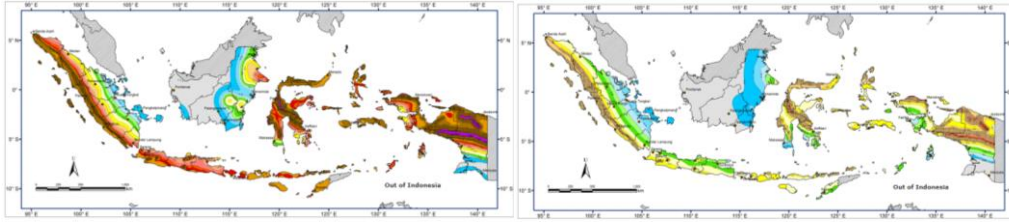
An Earthquake is one of the natural phenomena that cannot be avoided or cannot be prevented by its appearance which is very difficult to accurately predict both from the time and place of its occurrence. Shear wall system is used to increase the stiffness of many multi-storey building, in this case building that have more than 20 floors. Building structures with shear wall as retaining element of lateral force generally have good performance during an earthquake. Coupling beam is a connecting beam between two shear walls, this beam makes a series of shear walls works as a system that is able to withstand earthquake force. Coupling beam also make the working structure rigid and absorbs energy due to the very high rigidity of the coupling beam with shear wall behaving link two free cantilevers. Coupling beam is considered to be able to transmit shear force from one wall to another so that it can withstand large structural deformation. Structure design material strength for concrete f_c' 35MPa ~ f_c' 55'MPA and rebar (D10 & D13) using f_y 520MPa and f_y 420MPa for diameter >16mm. While the regulations used are SNI 1726: 2012, SNI 1727: 2013, and SNI 2847: 2013. Structural loading is given according to loading rules which are then analyzed using ETABS 2016 software.

Keywords: Earthquake ; Special Moment Frame ; Reinforced Concrete Shear Walls ; Coupling beam

INTRODUCTION

Indonesia is a country that has a high level of vulnerability to earthquakes, with geographical condition in parts of Indonesia within the Ring of Fire series where there are still many active volcanoes and the spread of areas that have faults and active tectonic plate faults that can trigger earthquake occurrence. This can be seen in various natural disasters that hit several region of Indonesia ranging from low, medium to high magnitudes. This condition requires the building designer to meet the criteria for building structure design to be able to withstand earthquake force with the aim at the time of the earthquake, the structure is able to provide security to building users from the risk of earthquake hazard.

Figure 1. map of the earthquake area of Indonesia



Source : Indonesia Hazard Book, 2017

Shear wall system is used to increase the stiffness of multi-storey buildings. In this case building that have more than 20 floors. Building structure with shear walls as a lateral retaining element generally have good performance during an earthquake, with the slightest damage occurring to the shear wall structural system during an earthquake. Coupling beam is a connecting beam between two shear walls, this beam makes a series of shear walls work as a system that is able to withstand earthquake forces. The beam also makes the working structure stiff and can absorb energy due to the very high rigidity of the coupling beam with shear walls behaving like two free cantilevers. Coupling beam can be mounted in a shear force from one wall to another so that large structural deformations can be removed.

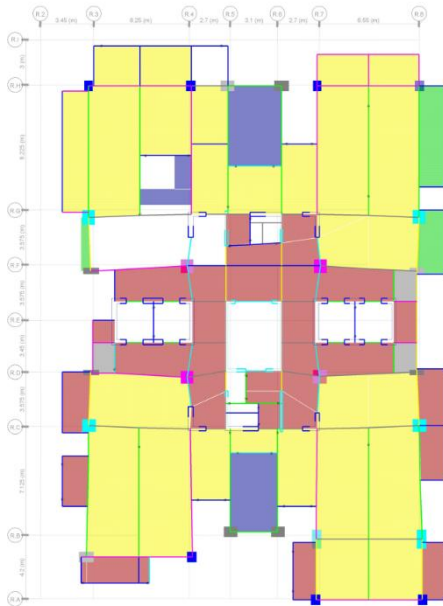
Design of this building used regulations from the Indonesian National standart as follows ;

- ASCE 7-10 Minimum load for building design and other structures [1]
- SNI 1727 : 2013 Minimum load for building design and other structures [2]
- SNI 1726 : 2012 Procedure of earthquake reistance design for building and non-building structure [3]
- SNI 2847 : 2013 Building code requirements for structural concrete [4]

RESEARCH METHODOLOGY

In this design the method used is the analysis method in building structure modeling where the planning will use the dual system method, namely the special moment frame and special reinforced concrete shear walls. The case study method is in the form of re-planning with a model made according to the condition of building. The planning method used has stage of input, analysis and output. At the input stage will be explained about the structure geometry, dimension, and specifications of structural elements, the determination of the burden of working with 3-dimensional modeling. Stage of analydis include modeling the structure using ETABS 2016 software. The final stage is the output stage which discusses the adjusted detailing of the internal forces that occur in the building structure. The final result of this plan is expected to be that the structure of this building especially in the part of the shear wall stiffener called the coupling beam will be able to match the optimum dimensions and strenght of the structure.

Figure 2. Modeling Plan



- Structure Material
- Concrete Strength : f_c' 35MPa - f_c' 55MPa
- Rebar Strength : (D10 & D13) 520MPa
>D16 420MPa
- Geometric Structure
- Number of Stories : 24th floor + roof
- Floor height : 4,2 - 4,5 meters
- Total height : 104 meters
- Function : Apartment
- Location : Jakarta, Indonesia
- Type of soil : Medium (Soil Type D)
- Structure System
- Special Moment Frame
- Special Reinforced Concrete Shear Wall

Source : ETABS Modeling

RESULTS AND DISCUSSION

Structural Loading

The loading design follows the provisions of SNI 1727 : 2013 and ASCE 7-10 for dead load and live load, then SNI 1726 : 2012 for earthquake load.

Dead Load

Dead load consist of the weight of all materials of construction incorporated into the building including, but not limmited to walls, floors, roofs, ceilings, starways, built-in partitions, finishes, cladding and othe similarly incorporated architectural and structural items, and fixed service eqiptment including the weight of cranes.[1]

Table 1. SIDL for 1st-23th floor

Material	Load (kN/m ²)	Reference
Ceramic	1.10	ASCE 7-10 Table C3-1 Ceramic or quarry tile (19mm) on 25mm mortar bed)
Mechanical Duct	0.19	ASCE 7-10 Table C3-1, Mecanical Duct Allowance)
Suspended Steel Channel	0.1	ASCE 7-10 Tabl C3-1, Suspended Steel Channel System
Acoustical Fiber Board	0.05	ASCE 7-10 Table C3-1, Acoustical fiberboard
Total	1.44	

Source : ASCE 7-10

Table 2. SIDL for roof floor

Material	Load (kN/m ²)	Reference
Waterproofing	0.05	ASCE 7-10 Tabel C3-1, Waterproofing Membrane Liquid Applied)
Ducting	0.19	ASCE 7-10 Table C3-1, Mecanical Duct Allowance)
Suspended Steel Channel	0.1	ASCE 7-10 Tabl C3-1, Suspended Steel Channel System
Acoustical fiber board	0.05	ASCE 7-10 Table C3-1, Acoustical fiberboard
Total	0.39	

Source : ASCE 7-10

Live Load

A load produced by the use and occupancy of the building or other structure that does not included construction of environmental loads, such as earthquake load.[1]

Table 3. Live Load

Load Type	Load (kN/m ²)	Reference
Residential	1,92	SNI 1727 :2013 tabel 4-1
Partition	0,72	SNI 1727 :2013 tabel 4.32
Total	2,64	

Source : SNI 1727 : 2013

Earthquake Load (Respon Spectrum Method)

Earthquake load is calculated based on SNI 1726 : 2012. Earthquake load is designed to be the probability of an earthquake of 2% within a period of 50 years or an earthquake return period of 500 years. This elastic earthquake response has 5% attenuation.[2]

- Building Locations : Jakarta, Indonesia
- Type of Soil : Medium (SD)
- Risk Category :

Table 4 Risk category of building and other structures for earthquake loads

Use or occupancy of Building and Structures	Risk Category
All building and other structures except those listed in Risk Categories I, III and IV	II

Source : ASCE 7-10

- Seismic Importance Factor

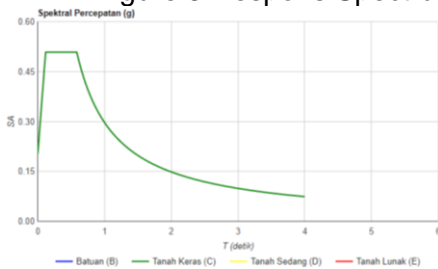
Table 5 Importance factors by risk category of building and other structures for earthquake loads

Risk Category	Seismic Importance Factor (I_e)
I	1.00

Source : ASCE 7-10

- Seismic design category based on short period respons acceleration parameter (S_{DS}) : 0.674
- Seismic design category based on 1-S Period respons acceleration parameter (S_{D1}) : 0.297

Figure 3 Respon Spectrum



The parameter taken from http://puskim.pu.go.id/Aplikasi/desain_spektra_indonesia_2011/

Source : puskim.pu.go.id

- Site Class

Table 6 Site Classification

Site class	\bar{V}_s (m/detik)	\bar{N} or \bar{N}_{ch}	\bar{S}_u (kPa)
SD (medium)	175-50	15-50	50-100

Source : SNI 1726 : 2012

- Site Coefficient (F_a)

Table 7 Site Coefficient (F_a)

Site Class	Mapped Risk-Targeted Maximum Considered Earthquake (MCER) Special Respon Acceleration parameter at short period				
	$S_s \leq 0,25$	$S_s = 0,5$	$S_s = 0,75$	$S_s = 1,0$	$S_s \geq 1,25$
SD	1,6	1,4	1,2	1,1	1,0

Source : SNI 1726 : 2012

- Site Coefficient (F_v)

Table 8 Site Coefficient (Fv)

Site Class	Mapped Risk-Targeted Maximum Considered Earthquake (MCER) Special Respons Acceleration parameter at 1-s period				
	$S_s \leq 0,25$	$S_s = 0,5$	$S_s = 0,75$	$S_s = 1,0$	$S_s \geq 1,25$
SD	1,6	1,4	1,2	1,1	1,0

Source : SNI 1726 : 2012

- Spectral response acceleration parameter at short periods (S_{MS})
 $SMS = Fa \times S_s = 1,1 \times 0,674 = 0,7414 \text{ g}$
- Spectral response acceleration parameter at a period of 1 s (S_{M1})
 $SM1 = Fv \times S1 = 1,8 \times 0,297 = 0,5346 \text{ g}$
- Spectral acceleration parameter at shor period (S_{DS})
 $SDS = 2/3 SMS = 2/3 \times 0,7414 = 0,494 \text{ g}$
- Spectral acceleration parameter at a period of 1 s (S_{D1})
 $SD1 = 2/3 SM1 = 2/3 \times 0,5346 = 0,356 \text{ g}$
- Fundamental period of the structure (T)

$$T_0 = 0,2 \frac{S_{D1}}{S_{DS}} = 0,2 \frac{0,3564}{0,494} = 0,144 \text{ s}$$

$$T_s = \frac{S_{D1}}{S_{DS}} = \frac{0,3564}{0,494} = 0,7214 \text{ s}$$

- Spectrum Acceleration (S_a)

$$\text{for } T < T_0, S_a = S_{DS} \left(0,4 + 0,6 \frac{T}{T_0}\right)$$

$$\text{for } T < T < T_s, S_a = S_{DS}$$

$$\text{for } T \geq T_s, \text{ maka, } S_a = \frac{S_{D1}}{T}$$

Table 9 Spectrum Acceleration

Periode T (sec)	Sa (g)	Periode T (sec)	Sa (g)	Periode T (sec)	Sa (g)	Periode T (sec)	Sa (g)	Periode T (sec)	Sa (g)
0.0	0.198	2.2	0.162	4.4	0.081	6.6	0.054	8.8	0.041
0.2	0.494	2.4	0.149	4.6	0.077	6.8	0.052	9.0	0.040
0.4	0.494	2.6	0.137	4.8	0.074	7.0	0.051	9.2	0.039
0.6	0.494	2.8	0.127	5.0	0.071	7.2	0.050	9.4	0.038
0.8	0.446	3.0	0.119	5.2	0.069	7.4	0.048	9.6	0.037
1.0	0.356	3.2	0.111	5.4	0.066	7.6	0.047	9.8	0.036
1.2	0.297	3.4	0.105	5.6	0.064	7.8	0.046	10	0.036
1.4	0.255	3.6	0.099	5.8	0.061	8.0	0.045		
1.6	0.223	3.8	0.094	6.0	0.059	8.2	0.043		
1.8	0.198	4.0	0.089	6.2	0.057	8.4	0.042		
2.0	0.178	4.2	0.085	6.4	0.056	8.6	0.041		

- Seismic Design Category based on short period response acceleration parameter

Table 10 Seismic Design Category

Value of S_{DS}	Risk Category	
	I or II or III	IV
$0.33 < S_{DS} < 0.50$	C	D

Source : ASCE 7-10

- Seismic Force-Resisting System

- Seismic Design Category Based 1-S Period Response Acceleration parameter

Table 11 Seismic Design Category

Value of S_{D1}	Risk Category	
	I or II or III	IV
$0.20 \leq S_{DS}$	D	D

Source : ASCE 7-10

Table 12 Seismic Force-Resisting System

Seismic Force-Resisting System	Response Modification Coefficient, R^a	Overstrength Factor, Ω_o^b	Deflection Amplification Factor, C_d^b	Structural System Limitations Including Structural Height h_n (m) ^c				
				Limits ^c				
				Seismic Design Category				
				B	C	D ^d	E ^d	F ^e
Dinding Geser beton bertulang khusus	7	$2\frac{1}{2}$	$5\frac{1}{2}$	NL	NL	NL	NL	NL

Load Combination

In the ultimate design, a combination of the load given to the building structure must be given in SNI 1727: 2013 article 4.2.2 with a more detailed earthquake load E of articles 7.3.4.2 and article 7.4.2. The redundancy factor must be charged to the earthquake barrier system in each of the two orthogonal directions for all structures according to this article. For structures designed for seismic design categories D, E, F = 1.3. Get the combination given to the building, i.e. combination 1 to 18:

Values $\rho = 1.3$ and $Sds = 0.494$ we get the combination of loading as follows

1. Comb. 1 : 1.4 DL + 1.2 SDL
2. Comb. 2 : 1.2 DL + 1.2 SDL + 1.6 LL
3. Comb. 3 : 1.3284 DL + 1.3284 SDL + LL + 0.39 EQx + 1.3 EQy
4. Comb. 4 : 1.2692 DL + 1.2692 SDL + LL + 0.39 EQx - 1.3 EQy
5. Comb. 5 : 1.1308 DL + 1.1308 SDL + LL - 0.39 EQx + 1.3 EQy
6. Comb. 6 : 1.0716 DL + 1.0716 SDL + LL - 0.39 EQx - 1.3 EQy
7. Comb. 7 : 1.3284 DL + 1.3284 SDL + LL + 1.3 EQx + 0.39 EQy
8. Comb. 8 : 1.1308 DL + 1.1308 SDL + LL + 1.3 EQx - 0.39 EQy
9. Comb. 9 : 1.2692 DL + 1.2692 SDL + LL - 1.3 EQx + 0.39 EQy
10. Comb. 10 : 1.0716 DL + 1.0716 SDL + LL - 1.3 EQx - 0.39 EQy
11. Comb. 11 : 0.7716 DL + 0.7716 SDL + 0.39 EQx + 1.3 EQy
12. Comb. 12 : 0.8308 DL + 0.8308 SDL + 0.39 EQx - 1.3 EQy
13. Comb. 13 : 0.9692 DL + 0.9692 SDL - 0.39 EQx + 1.3 EQy
14. Comb. 14 : 1.0284 DL + 1.0284 SDL - 0.39 EQx - 1.3 EQy
15. Comb. 15 : 0.7716 DL + 0.7716 SDL + 1.3 EQx + 0.39 EQy
16. Comb. 16 : 0.8308 DL + 0.8308 SDL - 1.3 EQx + 0.39 EQy
17. Comb. 17 : 0.9692 DL + 0.9692 SDL + 1.3 EQx - 0.39 EQy
18. Comb. 18 : 1.0284 DL + 1.0284 SDL - 1.3 EQx - 0.39 EQy
19. Gravity : 1,2 DL + 1 LL

Design Calculations

a. Calculate Weight of Building Structure (W)

The self-weight of building structures is calculated automatically by the ETABS 2016 program. The following results are the self-weight of building structures obtained:

Table 13. Calculation of Building Weight

Story	Weight (kg)	Story	Weight (kg)
Storey 12	1176969.61	Storey 24	1273878.85
Storey 11	1176969.73	Storey 23	1415795.79
Storey 10	1182658.49	Storey 22	1415778.98
Storey 9	1180267.77	Storey 21	1243757.6

			2
Storey 8	1190787.82	Storey 20	1229451.7 3
Storey 7	1187813.88	Storey 19	1211069.5 1
Storey 6	1190717.72	Storey 18	1119593.9 5
Storey 5	1201990.23	Storey 17	1122199.8 3
Storey 4	1201552.62	Storey 16	1122891.7 3
Storey 3	1216299.05	Storey 15	1126862.7 8
Storey 2	1216299.05	Storey 14	1151350.6 2
Storey 1	1217896.88	Storey 13	1181081.7 3
Base	-	Total	2831,17 (kN)

b. Calculating the Basic Seismic Shear Force

Calculation of basic seismic shear forces in the direction determined based on SNI 1726:2012 article 7.8.1 is determined by the equation :

$$V = C_s \cdot W$$

Seismic Base Shear Force

Table 14 Seismic Base Shear Force

Cs		W (kN)	V = C _s · W (kN)
C _{s-x}	0.01348	283941,17	3827,53
C _{s-y}	0.01386		3935.42

Lateral Earthquake Load Distribution

Based on SNI 1726: 2012 article 7.8.3, lateral earthquake forces (Fx) arising at all levels must be determined by the following equation:

$$F_x = C_{vx} \cdot V \text{ dan } C_{vx} = \frac{w_x h_x^k}{\sum_{i=1}^n w_i h_i^k}$$

c. Base Shear Force Scale (Static Base Shear Comparison and Dynamic Base Shear)

Based on SNI 1726:2012 earthquake 7.9.4.1 regarding the scale of the force, this regulation implies that the dynamic basic shear force must be greater than 85% of the static shear force. Formulated as follows :

$$V_{dynamic} > 0.85 V_{static}$$

Table 15 Base Shear

Seismic Load		Fx (kN)	Fy (kN)	85% Static	V _{dynamic} > 0.85 V _{static}
Static	Ex	8804.27		7483.63	OK
	Ey		9079.09	7717.22	OK
Dynamic	RSx	906349.8			
	Rsy		933423		

d. Displacement

Type of structure is a structure using a shearwall then the deviation between floors permits atea risk category II then using the formula:

$$\Delta_a = 0.020 \times h_x$$

Following are the displacement data from ETABS 2016 :

Table 16 Storey Displacement

Story	Elevation	X-Dir	Y-Dir	Story	Elevation	X-Dir	Y-Dir
	m	mm	mm		m	mm	mm
Storey 12	51.2	4.422	6.263	Storey 24	104	9.277	14.777
Storey 11	47.0	3.972	5.579	Storey 23	99.2	9.092	14.303
Storey 10	42.8	3.528	4.907	Storey 22	94.4	8.846	13.762
Storey 9	38.6	3.098	4.259	Storey 21	89.6	8.262	12.471
Storey 8	34.4	2.683	3.638	Storey 20	84.8	7.882	11.797
Storey 7	30.2	2.275	3.037	Storey 19	80.6	7.515	11.164
Storey 6	26.0	1.872	2.456	Storey 18	76.4	7.113	10.494
Storey 5	21.8	1.483	1.906	Storey 17	72.2	6.683	9.794
Storey 4	17.6	1.113	1.393	Storey 16	68	6.23	9.073
Storey 3	13.4	0.762	0.925	Storey 15	63.8	5.771	8.353
Storey 2	9.2	0.439	0.514	Storey 14	59.6	5.313	7.643
Storey 1	5.0	0.166	0.187	Storey 13	55.4	4.87	6.952
Base	0.0	0	0				

Coupling Beam Calculation

Coupling beam with $l_n/h \geq 4$ must satisfy the requirement for flextural member of special moment frames,if it can be shown that the beam has adequate lateral stability. Two intersecting groups of diagonally-placed bars symmetrical about the midspan are required for deep coupling beam ($l_n/h < 2$) with a factored shear force V_u greater than $0,33\lambda A_c w \sqrt{f_c}$, unless it can be shown otherwise that safety and stability are not compormised. Expertiment have shown that diagonally oriented reinforcement is effective only if the bars can be place at a large inclination. Two options are given for coupling beams that are not governed by 21.9.7.1 or 29.9.7.2 : two intersection groups of diagonally placed bars syemmetrical about the midspan may be provided or the beam can be reinforced according to the requirement of 21.5.2 through 21.5.4 (21.9.7.3)

- Properties Coupling Beam

Table 17 Properties Coupling Beam Type C

Storey	Material Strength			Dimension				
	fc'	fy	fys	b	h	Ln	ln/h	d=h-0,5
	MPa	MPa	MPa	mm	mm	mm		mm
1~5th	55	420	520	400	1600	1100	0.7	1550
6~10th	55	420	520	400	1600	1100	0.7	1550
11~15th	55	420	520	400	1600	1100	0.7	1550
16~19th	45	420	520	300	1600	1100	0.7	1550
20th	45	420	520	300	1600	1100	0.7	1550
21th	45	420	520	300	1600	1100	0.7	1550
22~23th	35	420	520	300	1600	1100	0.7	1550
24th	35	420	520	300	1600	1100	0.7	1550

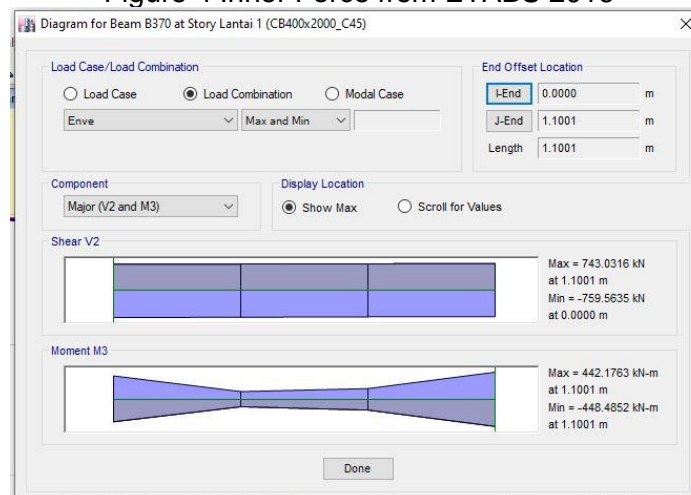
- Analysis of Coupling Beam Reinforcement Type C

In determining the type of reinforcement that will be installed on the beam coupling, the provisions are used If the value of $Ln / h < 2$ and $V_u > 0.33\sqrt{f_c'} \cdot A_{cw}$, then the beam coupling is automatically repeated with a diagonal reinforcement, this is done only checking on the beam coupling that has value of $Ln / h < 2$

Table 18 Checking Beam Coupling Design Type

Storey	Concrete Strength	Dimension				Vu Maks	0,33√fc' .Acw	Cek
	fc'	b	h	Ln	ln/h	kN	kN	Design Type
	MPa	mm	mm	mm				Type
1~5th	55	400	1600	1100	2	759.56	1566.30	Type C
6~10th	55	400	1600	1100	2	530.99	1566.30	Type C
11~15th	55	400	1600	1100	2	411.66	1216.77	Type C
16~19th	45	300	1600	1100	2	348.54	1216.77	Type C
20th	45	400	1600	1100	2	287.51	937.11	Type C
21th	45	300	1600	1100	2	293.84	937.11	Type C
22~23th	35	400	1600	1100	2	254.56	937.11	Type C
24th	35	300	600	1100	2	108.96	1249.48	Type C

Figure 4 Inner Force from ETABS 2016



- Analysis of Reinforcement Needs Calculation

Based on the results of the force on ETABS, taken from the 1st floor type S1 obtained $V_u = 759.56$ kN. Therefore, the coupling beam needs diagonal reinforcement. if $ln/h > 2$ because

of conditions <2 and >4. And if $\frac{Vu}{\lambda\sqrt{f'c'}Acw} > 0.33$ then calculated using $\frac{Vu}{b.h.\sqrt{f'c'}}$. Calculate $\frac{Vu}{\phi}$ as the following :

$$\frac{Vu}{\phi} = \frac{759.56}{0.75} = 1012.75kN$$

Calculating Vn must be calculated with the following formula in accordance with that written in SNI 1726-2012 chapter 21.9.7.4. To find out that Vn min and Vn max.

$$\begin{aligned} Vn &= 0.83\sqrt{f'c'Acw} \\ &= 124577.44 kN \end{aligned}$$

then $Vn > Vu/\phi$...OK !

- Vertical and Horizontal Components C dan T

$$\sin \alpha = \frac{0.8 \times h}{\sqrt{l^2 + (0.8h)^2}} = 0,758(\text{shear}) \quad \cos \alpha = \frac{L}{\sqrt{l^2 + (0.8h)^2}} = 0,652(\text{flex})$$

- Diagonal Reinforcement for Shear

If all shear formed on the beam is designed to be fully borne by a diagonal reinforcement, it will be calculated with SNI chapter 21.9.7.4

$$Vn = 2Avd.fy.\sin\alpha$$

$$Avd = \frac{\left(\frac{Vu}{\phi}\right)}{2fy.\sin\alpha} = 1589.70 \text{ mm}^2$$

$$Avd = \frac{Avd}{\frac{1}{4}\pi d^2} = \frac{1589.70}{\frac{1}{4} \times 3.14 \times 25^2} = 3.240 \sim 4D25$$

$$4 \times \frac{1}{4} \times 3.14 \times 25^2 = 1962.50 \text{ mm}^2 > 1589.70 \text{ mm}^2 \dots (\text{ok!})$$

- Transversal Reinforcement Requirement

Transversal spacing must be provided for the cross section of the whole beam that meets at 21.9.7.4. Following are the steps for determining the transverse reinforcement in the design of a coupling beam with full cross section full restraints

:

✓ Transverse reinforcement area :

Because the restraining area is the entire cross section of the beam, there is no minimum dimension for determining the gross area used in determining transverse reinforcement. It is known that the coupling beam has a height of 1600 and a width of 400mm with blankets on each side of 20mm. The diameter of the longitudinal reinforcement used is D13 and for transverse reinforcement it is assumed to require D16 reinforcement. So that parameters can be determined determining transverse reinforcement as follows:

$$\text{Clearance Height} = 1600 - (2 \times 40) = 1520 \text{ mm}$$

$$\text{Clearance width} = 400 - (2 \times 40) = 320 \text{ mm}$$

$$A_g = 400 \times 600 = 640000 \text{ mm}^2$$

$$A_{ch} = 360 \times 560 = 486400 \text{ mm}^2$$

This value is then used in calculating the transverse reinforcement requirements in chapter 21.6.4.2.

Condition 1 :

$$\frac{A_{sh}}{s} = 0.3 \frac{b_c f'_c}{f_{yt}} \left[\frac{A_g}{A_{ch}} - 1 \right]$$

$$\frac{A_{sh}}{s} = 3.21 \text{ mm}^2 / \text{mm}$$

Condition 2 :

$$\frac{A_{sh}}{s} = 0.09 \frac{b_c f'_c}{f_{yt}}$$

$$\frac{A_{sh}}{s} = 3.05 \text{ mm}^2 / \text{mm}$$

Of the two conditions, the largest value is used = 3.21 mm² / mm. With the minimum distance between diagonal reinforcement (hx) is 200mm, we can determine the value of the transverse reinforcement spacing.

✓ Transversal Spacing of chapter 21.6.4.3 (c):

$$100\text{mm} \leq S_o \leq 150\text{mm}$$

$$s_o = 100 + \left(\frac{350 - h_x}{3} \right)$$

$$s_o = 150\text{mm}$$

✓ Minimum Transversal Reinforcement Spacing

$$s_{min1} = 6 \text{ diameter diagonal} = 6 \times 25 = 150\text{mm}$$

$$s_{min2} = 150\text{mm}$$

Longitudinal spacing between 150mm transverse reinforcement is taken. From this transverse reinforcement space, it can be determined the need for transverse reinforcement

$$\text{requirement area} = s \times \frac{A_{sh}}{s}$$

$$\text{requirement area} = 150 \times 3,21 = 480.97\text{mm}^2$$

Mounted transverse reinforcement 4 feet D13, with an area of 530.66mm².

From the determination of transverse reinforcement is the installation of 4-foot D13-150mm reinforcement which curbs the entire cross section of the coupling beam.

- Confinement Reinforcement Requirements

Confinement reinforcement calculations will be carried out as follows for the x and y directions

$$A_{sh} = 0.3 \left(\frac{b_{cx} f'_c s}{f_y} \right) \left(\frac{A_g}{A_{ch}} - 1 \right)$$

$$A_{sh} = 545.49\text{mm}^2$$

A_{sh} min that must be installed for the x direction is 545.49 mm². So for Ash to be installed A_{sh} = 5 .0.25 .π .d² = 3 x 0.25 x 3.14 x 13² = 663.352mm². So that is attached to the x 5D13 direction hook

$$A_{sh} = 0.3 \left(\frac{b_{cy} f'_c}{f_y} \right) \left(\frac{A_g}{A_{ch}} - 1 \right) s$$

$$A_{sh} = 761.54\text{mm}^2$$

A_{sh} min which must be installed for y direction is 761.54mm². So for Ash to be installed A_{sh} = 5 .0.25 .π .d² = 4 x 0.25 x 3.14 x 13² = 816.4mm². So that will be attached to the x 5D13 direction hook

- Reinforcement for Longitudinal

Calculations for longitudinal reinforcement are as follows:

$$\phi M_n = (\phi \times A_{vd} \times f_y \times \cos \alpha) \times (h - 100) / 10^6$$

$$\phi M_n = 683.61 \text{ kNm}$$

Based on the results of the moment on ETABS, taken from the 1st floor type A obtained Mu (etabs) = 448.49 kNm. And to calculate the need for longitudinal reinforcement as follows

$A_s \text{ min} = \frac{0.25 \times \sqrt{f'_c}}{f_y} b_w d$ and may not be smaller than $A_s \text{ min} = \frac{1.4}{f_y} b_w d$, so :

$$A_s \text{ min} = \frac{0.25}{f_y} b_w d = \frac{0.25}{420} .400.52.5 = 2205\text{mm}^2$$

$$A_s = 5 * \frac{1}{4} * \pi * d^2 = 2 * \frac{1}{4} * 3.14 * 25^2 = 2453.13\text{mm}^2$$

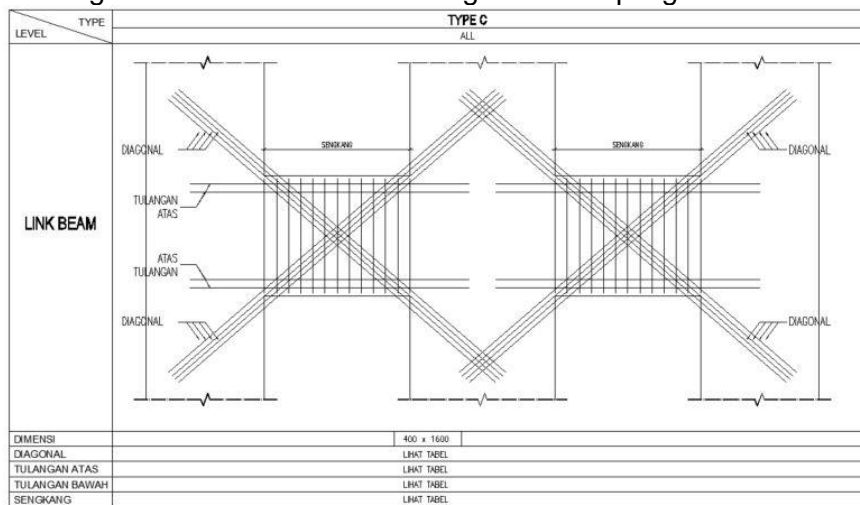
So for As that will be used 5D25

- Coupling Beam Reinforcement

Table 19 Coupling Beam Reinforcement

Storey	Diagonal		Transversal			Confinement			Longitudinal	
	qty	Dia (mm)	Dia (mm)	qty	spacing (mm)	Dia (mm)	qty	spacing (mm)	qty	Dia (mm)
1~5th	4	D25	D13	4	150	D13	5	150	5	D25
6~10th	3	D25	D13	4	150	D13	5	150	5	D25
11~15th	3	D25	D13	3	150	D13	4	150	5	D25
16~19th	2	D25	D13	3	150	D13	4	150	5	D25
20th	2	D25	D13	3	150	D13	4	150	5	D25
21th	2	D25	D13	3	150	D13	3	150	4	D25
22~23th	2	D25	D13	3	150	D13	3	150	4	D25
24th	2	D25	D13	3	150	D13	4	150	4	D25

Figure 5 Schematic of mounting beam coupling reinforcement



CONCLUSIONS

Based on the results of the design of the Residence building structure in the The Jakarta Stature project with a focus on the beam coupling with the special moment bearing frame system and the sliding wall system the following conclusions can be drawn :

a. Earthquake Analysis (structural properties of earthquakes) between designs is as follows::

✓ Natural Periode

The natural period of the design structure modeled by ETABS meets the requirements with a maximum limit according to SNI 1726: 2012 article 7.8.2 :

$$T_a(T_{min}) = 0.0488 \times 104^{0.9} = 3.1897 \text{ s}$$

$$T_{maks} = 1.4 \times 3.1897 = 4.4656 \text{ s}$$

Tabel 20 Periode Struktur Out Put Etabs

	T_x	T_y	Note
Design	3,773 s	3.699 s	OK

- ✓ Displacement (Story Drift)
All designs have fulfilled the permit deviation specified in SNI 1726: 2012 article 7.8.6 where the largest deviation value is on the 24th floor with direction value $x = 9.277$ and y direction = 14.77mm

b. Beam Coupling Dimensions and Reinforcement Details

From the analysis results obtained calculation of reinforcement requirements for TYPE C beam coupling which has been mentioned in the previous chapter that this type of beam coupling will be adjusted due to design clashes with the needs of mechanical and architectural work, therefore according to the results of this Type C coupling beam analysis can be adjusted to a new dimension with a height of 1600mm from the previous 2000mm.

Suggestions

Based on the results that have been studied can be given suggestions, including:

- In planning this structure using the burdens of the Indonesian National Standard (SNI). When analyzing the structure to be more accurate, it is recommended to use the burdens that have been imposed on the structure design by the planner (consultant).
- To get the optimum design and avoid the design clash with other disciplines in structural planning, it needs to be considered in more detail, especially for needs that must meet the minimum specifications.
- In planning this coupling beam only designed using diagonal reinforcement, for further research the authors suggest that in similar cases the beam coupling is designed with a strut and tie model so that a comparison of steel tonnage between the two methods will be obtained.

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