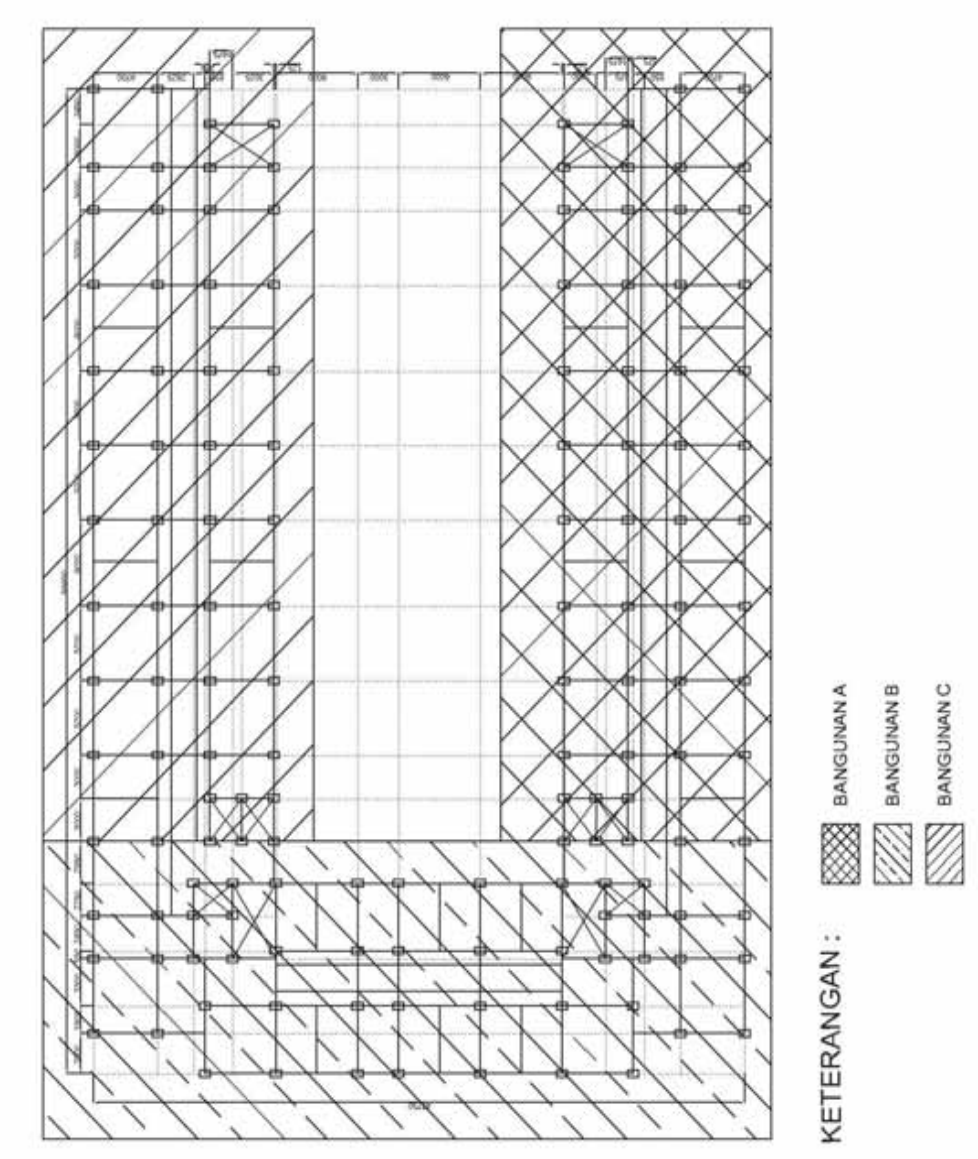
BAB III

ESTIMASI DIMENSI ELEMEN STRUKTUR

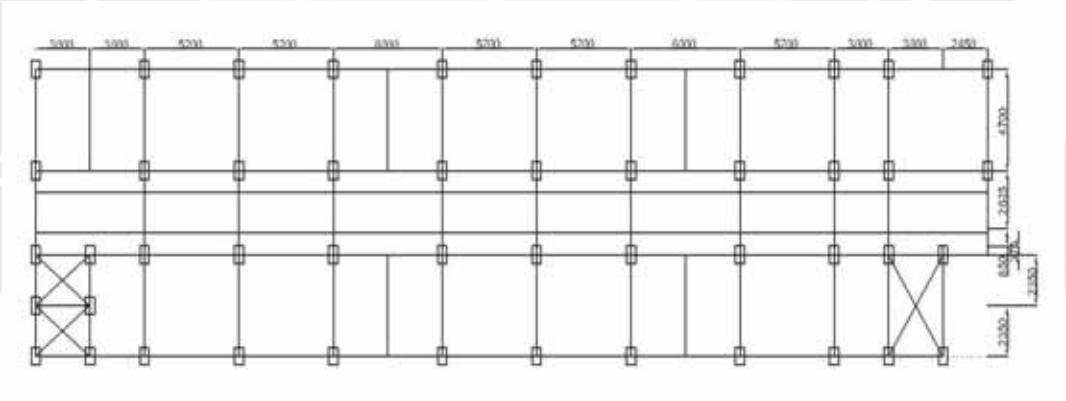
3.1. Denah Bangunan

Dalam tugas akhir ini penulis merancang suatu struktur bangunan dengan denah seperti berikut :



Gambar 3.1. Denah bangunan

Dilihat dari bentuk denah bangunan yang akan dirancang bentuk U sangat beresiko terjadinya torsi pada bangunan. Bila terjadi torsi pada bangunan maka bangunan akan mudah rusak maupun hancur. Maka untuk mengatasi masalah tersebut penulis melakukan dilatasi pada bangunan tersebut menjadi 3 bagian Bangunan A, Bangunan B, dan Bangunan C. Penulis mengambil salah satu bangunan untuk penyelesaian Tugas Akhir. Bangunan yang akan ditinjau sebagai Tugas Akhir adalah Bangunan A, Berikut denah Bangunan A :



Gambar 3.2. Denah Bangunan A

3.2. Estimasi Balok

Berdasarkan Tabel 9.5(a) SNI 03-2847-2013 pasal 9.5 perencanaan tinggi minimum dan lebar balok dapat direncanakan.

1. Untuk panjang bentang (L) = 6000 mm

   - Balok Induk (dua tumpuan sederhana)

     Tinggi minimum (h_{min})$= \frac{l}{16}\left(0{,}4+\frac{fy}{700}\right)=\frac{6000}{16}\left(0{,}4+\frac{400}{700}\right)$ = 364,2857 mm

     Dipakai h = 500 mm

Lebar balok induk (b) = $\frac{2}{3}h = \frac{2}{3}.500 = 333{,}333$ mm

Jadi dipakai balok induk ukuran 300/500

- Balok Anak (kedua ujung menerus)

Tinggi minimum (h_{min})= $\frac{l}{21}\left(0{,}4+\frac{fy}{700}\right)=\frac{6000}{21}\left(0{,}4+\frac{400}{700}\right)$ =277,5510 mm

Dipakai h = 400 mm

Lebar balok anak (b) = $\frac{2}{3}h = \frac{2}{3}.400 = 266{,}67$ mm

Jadi dipakai balok anak ukuran 250/400

2. Untuk panjang bentang (L) = 5200 mm

- Balok Induk (dua tumpuan sederhana)

Tinggi minimum (h_{min})= $\frac{l}{16}\left(0{,}4+\frac{fy}{700}\right)= \frac{5200}{16}\left(0{,}4+\frac{400}{700}\right) = 315{,}7143$ mm

Dipakai h = 450 mm

Lebar balok induk (b) = $\frac{2}{3}h = \frac{2}{3}.450 = 300$ mm

Jadi dipakai balok induk ukuran 300/450

- Balok Anak (kedua ujung menerus)

Tinggi minimum $(h_{min}) = \frac{l}{21}\left(0{,}4 + \frac{fy}{700}\right) = \frac{5200}{21}\left(0{,}4 + \frac{400}{700}\right)$ = 240,5442 mm

Dipakai h = 400 mm

Lebar balok anak (b) = $\frac{2}{3}h = \frac{2}{3}.400$ = 266,67 mm

Jadi dipakai balok anak ukuran 250/400

3. Untuk panjang bentang (L) = 4700 mm

- Balok Induk (dua tumpuan sederhana)

Tinggi minimum $(h_{min}) = \frac{l}{16}\left(0{,}4 + \frac{fy}{700}\right) = \frac{4700}{16}\left(0{,}4 + \frac{400}{700}\right)$ = 285,3571 mm

Dipakai h = 400 mm

Lebar balok induk (b) = $\frac{2}{3}h = \frac{2}{3}.400$ = 266,67 mm

Jadi dipakai balok induk ukuran 250/400

- Balok Anak (kedua ujung menerus)

Tinggi minimum $(h_{min}) = \frac{l}{21}\left(0{,}4 + \frac{fy}{700}\right) = \frac{4700}{21}\left(0{,}4 + \frac{400}{700}\right)$ = 217,4150 mm

Dipakai h = 400 mm

Lebar balok anak (b) = $\frac{2}{3}h = \frac{2}{3}.400$ = 266,67 mm

Jadi dipakai balok anak ukuran 250/400

4. Untuk panjang bentang (L) = 3000 mm

   • Balok Induk (dua tumpuan sederhana)

   Tinggi minimum (h_{min})= $\frac{l}{16}\left(0{,}4+\frac{fy}{700}\right)=\frac{3000}{16}\left(0{,}4+\frac{400}{700}\right)$ =182,1429 mm

   Dipakai h = 400 mm

   Lebar balok induk (b) = $\frac{2}{3}h=\frac{2}{3}.400$ = 266,67 mm

   Jadi dipakai balok induk ukuran 250/400

5. Untuk panjang bentang (L) = 3850 mm

   • Balok Induk (dua tumpuan sederhana)

   Tinggi minimum (h_{min})= $\frac{l}{16}\left(0{,}4+\frac{fy}{700}\right)=\frac{3850}{16}\left(0{,}4+\frac{400}{700}\right)$ = 233,75 mm

   Dipakai h = 400 mm

   Lebar balok induk (b) = $\frac{2}{3}h=\frac{2}{3}.400$ = 266,67 mm

   Jadi dipakai balok induk ukuran 250/400

6. Untuk panjang bentang (L) = 3300 mm

   • Balok Induk (satu ujung menerus)

   Tinggi minimum (h_{min})= $\frac{l}{18{,}5}\left(0{,}4+\frac{fy}{700}\right)=\frac{3300}{18{,}5}\left(0{,}4+\frac{400}{700}\right)$=173,2819 mm

Dipakai h = 400 mm

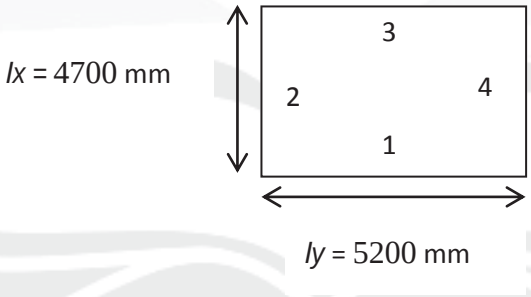
Lebar balok induk (b) = $\frac{2}{3}h = \frac{2}{3}.400$ = 266,67 mm

Jadi dipakai balok induk ukuran 250/400

3.3. Perencanaan Pelat

3.3.1. Estimasi Pelat

Taksiran dimensi awal pelat lantai biasanya dipilih pelat terbesar yang dapat mewakili seluruh pelat. Tebal pelat harus memenuhi syarat ketebalan pelat minimum pada SNI 03-2847-2013 pasal 9.5.3.3.



Gambar 3.3. Dimensi Pelat Lantai

Dengan ukuran balok:

b1 = b3 = 300/450

b2 = b4 = 250/400

Menghitung nilai β dimana :

$\beta = \frac{ly}{lx} = \frac{5200}{4700} = 1{,}1064 \leq 2$, jadi digunakan pelat dua arah.

Pada perhitungan awal tebal pelat lantai diasumsikan 120 mm

Mencari nilai α_m

$\alpha_m = \frac{Ecb.Ib}{Ecs.Is}$ karena $Ecb = Ecs$ maka $\alpha_m = \frac{Ib}{Is}$

$$\alpha_1 = \alpha_3 = \frac{Ib_2}{Is_2} = \frac{\frac{1}{12} x300x450^3}{\frac{1}{12} x5200x120^3} = 3{,}0424$$

$$\alpha_2 = \alpha_4 = \frac{Ib_2}{Is_2} = \frac{\frac{1}{12} x250x400^3}{\frac{1}{12} x4700x120^3} = 1{,}9701$$

$$\alpha_m = \frac{\sum \alpha_i}{n} = \frac{2\,(3{,}0424) + 2\,(1{,}9701)}{4} = 2{,}50625$$

Berdasarkan SNI 03-2847-2013, pasal 9.5.3.3, untuk α_m > 2,0 , maka tebal minimum pelat harus memenuhi rumus berikut:

$$h = \frac{L_n\left(0{,}8 + \frac{f_y}{1400}\right)}{36 + 9\beta} \geq 90\,mm$$

dengan :

L_n = 5200-250/2-250/2 = 4950

f_y = 240 Mpa

$$\beta = \frac{4950}{4700-(300/2)-(300/2)} = 1{,}125$$

$$h_{min} = \frac{4950.\left(0{,}8+\frac{240}{1400}\right)}{36+9.1{,}125} = 104{,}2509 \text{ mm} \geq 90 \text{ mm (oke!)}$$

Maka digunakan tebal pelat 120 mm.

3.3.2. Pembebanan Pelat

Pelat lantai merupakan suatu struktur yang membentang lebar yang berfungsi sebagai penahan beban yang nantinya akan disalurkan ke balok, kolom, fondasi dan akhirnya ke tanah. Jenis pelat yang ditinjau terdiri dari dua jenis, yaitu pelat satu arah dan pelat dua arah.

Beban Rencana Pelat Atap

Beban mati

Berat sendiri pelat atap	= 0,12 . 24	= 2,88	KN/m^2
Berat pasir	= 0,03 . 16	= 0,48	KN/m^2
Berat spesi	= 0,02 . 21	= 0,42	KN/m^2
Berat plafond dan penggantung		= 0,18	KN/m^2
Berat mekanikal dan elektrikal		= 0,15	KN/m^2
		+	
	$Q_{DL\ atap}$	= 4,11	KN/m^2

Beban hidup

Beban hidup pelat atap = 1 KN/m^2

Beban Rencana Pelat Lantai

Beban mati

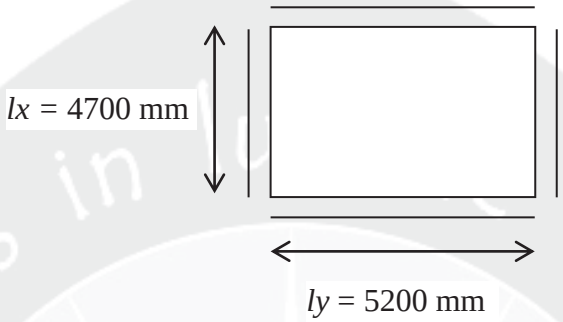
Berat sendiri pelat lantai	= 0,12 . 24	=	2,88	KN/m^2
Berat pasir	= 0,03 . 16	=	0,48	KN/m^2
Berat penutup lantai	= 0,01 . 24	=	0,24	KN/m^2
Berat spesi	= 0,02 . 21	=	0,42	KN/m^2
Berat plafond dan penggantung		=	0,18	KN/m^2
Berat mekanikal dan elektrikal		=	0,15	KN/m^2 +
	$Q_{DL\ lantai}$	=	4,35	KN/m^2

Beban hidup

Beban hidup pelat lantai = 2,5 KN/m^2

3.3.3. Penulangan Pelat Atap dan Pelat Lantai

- Pelat Atap Tipe A (5200 x 4700)



Gambar 3.4. Pelat Lantai Atap Tipe A 5200 x 4700

$\beta = \frac{ly}{lx} = \frac{5200}{4700} = 1{,}1 \leq 2$, jadi digunakan pelat dua arah.

Beban rencana (q) = 1,2 . qd + 1,6 . ql

= 1,2 . 4,11 + 1,6 . 1 = 6,532 KN/m^2

Nilai-nilai koefisien momen (x) untuk nilai $\frac{ly}{lx}$ = 1,1 , sebagai berikut:

Tabel 3.1. Nilai Koefisien Momen Untuk ly/lx = 1,1

ly	lx	ly/lx	Mlx	Mly	Mtx	Mty
5,2	4,7	1,1	29,5	23,5	57	52,5

M_{lx} = 0,001 . W_u . l_x^2 . x_1

= 0,001 . 6,532 . 4,7^2 . 29,5 = 4,2566 KNm

M_{tx} = -0,001 . W_u . l_x^2 . x_2

= -0,001 . 6,532 . 4,7^2 . 57 = -8,2246 KNm

M_{ly} = 0,001 . W_u . l_x^2 . x_3

= 0,001 . 6,532 . $4,7^2$. 23,5 = 3,3909 KNm

M_{ty} = -0,001 . W_u . l_x^2 . x_4

= -0,001 . 6,532 . $4,7^2$. 52,5 = -7,5753 KNm

Selimut beton untuk pelat lantai 25 mm

Dipakai tulangan Ø 10 mm

H efektif arah x

d_x = 120 – 25 – ½ . 10 = 90 mm

H efektif arah y

d_y = 120 – 25 – 10 - ½ . 10 = 80 mm

- Tinjauan momen arah x

M_{lx} = 4,2566 KNm = 4,2566. 10^6 Nmm

$$R_n = \frac{M_u}{0,9.b.d^2} = \frac{4,2566.10^6}{0,9.1000.90^2} = 0,5839$$

ρ = 0,0021

$$\rho_{perlu} = \frac{0,85.f'_c}{f_y}\left(1-\sqrt{1-\frac{2.R_n}{0,85.f'_c}}\right)$$

$$= \frac{0,85.25}{240}\left(1-\sqrt{1-\frac{2.0,5839}{0,85.25}}\right)$$

= 0,0025

$$\rho_{maks} = 0{,}75\left(\frac{0{,}85.f'c}{fy}\beta_1\frac{600}{600+fy}\right)$$

$$= 0{,}75\left(\frac{0{,}85.25}{240}0{,}85\frac{600}{600+240}\right) = 0{,}0403$$

$\rho_{perlu} < \rho_{maks}$

As_{min} = 0,0021 . 1000 . 120 = 252 mm^2

As = 0,0025 . 1000 . 90 = 225 mm^2

Karena $As_{min} > As$, maka digunakan As = 252 mm^2

$$\text{Spasi} = \frac{1000.\frac{1}{4}.\pi.d^2}{A_s} = \frac{1000.\frac{1}{4}.\pi.10^2}{252} = 311{,}6659 \text{ mm} \approx 200 \text{ mm}.$$

$$As = \frac{1000.\frac{1}{4}.\pi.d^2}{S} = \frac{1000.\frac{1}{4}.\pi.10^2}{200} = 392{,}6991 \text{ mm}^2 > 252 \text{ mm}^2 \text{ (ok!)}$$

Digunakan P10-200 (As = 392,6991 mm^2)

M_{tx} = 8,2246 KNm = 8,2246 .10^6 Nmm

$$R_n = \frac{M_u}{0{,}9.b.d^2} = \frac{8{,}2246.10^6}{0{,}9.1000.80^2} = 1{,}4279$$

ρ = 0,0021

$$\rho_{perlu} = \frac{0{,}85.f'_c}{f_y}\left(1-\sqrt{1-\frac{2.R_n}{0{,}85.f'_c}}\right)$$

$$= \frac{0{,}85.25}{240}\left(1-\sqrt{1-\frac{2.1{,}4279}{0{,}85.25}}\right)$$

$$= 0{,}0062$$

$$\rho_{maks} = 0{,}75\left(\frac{0{,}85.f'c}{fy}\beta_1\frac{600}{600+fy}\right)$$

$$= 0{,}75\left(\frac{0{,}85.25}{240}0{,}85\frac{600}{600+240}\right) = 0{,}0403$$

$\rho_{perlu} < \rho_{maks}$

$As_{min} = 0{,}0021 \,.\, 1000 \,.\, 120 = 252 \text{ mm}^2$

$As = 0{,}0062.\, 1000 \,.\, 80 = 496 \text{ mm}^2$

Karena $As_{min} < As$, maka digunakan $As = 496 \text{ mm}^2$.

$$\text{Spasi} = \frac{1000.\frac{1}{4}.\pi.d^2}{A_s} = \frac{1000.\frac{1}{4}.\pi.10^2}{496} = 158{,}3464 \text{ mm} \approx 150 \text{ mm}.$$

$$As = \frac{1000.\frac{1}{4}.\pi.d^2}{S} = \frac{1000.\frac{1}{4}.\pi.10^2}{150} = 523{,}5988 \text{ mm}^2 > 496 \text{ mm}^2 \text{ (ok!)}$$

Digunakan P10-150 ($As = 523{,}5988 \text{ mm}^2$)

- Tinjauan momen arah y

$M_{ly} = 3{,}3909$ KNm $= 3{,}3909.\, 10^6$ Nmm

$$R_n = \frac{M_u}{0{,}9.b.d^2} = \frac{3{,}3909.10^6}{0{,}9.1000.90^2} = 0{,}4651$$

ρ = 0,0021

$$\rho_{perlu} = \frac{0{,}85.f'_c}{f_y}\left(1-\sqrt{1-\frac{2.R_n}{0{,}85.f'_c}}\right)$$

$$= \frac{0{,}85.25}{240}\left(1-\sqrt{1-\frac{2.0{,}4651}{0{,}85.25}}\right)$$

= 0,0020

$$\rho_{maks} = 0{,}75\left(\frac{0{,}85.f'c}{fy}\beta_1\frac{600}{600+fy}\right)$$

$$= 0{,}75\left(\frac{0{,}85.25}{240}0{,}85\frac{600}{600+240}\right) = 0{,}0403$$

$\rho_{perlu} < \rho_{maks}$

As_{min} = 0,0021 . 1000 . 120 = 252 mm^2

As = 0,0020 . 1000 . 90 = 180 mm^2

Karena $As_{min} > As$, maka digunakan As = 252 mm^2

$$\text{Spasi} = \frac{1000.\frac{1}{4}.\pi.d^2}{A_s} = \frac{1000.\frac{1}{4}.\pi.10^2}{252} = 311{,}6659 \text{ mm} \approx 200 \text{ mm}.$$

$$As = \frac{1000.\frac{1}{4}.\pi.d^2}{S} = \frac{1000.\frac{1}{4}.\pi.10^2}{200} = 392{,}6991 \text{ mm}^2 > 252 \text{ mm}^2 \text{ (ok!)}$$

Digunakan P10-200 (As = 392,6991 mm^2)

M_{ty} = 7,5753 KNm = 7,5753 .10^6 Nmm

$$R_n = \frac{M_u}{0{,}9.b.d^2} = \frac{7{,}5753.10^6}{0{,}9.1000.80^2} = 1{,}3152$$

ρ = 0,0021

$$\rho_{\text{perlu}} = \frac{0{,}85.f'_c}{f_y}\left(1-\sqrt{1-\frac{2.R_n}{0{,}85.f'_c}}\right)$$

$$= \frac{0{,}85.25}{240}\left(1-\sqrt{1-\frac{2.1{,}3152}{0{,}85.25}}\right)$$

$$= 0{,}0057$$

$$\rho_{maks} = 0{,}75\left(\frac{0{,}85.f'c}{fy}\beta_1\frac{600}{600+fy}\right)$$

$$= 0{,}75\left(\frac{0{,}85.25}{240}0{,}85\frac{600}{600+240}\right) = 0{,}0404$$

$\rho_{\text{perlu}} < \rho_{maks}$

As_{min} = 0,0021 . 1000 . 120 = 252 mm^2

As = 0,0057. 1000 . 80 = 456 mm^2

Karena $As_{min} < As$, maka digunakan As = 456 mm^2.

$$\text{Spasi} = \frac{1000.\frac{1}{4}.\pi.d^2}{A_s} = \frac{1000.\frac{1}{4}.\pi.10^2}{456} = 172{,}2364 \text{ mm} \approx 150 \text{ mm}.$$

$$As = \frac{1000.\frac{1}{4}.\pi.d^2}{S} = \frac{1000.\frac{1}{4}.\pi.10^2}{150} = 523{,}5988 \text{ mm}^2 > 425 \text{ mm}^2 \text{ (ok!)}$$

Digunakan P10-150 (As = 523,5988 mm^2)

- Tulangan susut

Kebutuhan tulangan susut diambil sebesar kebutuhan tulangan minimum.

As = 0,0021 . 1000 . 120

= 252 mm^2

digunakan tulangan Ø 8 mm

Jarak antar tulangan

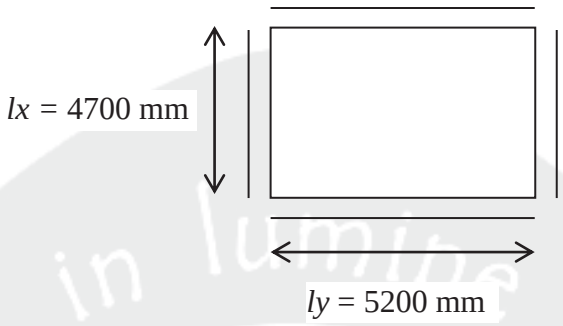
$$S = \frac{1000.\frac{1}{4}.\pi.d^2}{As}$$

$$= \frac{1000.\frac{1}{4}.\pi.8^2}{252} = 199{,}4662 \approx 150 \text{ mm}$$

$$As = \frac{1000.\frac{1}{4}.\pi.d^2}{Spasi} = \frac{1000.\frac{1}{4}.\pi.8^2}{150} = 335{,}1032 \text{ mm}^2 > 252 \text{ mm}^2 \text{ (ok!)}$$

Digunakan tulangan susut P8-150

➢ Pelat Lantai Tipe D (5200 x 4700)



Gambar 3.5. Pelat Lantai Tipe D 5200 x 4700

$\beta = \frac{ly}{lx} = \frac{5200}{4700} = 1{,}1 \leq 2$, jadi digunakan pelat dua arah.

Beban rencana (q) = 1,2 . qd + 1,6 . ql

= 1,2 . 4,35 + 1,6 . 2,5 = 9,22 KN/m^2

Nilai-nilai koefisien momen (x) untuk nilai $\frac{ly}{lx}$ = 1,1 , sebagai berikut:

Tabel 3.2. Nilai Koefisien Momen Untuk ly/lx = 1,1

ly	lx	ly/lx	Mlx	Mly	Mtx	Mty
5,2	4,7	1,1	29,5	23,5	57	52,5

M_{lx} = 0,001 . W_u . l_x^2 . x_1

= 0,001 . 9,22 . 4,7^2 . 29,5 = 6,0083 KNm

M_{tx} = -0,001 . W_u . l_x^2 . x_2

= -0,001 . 9,22 . 4,7^2 . 57 = -11,6092 KNm

M_{ly} = 0,001 . W_u . l_x^2 . x_3

= 0,001 . 9,22 . $4,7^2$. 23,5 = 4,7862 KNm

M_{ty} = -0,001 . W_u . l_x^2 . x_4

= -0,001 . 9,22 . $4,7^2$. 52,5 = -10,6927 KNm

Selimut beton untuk pelat lantai 25 mm

Dipakai tulangan Ø 10 mm

H efektif arah x

d_x = 120 – 25 – ½ . 10 = 90 mm

H efektif arah y

d_y = 120 – 25 – 10 - ½ . 10 = 80 mm

- Tinjauan momen arah x

M_{lx} = 6,0083 KNm = 6,0083. 10^6 Nmm

$$R_n = \frac{M_u}{0,9.b.d^2} = \frac{6,0083.10^6}{0,9.1000.90^2} = 0,8242$$

ρ = 0,0021

$$\rho_{perlu} = \frac{0,85.f'_c}{f_y}\left(1-\sqrt{1-\frac{2.R_n}{0,85.f'_c}}\right)$$

$$= \frac{0,85.25}{240}\left(1-\sqrt{1-\frac{2.0,8242}{0,85.25}}\right)$$

= 0,0035

$$\rho_{maks} = 0{,}75\left(\frac{0{,}85.f'c}{fy}\beta_1\frac{600}{600+fy}\right)$$

$$= 0{,}75\left(\frac{0{,}85.25}{240}0{,}85\frac{600}{600+240}\right) = 0{,}0403$$

$\rho_{perlu} < \rho_{maks}$

As_{min} = 0,0021 . 1000 . 120 = 252 mm^2

As = 0,0035 . 1000 . 90 = 315 mm^2

Karena $As_{min} < As$, maka digunakan As = 315 mm^2

Spasi = $\frac{1000.\frac{1}{4}.\pi.d^2}{A_s} = \frac{1000.\frac{1}{4}.\pi.10^2}{315}$ = 249,3328 mm ≈ 200 mm.

$As = \frac{1000.\frac{1}{4}.\pi.d^2}{S} = \frac{1000.\frac{1}{4}.\pi.10^2}{200}$ = 392,6991 mm^2 > 315 mm^2 (ok!)

Digunakan P10-200 (As = 392,6991 mm^2)

M_{tx} = 11,6092 KNm = 11,6092 .10^6 Nmm

$$R_n = \frac{M_u}{0{,}9.b.d^2} = \frac{11{,}6092.10^6}{0{,}9.1000.80^2} = 2{,}0155$$

ρ = 0,0021

$$\rho_{perlu} = \frac{0{,}85.f'_c}{f_y}\left(1-\sqrt{1-\frac{2.R_n}{0{,}85.f'_c}}\right)$$

$$= \frac{0{,}85.25}{240}\left(1-\sqrt{1-\frac{2.2{,}0155}{0{,}85.25}}\right)$$

$$= 0{,}0088$$

$$\rho_{maks} = 0{,}75\left(\frac{0{,}85.f'c}{fy}\beta_1\frac{600}{600+fy}\right)$$

$$= 0{,}75\left(\frac{0{,}85.25}{240}0{,}85\frac{600}{600+240}\right) = 0{,}0403$$

$\rho_{perlu} < \rho_{maks}$

$As_{min} = 0{,}0021 \,.\, 1000 \,.\, 120 = 252 \text{ mm}^2$

$As = 0{,}0088.\, 1000 \,.\, 80 = 704 \text{ mm}^2$

Karena $As_{min} < As$, maka digunakan $As = 704 \text{ mm}^2$.

$$\text{Spasi} = \frac{1000.\tfrac{1}{4}.\pi.d^2}{A_s} = \frac{1000.\tfrac{1}{4}.\pi.10^2}{704} = 111{,}5622 \text{ mm} \approx 100 \text{ mm}.$$

$$As = \frac{1000.\tfrac{1}{4}.\pi.d^2}{S} = \frac{1000.\tfrac{1}{4}.\pi.10^2}{100} = 785{,}3982 \text{ mm}^2 > 704 \text{ mm}^2 \text{ (ok!)}$$

Digunakan P10-100 (As = 785,3982 mm^2)

- Tinjauan momen arah y

$M_{ly} = 4{,}7862 \text{ KNm} = 4{,}7862.\, 10^6 \text{ Nmm}$

$$R_n = \frac{M_u}{0{,}9.b.d^2} = \frac{4{,}7862.10^6}{0{,}9.1000.90^2} = 0{,}6565$$

ρ = 0,0021

$$\rho_{perlu} = \frac{0{,}85.f'_c}{f_y}\left(1-\sqrt{1-\frac{2.R_n}{0{,}85.f'_c}}\right)$$

$$= \frac{0{,}85.25}{240}\left(1-\sqrt{1-\frac{2.0{,}6565}{0{,}85.25}}\right)$$

= 0,0028

$$\rho_{maks} = 0{,}75\left(\frac{0{,}85.f'c}{fy}\beta_1\frac{600}{600+fy}\right)$$

$$= 0{,}75\left(\frac{0{,}85.25}{240}0{,}85\frac{600}{600+240}\right) = 0{,}0403$$

$\rho_{perlu} < \rho_{maks}$

As_{min} = 0,0021 . 1000 . 120 = 252 mm^2

As = 0,0028 . 1000 . 90 = 252 mm^2

Karena $As_{min} = As$, maka digunakan As = 252 mm^2

$$\text{Spasi} = \frac{1000.\frac{1}{4}.\pi.d^2}{A_s} = \frac{1000.\frac{1}{4}.\pi.10^2}{252} = 311{,}6659 \text{ mm} \approx 200 \text{ mm}.$$

$$As = \frac{1000.\frac{1}{4}.\pi.d^2}{S} = \frac{1000.\frac{1}{4}.\pi.10^2}{200} = 392{,}6991 \text{ mm}^2 > 252 \text{ mm}^2 \text{ (ok!)}$$

Digunakan P10-200 (As = 392,6991 mm^2)

M_{ty} = 10,6927 KNm = 10,6927 .10^6 Nmm

$$R_n = \frac{M_u}{0{,}9.b.d^2} = \frac{10{,}6927.10^6}{0{,}9.1000.80^2} = 1{,}8564$$

ρ = 0,0021

$$\rho_{\text{perlu}} = \frac{0{,}85.f'_c}{f_y}\left(1-\sqrt{1-\frac{2.R_n}{0{,}85.f'_c}}\right)$$

$$= \frac{0{,}85.25}{240}\left(1-\sqrt{1-\frac{2.1{,}8564}{0{,}85.25}}\right)$$

= 0,0081

$$\rho_{maks} = 0{,}75\left(\frac{0{,}85.f'c}{fy}\beta_1\frac{600}{600+fy}\right)$$

$$= 0{,}75\left(\frac{0{,}85.25}{240}0{,}85\frac{600}{600+240}\right) = 0{,}0404$$

$\rho_{\text{perlu}} < \rho_{maks}$

As_{min} = 0,0021 . 1000 . 120 = 252 mm^2

As = 0,0081. 1000 . 80 = 648 mm^2

Karena $As_{min} < As$, maka digunakan As = 648 mm^2.

$$\text{Spasi} = \frac{1000.\frac{1}{4}.\pi.d^2}{A_s} = \frac{1000.\frac{1}{4}.\pi.10^2}{648} = 121{,}2034 \text{ mm} \approx 100 \text{ mm}.$$

$$As = \frac{1000.\frac{1}{4}.\pi.d^2}{S} = \frac{1000.\frac{1}{4}.\pi.10^2}{100} = 785{,}3982 \text{ mm}^2 > 648 \text{ mm}^2 \text{ (ok!)}$$

Digunakan P10-100 (As = 785,3982 mm^2)

- Tulangan susut

Kebutuhan tulangan susut diambil sebesar kebutuhan tulangan minimum.

As = 0,0021 . 1000 . 120

= 252 mm^2

digunakan tulangan Ø 8 mm

Jarak antar tulangan

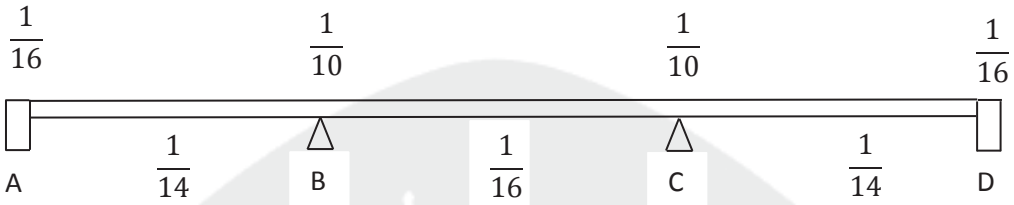
$$S = \frac{1000.\frac{1}{4}.\pi.d^2}{As}$$

$$= \frac{1000.\frac{1}{4}.\pi.8^2}{252} = 199{,}4662 \approx 150 \text{ mm}$$

$$As = \frac{1000.\frac{1}{4}.\pi.d^2}{Spasi} = \frac{1000.\frac{1}{4}.\pi.8^2}{150} = 335{,}1032 \text{ mm}^2 > 252 \text{ mm}^2 \text{ (ok!)}$$

Digunakan tulangan susut P8-150

➢ Pelat Lantai Tipe F



Gambar 3.6. Pelat Lantai Tipe F (3 Bentang atau Lebih)

Untuk menghitung momen terfaktor digunakan rumus:

$M_u = C_m .(W_u .L^2)$, dengan C_m = koefisien momen.

Momen pelat lantai

M_u Tump(A dan D) = $\frac{1}{16}$ $.W_u .L^2 = \frac{1}{16}$ $.9{,}22 .1^2$ = 0,5763 KNm

M_u Tump(B dan C) = $\frac{1}{10}$ $.W_u .L^2 = \frac{1}{10}$ $.9{,}22 .1{,}85^2$ = 3,1555 KNm

M_u Lap(A-B dan C-D) = $\frac{1}{14}$ $.W_u .L^2 = \frac{1}{14}$ $.9{,}22 .1^2$ = 0,6586 KNm

M_u Lap(B-C) = $\frac{1}{16}$ $.W_u .L^2 = \frac{1}{16}$ $.9{,}22 .1{,}85^2$ = 1,9722 KNm

Yang dipakai adalah momen terbesar, sehingga M_u = 3,1555 KNm.

Digunakan tulangan pokok P10 (luas 1P10 = 78,5 mm2) dan tulangan susut dan suhu P8 (luas 1P8 = 50,3 mm2).

Selimut beton untuk pelat 25 mm.

Tinggi efektif (d) = Tebal pelat – (selimut beton + 0,5 . diameter tulangan pokok)

= 120 – (25 + 0,5 . 10) = 90 mm.

1. Tulangan Pokok

M_u = 3,1555 KNm = 3,1555. 10^6 Nmm

$$R_n = \frac{M_u}{0{,}9.b.d^2} = \frac{3{,}1555.10^6}{0{,}9.1000.90^2} = 0{,}4329$$

ρ = 0,0021

$$\rho_{\text{perlu}} = \frac{0{,}85.f'_c}{f_y}\left(1-\sqrt{1-\frac{2.R_n}{0{,}85.f'_c}}\right)$$

$$= \frac{0{,}85.25}{240}\left(1-\sqrt{1-\frac{2.0{,}4329}{0{,}85.25}}\right)$$

$$= 0{,}0018$$

$$\rho_{maks} = 0{,}75\left(\frac{0{,}85.f'c}{fy}\beta_1\frac{600}{600+fy}\right)$$

$$= 0{,}75\left(\frac{0{,}85.25}{240}0{,}85\frac{600}{600+240}\right) = 0{,}0403$$

$\rho_{\text{perlu}} < \rho_{maks}$

As_{min} = 0,0021 . 1000 . 120 = 252 mm^2

As = 0,0018 . 1000 . 90 = 162 mm^2

Karena $As < As_{min}$, maka digunakan As = 252 mm^2

$$\text{Spasi} = \frac{1000.\frac{1}{4}.\pi.d^2}{A_s} = \frac{1000.\frac{1}{4}.\pi.10^2}{252} = 311{,}6659 \text{ mm} \approx 200 \text{ mm}.$$

$$As = \frac{1000.\frac{1}{4}.\pi.d^2}{S} = \frac{1000.\frac{1}{4}.\pi.10^2}{200} = 392{,}6991 \text{ mm}^2 > 252 \text{ mm}^2 \text{ (ok!)}$$

Digunakan P10-200 (As = 392,6991 mm^2)

2. Tulangan Susut dan Suhu

As_{min} = 0,0021 . 1000 . 120 = 252 mm^2

digunakan tulangan Ø 8 mm

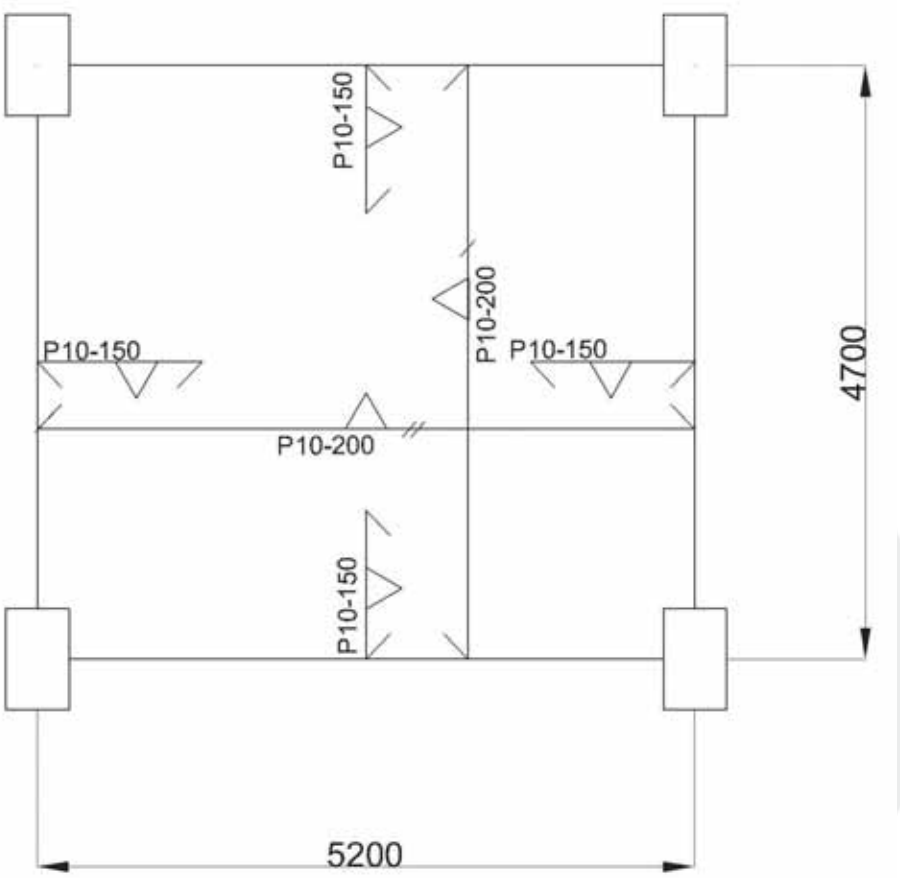
Jarak antar tulangan

$$S = \frac{1000.\frac{1}{4}.\pi.d^2}{As}$$

$$= \frac{1000.\frac{1}{4}.\pi.8^2}{252} = 199{,}4662 \approx 150 \text{ mm}$$

$$As = \frac{1000.\frac{1}{4}.\pi.d^2}{Spasi} = \frac{1000.\frac{1}{4}.\pi.8^2}{150} = 335{,}1032 \text{ mm}^2 > 252 \text{ mm}^2 \text{ (ok!)}$$

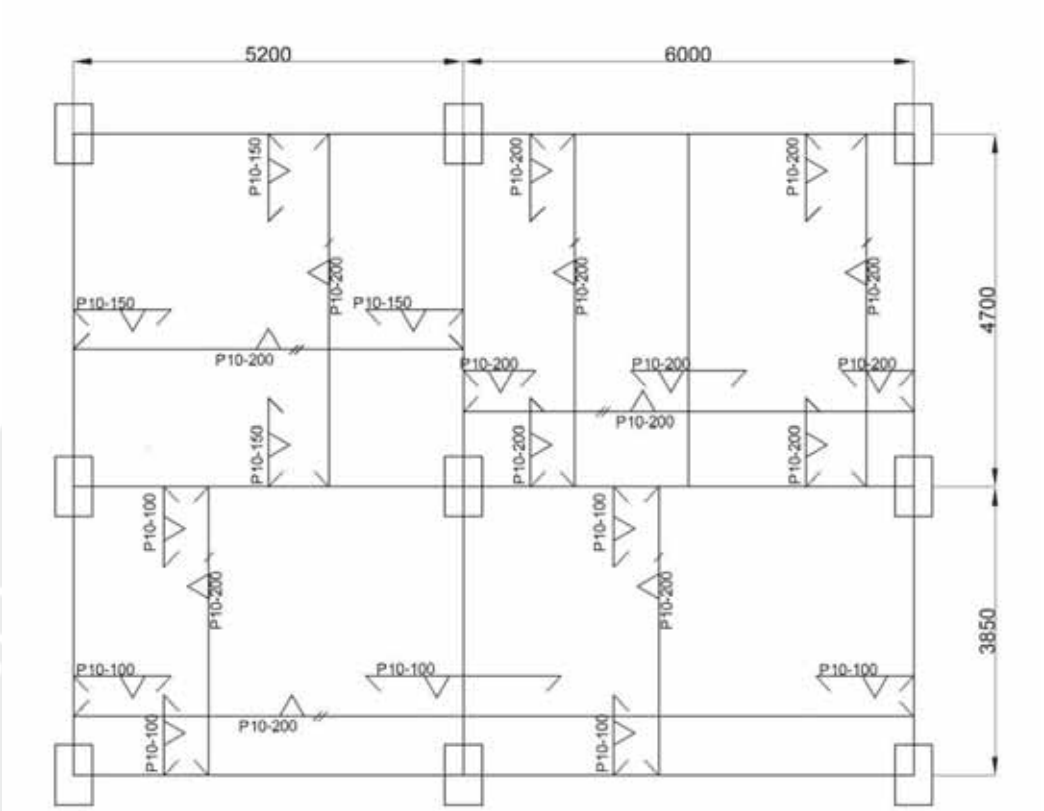
Digunakan tulangan P8-150 mm



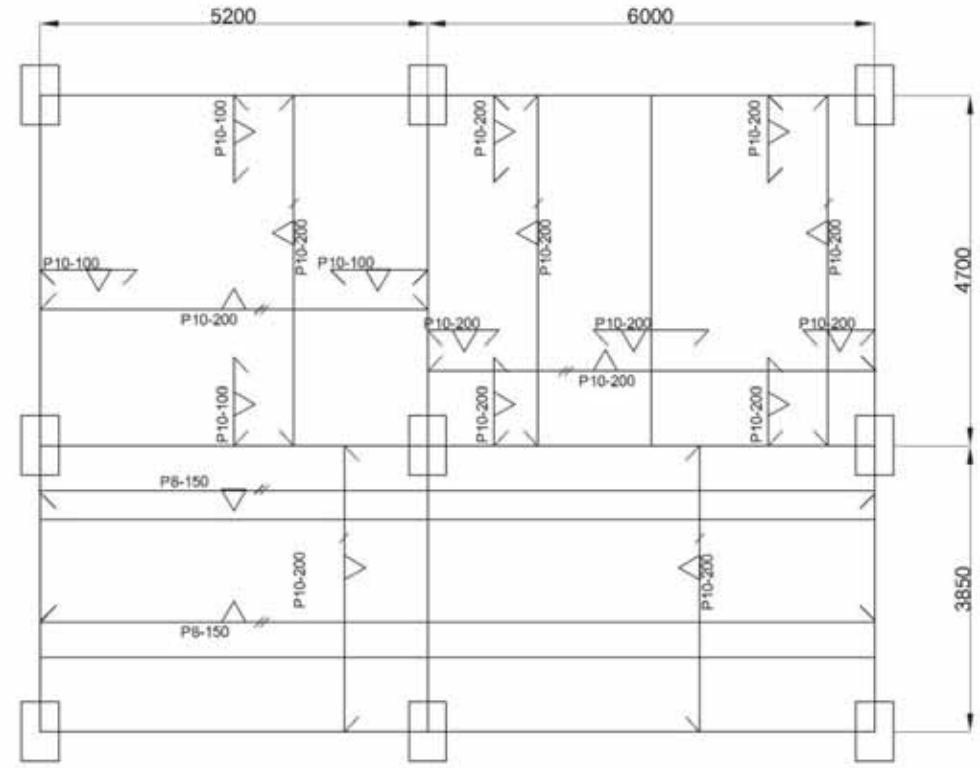
Gambar 3.7. Penulangan Pelat Lantai Tipe A

Tabel 3.3.. Hasil Pelat Lantai dan Atap

$\frac{Ly}{Lx}$ = 1,6; pelat lantai tipe E				
	Mlx	Mtx	Mly	Mty
Mu	4,066	6,4724	1,2447	4,4809
Rn	0,5578	0,1704	1,1237	0,7779
As	392,6991	392,6991	392,6991	392,6991
Tul. Pokok	P10-200	P10-200	P10-200	P10-200
Tul. Susut	P8-150	P8-150	P8-150	P8-150
$\frac{Ly}{Lx}$ = 1,6; pelat lantai atap tipe B				
	Mlx	Mtx	Mly	Mty
Mu	2,8806	4,5855	0,8818	3,1746
Rn	0,3951	0,121	0,7961	0,5511
As	392,6991	392,6991	392,6991	392,6991
Tul. Pokok	P10-200	P10-200	P10-200	P10-200
Tul. Susut	P8-150	P8-150	P8-150	P8-150
$\frac{Ly}{Lx}$ = 1,6; pelat lantai atap tipe C				
	Mlx	Mtx	Mly	Mty
Mu	5,4831	9,7397	2,8858	7,8639
Rn	0,7521	0,3959	1,691	1,3653
As	392,6991	392,6991	785,3982	785,3982
Tul. Pokok	P10-200	P10-100	P10-200	P10-100
Tul. Susut	P8-150	P8-150	P8-150	P8-150



Gambar 3.8. Penulangan Pelat Lantai Atap



Gambar 3.9. Penulangan Pelat Lantai

3.4. Estimasi Dimensi Kolom

Perencanaan awal dimensi kolom bersifat pendekatan saja, dengan hanya memperhitungkan beban aksial saja. Beban yang digunakan adalah beban mati dan beban hidup pada bagian luasan yang membebani kolom yang bersangkutan.

Pembebanan pada pelat:

- Beban Mati

a. Pelat Atap

Berat sendiri pelat atap	= 0,12 . 24	= 2,88	KN/m^2
Berat pasir	= 0,03 . 16	= 0,48	KN/m^2
Berat spesi	= 0,02 . 21	= 0,42	KN/m^2
Berat plafond dan penggantung		= 0,18	KN/m^2
Berat mekanikal dan elektrikal		= 0,15	KN/m^2 +
	$Q_{DL\ atap}$	= 4,11	KN/m^2

b. Pelat Lantai

Berat sendiri pelat lantai	= 0,12 . 24	= 2,88	KN/m^2
Berat pasir	= 0,03 . 16	= 0,48	KN/m^2
Berat penutup lantai	= 0,01 . 24	= 0,24	KN/m^2
Berat spesi	= 0,02 . 21	= 0,42	KN/m^2
Berat plafond dan penggantung		= 0,18	KN/m^2

Berat mekanikal dan elektrikal = 0,15 KN/m^2 +

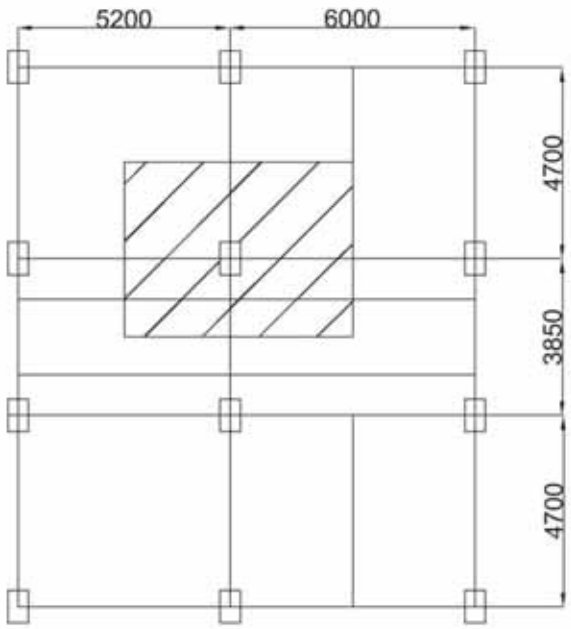
$Q_{DL\ atap}$ = 4,35 KN/m^2

- Beban Hidup

a. Pelat atap = 1 KN/m^2

b. Pelat lantai = 2,5 KN/m^2

3.4.1. Kolom Tengah



Gambar 3.10. *Tributary Area* Kolom Tengah

1. Kolom K11

   a. Beban mati :

   Beban dari pelat atap = 4,11 . 5,6 . 4,275 = 98,4 KN

   Balok induk 250/400 = 0,25 . (0,40-0,12) . (4,275) . 24 = 7,182 KN

   Balok induk 300/450 = 0,3 . (0,45-0,12) . (2,6) . 24 = 6,1776KN

Balok induk 300/500 = 0,3 . (0,50-0,12) . (3) . 24 = 8,208 KN

Balok anak 250/400 = 0,25 . (0,40-0,12) . (5,6) . 24 = 9,408 KN

Balok anak 250/400 = 0,25 . (0,40-0,12) . (2,35) . 24 = 3,948 KN +

N_{DL} = 133,3236 KN

b. Beban Hidup :

N_{LL} = 1 . 5,6. 4,275 = 23,94 KN

$P_u = 1,2 . N_{DL} + 1,6 . N_{LL}$

$= 1,2 . 133,3236 + 1,6 . 23,94$

$= 198,2923$ KN

ø . $P_n = P_u$ ➔ $P_n = \frac{P_u}{\phi}$, dengan ø = 0,65 untuk kolom pengikat sengkang.

$P_n = 0,80 . \{0,85 . f'_c . (A_g - A_{st}) + f_y . A_{st}\}$

$= 0,80 . \{0,85 . 25 . (A_g - 0,02 . A_g) + 400 . 0,02 . A_g\}$

$= 0,8 . \{21,25 . A_g - 0,425 . A_g + 8 . A_g\}$

$= 23,06 A_g$

$A_g = \frac{P_n}{23,06} = \frac{\frac{P_u}{\phi}}{23,06} = \frac{\frac{198292,3}{0,65}}{23,06} = 13229,1881$ mm^2

b = h = $\sqrt{A_g}$ = $\sqrt{13229,1881}$ = 115,0182 mm.

Diambil dimensi kolom sebesar 400 x 400 mm^2

2. Kolom K10

a. Beban mati :

Beban kolom diatasnya	= (0,4 . 0,4 . 3 . 24) + 133,3236	= 144,8436	KN
Beban dari pelat lantai	= 4,35 . 5,6 . 4,275	= 104,139	KN
Balok induk 250/400	= 0,25 . (0,40-0,12) . (4,275) . 24	= 7,182	KN
Balok induk 300/450	= 0,3 . (0,45-0,12) . (2,6) . 24	= 6,1776	KN
Balok induk 300/500	= 0,3 . (0,50-0,12) . (3) . 24	= 8,208	KN
Balok anak 250/400	= 0,25 . (0,40-0,12) . (5,6) . 24	= 9,408	KN
Balok anak 250/400	= 0,25 . (0,40-0,12) . (2,35) . 24	= 3,948	KN +
		N_{DL} = 283,9062	KN

b. Beban Hidup :

Beban hidup lantai 11		= 23,94	KN
Beban hidup lantai 10	= 2,5 . 5,6 . 4,275	= 59,85	KN +
		N_{LL} = 83,79	KN

$P_u = 1,2 \cdot N_{DL} + 1,6 \cdot N_{LL}$

$= 1,2 \cdot 283,9062 + 1,6 \cdot 83,79$

$= 474,7514$ KN

ø . $P_n = P_u$ ➔ $P_n = \frac{P_u}{\phi}$, dengan ø = 0,65 untuk kolom pengikat sengkang.

$P_n = 0,80 \cdot \{0,85 \cdot f'_c \cdot (A_g - A_{st}) + f_y \cdot A_{st}\}$

$= 0,80 \cdot \{0,85 \cdot 25 \cdot (A_g - 0,02 \cdot A_g) + 400 \cdot 0,02 \cdot A_g\}$

$= 0,8 \cdot \{21,25 \cdot A_g - 0,425 \cdot A_g + 8 \cdot A_g\}$

$= 23,06\, A_g$

$A_g = \frac{P_n}{23,06} = \frac{\frac{P_u}{\phi}}{23,06} = \frac{\frac{474751,4}{0,65}}{23,06} = 31673,3204 \text{ mm}^2$

b = h = $\sqrt{A_g}$ = $\sqrt{31673,3204}$ = 177,97 mm.

Diambil dimensi kolom sebesar 400 x 400 mm^2

3. Kolom K9

a. Beban mati :

Beban kolom diatasnya	= (0,4 . 0,4 . 3 . 24) + 283,9062	= 295,4262	KN
Beban dari pelat lantai	= 4,35 . 5,6 . 4,275	= 104,139	KN
Balok induk 250/400	= 0,25 . (0,40-0,12) . (4,275) . 24	= 7,182	KN
Balok induk 300/450	= 0,3 . (0,45-0,12) . (2,6) . 24	= 6,1776	KN
Balok induk 300/500	= 0,3 . (0,50-0,12) . (3) . 24	= 8,208	KN
Balok anak 250/400	= 0,25 . (0,40-0,12) . (5,6) . 24	= 9,408	KN
Balok anak 250/400	= 0,25 . (0,40-0,12) . (2,35) . 24	= 3,948	KN +
		N_{DL} = 434,4888	KN

b. Beban Hidup :

Beban hidup lantai 10		= 83,79	KN
Beban hidup lantai 9	= 2,5 . 5,6 . 4,275	= 59,85	KN +
		N_{LL} = 143,64	KN

$P_u = 1,2 . N_{DL} + 1,6 . N_{LL}$

= 1,2 . 434,4888 + 1,6 . 143,64

= 751,2106 KN

ø . $P_n = P_u$ ➔ $P_n = \frac{P_u}{\phi}$, dengan ø = 0,65 untuk kolom pengikat sengkang.

$P_n = 0{,}80 \,.\, \{0{,}85 \,.\, f'_c \,.\, (A_g - A_{st}) + f_y \,.\, A_{st}\}$

$= 0{,}80 \,.\, \{0{,}85 \,.\, 25 \,.\, (A_g - 0{,}02 \,.\, A_g) + 400 \,.\, 0{,}02 \,.\, A_g\}$

$= 0{,}8 \,.\, \{21{,}25 \,.\, A_g - 0{,}425 \,.\, A_g + 8 \,.\, A_g\}$

$= 23{,}06\, A_g$

$A_g = \frac{P_n}{23{,}06} = \frac{\frac{P_u}{\phi}}{23{,}06} = \frac{\frac{751210{,}6}{0{,}65}}{23{,}06} = 50117{,}4595 \text{ mm}^2$

b = h = $\sqrt{A_g}$ = $\sqrt{50117{,}4595}$ = 223,8693 mm.

Diambil dimensi kolom sebesar 400 x 400 mm^2

4. Kolom K8

a. Beban mati :

Beban kolom diatasnya	= (0,4 . 0,4 . 3 . 24) + 434,8888	= 446,4088	KN
Beban dari pelat lantai	= 4,35 . 5,6 . 4,275	= 104,139	KN
Balok induk 250/400	= 0,25 . (0,40-0,12) . (4,275) . 24	= 7,182	KN
Balok induk 300/450	= 0,3 . (0,45-0,12) . (2,6) . 24	= 6,1776	KN
Balok induk 300/500	= 0,3 . (0,50-0,12) . (3) . 24	= 8,208	KN
Balok anak 250/400	= 0,25 . (0,40-0,12) . (5,6) . 24	= 9,408	KN
Balok anak 250/400	= 0,25 . (0,40-0,12) . (2,35) . 24	= 3,948	KN +
		N_{DL} = 585,4714	KN

b. Beban Hidup :

Beban hidup lantai 9 = 143,64 KN

Beban hidup lantai 8 = 2,5 . 5,6 . 4,275 = 59,85 KN +

N_{LL} = 203,49 KN

$P_u = 1,2 . N_{DL} + 1,6 . N_{LL}$

$= 1,2 . 585,4714 + 1,6 . 203,49$

$= 1028,15$ KN

ø . $P_n = P_u$ ➔ $P_n = \frac{P_u}{\phi}$, dengan ø = 0,65 untuk kolom pengikat sengkang.

$P_n = 0,80 . \{0,85 . f'_c . (A_g - A_{st}) + f_y . A_{st}\}$

$= 0,80 . \{0,85 . 25 . (A_g - 0,02 . A_g) + 400 . 0,02 . A_g\}$

$= 0,8 . \{21,25 . A_g - 0,425 . A_g + 8 . A_g\}$

$= 23,06 A_g$

$A_g = \frac{P_n}{23,06} = \frac{\frac{P_u}{\phi}}{23,06} = \frac{\frac{1028150}{0,65}}{23,06} = 68593,6353 \text{ mm}^2$

$b = h = \sqrt{A_g} = \sqrt{68593,6353} = 261,9039$ mm.

Diambil dimensi kolom sebesar 500 x 500 mm^2

5. Kolom K7

a. Beban mati :

Beban kolom diatasnya = (0,5 . 0,5 . 3 . 24) + 585,4714 = 603,4714 KN

Beban dari pelat lantai = 4,35 . 5,6 . 4,275 = 104,139 KN

Balok induk 250/400 = 0,25 . (0,40-0,12) . (4,275) . 24 = 7,182 KN

Balok induk 300/450	= 0,3 . (0,45-0,12) . (2,6) . 24	= 6,1776	KN
Balok induk 300/500	= 0,3 . (0,50-0,12) . (3) . 24	= 8,208	KN
Balok anak 250/400	= 0,25 . (0,40-0,12) . (5,6) . 24	= 9,408	KN
Balok anak 250/400	= 0,25 . (0,40-0,12) . (2,35) . 24	= 3,948	KN +
		N_{DL} = 742,534	KN

b. Beban Hidup :

Beban hidup lantai 8	= 203,49	KN
Beban hidup lantai 7 = 2,5 . 5,6 . 4,275	= 59,85	KN +
	N_{LL} = 263,34	KN

$P_u = 1,2 \cdot N_{DL} + 1,6 \cdot N_{LL}$

$= 1,2 \cdot 742,534 + 1,6 \cdot 263,34$

$= 1312,3848$ KN

ø . $P_n = P_u$ ➔ $P_n = \frac{P_u}{\phi}$, dengan ø = 0,65 untuk kolom pengikat sengkang.

$P_n = 0,80 \cdot \{0,85 \cdot f'_c \cdot (A_g - A_{st}) + f_y \cdot A_{st}\}$

$= 0,80 \cdot \{0,85 \cdot 25 \cdot (A_g - 0,02 \cdot A_g) + 400 \cdot 0,02 \cdot A_g\}$

$= 0,8 \cdot \{21,25 \cdot A_g - 0,425 \cdot A_g + 8 \cdot A_g\}$

$= 23,06\, A_g$

$$A_g = \frac{P_n}{23,06} = \frac{\frac{P_u}{\phi}}{23,06} = \frac{\frac{1312384,8}{0,65}}{23,06} = 87556,5281 \text{ mm}^2$$

$b = h = \sqrt{A_g} = \sqrt{87556,5281} = 295,8995$ mm.

Diambil dimensi kolom sebesar 500 x 500 mm^2

6. Kolom K6

a. Beban mati :

Beban kolom diatasnya	= (0,5 . 0,5 . 3 . 24) + 742,534	= 760,534	KN
Beban dari pelat lantai	= 4,35 . 5,6 . 4,275	= 104,139	KN
Balok induk 250/400	= 0,25 . (0,40-0,12) . (4,275) . 24	= 7,182	KN
Balok induk 300/450	= 0,3 . (0,45-0,12) . (2,6) . 24	= 6,1776	KN
Balok induk 300/500	= 0,3 . (0,50-0,12) . (3) . 24	= 8,208	KN
Balok anak 250/400	= 0,25 . (0,40-0,12) . (5,6) . 24	= 9,408	KN
Balok anak 250/400	= 0,25 . (0,40-0,12) . (2,35) . 24	= 3,948	KN +
		N_{DL} = 899,5966	KN

b. Beban Hidup :

Beban hidup lantai 7		= 263,34	KN
Beban hidup lantai 6	= 2,5 . 5,6 . 4,275	= 59,85	KN +
		N_{LL} = 323,19	KN

$P_u = 1,2 . N_{DL} + 1,6 . N_{LL}$

= 1,2 . 899,5966 + 1,6 . 323,19

= 1596,6199 KN

ø . $P_n = P_u$ ➔ $P_n = \frac{P_u}{\phi}$, dengan ø = 0,65 untuk kolom pengikat sengkang.

$P_n = 0{,}80 \,.\, \{0{,}85 \,.\, f'_c \,.\, (A_g - A_{st}) + f_y \,.\, A_{st}\}$

$= 0{,}80 \,.\, \{0{,}85 \,.\, 25 \,.\, (A_g - 0{,}02 \,.\, A_g) + 400 \,.\, 0{,}02 \,.\, A_g\}$

$= 0{,}8 \,.\, \{21{,}25 \,.\, A_g - 0{,}425 \,.\, A_g + 8 \,.\, A_g\}$

$= 23{,}06\, A_g$

$$A_g = \frac{P_n}{23{,}06} = \frac{\frac{P_u}{\phi}}{23{,}06} = \frac{\frac{1596619{,}9}{0{,}65}}{23{,}06} = 106519{,}4409 \text{ mm}^2$$

b = h = $\sqrt{A_g}$ = $\sqrt{106519{,}4409}$ = 326,3732 mm.

Diambil dimensi kolom sebesar 500 x 500 mm^2

7. Kolom K5

a. Beban mati :

Beban kolom diatasnya	= (0,5 . 0,5 . 3 . 24) + 899,5966	= 917,5966	KN
Beban dari pelat lantai	= 4,35 . 5,6 . 4,275	= 104,139	KN
Balok induk 250/400	= 0,25 . (0,40-0,12) . (4,275) . 24	= 7,182	KN
Balok induk 300/450	= 0,3 . (0,45-0,12) . (2,6) . 24	= 6,1776	KN
Balok induk 300/500	= 0,3 . (0,50-0,12) . (3) . 24	= 8,208	KN
Balok anak 250/400	= 0,25 . (0,40-0,12) . (5,6) . 24	= 9,408	KN
Balok anak 250/400	= 0,25 . (0,40-0,12) . (2,35) . 24	= 3,948	KN +
		N_{DL} = 1056,6592	KN

b. Beban Hidup :

Beban hidup lantai 6 = 323,19 KN

Beban hidup lantai 5 = 2,5 . 5,6 . 4,275 = 59,85 KN +

N_{LL} = 383,04 KN

$P_u = 1{,}2 \cdot N_{DL} + 1{,}6 \cdot N_{LL}$

$= 1{,}2 \cdot 1056{,}6592 + 1{,}6 \cdot 382{,}04$

= 1879,255 KN

ø . $P_n = P_u$ ➔ $P_n = \frac{P_u}{\phi}$, dengan ø = 0,65 untuk kolom pengikat sengkang.

$P_n = 0{,}80 \cdot \{0{,}85 \cdot f'_c \cdot (A_g - A_{st}) + f_y \cdot A_{st}\}$

$= 0{,}80 \cdot \{0{,}85 \cdot 25 \cdot (A_g - 0{,}02 \cdot A_g) + 400 \cdot 0{,}02 \cdot A_g\}$

$= 0{,}8 \cdot \{21{,}25 \cdot A_g - 0{,}425 \cdot A_g + 8 \cdot A_g\}$

$= 23{,}06\, A_g$

$A_g = \frac{P_n}{23{,}06} = \frac{\frac{P_u}{\phi}}{23{,}06} = \frac{\frac{1879255}{0{,}65}}{23{,}06} = 125375{,}6088 \text{ mm}^2$

$b = h = \sqrt{A_g} = \sqrt{125375{,}6088} = 354{,}0842$ mm.

Diambil dimensi kolom sebesar 500 x 500 mm^2

8. Kolom K4

a. Beban mati :

Beban kolom diatasnya = (0,5 . 0,5 . 3 . 24) + 1056,6592 = 1074,6592 KN

Beban dari pelat lantai = 4,35 . 5,6 . 4,275 = 104,139 KN

Balok induk 250/400 = 0,25 . (0,40-0,12) . (4,275) . 24 = 7,182 KN

Balok induk 300/450	= 0,3 . (0,45-0,12) . (2,6) . 24	= 6,1776	KN
Balok induk 300/500	= 0,3 . (0,50-0,12) . (3) . 24	= 8,208	KN
Balok anak 250/400	= 0,25 . (0,40-0,12) . (5,6) . 24	= 9,408	KN
Balok anak 250/400	= 0,25 . (0,40-0,12) . (2,35) . 24	= 3,948	KN +
		N_{DL} = 1213,7218	KN

b. Beban Hidup :

Beban hidup lantai 5		= 383,04	KN
Beban hidup lantai 4 = 2,5 . 5,6 . 4,275		= 59,85	KN +
	N_{LL}	= 442,89	KN

$P_u = 1,2 \cdot N_{DL} + 1,6 \cdot N_{LL}$

$= 1,2 \cdot 1213,7218 + 1,6 \cdot 442,89$

$= 2165,0902$ KN

ø . $P_n = P_u$ ➔ $P_n = \frac{P_u}{\phi}$, dengan ø = 0,65 untuk kolom pengikat sengkang.

$P_n = 0,80 \cdot \{0,85 \cdot f'_c \cdot (A_g - A_{st}) + f_y \cdot A_{st}\}$

$= 0,80 \cdot \{0,85 \cdot 25 \cdot (A_g - 0,02 \cdot A_g) + 400 \cdot 0,02 \cdot A_g\}$

$= 0,8 \cdot \{21,25 \cdot A_g - 0,425 \cdot A_g + 8 \cdot A_g\}$

$= 23,06\, A_g$

$A_g = \frac{P_n}{23,06} = \frac{\frac{P_u}{\phi}}{23,06} = \frac{\frac{2165090,2}{0,65}}{23,06} = 144445,2732$ mm^2

$b = h = \sqrt{A_g} = \sqrt{144445,2732} = 380,0596$ mm.

Diambil dimensi kolom sebesar 600 x 600 mm^2

9. Kolom K3

a. Beban mati :

Beban kolom diatasnya	= (0,6 . 0,6 . 3 . 24) + 1213,7218	= 1239,6418	KN
Beban dari pelat lantai	= 4,35 . 5,6 . 4,275	= 104,139	KN
Balok induk 250/400	= 0,25 . (0,40-0,12) . (4,275) . 24	= 7,182	KN
Balok induk 300/450	= 0,3 . (0,45-0,12) . (2,6) . 24	= 6,1776	KN
Balok induk 300/500	= 0,3 . (0,50-0,12) . (3) . 24	= 8,208	KN
Balok anak 250/400	= 0,25 . (0,40-0,12) . (5,6) . 24	= 9,408	KN
Balok anak 250/400	= 0,25 . (0,40-0,12) . (2,35) . 24	= 3,948	KN +
		N_{DL} = 1378,7044	KN

b. Beban Hidup :

Beban hidup lantai 4		= 442,89	KN
Beban hidup lantai 3	= 2,5 . 5,6 . 4,275	= 59,85	KN +
		N_{LL} = 502,74	KN

$P_u = 1,2 . N_{DL} + 1,6 . N_{LL}$

= 1,2 . 1378,7044 + 1,6 . 502,74

= 2458,8293 KN

ø . $P_n = P_u$ ➔ $P_n = \frac{P_u}{\phi}$, dengan ø = 0,65 untuk kolom pengikat sengkang.

$P_n = 0{,}80 \,.\, \{0{,}85 \,.\, f'_c \,.\, (A_g - A_{st}) + f_y \,.\, A_{st}\}$

$= 0{,}80 \,.\, \{0{,}85 \,.\, 25 \,.\, (A_g - 0{,}02 \,.\, A_g) + 400 \,.\, 0{,}02 \,.\, A_g\}$

$= 0{,}8 \,.\, \{21{,}25 \,.\, A_g - 0{,}425 \,.\, A_g + 8 \,.\, A_g\}$

$= 23{,}06\, A_g$

$$A_g = \frac{P_n}{23{,}06} = \frac{\frac{P_u}{\phi}}{23{,}06} = \frac{\frac{2458829{,}3}{0{,}65}}{23{,}06} = 164042{,}251 \text{ mm}^2$$

b = h = $\sqrt{A_g}$ = $\sqrt{164042{,}251}$ = 405,0213 mm.

Diambil dimensi kolom sebesar 600 x 600 mm^2

10. Kolom K2

a. Beban mati :

Beban kolom diatasnya	= (0,6 . 0,6 . 3 . 24) + 1378,7044	= 1404,6244	KN
Beban dari pelat lantai	= 4,35 . 5,6 . 4,275	= 104,139	KN
Balok induk 250/400	= 0,25 . (0,40-0,12) . (4,275) . 24	= 7,182	KN
Balok induk 300/450	= 0,3 . (0,45-0,12) . (2,6) . 24	= 6,1776	KN
Balok induk 300/500	= 0,3 . (0,50-0,12) . (3) . 24	= 8,208	KN
Balok anak 250/400	= 0,25 . (0,40-0,12) . (5,6) . 24	= 9,408	KN
Balok anak 250/400	= 0,25 . (0,40-0,12) . (2,35) . 24	= 3,948	KN +
		N_{DL} = 1543,687	KN

b. Beban Hidup :

Beban hidup lantai 3 = 502,74 KN

Beban hidup lantai 2 = 2,5 . 5,6 . 4,275 = 59,85 KN +

N_{LL} = 562,59 KN

$P_u = 1{,}2 \cdot N_{DL} + 1{,}6 \cdot N_{LL}$

$= 1{,}2 \cdot 1543{,}687 + 1{,}6 \cdot 562{,}59$

$= 2752{,}5684$ KN

$\phi \cdot P_n = P_u \rightarrow P_n = \frac{P_u}{\phi}$, dengan ø = 0,65 untuk kolom pengikat sengkang.

$P_n = 0{,}80 \cdot \{0{,}85 \cdot f'_c \cdot (A_g - A_{st}) + f_y \cdot A_{st}\}$

$= 0{,}80 \cdot \{0{,}85 \cdot 25 \cdot (A_g - 0{,}02 \cdot A_g) + 400 \cdot 0{,}02 \cdot A_g\}$

$= 0{,}8 \cdot \{21{,}25 \cdot A_g - 0{,}425 \cdot A_g + 8 \cdot A_g\}$

$= 23{,}06\, A_g$

$A_g = \frac{P_n}{23{,}06} = \frac{\frac{P_u}{\phi}}{23{,}06} = \frac{\frac{2752568{,}4}{0{,}65}}{23{,}06} = 183639{,}2288 \text{ mm}^2$

$b = h = \sqrt{A_g} = \sqrt{183639{,}2288} = 428{,}5315$ mm.

Diambil dimensi kolom sebesar 600 x 600 mm^2

11. Kolom K1

a. Beban mati :

Beban kolom diatasnya = (0,6 . 0,6 . 3,5 . 24) + 1543,687 = 1573,927 KN

Beban dari pelat lantai = 4,35 . 5,6 . 4,275 = 104,139 KN

Balok induk 250/400 = 0,25 . (0,40-0,12) . (4,275) . 24 = 7,182 KN

Balok induk 300/450	= 0,3 . (0,45-0,12) . (2,6) . 24	= 6,1776	KN
Balok induk 300/500	= 0,3 . (0,50-0,12) . (3) . 24	= 8,208	KN
Balok anak 250/400	= 0,25 . (0,40-0,12) . (5,6) . 24	= 9,408	KN
Balok anak 250/400	= 0,25 . (0,40-0,12) . (2,35) . 24	= 3,948	KN +
		N_{DL} = 1712,9896	KN

b. Beban Hidup :

Beban hidup lantai 2		= 562,59	KN
Beban hidup lantai 1 = 2,5 . 5,6 . 4,275		= 59,85	KN +
	N_{LL}	= 622,44	KN

$P_u = 1,2 \cdot N_{DL} + 1,6 \cdot N_{LL}$

$= 1,2 \cdot 1712,9896 + 1,6 \cdot 622,44$

$= 3051,4915$ KN

ø . $P_n = P_u$ ➔ $P_n = \frac{P_u}{\phi}$, dengan ø = 0,65 untuk kolom pengikat sengkang.

$P_n = 0,80 \cdot \{0,85 \cdot f'_c \cdot (A_g - A_{st}) + f_y \cdot A_{st}\}$

$= 0,80 \cdot \{0,85 \cdot 25 \cdot (A_g - 0,02 \cdot A_g) + 400 \cdot 0,02 \cdot A_g\}$

$= 0,8 \cdot \{21,25 \cdot A_g - 0,425 \cdot A_g + 8 \cdot A_g\}$

$= 23,06\, A_g$

$A_g = \frac{P_n}{23,06} = \frac{\frac{P_u}{\phi}}{23,06} = \frac{\frac{3051491,5}{0,65}}{23,06} = 203582,0602$ mm^2

$b = h = \sqrt{A_g} = \sqrt{203582,0602} = 451,2007$ mm.

Diambil dimensi kolom sebesar 700 x 700 mm^2

12. Kolom Basement

a. Beban mati :

Beban kolom diatasnya = (0,7 . 0,7 . 3,5 . 24)+1712,9896 = 1754,1496 KN

Beban dari pelat lantai = 4,35 . 5,6 . 4,275 = 104,139 KN

Balok induk 250/400 = 0,25 . (0,40-0,12) . (4,275) . 24 = 7,182 KN

Balok induk 300/450 = 0,3 . (0,45-0,12) . (2,6) . 24 = 6,1776 KN

Balok induk 300/500 = 0,3 . (0,50-0,12) . (3) . 24 = 8,208 KN

Balok anak 250/400 = 0,25 . (0,40-0,12) . (5,6) . 24 = 9,408 KN

Balok anak 250/400 = 0,25 . (0,40-0,12) . (2,35) . 24 = 3,948 KN +

N_{DL} = 1893,2122 KN

b. Beban Hidup :

Beban hidup lantai 1 = 622,44 KN

Beban hidup lantai Basement = 2,5 . 5,6 . 4,275 = 59,85 KN +

N_{LL} = 682,29 KN

$P_u = 1,2 . N_{DL} + 1,6 . N_{LL}$

$= 1,2 . 1893,2122 + 1,6 . 682,29$

$= 3363,5186$ KN

ø . $P_n = P_u$ ➔ $P_n = \frac{P_u}{\phi}$, dengan ø = 0,65 untuk kolom pengikat sengkang.

$P_n = 0{,}80 \,.\, \{0{,}85 \,.\, f'_c \,.\, (A_g - A_{st}) + f_y \,.\, A_{st}\}$

$= 0{,}80 \,.\, \{0{,}85 \,.\, 25 \,.\, (A_g - 0{,}02 \,.\, A_g) + 400 \,.\, 0{,}02 \,.\, A_g\}$

$= 0{,}8 \,.\, \{21{,}25 \,.\, A_g - 0{,}425 \,.\, A_g + 8 \,.\, A_g\}$

$= 23{,}06\, A_g$

$$A_g = \frac{P_n}{23{,}06} = \frac{\frac{P_u}{\phi}}{23{,}06} = \frac{\frac{3363518{,}6}{0{,}65}}{23{,}06} = 224399{,}1327 \text{ mm}^2$$

$b = h = \sqrt{A_g} = \sqrt{224399{,}1327} = 473{,}7079$ mm.

Diambil dimensi kolom sebesar 700 x 700 mm^2

Tabel 3.4. Hasil Estimasi Dimensi Kolom Tengah

Lantai	P_u KN	A_g (mm^2)	$\sqrt{A_g}$ (mm)	Dimensi Kolom (mm)
K11	198,2923	13229,1881	115,0182	400 x 400
K10	474,7514	31673,3204	177,97	400 x 400
K9	751,2106	50117,4595	223,8693	400 x 400
K8	1028,15	68593,6353	261,9039	500 x 500
K7	1312,3848	87556,5281	295,8995	500 x 500
K6	1596,6199	106519,4409	326,3732	500 x 500
K5	1879,255	125375,6088	354,0842	500 x 500
K4	2165,0902	144445,2732	380,0596	600 x 600
K3	2458,8293	164042,251	405,0213	600 x 600
K2	2752,5684	183639,2288	428,5315	600 x 600
K1	3051,4915	203582,0602	451,2007	700 x 700
Basement	3363,5186	224399,1327	473,7079	700 x 700

Tabel 3.5. Hasil Estimasi Dimensi Kolom Tepi

Lantai	P_u KN	A_g (mm^2)	$\sqrt{A_g}$ (mm)	Dimensi Kolom (mm)
K11	112,699	7518,7804	86,7109	400 x 400
K10	274,5962	18319,8479	135,3508	400 x 400
K9	436,4933	29120,9087	170,6485	400 x 400
K8	598,3904	39921,9694	199,8048	500 x 500
K7	768,0635	51241,8107	226,3665	500 x 500
K6	937,7366	62561,6519	250,1233	500 x 500
K5	1107,4098	73881,4998	271,8115	500 x 500
K4	1277,0829	85201,341	291,8927	600 x 600
K3	1456,26	97155,2472	311,6974	600 x 600
K2	1635,4371	109109,1534	330,3167	600 x 600
K1	1819,7982	121408,9132	348,4378	700 x 700
Basement	2017,2634	134582,9208	366,8554	700 x 700

3.5. Perencanaan Tangga

3.5.1. Perencanaan Dimensi Tangga

Diketahui data sebagai berikut:

Selisih tinggi lantai = 3 m.

Lebar ruang tangga = 3 m.

Panjang ruang tangga = 4,7 m.

Tinggi anak tangga (*Optrade*) = 0,15 m.

Lebar anak tangga (*Antrade*) = 0,30 m.

Jumlah anak tangga :

$$\frac{H}{Op} - 1 = \left(\frac{300}{15}\right) - 1 = 19 \text{ anak tangga}$$

Lebar bordes direncanakan = 150 cm.

Syarat kenyamanan tangga : $60 \leq 2.\ Op + An \leq 65$

$$60 \leq 2\ .\ 15 + 30 \leq 65$$

$$60 \leq 60 \leq 65 \quad \text{(OK)}$$

Kemiringan tangga:

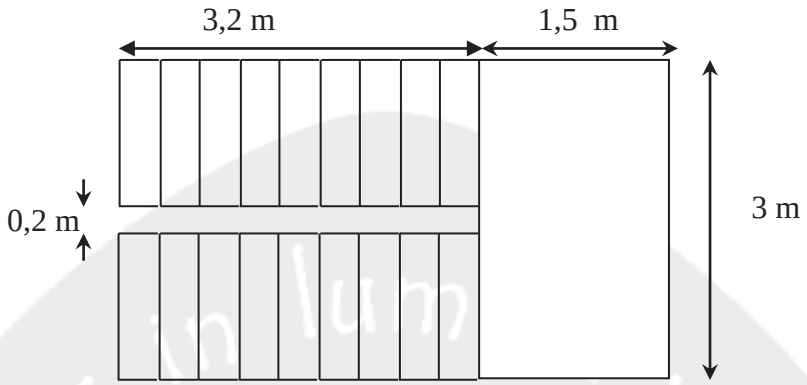
$$Tan\ \alpha = arc\ tan\ \frac{Op}{An} = arc\ tan\ \frac{15}{30} = 26{,}5651\ ^{o}$$

$$tt' = \frac{0{,}5.Optrade.Antrade}{\sqrt{Optrade^2 + Antrade^2}} = \frac{0{,}5\,x15x30}{\sqrt{15^2 + 30^2}} = 6{,}7082 \text{ cm.}$$

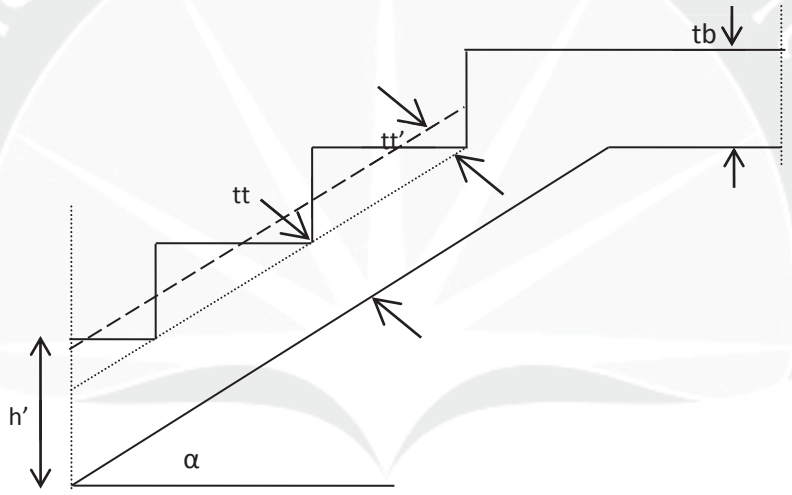
Tebal pelat tangga = tebal bordes = *tt* = 12 cm.

$$h' = \frac{tt + tt'}{\cos\alpha} = \frac{12 + 6{,}7082}{\cos\ 26{,}5651}$$

h’ = 20,9164 cm = 0,2092 m



Gambar 3.11. Ruang Tangga



Gambar 3.12. Penampang Tangga

3.5.2. Pembebanan Pada Tangga

Hitungan beban per meter lebar tangga

Beban Mati

Pelat tangga dan anak tangga = 0,2092. 1 . 24 = 5,0208 KN/m

Beban ubin + spesi setebal 50 mm = 0,05. 21 = 1,05 KN/m

Beban pasir setebal 30 mm = 0,03. 16 = 0,48 KN/m

Railing (asumsi) = 1 KN/m +

qdl = 7,5508 KN/m

Beban Hidup

qll = 1 . 3 = 3 KN/m

qu pelat tangga = 1,2 . *qdl* + 1,6 . *qll*

= 1,2 . 7,5508 + 1,6 . 3 = 13,86096 KN/m

Hitungan beban per meter lebar bordes

Beban Mati

Pelat bordes = 0,12. 1 . 24 = 2,88 KN/m

Beban ubin + spesi setebal 50 mm = 0,05. 21 = 1,05 KN/m

Beban pasir setebal 30 mm = 0,03. 16 = 0,48 KN/m

Railing (asumsi) = 1 KN/m +

qdl = 5,41 KN/m

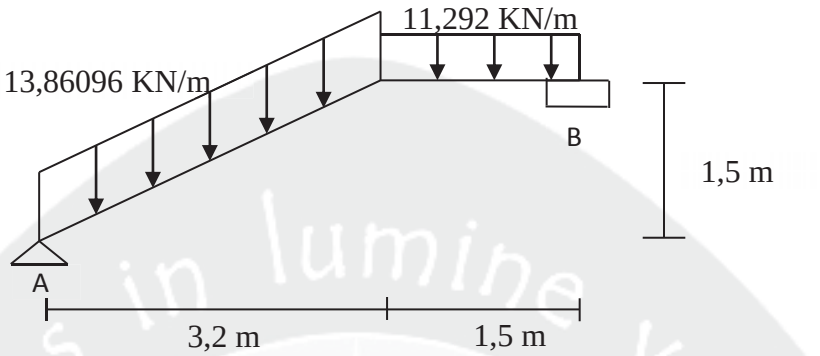
Beban Hidup

qll = 1 . 3 = 3 KN/m

qu pelat tangga = 1,2 . *qdl* + 1,6 . *qll*

= 1,2 . 5,41 + 1,6 . 3 = 11,292 KN/m

Jadi pembebanan tangga adalah sebagai berikut.



Gambar 3.13. Pembebanan Pada Tangga

Gaya-gaya yang terjadi pada tangga dapat diperoleh dari analisis dengan *software ETABS 9.0* Gaya-gaya ini sebesar :

a. Momen Lapangan

Pelat tangga = 12,54 KNm

Pelat bordes = 3,329 KNm

b. Momen Tumpuan

Pelat tangga = 0 KNm

Pelat bordes = 1,796 KNm

3.5.3. Penulangan Pelat Tangga dan Pelat Bordes

Data yang digunakan untuk perancangan adalah seperti dibawah ini.

1. Tebal selimut beton = 25 mm
2. Tulangan yang digunakan = D13 (fy = 400 MPa)
3. Tulangan susut = P10 (fy = 240 MPa)

4. Tebal Pelat = 120 mm

5. f'c = 25 MPa

Perhitungan :

a. Lapangan

Mu = 12,54 KNm

b = 1000 mm

d' = 25 + 0,5 . 13 = 31,5 mm

d = 120 – 31,5 = 88,5 mm

$$Rn = \frac{Mu}{0{,}9.b.d^2} = \frac{12{,}54.10^6}{0{,}9.1000.88{,}5^2} = 1{,}779$$

ρ_{min} = 0,0018

$$\rho_{perlu} = \frac{0{,}85.f'c}{fy}\left(1-\sqrt{1-\frac{2.Rn}{0{,}85.f'c}}\right)$$

$$= \frac{0{,}85.25}{400}\left(1-\sqrt{1-\frac{2.1{,}779}{0{,}85.25}}\right)$$

= 0,0047

$$\rho_{maks} = 0{,}75\left(\frac{0{,}85.f'c}{fy}\beta_1\frac{600}{600+fy}\right)$$

$$= 0{,}75\left(\frac{0{,}85.25}{400}0{,}85\frac{600}{600+400}\right)$$

= 0,0203

$\rho_g < \rho_{perlu} < \rho_{maks}$

0,0018 < 0,0041 < 0,0203

As_{min} = 0,0018 . 1000 . 120 = 216 mm^2

As = 0,0047 . 1000 . 88,5 = 415,95 mm^2

Karena *As min* < *As* maka digunakan *As* = 415,95 mm^2

$$Spasi = 1000 \frac{\frac{1}{4}\pi D^2}{As} = 1000 \frac{\frac{1}{4}\pi 13^2}{415{,}95} = 319{,}1064 \text{ mm} \approx 200 \text{ mm}.$$

$$As = 1000 \frac{\frac{1}{4}\pi D^2}{Spasi} = 1000 \frac{\frac{1}{4}\pi 13^2}{200} = 663{,}6614 \text{ mm}^2 > 415{,}95 \text{ mm}^2$$

Dipakai D13 – 200 (*As* = 663,6614 mm^2)

b. Tumpuan

Mu = 1,796 KNm

b = 1000 mm

d' = 25 + 0,5 . 13 = 31,5 mm

d = 120 – 31,5 = 88,5 mm

$$Rn = \frac{Mu}{0{,}9.b.d^2} = \frac{1{,}796.10^6}{0{,}9.1000.88{,}5^2} = 0{,}2548$$

ρ_{min} = 0,0018

$$\rho = \frac{0{,}85.f'c}{fy}\left(1-\sqrt{1-\frac{2.Rn}{0{,}85.f'c}}\right)$$

$$= \frac{0{,}85.25}{400}\left(1-\sqrt{1-\frac{2.0{,}2548}{0{,}85.25}}\right)$$

$$= 0{,}0006$$

$$\rho_{maks} = 0{,}75\left(\frac{0{,}85.f'c}{fy}\beta_1\frac{600}{600+fy}\right)$$

$$= 0{,}75\left(\frac{0{,}85.25}{400}0{,}85\frac{600}{600+400}\right)$$

$$= 0{,}0203$$

$\rho_{perlu} < \rho_{min} < \rho_{maks}$

$0{,}0006 < 0{,}0018 < 0{,}0203$

$As_{min} = 0{,}0018 \,.\, 1000.\, 120 = 216\ \text{mm}^2$

$As = 0{,}0006 \,.\, 1000 \,.\, 88{,}5 = 53{,}1\ \text{mm}^2$

Karena $As < As\ min$ maka digunakan $As\ min = 216\ \text{mm}^2$

$$Spasi = 1000\,\frac{\frac{1}{4}\pi D^2}{As} = 1000\,\frac{\frac{1}{4}\pi 13^2}{216} = 614{,}5013\ \text{mm} \approx 200\ \text{mm}.$$

$$As = 1000\,\frac{\frac{1}{4}\pi D^2}{Spasi} = 1000\,\frac{\frac{1}{4}\pi 13^2}{200} = 663{,}6614\ \text{mm}^2 > 216\ \text{mm}^2$$

Dipakai D13 – 200 ($As = 663{,}6614\ \text{mm}^2$)

c. Tulangan Susut

Dipakai tulangan diameter 10 mm (*fy* = 240 Mpa)

$\rho_{min} = 0{,}0021$

$A_{s\ susut} = 0{,}0021.\ 1000\ .\ 120 = 252\ \text{mm}^2.$

$$Spasi = \frac{\frac{\pi}{4}.10^2.1000}{252} = 311{,}6659 \approx 250\ \text{mm}.$$

$$As = 1000\ .\frac{\frac{1}{4}.\pi.\ D^2}{Spasi} = 1000\ .\ \frac{\frac{1}{4}.\pi.10^2}{250} = 314{,}1593\ \text{mm}^2.$$

Maka digunakan tulangan P10 – 250 (*As* = 314,1593 mm^2)

d. Kontrol Terhadap Geser

d = 88,5

Gaya geser (*Vu*) = 26,17 KN

$$V_C = \frac{1}{6}.\sqrt{f_c'}.b.d = \frac{1}{6}.\sqrt{25}.1000.88{,}5 = 73750\ \text{N} = 73{,}750\ \text{KN}$$

V_u = 26,17 KN < ϕ. *Vc* = 0,75 . 73,750

26,17 KN < 55,3125 KN

Dari hasil perhitungan, ternyata tulangan geser tidak diperlukan karena dari penampang beton sendiri sudah bisa mengatasi geser yang terjadi.

3.5.4. Penulangan Balok Bordes

Digunakan balok bordes ukuran 250/400

fc = 25 MPa

β_1 = 0,85

fy = 400 MPa

diameter tulangan lentur = 16 mm

diameter tulangan geser (sengkang) = 10 mm

selimut beton = 40 mm

tinggi efektif balok :

d' = selimut beton + diameter sengkang + 0,5. diameter tulangan lentur

= 40 + 10 + 0,5 . 16 = 58 mm

d = $h - d'$

= 400 – 58 = 342 mm

Beban rencana

Berat sendiri = 0,25 . 0,4 . 24 = 2,4 KN/m

Berat dinding = 2,5 . 1,5 = 3,75 KN/m

Reaksi tangga (qu) per meter lebar = 2,13 KN/m +

q_u = 8,28 KN/m

1. Penulangan lentur tumpuan

$$Mu = \frac{1}{12} \times qu \times l^2 = \frac{1}{12} \times 8{,}28 \times 3^2 = 6{,}21 \text{KN/m}$$

$$Rn = \frac{Mu}{0{,}8.b.d^2} = \frac{6{,}21.10^6}{0{,}8.250.342^2} = 0{,}2655$$

$$\rho_{perlu} = \frac{0{,}85.f'c}{fy}\left(1 - \sqrt{1 - \frac{2.Rn}{0{,}85.f'c}}\right)$$

$$= \frac{0{,}85.25}{400}\left(1 - \sqrt{1 - \frac{2.0{,}2655}{0{,}85.25}}\right)$$

$$= 0{,}0007$$

Menghitung rasio tulangan maksimum

$$\rho_{maks} = 0{,}75\left(\frac{0{,}85.f'c}{fy}\beta_1 \frac{600}{600 + fy}\right)$$

$$= 0{,}75\left(\frac{0{,}85.25}{400}0{,}85\frac{600}{600 + 400}\right)$$

= 0,0203

Menghitung rasio tulangan minimum

$$\rho_{\min 1} = \frac{\sqrt{f'c}}{4.fy} = \frac{\sqrt{25}}{4.400} = 0{,}0031$$

$$\rho_{\min 2} = \frac{1{,}4}{fy} = \frac{1{,}4}{400} = 0{,}0035$$

As_{min} = 0,0035 . 250. 342 = 299,25 mm^2.

As = 0,0007 . 250 . 342 = 59,85 mm^2.

As_{maks} = 0,0203 . 250 . 342 = 1735,65 mm^2.

Karena $As_{min} > As$, maka digunakan As =299,25 mm^2.

Jumlah Tulangan = $\frac{299{,}25}{\frac{1}{4}\pi 16^2} = 1{,}49 \approx 3$

Jadi untuk tulangan tarik digunakan 3D16 (As = 603,1858 mm^2), sedangkan untuk tulangan tekan digunakan 2D16 (As = 402,1239 mm^2)

2. Penulangan lentur Lapangan

$$Mu = \frac{1}{24} \times qu \times l^2 = \frac{1}{24} \times 8{,}28 \times 3^2 = 3{,}105\,\text{KNm}$$

$$Rn = \frac{Mu}{0{,}8.b.d^2} = \frac{3{,}105.10^6}{0{,}8.250.342^2} = 0{,}1327$$

$$\rho_{perlu} = \frac{0{,}85.f'c}{fy}\left(1 - \sqrt{1 - \frac{2.Rn}{0{,}85.f'c}}\right)$$

$$= \frac{0{,}85.25}{400}\left(1-\sqrt{1-\frac{2.0{,}1327}{0{,}85.25}}\right)$$

$$= 0{,}0003$$

Menghitung rasio tulangan maksimum

$$\rho_{maks} = 0{,}75\left(\frac{0{,}85.f'c}{fy}\beta_1\frac{600}{600+fy}\right)$$

$$= 0{,}75\left(\frac{0{,}85.25}{400}0{,}85\frac{600}{600+400}\right)$$

$$= 0{,}0203$$

Menghitung rasio tulangan minimum

$$\rho_{\min 1} = \frac{\sqrt{f'c}}{4.fy} = \frac{\sqrt{25}}{4.400} = 0{,}0031$$

$$\rho_{\min 2} = \frac{1{,}4}{fy} = \frac{1{,}4}{400} = 0{,}0035$$

As_{min} = 0,0035 . 250. 342 = 299,25 mm^2.

As = 0,0003. 250 . 342 = 25,65 mm^2.

As_{maks} = 0,0203 . 250 . 342 = 1735,65 mm^2.

Karena $As < As_{min} < As_{maks}$, maka digunakan As_{min} = 299,25 mm^2.

Jumlah Tulangan = $\frac{299{,}25}{\frac{1}{4}\pi 16^2} = 1{,}4891 \approx 3$

Jadi untuk tulangan tarik digunakan 3D16 (As = 603,1858 mm^2), sedangkan untuk tulangan tekan digunakan 2D16 (As = 402,1239 mm^2)

3. Penulangan geser

$$V_c = \frac{1}{6}\sqrt{f'_c}.b.d = \frac{1}{6}\sqrt{25}.250.342 = 71250\text{N} = 71{,}25\ \text{KN}$$

$$Vu = \frac{1}{2}qu.l = \frac{1}{2}.8{,}28.3 = 12{,}42\ \text{KN}$$

$$Vs = \frac{Vu}{\phi} = \frac{12{,}42}{0{,}75} = 16{,}56\,\text{KN}$$

Kuat geser V_s tidak boleh lebih dari V_s maksimum, yaitu :

$$V_{s,\ maks} = \frac{2}{3}.\sqrt{f'_c}.b_w.d = \frac{2}{3}.\sqrt{25}.250.342 = 285\ \text{KN}$$

Digunakan tulangan geser 2 kaki P10

$Vu \quad < \Phi\ Vc$

12,42 < 0,75 .71,25 = 53,4375

Dengan memakai tulangan geser 2 kaki P10 (*As* = 157,0763 mm2) diperoleh S sebesar :

$$S = \frac{As\ f_y\ d}{V_s} = \frac{157{,}0763.240.342}{16{,}56.10^3} = 778{,}5521\,mm$$

Karena $V_{s,} \leq \frac{1}{3}.\sqrt{f'_c}.b_w.d = \frac{1}{3}.\sqrt{25}.250.342 = 142{,}5\ \text{KN}$

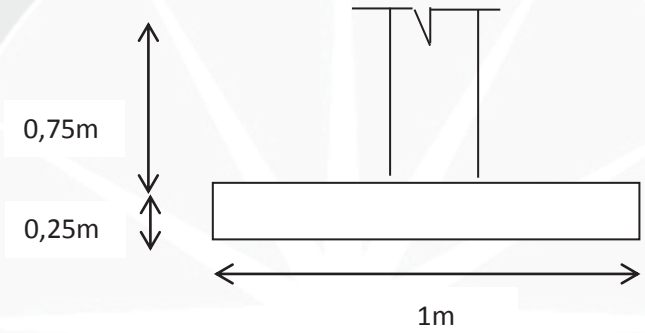
16,56 KN ≤ 142,5 KN

Maka spasi maksimum diambil nilai terkecil dari :

$$s_{maks} = \frac{d}{2} = \frac{342}{2} = 171\,mm$$

Jadi digunakan sengkang 2P10 – 150 mm.

3.5.5. Penulangan Pondasi Tangga



Gambar 3.14. Tampang Pondasi Tangga

h = 250 mm

Ukuran alas = 1500 x 1000 mm

Berat jenis tanah = 1,8 t/m^3

Pu = 68,05 KN = 6805 kg

d = 250 – 30 – ½ .12

= 214 mm

Pembebanan pondasi

Berat telapak pondasi = 1,5 x 1 x 0,25 x 2400 = 900 kg

Berat tanah = (0,4 x 0,75 x 1,5) x 2 x 1800 =1620 kg

Berat kolom = (0,2 x 1,5 x 0,75) x 2400 = 540 kg

Pu = 6805 kg +

Vtotal = 9865 kg

$$\sigma = \frac{Vtotal}{A} = \frac{9865}{1{,}5.1} = 6576{,}67 \text{ kg/m}^2$$

Penulangan arah panjang

$M_u = 0{,}5 \,.\, Q_u \,.\, c^2 = 0{,}5 \,.\, 6576{,}67 \,.\, 0{,}5^2 = 820{,}875$ kg/m

$$R_n = \frac{M_u}{\phi \cdot b \cdot d^2} = \frac{8{,}21 \cdot 10^6}{0{,}9 \cdot 1500 \cdot 214^2} = 0{,}1328$$

$$\rho = \frac{0{,}85 \cdot f'_c}{f_y}\left(1 - \sqrt{1 - \frac{2 \cdot R_n}{0{,}85 \cdot f'_c}}\right) = \frac{0{,}85 \cdot 25}{240}\left(1 - \sqrt{1 - \frac{2 \cdot 0{,}1328}{0{,}85 \cdot 25}}\right) = 0{,}0006$$

$A_s = \rho \,.\, b \,.\, d$ $= 0{,}0006 \,.\, 1500 \,.\, 214 = 192{,}6 \text{ mm}^2$

Menghitung luas tulangan maksimum:

$$\rho_{\max} = 0{,}75 \cdot \left(\frac{0{,}85 \cdot f'_c \cdot \beta_1}{f_y} \cdot \frac{600}{600 + f_y}\right) = 0{,}75 \cdot \left(\frac{0{,}85 \cdot 25 \cdot 0{,}85}{240} \cdot \frac{600}{600 + 240}\right)$$

$= 0{,}0403$

$A_{s\,max} = \rho_{max} \,.\, b \,.\, d = 0{,}0403 \,.\, 1500 \,.\, 214 = 12936{,}3 \text{ mm}^2$

Menghitung luas tulangan minimum:

$\rho_g = 0{,}0018$

$As_{min} = 0{,}0018 \,.\, 1500 \,.\, 1000 = 2700 \text{ mm}^2$

Karena $As < As_{min} < As_{max}$,

$192{,}6 < 2700 < 12936{,}3$

maka digunakan $As = 2700 \text{ mm}^2$

$$s = \frac{\left(\frac{1}{4} \cdot \pi \cdot D^2\right) \cdot b}{A_s} = \frac{\left(\frac{1}{4} \cdot \pi \cdot 12^2\right) \cdot 1500}{2700} = 62{,}83 \approx 60 \text{ mm}$$

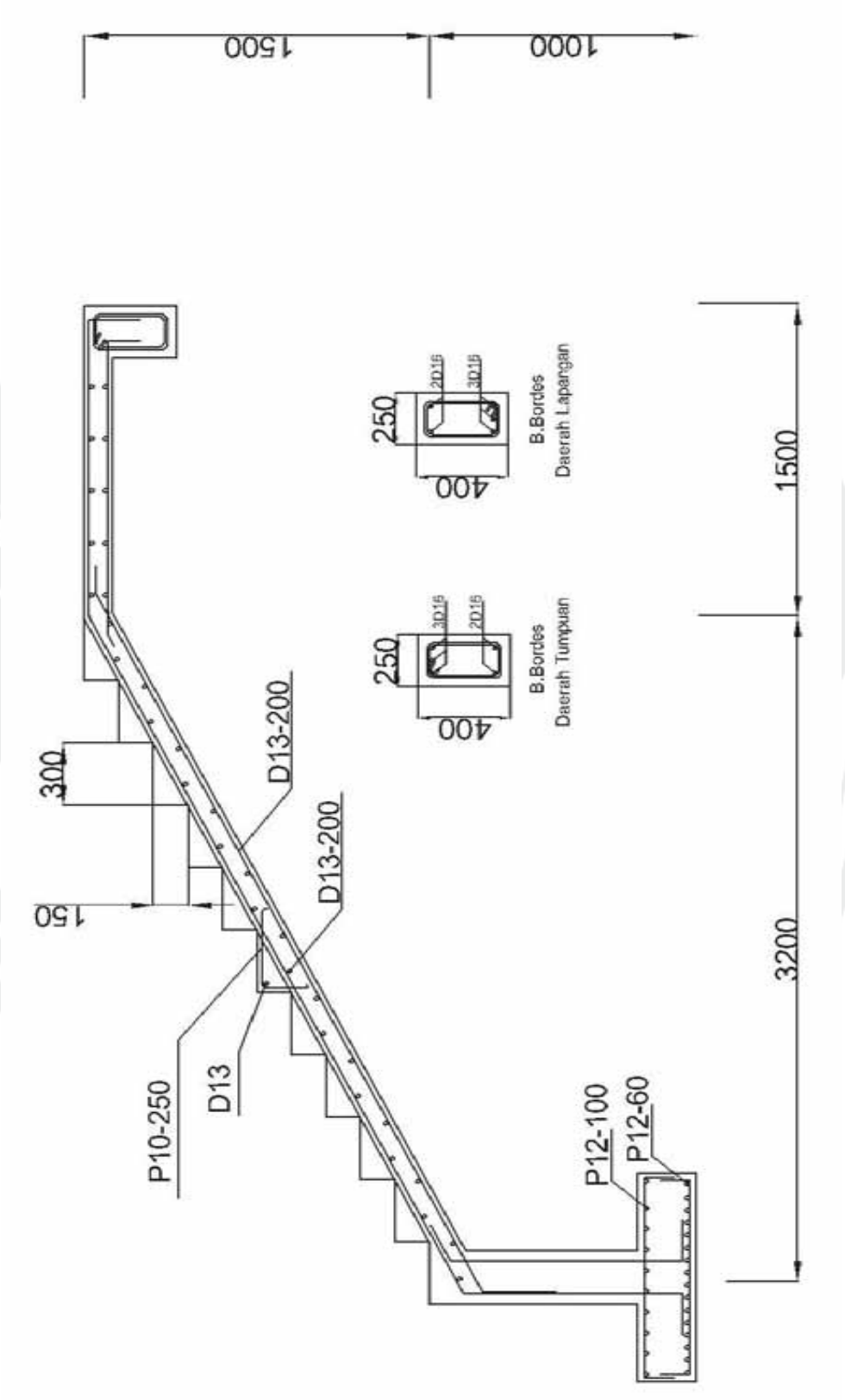
Dipakai tulangan P12–60 mm.

Penulangan untuk bagian atas pondasi

$As = 50\% \text{ x } 2700 = 1350 \text{ mm}^2$

$$s = \frac{\left(\frac{1}{4} \cdot \pi \cdot D^2\right) \cdot b}{A_s} = \frac{\left(\frac{1}{4} \cdot \pi \cdot 12^2\right) \cdot 1500}{1350} = 125{,}66 \approx 100$$

Dipakai tulangan P12–100 mm.



Gambar 3.15. Penulangan Tangga