BAB V
STRUKTUR SEKUNDER

5.1 Struktur Sekunder

Struktur Sekunder adalah struktur yang dirancang untuk menerima beban gravitasi dan tidak dirancang untuk menerima gaya lateral akibat gempa. Struktur Sekunder turut membebani Struktur Primer, tetapi dalam perhitungannya dapat dihitung secara terpisah dari Struktur Primer.

5.2 Pelat Atap

5.2.1 Pembebanan Pelat Atap

Beban Mati (DL)

Berat Sendiri	: 0,12 x 2.400	= 288	Kg/m^2	
Plafond	: 11	= 11	Kg/m^2	
Penggantung	: 7	= 7	Kg/m^2	
Plumbing	: 10	= 10	Kg/m^2	
Ducting AC	: 20	= 20	Kg/m^2	
Aspal 1 cm	: 1 x 14	= 14	Kg/m^2	
Spesi 2 cm	: 2 x 21	= 42	Kg/m^2	+
Beban Mati Pelat Atap (DL)		= 392	Kg/m^2	

Beban Hidup (LL)

Beban Hidup Pelat Atap (LL) = 100 Kg/m^2

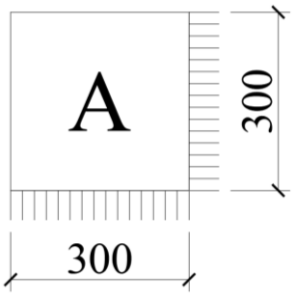
Beban Ultimate (Qu)

Qu = 1,2DL + 1,6LL

Qu = (1,2 x 392) + (1,6 x 100)

Qu = 630,4 Kg/m^2

5.2.2 Momen Pelat Atap



Gambar 5.1 Pelat Atap

Plat jepit penuh, two way slab

$$\frac{Ly}{Lx} = \frac{3}{3} = 1 < 2{,}5$$

Perhitungan Momen

Mlx = + 0,001 . q . lx^2 . C = + 0,001 x 630,4 x 3^2 x 28 = + 159 Kg.m

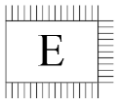
Mly = + 0,001 . q . lx^2 . C = + 0,001 x 630,4 x 3^2 x 28 = + 159 Kg.m

Mtx = – 0,001 . q . lx^2 . C = – 0,001 x 630,4 x 3^2 x 68 = – 386 Kg.m

Mty = – 0,001 . q . lx^2 . C = – 0,001 x 630,4 x 3^2 x 68 = – 386 Kg.m

Tabel 5.1 Momen Pelat Atap

Tipe Pelat	Ukuran (m)	Ly/ Lx	Jenis	Mlx (Kgm)	Mly (Kgm)	Mtx (Kgm)	Mty (Kgm)	Penulangan
A	3 x 3	1	Two way slab	159	159	-386	-386	Arax X = D10–300 Arax Y = D10–300
B	3 x 3	1	Two way slab	119	148	-312	-340	Arax X = D10–300 Arax Y = D10–300
C	3 x 3	1	Two way slab	119	119	-295	-295	Arax X = D10–300 Arax Y = D10–300
D	3 x 2	1,5	Two way slab	91	43	-192	-144	Arax X = D10–300 Arax Y = D10–300

	3 x 2	1,5	Two way slab	96	38	-199	-144	Arax X = D10–300 Arax Y = D10–300

5.2.3 Syarat Batas Penulangan Pelat Atap

Reduksi Kuat Tekan Beton berdasarkan SNI 2847:2019 Tabel 22.2.2.4.3, karena fc' > 28 MPa, maka:

$$\beta_1 = 0{,}85 - \left(\frac{0{,}05\cdot(fc'-28)}{7}\right) = 0{,}85 - \left(\frac{0{,}05\cdot(35-28)}{7}\right) = 0{,}8$$

$$\rho_b = \frac{0{,}85\cdot fc\cdot\beta_1}{fy}\left(\frac{600}{600+fy}\right) = \frac{0{,}85\cdot 35\cdot 0{,}8}{420}\left(\frac{600}{600+420}\right) = 0{,}033$$

$$\rho_{max} = \rho_b \cdot 0{,}75 = 0{,}033 \cdot 0{,}75 = 0{,}025$$

Berdasarkan SNI 2847:2019 Tabel 8.6.1.1, nilai ρ_{min} adalah:

$$\rho_{min} = \frac{0{,}0018\cdot 420}{fy} = \frac{0{,}0018\cdot 420}{420} = 0{,}0018$$

5.2.4 Penulangan Pelat Atap

Tulangan Arah X

Tebal Pelat Atap (h) = 120 mm

Tebal Selimut Beton (s) = 20 mm (SNI 2847:2019 Tabel 20.6.1.3.1)

Diameter Tulangan Utama (D) = 10 mm

Diameter Tulangan Susut (Ø) = 8 mm

d = h – s – ½D = 120 – 20 – ½8 = 96 mm

d' = h – s – D – ½D_s = 120 – 20 – 8 – ½10 = 87 mm

Mu = 386 Kgm = 3.860.000 Nmm

$$m = \frac{fy}{0{,}85\cdot fc} = \frac{420}{0{,}85\cdot 35} = 14{,}12$$

$$Mn = \frac{Mu}{\varnothing} = \frac{3.860.000}{0{,}8} = 4.825.000 \text{ Nmm}$$

$$Rn = \frac{Mn}{b\cdot d^2} = \frac{4.825.000}{1.000\cdot 96^2} = 0{,}53$$

$$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2\cdot m\cdot Rn}{fy}}\right) = \frac{1}{14{,}12}\left(1 - \sqrt{1 - \frac{2\cdot 14{,}12\cdot 0{,}53}{420}}\right)$$

$\rho = 0{,}0013 < \rho_{min}$

Tulangan yang Dibutuhkan Arah X

$As = \rho \cdot b \cdot d = 0{,}0018 \cdot 1.000 \cdot 96 = 173 \text{ mm}^2$

Dipakai D10–300 (262mm^2)

Tulangan Susut

$Ass = \rho_{min} \cdot b \cdot d' = 0{,}0018 \cdot 1.000 \cdot 87 = 157\ mm^2$

Dipakai D8–300 (168 mm^2)

Tulangan Arah Y

Tebal Pelat Atap (h) = 120 mm

Tebal Selimut Beton (s) = 20 mm (SNI 2847:2019 Tabel 20.6.1.3.1)

Diameter Tulangan Utama (D) = 10 mm

Diameter Tulangan Susut (Ø) = 8 mm

d = h – s – ½D = 120 – 20 – ½8 = 96 mm

Mu = 159 Kgm = 1.590.000 Nmm

$m = \frac{fy}{0{,}85 \cdot fc} = \frac{420}{0{,}85 \cdot 35} = 14{,}12$

$Mn = \frac{Mu}{\varnothing} = \frac{1.590.000}{0{,}8} = 1.987.500\ Nmm$

$Rn = \frac{Mn}{b \cdot d^2} = \frac{1.987.500}{1.000 \cdot 96^2} = 0{,}22$

$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2 \cdot m \cdot Rn}{fy}}\right) = \frac{1}{14{,}12}\left(1 - \sqrt{1 - \frac{2 \cdot 14{,}12 \cdot 0{,}22}{420}}\right)$

$\rho = 0{,}0005 < \rho_{min}$

Tulangan yang Dibutuhkan

$As = \rho \cdot b \cdot d = 0{,}0018 \cdot 1.000 \cdot 96 = 173\ mm^2$

Dipakai D10–300 (262 mm^2)

Tulangan Susut

$Ass = \rho_{min} \cdot b \cdot d' = 0{,}0018 \cdot 1.000 \cdot 87 = 157\ mm^2$

Dipakai D8–300 (168 mm^2)

5.2.5 Kontrol Kekuatan Pelat Atap

Arah X

$\rho = \frac{As\ pakai}{b \cdot d} = \frac{262}{1.000 \cdot 96} = 0{,}003$

$\rho_{min} < \rho < \rho_{max}$ (OK)

$a = \frac{As \cdot fy}{0{,}85 \cdot fc' \cdot b} = \frac{262 \cdot 420}{0{,}85 \cdot 35 \cdot 1.000} = 3{,}7\ mm$

$Mn = As \cdot fy \cdot \left(d - \frac{a}{2}\right) = 262 \cdot 420 \cdot \left(96 - \frac{3{,}7}{2}\right)$

$Mn = 10.360.266\ Nmm$

Mn > Mn Beban (OK)

Tulangan yang Dibutuhkan

Jarak tulangan ≤ 3 x Tebal Plat

300 ≤ 3 x 120 mm

300 mm ≤ 360 mm (OK)

Tulangan bagi

$$Asb = \frac{1}{4} \cdot D^2 \cdot \pi \cdot \frac{b}{s} = \frac{1}{4} \cdot 10^2 \cdot \frac{22}{7} \cdot \frac{1.000}{300} = 262 \text{ mm}^2$$

Asb ≥ Asb yg dipakai (OK)

Arah Y

$$\rho = \frac{\text{As pakai}}{b \cdot d} = \frac{262}{1.000 \cdot 96} = 0{,}003$$

$\rho_{min} < \rho < \rho_{max}$ (OK)

$$a = \frac{As \cdot fy}{0{,}85 \cdot fc' \cdot b} = \frac{262 \cdot 420}{0{,}85 \cdot 35 \cdot 1.000} = 3{,}7 \text{ mm}$$

$$Mn = As \cdot fy \cdot \left(d - \frac{a}{2}\right) = 262 \cdot 420 \cdot \left(96 - \frac{3{,}7}{2}\right)$$

$$Mn = 10.360.266 \text{ Nmm}$$

Mn > Mn Beban (OK)

Tulangan yang Dibutuhkan

Jarak tulangan ≤ 3 x Tebal Plat

300 ≤ 3 x 120 mm

300 mm ≤ 360 mm (OK)

5.2.6 Kontrol Retak Pelat Atap

$$fs = 60\% \cdot fy = 0{,}6 \cdot 420 = 252 \text{ MPa}$$

$$dc = s + \frac{1}{2} \cdot D = 20 + \frac{1}{2} \cdot 10 = 25 \text{ mm}$$

$$A = 2 \cdot dc \cdot h = 2 \cdot 25 \cdot 120 = 6.000 \text{ mm}^2$$

$$Z = fs \cdot \sqrt[3]{dc \cdot A} = 252 \cdot \sqrt[3]{25 \cdot 6.000} = 13{,}39 \text{ MN/m}$$

Untuk penampang yang di pengaruhi cuaca luar, nilai $Z = 25$ MN/m.

Z kontrol < Z max (OK)

5.3 Pelat Lantai

5.3.1 Pembebanan Pelat Lantai

Beban Mati (DL)

Berat sendiri : 0,12 x 2.400 = 288 Kg/m^2

Plafond	: 11	=	11	Kg/m^2
Penggantung	: 7	=	7	Kg/m^2
Plumbing	: 10	=	10	Kg/m^2
Ducting AC	: 20	=	20	Kg/m^2
Keramik	: 24	=	24	Kg/m^2
Spesi 2 cm	: 2 x 21	=	42	Kg/m^2
Beban Mati Pelat Lantai (DL)		=	402	Kg/m^2 +

Beban Hidup (LL)

Beban Hidup Pelat Lantai (LL) = 250 Kg/m^2

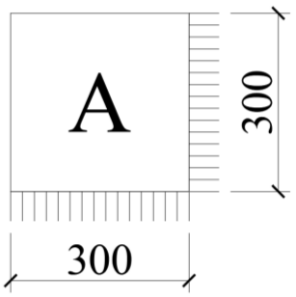
Beban Ultimate (Qu)

Qu = 1,2DL + 1,6LL

Qu = (1,2 x 402) + (1,6 x 250)

Qu = 882,4 Kg/m^2

5.3.2 Momen Pelat Lantai



Gambar 5.2 Pelat Lantai

Plat jepit penuh, two way slab

$$\frac{Ly}{Lx} = \frac{3}{3} = 1 < 2{,}5$$

Perhitungan Momen

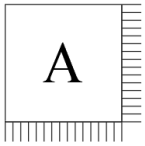
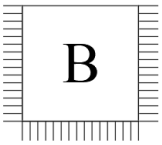
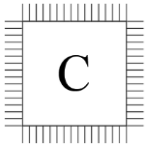
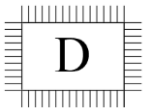
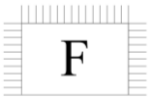
Mlx = + 0,001 . q . lx^2 . C = + 0,001 x 882,4 x 3^2 x 28 = + 222 Kg.m

Mly = + 0,001 . q . lx^2 . C = + 0,001 x 882,4 x 3^2 x 28 = + 222 Kg.m

Mtx = – 0,001 . q . lx^2 . C = – 0,001 x 882,4 x 3^2 x 68 = – 540 Kg.m

Mty = – 0,001 . q . lx^2 . C = – 0,001 x 882,4 x 3^2 x 68 = – 540 Kg.m

Tabel 5.2 Momem Pelat Lantai

Tipe Pelat	Ukuran (m)	Ly/ Lx	Jenis	Mlx (Kgm)	Mly (Kgm)	Mtx (Kgm)	Mty (Kgm)	Penulangan
	3 x 3	1	Two way slab	222	222	-540	-540	Arax X = D10–300 Arax Y = D10–300
	3 x 3	1	Two way slab	167	206	-437	-476	Arax X = D10–300 Arax Y = D10–300
	3 x 3	1	Two way slab	167	167	-413	-413	Arax X = D10–300 Arax Y = D10–300
	3 x 2	1,5	Two way slab	127	60	-268	-201	Arax X = D10–300 Arax Y = D10–300
	3 x 2	1,5	Two way slab	134	53	-279	-201	Arax X = D10–300 Arax Y = D10–300
	3 x 2	1,5	Two way slab	152	92	-332	-268	Arax X = D10–300 Arax Y = D10–300

5.3.3 Syarat Batas Penulangan Pelat Lantai

Reduksi Kuat Tekan Beton berdasarkan SNI 2847:2019 Tabel 22.2.2.4.3, karena fc' > 28 MPa, maka:

$$\beta_1 = 0{,}85 - \left(\frac{0{,}05\cdot(fc'-28)}{7}\right) = 0{,}85 - \left(\frac{0{,}05\cdot(35-28)}{7}\right) = 0{,}8$$

$$\rho_b = \frac{0{,}85\cdot fc\cdot\beta_1}{fy}\left(\frac{600}{600+fy}\right) = \frac{0{,}85\cdot 35\cdot 0{,}8}{420}\left(\frac{600}{600+420}\right) = 0{,}033$$

$$\rho_{max} = \rho_b \cdot 0{,}75 = 0{,}033 \cdot 0{,}75 = 0{,}025$$

Berdasarkan SNI 2847:2019 Tabel 8.6.1.1, nilai ρ_{min} adalah:

$$\rho_{min} = \frac{0{,}0018\cdot 420}{fy} = \frac{0{,}0018\cdot 420}{420} = 0{,}0018$$

5.3.4 Penulangan Pelat Lantai

Arah X

Tebal Pelat Atap (h) = 120 mm

Tebal Selimut Beton (s) = 20 mm (SNI 2847:2019 Tabel 20.6.1.3.1)

Diameter Tulangan Utama (D) = 10 mm

Diameter Tulangan Susut (Ø) = 8 mm

d = h – s – ½D = 120 – 20 – ½8 = 96 mm

d' = h – s – D – ½D_s = 120 – 20 – 8 – ½10 = 87 mm

Mu = 540 Kgm = 5.400.000 Nmm

$$m = \frac{fy}{0{,}85 \cdot fc} = \frac{420}{0{,}85 \cdot 35} = 14{,}12$$

$$Mn = \frac{Mu}{\varnothing} = \frac{5.400.000}{0{,}8} = 6.750.000 \text{ Nmm}$$

$$Rn = \frac{Mn}{b \cdot d^2} = \frac{6.750.000}{1.000 \cdot 96^2} = 0{,}73$$

$$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2 \cdot m \cdot Rn}{fy}}\right) = \frac{1}{14{,}12}\left(1 - \sqrt{1 - \frac{2 \cdot 14{,}12 \cdot 0{,}73}{420}}\right)$$

$$\rho = 0{,}0018$$

Tulangan yang Dibutuhkan

$$As = \rho \cdot b \cdot d = 0{,}0018 \cdot 1.000 \cdot 96 = 173 \text{ mm}^2$$

Dipakai D10–300 (262 mm^2)

Tulangan Susut

$$Ass = \rho_{min} \cdot b \cdot d' = 0{,}0018 \cdot 1.000 \cdot 87 = 157 \text{ mm}^2$$

Dipakai D8–300 (168 mm^2)

Arah Y

Tebal Pelat Atap (h) = 120 mm

Tebal Selimut Beton (s) = 20 mm (SNI 2847:2019 Tabel 20.6.1.3.1)

Diameter Tulangan Utama (D) = 10 mm

Diameter Tulangan Susut (Ø) = 8 mm

d = h – s – ½D = 120 – 20 – ½8 = 96 mm

Mu = 222 Kgm = 2.220.000 Nmm

$$m = \frac{fy}{0{,}85 \cdot fc} = \frac{420}{0{,}85 \cdot 35} = 14{,}12$$

$$Mn = \frac{Mu}{\varnothing} = \frac{2.220.000}{0{,}8} = 2.775.000 \text{ Nmm}$$

$$Rn = \frac{Mn}{b \cdot d^2} = \frac{2.775.000}{1.000 \cdot 96^2} = 0{,}31$$

$$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2 \cdot m \cdot Rn}{fy}}\right) = \frac{1}{14{,}12}\left(1 - \sqrt{1 - \frac{2 \cdot 14{,}12 \cdot 0{,}31}{420}}\right)$$

$\rho = 0{,}0007 < \rho_{min}$

Tulangan yang Dibutuhkan

$As = \rho \cdot b \cdot d = 0{,}0018 \cdot 1.000 \cdot 96 = 173\ mm^2$

Dipakai D10–300 (262 mm^2)

Tulangan Susut

$Ass = \rho_{min} \cdot b \cdot d' = 0{,}0018 \cdot 1.000 \cdot 87 = 157\ mm^2$

Dipakai D8–300 (168 mm^2)

5.3.5 Kontrol Kekuatan Pelat lantai

Arah X

$$\rho = \frac{As\ pakai}{b \cdot d} = \frac{262}{1.000 \cdot 96} = 0{,}003$$

$\rho_{min} < \rho < \rho_{max}$ (OK)

$$a = \frac{As \cdot fy}{0{,}85 \cdot fc' \cdot b} = \frac{262 \cdot 420}{0{,}85 \cdot 35 \cdot 1.000} = 3{,}7\ mm$$

$$Mn = As \cdot fy \cdot \left(d - \frac{a}{2}\right) = 262 \cdot 420 \cdot \left(96 - \frac{3{,}7}{2}\right)$$

$Mn = 10.360.266\ Nmm$

Mn > Mn Beban (OK)

Tulangan yang Dibutuhkan

Jarak tulangan ≤ 3 x Tebal Plat

300 ≤ 3 x 120 mm

300 mm ≤ 360 mm (OK)

Tulangan bagi

$$Asb = \frac{1}{4} \cdot D^2 \cdot \pi \cdot \frac{b}{s} = \frac{1}{4} \cdot 10^2 \cdot \frac{22}{7} \cdot \frac{1.000}{300} = 262\ mm^2$$

Asb ≥ Asb yg dipakai (OK)

Arah Y

$$\rho = \frac{As\ pakai}{b \cdot d} = \frac{262}{1.000 \cdot 96} = 0{,}003$$

$\rho_{min} < \rho < \rho_{max}$ (OK)

$$a = \frac{As \cdot fy}{0{,}85 \cdot fc' \cdot b} = \frac{262 \cdot 420}{0{,}85 \cdot 35 \cdot 1.000} = 3{,}7\ mm$$

$$Mn = As \cdot fy \cdot \left(d - \frac{a}{2}\right) = 262 \cdot 420 \cdot \left(96 - \frac{3{,}7}{2}\right)$$

$Mn = 10.360.266$ Nmm

Mn > Mn Beban (OK)

Tulangan yang Dibutuhkan

Jarak tulangan ≤ 3 x Tebal Plat

300 ≤ 3 x 120 mm

300 mm ≤ 360 mm (OK)

5.3.6 Kontrol Retak Pelat Lantai

$fs = 60\% \cdot fy = 0{,}6 \cdot 420 = 252$ MPa

$dc = s + \frac{1}{2} \cdot D = 20 + \frac{1}{2} \cdot 10 = 25$ mm

$A = 2 \cdot dc \cdot h = 2 \cdot 25 \cdot 120 = 6.000$ mm^2

$Z = fs \cdot \sqrt[3]{dc \cdot A} = 252 \cdot \sqrt[3]{25 \cdot 6.000} = 13{,}39$ MN/m

Untuk penampang yang di pengaruhi cuaca luar, nilai $Z = 25$ MN/m.

Z kontrol < Z max (OK)

5.4 Balok Anak Atap

5.4.1 Pembebanan Balok Anak Atap

Beban Mati

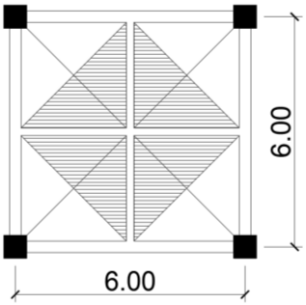
Berat Sendiri Pelat Atap	: 0,12 x 2.400	= 288	Kg/m^2
Plafond	: 11	= 11	Kg/m^2
Penggantung	: 7	= 7	Kg/m^2
Plumbing	: 10	= 10	Kg/m^2
Ducting AC	: 20	= 20	Kg/m^2
Aspal 1 cm	: 1 x 14	= 14	Kg/m^2
Spesi 2 cm	: 2 x 21	= 42	Kg/m^2
Beban Mati Pelat Atap		= 392	Kg/m^2

+

Beban Hidup

Beban Hidup Pelat Atap = 100 Kg/m^2

Pembebanan Segitiga pada Balok Anak Atap



Gambar 5.3 Pembebanan Segitiga pada Balok Anak Atap

Beban Mati (DL)

Berat Sendiri	= 0,2 x 0,4 x 2.400	= 192	Kg/m
Beban Ekivalen	$= \frac{1}{3} \cdot 392 \cdot 3 \cdot 2$	= 784	Kg/m
Total Beban Mati (DL)		= 976	Kg/m

+

Beban Hidup (LL)

Beban Ekivalen	$= \frac{1}{3} \cdot 100 \cdot 3 \cdot 2$	= 200	Kg/m
Total Beban Hidup (LL)		= 200	Kg/m

Beban Ultimate (Qu)

Qu = 1,2DL + 1,6LL + 0,5R

Qu = (1,2 x 976) + (1,6 x 200)

Qu = 1.491,2 Kg/m

5.4.2 Perhitungan Gaya Dalam Balok Anak Atap

$\text{Momen}_{\text{tumpuan}} = \frac{1}{11} \cdot Q_u \cdot L^2 = \frac{1}{11} \cdot 1.491{,}2 \cdot 6^2 = 4.880{,}3 \text{ Kgm}$

$\text{Momen}_{\text{lapangan}} = \frac{1}{16} \cdot Q_u \cdot L^2 = \frac{1}{16} \cdot 1.491{,}2 \cdot 6^2 = 3.355{,}2 \text{ Kgm}$

$V_1 = V_2 = \frac{1}{2} \cdot Q_u \cdot L = \frac{1}{2} \cdot 1.491{,}2 \cdot 6 = 4.473{,}6 \text{ Kg}$

5.4.3 Syarat Batas Penulangan Balok Anak Atap

Reduksi Kuat Tekan Beton berdasarkan SNI 2847:2019 Tabel 22.2.2.4.3, karena fc' > 28 MPa, maka:

$\beta_1 = 0{,}85 - \left(\frac{0{,}05 \cdot (fc' - 28)}{7}\right) = 0{,}85 - \left(\frac{0{,}05 \cdot (35 - 28)}{7}\right) = 0{,}8$

$\rho_b = \frac{0,85 \cdot fc \cdot \beta_1}{fy}\left(\frac{600}{600+fy}\right) = \frac{0,85 \cdot 35 \cdot 0,8}{420}\left(\frac{600}{600+420}\right) = 0,033$

$\rho_{max} = \rho_b \cdot 0,75 = 0,033 \cdot 0,75 = 0,025$

Berdasarkan SNI 2847:2019 Pasal 9.6.1.2, nilai ρ_{min} adalah:

$\rho_{min} = \frac{0,25 \cdot \sqrt{fc'}}{fy} = \frac{0,25 \cdot \sqrt{35}}{420} = 0,0035$

5.4.4 Penulangan Lentur Balok Anak Atap

Daerah Tumpuan

Penulangan

Tinggi Balok Anak (h) = 400 mm

Tebal Selimut Beton (s) = 40 mm (SNI 2847:2019 Tabel 20.6.1.3.1)

Diameter Tulangan Utama (D) = D12 mm

Diameter Tulangan Sengkang (∅) = ∅10 mm

d = h – s – D – ½∅ = 400 – 40 – 10 – ½12 = 344 mm

d' = h – d = 400 – 344 = 56 mm

$Momen_{tumpuan} = 4.880,3$ Kgm = 48.803.000 Nmm

$Mn = \frac{Mu}{\emptyset} = \frac{48.803.000}{0,8} = 61.003.750$ Nmm

Xmin = d` = 56 mm

$Xmax = 0,75 \cdot \left(\frac{600 \cdot d}{600+fy}\right) = 0,75 \cdot \left(\frac{600 \cdot 344}{600+420}\right) = 151,3$ mm

Digunakan X = 75 mm

$Asc = \frac{0,85 \cdot fc' \cdot \beta \cdot b \cdot X}{fy} = \frac{0,85 \cdot 35 \cdot 0,85 \cdot 200 \cdot 75}{420} = 903\ mm^2$

$Mnc = Asc \cdot fy \cdot \left(d - \frac{\beta - X}{2}\right) = 903 \cdot 420 \cdot \left(344 - \frac{0,85-75}{2}\right) = 144.167.198$ Nmm

$Mnc > Mn$ (OK)

Mns = Mn – Mnc = 61.003.750 – 144.167.198 = −83.163.448 Nmm

Karena, Mn – Mnc < 0, maka tidak perlu tulangan tekan. Sehingga didesain dengan menggunakan tulangan tunggal.

$Rn = \frac{Mn}{b \cdot d^2} = \frac{61.003.750}{200 \cdot 344^2} = 2,6$

$m = \frac{fy}{0,85 \cdot fc} = \frac{420}{0,85 \cdot 35} = 14,12$

$$\rho = \frac{1}{m} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot Rn}{fy}}\right) = \frac{1}{14,12} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 14,12 \cdot 2,6}{420}}\right)$$

$$\rho = 0,006$$

Luas Tulangan Tarik

$$As = \rho \cdot b \cdot d = 0,006 \cdot 200 \cdot 344 = 413 \text{ mm}^2$$

Dipakai 4D12 (452 mm^2)

Luas Tulangan Tekan

$$As' = 0,5 \cdot As = 0,5 \cdot 413 = 206 \text{ mm}^2$$

Dipakai 2D12 (226 mm^2)

Kontrol Kekuatan

$$\rho = \frac{As \text{ pakai}}{b \cdot d} = \frac{452}{200 \cdot 344} = 0,007$$

$$\rho_{min} < \rho < \rho_{max} \text{ (OK)}$$

$$a = \frac{As \cdot fy}{0,85 \cdot fc' \cdot b} = \frac{452 \cdot 420}{0,85 \cdot 35 \cdot 200} = 31,9 \text{ mm}$$

$$Mn = As \cdot fy \cdot \left(d - \frac{a}{2}\right) = 452 \cdot 420 \cdot \left(344 - \frac{31,9}{2}\right)$$

$$Mn = 62.086.614 \text{ Nmm}$$

Mn > Mn Beban (OK)

Daerah Lapangan

Penulangan

Tinggi Balok Anak (h) = 400 mm

Tebal Selimut Beton (s) = 40 mm (SNI 2847:2019 Tabel 20.6.1.3.1)

Diameter Tulangan Utama (D) = D12 mm

Diameter Tulangan Sengkang (∅) = ∅10 mm

d = h – s – D – ½∅ = 400 – 40 – 10 – ½12 = 344 mm

d' = h – d = 400 – 344 = 56 mm

$$Momen_{lapangan} = 3.355,2 \text{ Kgm} = 33.552.000 \text{ Nmm}$$

$$Mn = \frac{Mu}{\emptyset} = \frac{33.552.000}{0,8} = 41.940.000 \text{ Nmm}$$

Xmin = d` = 56 mm

$$Xmax = 0,75 \cdot \left(\frac{600 \cdot d}{600 + fy}\right) = 0,75 \cdot \left(\frac{600 \cdot 344}{600 + 420}\right) = 151,3 \text{ mm}$$

Digunakan X = 75 mm

$$Asc = \frac{0,85 \cdot fc' \cdot \beta \cdot b \cdot X}{fy} = \frac{0,85 \cdot 35 \cdot 0,85 \cdot 200 \cdot 75}{420} = 903 \text{ mm}^2$$

$$Mnc = Asc \cdot fy \cdot \left(d - \frac{\beta - X}{2}\right) = 903 \cdot 420 \cdot \left(344 - \frac{0{,}85 - 75}{2}\right) = 144.167.198 \text{ Nmm}$$

$Mnc > Mn$ (OK)

Mns = Mn – Mnc = 41.940.000 – 144.167.198 = $-102.227.198$ Nmm

Karena, Mn – Mnc < 0, maka tidak perlu tulangan tekan. Sehingga didesain dengan menggunakan tulangan tunggal.

$$Rn = \frac{Mn}{b \cdot d^2} = \frac{41.940.000}{200 \cdot 344^2} = 1{,}8$$

$$m = \frac{fy}{0{,}85 \cdot fc} = \frac{420}{0{,}85 \cdot 35} = 14{,}12$$

$$\rho = \frac{1}{m} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot Rn}{fy}}\right) = \frac{1}{14{,}12} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 14{,}12 \cdot 1{,}8}{420}}\right)$$

$$\rho = 0{,}004$$

Luas Tulangan Tarik

$$As = \rho \cdot b \cdot d = 0{,}004 \cdot 200 \cdot 344 = 275 \text{ mm}^2$$

Dipakai 3D14 (339 mm^2)

Luas Tulangan Tekan

$$As' = 0{,}5 \cdot As = 0{,}5 \cdot 275 = 138 \text{ mm}^2$$

Dipakai 2D12 (226 mm^2)

Kontrol Kekuatan

$$\rho = \frac{As \text{ pakai}}{b \cdot d} = \frac{339}{200 \cdot 344} = 0{,}005$$

$\rho_{min} < \rho < \rho_{max}$ (OK)

$$a = \frac{As \cdot fy}{0{,}85 \cdot fc' \cdot b} = \frac{339 \cdot 420}{0{,}85 \cdot 35 \cdot 200} = 23{,}9 \text{ mm}$$

$$Mn = As \cdot fy \cdot \left(d - \frac{a}{2}\right) = 339 \cdot 420 \cdot \left(344 - \frac{23{,}9}{2}\right)$$

$$Mn = 47.132.805 \text{ Nmm}$$

Mn > Mn Beban (OK)

5.4.5 Penulangan Geser Balok Anak Atap

Daerah Tumpuan

Beban Geser Terfaktor (Vu) = 4.473,6 Kg = 44.736 N

Kekuatan Geser Beton (Vc) $= \frac{1}{6} \cdot \sqrt{fc'} \cdot bw \cdot d = \frac{1}{6} \cdot \sqrt{35} \cdot 200 \cdot 343 = 67.640{,}5$ N

Kategori Desain

$\frac{1}{2} \cdot \varphi \cdot Vc$ $= \frac{1}{2} \cdot 0{,}6 \cdot 67.640{,}5$ = 20.292 N

$\varphi \cdot Vc$ $= 0{,}6 \cdot 67.640{,}5$ $= 40.584$ N

$\varphi \cdot Vc + \varphi min \cdot Vs$ $= 40.584 + \left(0{,}6 \cdot \frac{1}{3} \cdot 200 \cdot 343\right)$ $= 54.304$ N

$\varphi \cdot Vc + \varphi \cdot \frac{1}{3} \cdot \sqrt{fc'} \cdot bw \cdot d$ $= 40.584 + \left(0{,}6 \cdot \frac{1}{3} \cdot \sqrt{35} \cdot 200 \cdot 343\right)$ $= 121.753$ N

$\varphi \cdot Vc + \varphi \cdot \frac{2}{3} \cdot \sqrt{fc'} \cdot bw \cdot d$ $= 40.584 + \left(0{,}6 \cdot \frac{2}{3} \cdot \sqrt{35} \cdot 200 \cdot 343\right)$ $= 202.922$ N

Berdasarkan perhitungan di atas, maka masuk ke dalam Kategori Desain 3

$$(\varphi \cdot Vc) < Vu < (\varphi \cdot Vc + \varphi min \cdot Vs)$$

Dipakai sengkang 2 kaki (∅10-100)

$s \leq \frac{d}{2} \leq 600$ mm

$100 \text{ mm} \leq \frac{343}{2} \leq 600$ mm

$100 \text{ mm} \leq 171{,}5 \text{ mm} \leq 600 \text{ mm}$ (OK)

Daerah Lapangan

Beban Geser Terfaktor (Vu) = 4.473,6 Kg = 44.736 N

Nilai y = $\frac{Vu \cdot \left(\frac{L}{2} - \frac{b}{2} - d\right)}{\frac{L}{2}} = \frac{44.736 \times \left(\frac{6.000}{2} - \frac{200}{2} - 343\right)}{\frac{6.000}{2}} = 38.130$ N

Kekuatan Geser Beton (Vc) $= \frac{1}{6} \cdot \sqrt{fc'} \cdot bw \cdot d = \frac{1}{6} \cdot \sqrt{35} \cdot 200 \cdot 343 = 67.640{,}5$ N

Kategori Desain

$\frac{1}{2} \cdot \varphi \cdot Vc$ $= \frac{1}{2} \cdot 0{,}6 \cdot 67.640{,}5$ $= 20.292$ N

$\varphi \cdot Vc$ $= 0{,}6 \cdot 67.640{,}5$ $= 40.584$ N

$\varphi \cdot Vc + \varphi min \cdot Vs$ $= 40.584 + \left(0{,}6 \cdot \frac{1}{3} \cdot 200 \cdot 343\right)$ $= 54.304$ N

$\varphi \cdot Vc + \varphi \cdot \frac{1}{3} \cdot \sqrt{fc'} \cdot bw \cdot d$ $= 40.584 + \left(0{,}6 \cdot \frac{1}{3} \cdot \sqrt{35} \cdot 200 \cdot 343\right)$ $= 121.753$ N

$\varphi \cdot Vc + \varphi \cdot \frac{2}{3} \cdot \sqrt{fc'} \cdot bw \cdot d$ $= 40.584 + \left(0{,}6 \cdot \frac{2}{3} \cdot \sqrt{35} \cdot 200 \cdot 343\right)$ $= 202.922$ N

Berdasarkan perhitungan di atas, maka masuk ke dalam Kategori Desain 3

$$(\varphi \cdot Vc) < Vu < (\varphi \cdot Vc + \varphi min \cdot Vs)$$

Dipakai sengkang 2 kaki (∅10-100)

$s \leq \frac{d}{2} \leq 600$ mm

$100 \text{ mm} \leq \frac{343}{2} \leq 600$ mm

$100 \text{ mm} \leq 171{,}5 \text{ mm} \leq 600 \text{ mm}$ (OK)

5.5 Balok Anak Lantai

5.5.1 Pembebanan Balok Anak Lantai

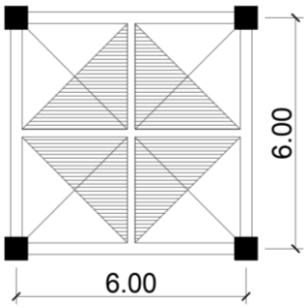
Beban Mati

Berat Sendiri Pelat Lantai	: 0,12 x 2.400	= 288	Kg/m^2
Plafond	: 11	= 11	Kg/m^2
Penggantung	: 7	= 7	Kg/m^2
Plumbing	: 10	= 10	Kg/m^2
Ducting AC	: 20	= 20	Kg/m^2
Keramik	: 24	= 24	Kg/m^2
Spesi 2 cm	: 2 x 21	= 42	Kg/m^2
Beban Mati Pelat Lantai		= 402	Kg/m^2 +

Beban Hidup

Beban Hidup Pelat Lantai		= 250	Kg/m^2

Pembebanan Segitiga pada Balok Anak Lantai



Gambar 5.4 Pembebanan Segitiga pada Balok Anak Lantai

Beban Mati (DL)

Berat Sendiri	: 0,2 x 0,4 x 2.400	= 192	Kg/m
Beban Ekivalen	: $\frac{1}{3} \cdot 402 \cdot 3 \cdot 2$	= 804	Kg/m
Total Beban Mati (DL)		= 996	Kg/m +

Beban Hidup (LL)

Beban Ekivalen	: $\frac{1}{3} \cdot 250 \cdot 3 \cdot 2$	= 500	Kg/m
Total Beban Hidup (LL)		= 500	Kg/m

Beban Ultimate (Qu)

Qu = 1,2DL + 1,6LL

Qu = (1,2 x 996) + (1,6 x 500)

Qu = 1.995,2 Kg/m

5.5.2 Gaya Dalam Balok Anak Lantai

$\text{Momen}_{\text{tumpuan}} = \frac{1}{11} \cdot Q_u \cdot L^2 = \frac{1}{11} \cdot 1.995{,}2 \cdot 6^2 = 6.529{,}7$ Kgm

$\text{Momen}_{\text{lapangan}} = \frac{1}{16} \cdot Q_u \cdot L^2 = \frac{1}{16} \cdot 1.995{,}2 \cdot 6^2 = 4.489{,}2$ Kgm

$V_1 = V_2 = \frac{1}{2} \cdot Q_u \cdot L = \frac{1}{2} \cdot 1.995{,}2 \cdot 6 = 5.985{,}6$ Kg

5.5.3 Syarat Batas Penulangan Balok Anak Lantai

Reduksi Kuat Tekan Beton berdasarkan SNI 2847:2019 Tabel 22.2.2.4.3, karena fc' > 28 MPa, maka:

$\beta_1 = 0{,}85 - \left(\frac{0{,}05 \cdot (fc' - 28)}{7}\right) = 0{,}85 - \left(\frac{0{,}05 \cdot (35-28)}{7}\right) = 0{,}8$

$\rho_b = \frac{0{,}85 \cdot fc \cdot \beta_1}{fy}\left(\frac{600}{600+fy}\right) = \frac{0{,}85 \cdot 35 \cdot 0{,}8}{420}\left(\frac{600}{600+420}\right) = 0{,}033$

$\rho_{max} = \rho_b \cdot 0{,}75 = 0{,}033 \cdot 0{,}75 = 0{,}025$

Berdasarkan SNI 2847:2019 Pasal 9.6.1.2, nilai ρ_{min} adalah:

$\rho_{min} = \frac{0{,}25 \cdot \sqrt{fc'}}{fy} = \frac{0{,}25 \cdot \sqrt{35}}{420} = 0{,}0035$

5.5.4 Penulangan Lentur Balok Anak Lantai

Daerah Tumpuan

Penulangan

Tinggi Balok Anak (h) = 400 mm

Tebal Selimut Beton (s) = 40 mm (SNI 2847:2019 Tabel 20.6.1.3.1)

Diameter Tulangan Utama (D) = D14 mm

Diameter Tulangan Sengkang (∅) = ∅10 mm

d = h – s – D – ½∅ = 400 – 40 – 10 – ½14 = 343 mm

d' = h – d = 400 – 343 = 57 mm

$\text{Momen}_{\text{tumpuan}} = 6.529{,}7$ Kgm = 65.297.000 Nmm

$Mn = \frac{Mu}{\emptyset} = \frac{65.297.000}{0{,}8} = 81.621.250$ Nmm

Xmin = d` = 57 mm

$$\text{Xmax} = 0{,}75 \cdot \left(\frac{600 \cdot \text{d}}{600+\text{fy}}\right) = 0{,}75 \cdot \left(\frac{600 \cdot 343}{600+420}\right) = 150{,}4 \text{ mm}$$

Digunakan X = 75 mm

$$\text{Asc} = \frac{0{,}85 \cdot \text{fc}' \cdot \beta \cdot \text{b} \cdot \text{X}}{\text{fy}} = \frac{0{,}85 \cdot 35 \cdot 0{,}85 \cdot 200 \cdot 75}{420} = 903 \text{ mm}^2$$

$$\text{Mnc} = \text{Asc} \cdot \text{fy} \cdot \left(\text{d} - \frac{\beta - \text{X}}{2}\right) = 903 \cdot 420 \cdot \left(343 - \frac{0{,}85 - 75}{2}\right) = 143.408.573 \text{ Nmm}$$

$$\text{Mnc} > \text{Mn (OK)}$$

Mns = Mn – Mnc = 81.621.250 – 143.408.573 = −61.787.323 Nmm

Karena, Mn – Mnc < 0, maka tidak perlu tulangan tekan. Sehingga didesain dengan menggunakan tulangan tunggal.

$$\text{Rn} = \frac{\text{Mn}}{\text{b} \cdot \text{d}^2} = \frac{81.621.250}{200 \cdot 343^2} = 3{,}4$$

$$\text{m} = \frac{\text{fy}}{0{,}85 \cdot \text{fc}} = \frac{420}{0{,}85 \cdot 35} = 14{,}12$$

$$\rho = \frac{1}{\text{m}} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot \text{m} \cdot \text{Rn}}{\text{fy}}}\right) = \frac{1}{14{,}12} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 14{,}12 \cdot 3{,}4}{420}}\right)$$

$$\rho = 0{,}0086$$

Luas Tulangan Tarik

$$\text{As} = \rho \cdot \text{b} \cdot \text{d} = 0{,}0086 \cdot 200 \cdot 343 = 591 \text{ mm}^2$$

Dipakai 4D14 (616 mm^2)

Luas Tulangan Tekan

$$\text{As}' = 0{,}5 \cdot \text{As} = 0{,}5 \cdot 591 = 295{,}5 \text{ mm}^2$$

Dipakai 2D14 (308 mm^2)

Kontrol Kekuatan

$$\rho = \frac{\text{As pakai}}{\text{b} \cdot \text{d}} = \frac{616}{200 \cdot 343} = 0{,}009$$

$$\rho_{\text{min}} < \rho < \rho_{\text{max}} \text{ (OK)}$$

$$\text{a} = \frac{\text{As} \cdot \text{fy}}{0{,}85 \cdot \text{fc}' \cdot \text{b}} = \frac{616 \cdot 420}{0{,}85 \cdot 35 \cdot 200} = 43{,}5 \text{ mm}$$

$$\text{Mn} = \text{As} \cdot \text{fy} \cdot \left(\text{d} - \frac{\text{a}}{2}\right) = 616 \cdot 420 \cdot \left(343 - \frac{43{,}5}{2}\right)$$

$$\text{Mn} = 82.598.643 \text{ Nmm}$$

Mn > Mn Beban (OK)

Daerah Lapangan

Penulangan

Tinggi Balok Anak (h) = 400 mm

Tebal Selimut Beton (s) = 40 mm (SNI 2847:2019 Tabel 20.6.1.3.1)

Diameter Tulangan Utama (D) = D14 mm

Diameter Tulangan Sengkang (∅) = ∅10 mm

d = h – s – D – ½∅ = 400 – 40 – 10 – ½14 = 343 mm

d' = h – d = 400 – 343 = 57 mm

$\text{Momen}_{\text{lapangan}} = 4.489{,}2$ Kgm = 44.890.000 Nmm

$\text{Mn} = \frac{\text{Mu}}{\emptyset} = \frac{44.890.000}{0{,}8} = 56.115.000$ Nmm

Xmin = d` = 59 mm

$\text{Xmax} = 0{,}75 \cdot \left(\frac{600 \cdot \text{d}}{600+\text{fy}}\right) = 0{,}75 \cdot \left(\frac{600 \cdot 341}{600+420}\right) = 150{,}4$ mm

Digunakan X = 75 mm

$\text{Asc} = \frac{0{,}85 \cdot \text{fc}' \cdot \beta \cdot \text{b} \cdot \text{X}}{\text{fy}} = \frac{0{,}85 \cdot 35 \cdot 0{,}85 \cdot 200 \cdot 75}{420} = 903 \text{ mm}^2$

$\text{Mnc} = \text{Asc} \cdot \text{fy} \cdot \left(\text{d} - \frac{\beta - \text{X}}{2}\right) = 903 \cdot 420 \cdot \left(341 - \frac{0{,}85-75}{2}\right) = 143.408.573$ Nmm

$\text{Mnc} > \text{Mn}$ (OK)

Mns = Mn – Mnc = 56.115.000 – 143.408.573 = −87.293.573 Nmm

Karena, Mn – Mnc < 0, maka tidak perlu tulangan tekan. Sehingga didesain dengan menggunakan tulangan tunggal.

$\text{Rn} = \frac{\text{Mn}}{\text{b} \cdot \text{d}^2} = \frac{56.115.000}{200 \cdot 343^2} = 2{,}4$

$\text{m} = \frac{\text{fy}}{0{,}85 \cdot \text{fc}} = \frac{420}{0{,}85 \cdot 35} = 14{,}12$

$\rho = \frac{1}{\text{m}} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot \text{m} \cdot \text{Rn}}{\text{fy}}}\right) = \frac{1}{14{,}12} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 14{,}12 \cdot 2{,}4}{420}}\right)$

$\rho = 0{,}006$

Luas Tulangan Tarik

$\text{As} = \rho \cdot \text{b} \cdot \text{d} = 0{,}006 \cdot 200 \cdot 343 = 412 \text{ mm}^2$

Dipakai 3D14 (462 mm^2)

Luas Tulangan Tekan

$\text{As}' = 0{,}5 \cdot \text{As} = 0{,}5 \cdot 412 = 206 \text{ mm}^2$

Dipakai 2D14 (308 mm^2)

Kontrol Kekuatan

$\rho = \frac{\text{As pakai}}{\text{b} \cdot \text{d}} = \frac{462}{200 \cdot 343} = 0{,}007$

$\rho_{\text{min}} < \rho < \rho_{\text{max}}$ (OK)

$a = \frac{As \cdot fy}{0{,}85 \cdot fc' \cdot b} = \frac{462 \cdot 420}{0{,}85 \cdot 35 \cdot 200} = 32{,}6 \text{ mm}$

$Mn = As \cdot fy \cdot \left(d - \frac{a}{2}\right) = 462 \cdot 420 \cdot \left(343 - \frac{32{,}6}{2}\right)$

$Mn = 63.003.647 \text{ Nmm}$

Mn > Mn Beban (OK)

5.5.5 Penulangan Geser Balok Anak Lantai

Daerah Tumpuan

Beban Geser Terfaktor (Vu) = 5.985,6 Kg = 59.856 N

Kekuatan Geser Beton (Vc) $= \frac{1}{6} \cdot \sqrt{fc'} \cdot bw \cdot d = \frac{1}{6} \cdot \sqrt{35} \cdot 200 \cdot 341 = 67.246{,}1 \text{ N}$

Kategori Desain

$\frac{1}{2} \cdot \varphi \cdot Vc$	$= \frac{1}{2} \cdot 0{,}6 \cdot 67.246{,}1$	= 20.174 N
$\varphi \cdot Vc$	$= 0{,}6 \cdot 67.246{,}1$	= 40.348 N
$\varphi \cdot Vc + \varphi min \cdot Vs$	$= 40.348 + \left(0{,}6 \cdot \frac{1}{3} \cdot 200 \cdot 341\right)$	= 53.988 N
$\varphi \cdot Vc + \varphi \cdot \frac{1}{3} \cdot \sqrt{fc'} \cdot bw \cdot d$	$= 40.348 + \left(0{,}6 \cdot \frac{1}{3} \cdot \sqrt{35} \cdot 200 \cdot 341\right)$	= 121.043 N
$\varphi \cdot Vc + \varphi \cdot \frac{2}{3} \cdot \sqrt{fc'} \cdot bw \cdot d$	$= 40.348 + \left(0{,}6 \cdot \frac{2}{3} \cdot \sqrt{35} \cdot 200 \cdot 341\right)$	= 201.738 N

Berdasarkan perhitungan di atas, maka masuk ke dalam Kategori Desain 4

$$(\varphi \cdot Vc + \varphi min \cdot Vs) < Vu < \left(\varphi \cdot Vc + \varphi \cdot \frac{1}{3} \cdot \sqrt{fc'} \cdot bw \cdot d\right)$$

Dipakai sengkang 2 kaki (∅10-100)

$s \leq \frac{d}{2} \leq 600 \text{ mm}$

$100 \text{ mm} \leq \frac{341}{2} \leq 600 \text{ mm}$

$100 \text{ mm} \leq 170{,}5 \text{ mm} \leq 600 \text{ mm}$ (OK)

Daerah Lapangan

Beban Geser Terfaktor (Vu) = 5.985,6 Kg = 59.856 N

Nilai y $= \frac{Vu \cdot \left(\frac{L}{2} - \frac{b}{2} - d\right)}{\frac{L}{2}} = \frac{59.856 \times \left(\frac{6.000}{2} - \frac{200}{2} - 341\right)}{\frac{6.000}{2}} = 51.057 \text{ N}$

Kekuatan Geser Beton (Vc) $= \frac{1}{6} \cdot \sqrt{fc'} \cdot bw \cdot d = \frac{1}{6} \cdot \sqrt{35} \cdot 200 \cdot 341 = 67.246{,}1 \text{ N}$

Kategori Desain

$\frac{1}{2} \cdot \varphi \cdot Vc$	$= \frac{1}{2} \cdot 0{,}6 \cdot 67.246{,}1$	= 20.174 N
$\varphi \cdot Vc$	$= 0{,}6 \cdot 67.246{,}1$	= 40.348 N

$\varphi \cdot Vc + \varphi min \cdot Vs = 40.348 + \left(0{,}6 \cdot \frac{1}{3} \cdot 200 \cdot 341\right) = 53.988$ N

$\varphi \cdot Vc + \varphi \cdot \frac{1}{3} \cdot \sqrt{fc'} \cdot bw \cdot d = 40.348 + \left(0{,}6 \cdot \frac{1}{3} \cdot \sqrt{35} \cdot 200 \cdot 341\right) = 121.043$ N

$\varphi \cdot Vc + \varphi \cdot \frac{2}{3} \cdot \sqrt{fc'} \cdot bw \cdot d = 40.348 + \left(0{,}6 \cdot \frac{2}{3} \cdot \sqrt{35} \cdot 200 \cdot 341\right) = 201.738$ N

Berdasarkan perhitungan di atas, maka masuk ke dalam Kategori Desain 4

$$(\varphi \cdot Vc + \varphi min \cdot Vs) < Vu < \left(\varphi \cdot Vc + \varphi \cdot \frac{1}{3} \cdot \sqrt{fc'} \cdot bw \cdot d\right)$$

Dipakai sengkang 2 kaki (∅10-100)

$s \leq \frac{d}{2} \leq 600$ mm

$100 \text{ mm} \leq \frac{341}{2} \leq 600 \text{ mm}$

$100 \text{ mm} \leq 170{,}5 \text{ mm} \leq 600 \text{ mm}$ (OK)

5.6 Tangga

Data Perencanaan Tangga pada Apartemen Niscala adalah sebagai berikut:

Beda Tinggi Lantai = 400 Cm

Elevasi Bordes = 200 Cm

Panjang Bordes = 300 Cm

Lebar Bordes = 200 Cm

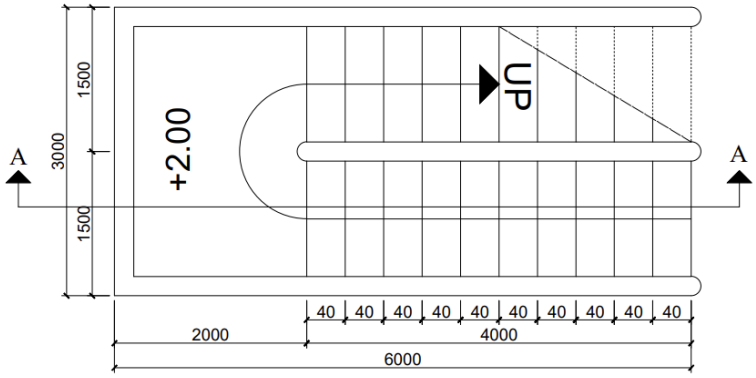
Tinggi Injakan = 20 Cm

Lebar Injakan = 40 Cm

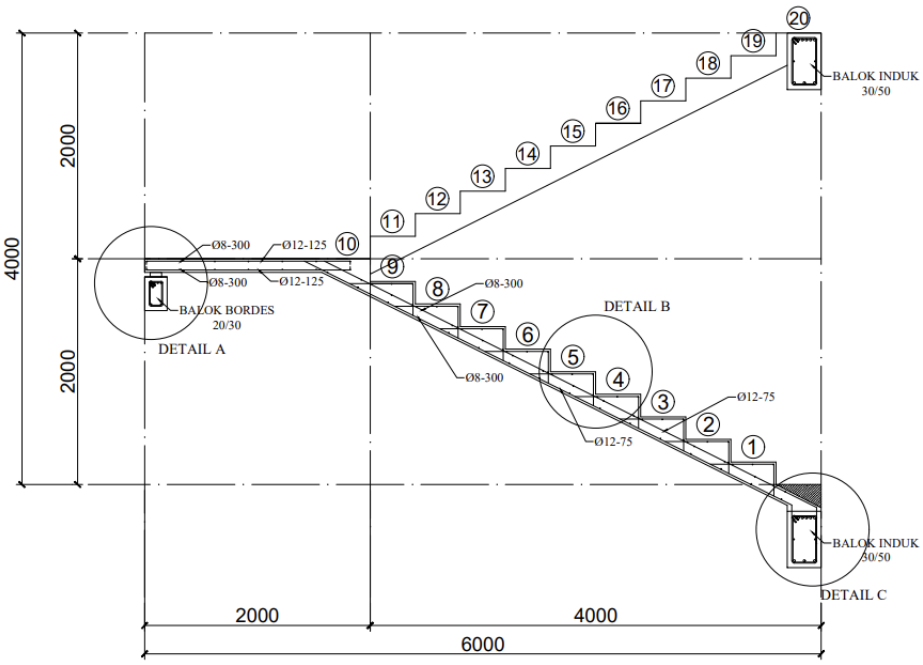
Jumlah Injakan Tangga = 10 Buah

Kemiringan Tangga $= \tan^{-1}\left(\frac{200}{400}\right) = 26{,}5° < 40°$ (OK)

Panjang Miring Tangga $= \sqrt{400^2 + 200^2} = 447{,}2$ Cm



Gambar 5.5 Denah Tangga



Gambar 5.6 Potongan A-A Tangga

5.6.1 Pembebanan Tangga

Beban Pelat Miring Tangga

Beban Mati (DL)

Berat Sendiri	: 0,12 x 2.400 x sec 26,5	= 321,8	Kg/m^2
Spesi 2 Cm	: 2 x 21	= 42	Kg/m^2
Keramik	: 24	= 24	Kg/m^2
Sandaran	: 30	= 30	Kg/m^2
Anak Tangga	: 0,089 x 2.400	= 213,6	Kg/m^2
Beban Mati Pelat Miring Tangga (DL)		= 631,4	Kg/m^2

+

Beban Hidup (LL)

Beban Hidup Pelat Miring Tangga (LL)	= 300	Kg/m^2

Beban Ultimate (Qu)

Qu = (1,2DL + 1,6LL) x 1,5

Qu = ((1,2 x 631,4) + (1,6 x 300)) x 1,5

Qu = 1.856,55 Kg/m’

Beban Pelat Bordes Tangga

Beban Mati (DL)

Berat Sendiri	: 0,12 x 2.400	= 288	Kg/m^2
Spesi 2 Cm	: 2 x 21	= 42	Kg/m^2
Keramik	: 24	= 24	Kg/m^2
Sandaran	: 30	= 30	Kg/m^2
Beban Mati Pelat Miring Tangga (DL)		= 384	Kg/m^2 +

Beban Hidup (LL)

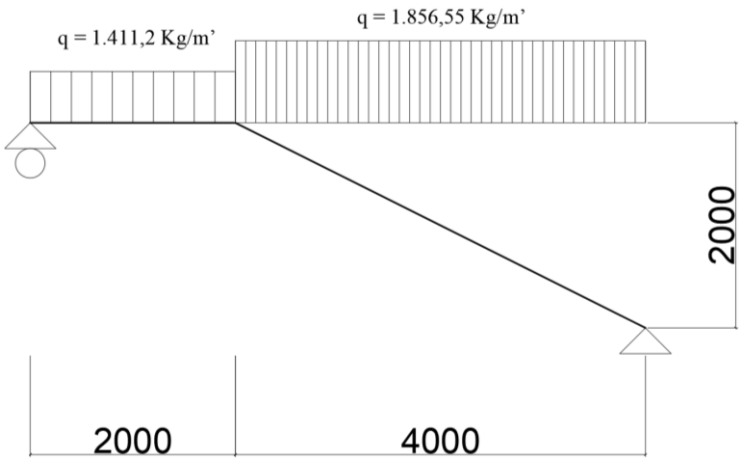
Beban Hidup Pelat Miring Tangga (LL) = 300 Kg/m^2

Beban Ultimate (Qu)

Qu = (1,2DL + 1,6LL) x 1,5

Qu = ((1,2 x 384) + (1,6 x 300)) x 1,5

Qu = 1.411,2 Kg/m’



Gambar 5.7 Analisa Statika Tangga

5.6.2 Syarat Batas Penulangan Tangga

Reduksi Kuat Tekan Beton berdasarkan SNI 2847:2019 Tabel 22.2.2.4.3, karena fc’ > 28 MPa, maka:

$$\beta_1 = 0{,}85 - \left(\frac{0{,}05\cdot(fc'-28)}{7}\right) = 0{,}85 - \left(\frac{0{,}05\cdot(35-28)}{7}\right) = 0{,}8$$

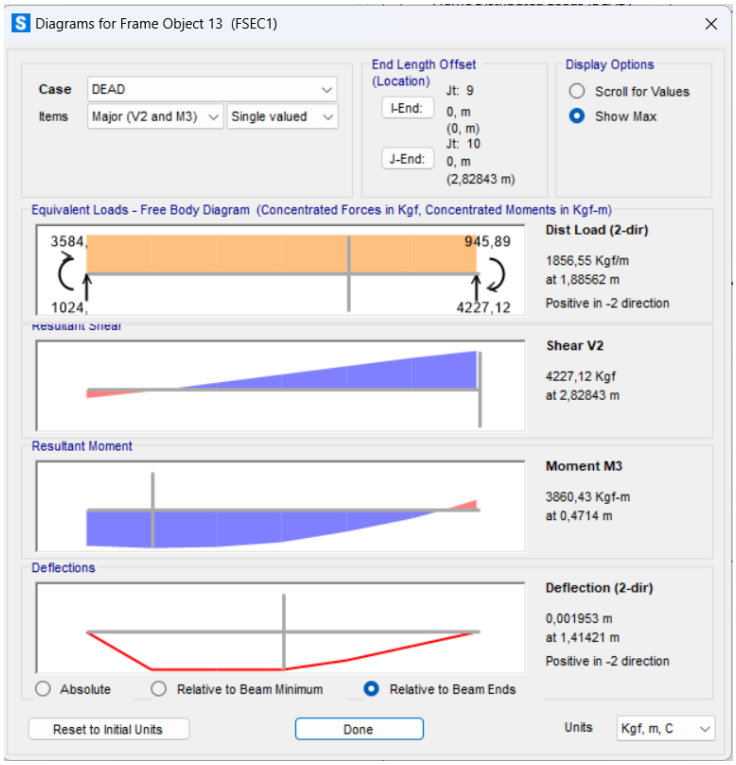
$$\rho_b = \frac{0{,}85\cdot fc\cdot\beta_1}{fy}\left(\frac{600}{600+fy}\right) = \frac{0{,}85\cdot 35\cdot 0{,}8}{420}\left(\frac{600}{600+420}\right) = 0{,}033$$

$$\rho_{max} = \rho_b \cdot 0{,}75 = 0{,}033 \cdot 0{,}75 = 0{,}025$$

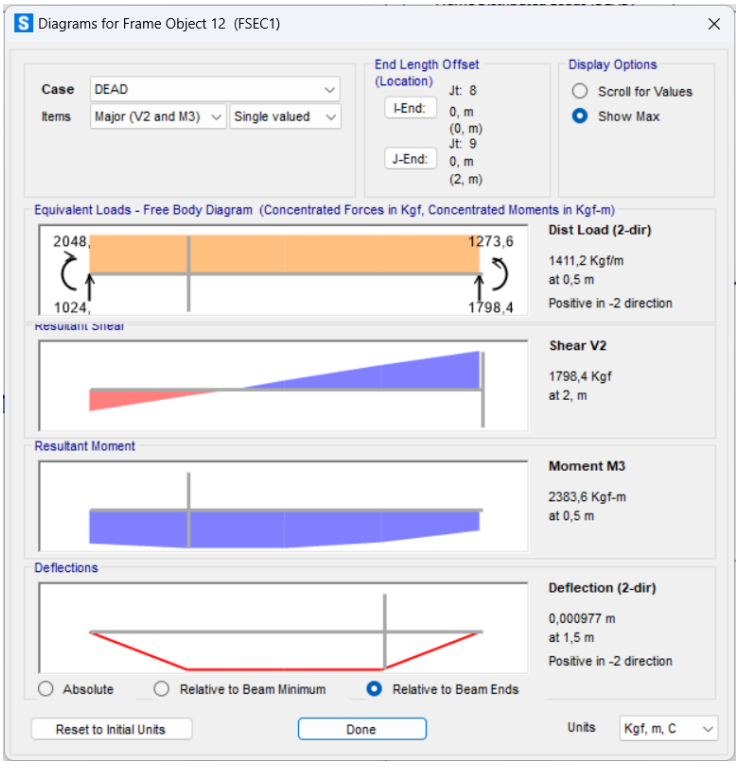
Berdasarkan SNI 2847:2019 Tabel 8.6.1.1, nilai ρ_{min} adalah:

$$\rho_{min} = \frac{0{,}0018\cdot 420}{fy} = \frac{0{,}0018\cdot 420}{420} = 0{,}0018$$

5.6.3 Gaya Dalam Tangga



Gambar 5.8 Gaya Dalam Pelat Miring Tangga



Gambar 5.9 Gaya Dalam Pelat Bordes Tangga

5.6.4 Penulangan Pelat Miring Tangga

Arah X

Penulangan

Tebal Pelat Tangga (h) = 120 mm

Tebal Selimut Beton (s) = 20 mm (SNI 2847:2019 Tabel 20.6.1.3.1)

Diameter Tulangan Utama (D) = 12 mm

Diameter Tulangan Susut (Ø) = 8 mm

d = h – s – ½D = 120 – 20 – ½12 = 94 mm

d' = h – s – D – ½D_s = 120 – 20 – 8 – ½12 = 86 mm

Mu = 3.860,43 Kgm = 38.604.300 Nmm

$$m = \frac{fy}{0{,}85 \cdot fc} = \frac{420}{0{,}85 \cdot 35} = 14{,}12$$

$$Mn = \frac{Mu}{\varnothing} = \frac{38.604.300}{0{,}8} = 48.255.375 \text{ Nmm}$$

$$Rn = \frac{Mn}{b \cdot d^2} = \frac{48.255.375}{1.000 \cdot 94^2} = 5{,}5$$

$$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2 \cdot m \cdot Rn}{fy}}\right) = \frac{1}{14{,}12}\left(1 - \sqrt{1 - \frac{2 \cdot 14{,}12 \cdot 5{,}5}{420}}\right)$$

$$\rho = 0{,}015$$

Tulangan yang Dibutuhkan

$$As = \rho \cdot b \cdot d = 0{,}015 \cdot 1.000 \cdot 94 = 1.410 \text{ mm}^2$$

Dipakai D12–75 (1.508 mm^2)

Kontrol Kekuatan

$$\rho = \frac{As \text{ pakai}}{b \cdot d} = \frac{1.508}{1.000 \cdot 94} = 0{,}016$$

$$\rho_{min} < \rho < \rho_{max} \text{ (OK)}$$

$$a = \frac{As \cdot fy}{0{,}85 \cdot fc' \cdot b} = \frac{1.508 \cdot 420}{0{,}85 \cdot 35 \cdot 1.000} = 21{,}29 \text{ mm}$$

$$Mn = As \cdot fy \cdot \left(d - \frac{a}{2}\right) = 1.508 \cdot 420 \cdot \left(94 - \frac{21{,}29}{2}\right)$$

$$Mn = 52.73.723 \text{ Nmm}$$

Mn > Mn Beban (OK)

Tulangan yang Dibutuhkan

Jarak tulangan ≤ 3 x Tebal Plat

75 ≤ 3 x 120 mm

75 mm ≤ 360 mm (OK)

Tulangan bagi

$$Asb = \frac{1}{4} \cdot D^2 \cdot \pi \cdot \frac{b}{s} = \frac{1}{4} \cdot 12^2 \cdot \frac{22}{7} \cdot \frac{1.000}{75} = 1.509 \text{ mm}^2$$

Asb ≥ Asb yg dipakai (OK)

Arah Y

Penulangan

Tebal Pelat Tangga (h) = 120 mm

Tebal Selimut Beton (s) = 20 mm (SNI 2847:2019 Tabel 20.6.1.3.1)

Diameter Tulangan Utama (D) = 12 mm

Diameter Tulangan Susut (Ø) = 8 mm

d = h – s – ½D = 120 – 20 – ½12 = 94 mm

d' = h – s – D – ½D_s = 120 – 20 – 8 – ½12 = 86 mm

Mu = 3.860,43 Kgm = 38.604.300 Nmm

$$m = \frac{fy}{0{,}85 \cdot fc} = \frac{420}{0{,}85 \cdot 35} = 14{,}12$$

$$Mn = \frac{Mu}{\varnothing} = \frac{38.604.300}{0{,}8} = 48.255.375 \text{ Nmm}$$

$$Rn = \frac{Mn}{b \cdot d^2} = \frac{48.255.375}{1.000 \cdot 94^2} = 5{,}5$$

$$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2 \cdot m \cdot Rn}{fy}}\right) = \frac{1}{14{,}12}\left(1 - \sqrt{1 - \frac{2 \cdot 14{,}12 \cdot 5{,}5}{420}}\right)$$

$$\rho = 0{,}015$$

Tulangan yang Dibutuhkan

$$As = \rho \cdot b \cdot d = 0{,}015 \cdot 1.000 \cdot 94 = 1.410 \text{ mm}^2$$

Dipakai D12–75 (1.508 mm^2)

Kontrol Kekuatan

$$\rho = \frac{As \text{ pakai}}{b \cdot d} = \frac{1.508}{1.000 \cdot 94} = 0{,}016$$

$\rho_{min} < \rho < \rho_{max}$ (OK)

$$a = \frac{As \cdot fy}{0{,}85 \cdot fc' \cdot b} = \frac{1.508 \cdot 420}{0{,}85 \cdot 35 \cdot 1.000} = 21{,}29 \text{ mm}$$

$$Mn = As \cdot fy \cdot \left(d - \frac{a}{2}\right) = 1.508 \cdot 420 \cdot \left(94 - \frac{21{,}29}{2}\right)$$

$$Mn = 52.73.723 \text{ Nmm}$$

Mn > Mn Beban (OK)

Tulangan yang Dibutuhkan

Jarak tulangan ≤ 3 x Tebal Plat

75 ≤ 3 x 120 mm

75 mm ≤ 360 mm (OK)

Tulangan bagi

$$Asb = \frac{1}{4} \cdot D^2 \cdot \pi \cdot \frac{b}{s} = \frac{1}{4} \cdot 12^2 \cdot \frac{22}{7} \cdot \frac{1.000}{75} = 1.509 \text{ mm}^2$$

Asb ≥ Asb yg dipakai (OK)

Kontrol Retak Pelat Miring Tangga

$$fs = 60\% \cdot fy = 0{,}6 \cdot 420 = 252 \text{ MPa}$$

$$dc = s + \frac{1}{2} \cdot D = 20 + \frac{1}{2} \cdot 10 = 25 \text{ mm}$$

$$A = 2 \cdot dc \cdot h = 2 \cdot 25 \cdot 120 = 6.000 \text{ mm}^2$$

$$Z = fs \cdot \sqrt[3]{dc \cdot A} = 252 \cdot \sqrt[3]{25 \cdot 6.000} = 13{,}39 \text{ MN/m}$$

Untuk penampang yang di pengaruhi cuaca luar, nilai $Z = 25$ MN/m.

Z kontrol < Z max (OK)

5.6.5 Penulangan Pelat Bordes Tangga

Arah X

Penulangan

Tebal Pelat Bordes (h) = 120 mm

Tebal Selimut Beton (s) = 20 mm (SNI 2847:2019 Tabel 20.6.1.3.1)

Diameter Tulangan Utama (D) = 12 mm

Diameter Tulangan Susut (Ø) = 8 mm

d = h – s – ½D = 120 – 20 – ½12 = 96 mm

d' = h – s – D – ½D_s = 120 – 20 – 12 – ½8 = 86 mm

Mu = 2.383,6 Kgm = 23.836.000 Nmm

$$m = \frac{fy}{0{,}85 \cdot fc} = \frac{420}{0{,}85 \cdot 35} = 14{,}12$$

$$Mn = \frac{Mu}{\varnothing} = \frac{23.836.000}{0{,}8} = 29.795.000 \text{ Nmm}$$

$$Rn = \frac{Mn}{b \cdot d^2} = \frac{29.795.000}{1.000 \cdot 94^2} = 3{,}4$$

$$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2 \cdot m \cdot Rn}{fy}}\right) = \frac{1}{14{,}12}\left(1 - \sqrt{1 - \frac{2 \cdot 14{,}12 \cdot 3{,}4}{420}}\right)$$

$$\rho = 0{,}009$$

Tulangan yang Dibutuhkan

$As = \rho \cdot b \cdot d = 0{,}009 \cdot 1.000 \cdot 94 = 846\ mm^2$

Dipakai D12–125 (905 mm^2)

Kontrol Kekuatan

$\rho = \frac{As\ pakai}{b \cdot d} = \frac{905}{1.000 \cdot 94} = 0{,}010$

$\rho_{min} < \rho < \rho_{max}$ (OK)

$a = \frac{As \cdot fy}{0{,}85 \cdot fc' \cdot b} = \frac{905 \cdot 420}{0{,}85 \cdot 35 \cdot 1.000} = 12{,}78\ mm$

$Mn = As \cdot fy \cdot \left(d - \frac{a}{2}\right) = 905 \cdot 420 \cdot \left(94 - \frac{12{,}78}{2}\right)$

$Mn = 33.300.561\ Nmm$

Mn > Mn Beban (OK)

Tulangan yang Dibutuhkan

Jarak tulangan ≤ 3 x Tebal Plat

125 ≤ 3 x 120 mm

125 mm ≤ 360 mm (OK)

Tulangan bagi

$Asb = \frac{1}{4} \cdot D^2 \cdot \pi \cdot \frac{b}{s} = \frac{1}{4} \cdot 12^2 \cdot \frac{22}{7} \cdot \frac{1.000}{125} = 905{,}14\ mm^2$

Asb ≥ Asb yg dipakai (OK)

Arah Y

Penulangan

Tebal Pelat Bordes (h) = 120 mm

Tebal Selimut Beton (s) = 20 mm (SNI 2847:2019 Tabel 20.6.1.3.1)

Diameter Tulangan Utama (D) = 12 mm

Diameter Tulangan Susut (Ø) = 8 mm

d = h – s – ½D = 120 – 20 – ½12 = 96 mm

d' = h – s – D – ½D_s = 120 – 20 – 12 – ½8 = 86 mm

Mu = 2.383,6 Kgm = 23.836.000 Nmm

$m = \frac{fy}{0{,}85 \cdot fc} = \frac{420}{0{,}85 \cdot 35} = 14{,}12$

$Mn = \frac{Mu}{\varnothing} = \frac{23.836.000}{0{,}8} = 29.795.000\ Nmm$

$Rn = \frac{Mn}{b \cdot d^2} = \frac{29.795.000}{1.000 \cdot 94^2} = 3{,}4$

$$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2 \cdot m \cdot Rn}{fy}}\right) = \frac{1}{14{,}12}\left(1 - \sqrt{1 - \frac{2 \cdot 14{,}12 \cdot 3{,}4}{420}}\right)$$

$$\rho = 0{,}009$$

Tulangan yang Dibutuhkan

$$As = \rho \cdot b \cdot d = 0{,}009 \cdot 1.000 \cdot 94 = 846 \text{ mm}^2$$

Dipakai D12–125 (905 mm^2)

Kontrol Kekuatan

$$\rho = \frac{As \text{ pakai}}{b \cdot d} = \frac{905}{1.000 \cdot 94} = 0{,}010$$

$$\rho_{min} < \rho < \rho_{max} \text{ (OK)}$$

$$a = \frac{As \cdot fy}{0{,}85 \cdot fc' \cdot b} = \frac{905 \cdot 420}{0{,}85 \cdot 35 \cdot 1.000} = 12{,}78 \text{ mm}$$

$$Mn = As \cdot fy \cdot \left(d - \frac{a}{2}\right) = 905 \cdot 420 \cdot \left(94 - \frac{12{,}78}{2}\right)$$

$$Mn = 33.300.561 \text{ Nmm}$$

Mn > Mn Beban (OK)

Tulangan yang Dibutuhkan

Jarak tulangan ≤ 3 x Tebal Plat

125 ≤ 3 x 120 mm

125 mm ≤ 360 mm (OK)

Tulangan bagi

$$Asb = \frac{1}{4} \cdot D^2 \cdot \pi \cdot \frac{b}{s} = \frac{1}{4} \cdot 12^2 \cdot \frac{22}{7} \cdot \frac{1.000}{125} = 905{,}14 \text{ mm}^2$$

Asb ≥ Asb yg dipakai (OK)

Kontrol Retak Pelat Bordes Tangga

$$fs = 60\% \cdot fy = 0{,}6 \cdot 420 = 252 \text{ MPa}$$

$$dc = s + \frac{1}{2} \cdot D = 20 + \frac{1}{2} \cdot 10 = 25 \text{ mm}$$

$$A = 2 \cdot dc \cdot h = 2 \cdot 25 \cdot 120 = 6.000 \text{ mm}^2$$

$$Z = fs \cdot \sqrt[3]{dc \cdot A} = 252 \cdot \sqrt[3]{25 \cdot 6.000} = 13{,}39 \text{ MN/m}$$

Untuk penampang yang di pengaruhi cuaca luar, nilai $Z = 25$ MN/m.

Z kontrol < Z max (OK)

5.7 Balok Bordes Tangga

Perencanaan dimensi balok bordes tangga pada Apartemen Niscala adalah:

Tinggi Balok Bordes Tangga $= \frac{1}{16} \times 300 = 18{,}75$ Cm (Digunakan h = 30 Cm)

Lebar Balok Bordes Tangga $= 0{,}3 \times 30 = 9$ Cm (Digunakan b = 20 Cm)

Dimensi Balok Bordes Tangga = 20/30 Cm

5.7.1 Pembebanan Balok Bordes Tangga

Beban Mati (DL)

Berat Sendiri	: 0,20 x 0,30 x 2.400	=	144	Kg/m^2
Beban Mati Balok Bordes Tangga (DL)		=	144	Kg/m^2

Beban Hidup (LL)

Beban Bekerja pada Pelat Miring Tangga	=	1.856,55	Kg/m^2
Beban Bekerja pada Pelat Bordes Tangga	=	1.411,2	Kg/m^2
Beban Hidup Balok Bordes Tangga (LL)	=	3.267,75	Kg/m^2

Beban Ultimate (Qu)

Qu = 1,2DL + 1,6LL

Qu = (1,2 x 144) + (1,6 x 3.267,75)

Qu = 5.401,2 Kg/m^2

5.7.2 Gaya Dalam Balok Bordes Tangga

$\text{Momen}_{\text{tumpuan}} = \frac{1}{11} \cdot Q_u \cdot L^2 = \frac{1}{11} \cdot 3.658{,}4 \cdot 3^2 = 2.993{,}2$ Kgm

$\text{Momen}_{\text{lapangan}} = \frac{1}{16} \cdot Q_u \cdot L^2 = \frac{1}{16} \cdot 3.658{,}4 \cdot 3^2 = 2.057{,}8$ Kgm

$V_1 = V_2 = \frac{1}{2} \cdot Q_u \cdot L = \frac{1}{2} \cdot 3.658{,}4 \cdot 3 = 5.487{,}6$ Kg

5.7.3 Syarat Batas Penulangan Balok Bordes Tangga

Reduksi Kuat Tekan Beton berdasarkan SNI 2847:2019 Tabel 22.2.2.4.3, karena fc' > 28 MPa, maka:

$\beta_1 = 0{,}85 - \left(\frac{0{,}05 \cdot (fc' - 28)}{7}\right) = 0{,}85 - \left(\frac{0{,}05 \cdot (35 - 28)}{7}\right) = 0{,}8$

$\rho_b = \frac{0{,}85 \cdot fc \cdot \beta_1}{fy}\left(\frac{600}{600 + fy}\right) = \frac{0{,}85 \cdot 35 \cdot 0{,}8}{420}\left(\frac{600}{600 + 420}\right) = 0{,}033$

$\rho_{max} = \rho_b \cdot 0{,}75 = 0{,}033 \cdot 0{,}75 = 0{,}025$

Berdasarkan SNI 2847:2019 Pasal 9.6.1.2, nilai ρ_{min} adalah:

$$\rho_{min} = \frac{0{,}25\cdot\sqrt{fc'}}{fy} = \frac{0{,}25\cdot\sqrt{35}}{420} = 0{,}0035$$

5.7.4 Penulangan Lentur Balok Bordes Tangga

Daerah Tumpuan

Penulangan

Tinggi Balok Bordes (h) = 300 mm

Tebal Selimut Beton (s) = 40 mm (SNI 2847:2019 Tabel 20.6.1.3.1)

Diameter Tulangan Utama (D) = D12 mm

Diameter Tulangan Sengkang (∅) = ∅10 mm

d = h – s – D – ½∅ = 300 – 40 – 10 – ½12 = 244 mm

d' = h – d = 300 – 244 = 56 mm

$\text{Momen}_{tumpuan} = 2.993{,}2$ Kgm = 29.932.000 Nmm

$$Mn = \frac{Mu}{\emptyset} = \frac{29.932.000}{0{,}8} = 37.415.000 \text{ Nmm}$$

Xmin = d` = 56 mm

$$Xmax = 0{,}75 \cdot \left(\frac{600\cdot d}{600+fy}\right) = 0{,}75 \cdot \left(\frac{600\cdot 244}{600+420}\right) = 107{,}2 \text{ mm}$$

Digunakan X = 60 mm

$$Asc = \frac{0{,}85\cdot fc'\cdot\beta\cdot b\cdot X}{fy} = \frac{0{,}85\cdot 35\cdot 0{,}85\cdot 200\cdot 60}{420} = 722{,}5 \text{ mm}^2$$

$$Mnc = Asc \cdot fy \cdot \left(d - \frac{\beta - X}{2}\right) = 722{,}5 \cdot 420 \cdot \left(244 - \frac{0{,}85-60}{2}\right) = 112.450.984 \text{ Nmm}$$

$Mnc > Mn$ (OK)

Mns = Mn – Mnc = 37.415.000 – 112.450.984 = −75.035.984 Nmm

Karena, Mn – Mnc < 0, maka tidak perlu tulangan tekan. Sehingga didesain dengan menggunakan tulangan tunggal.

$$Rn = \frac{Mn}{b\cdot d^2} = \frac{37.415.000}{200\cdot 244^2} = 3{,}2$$

$$m = \frac{fy}{0{,}85\cdot fc} = \frac{420}{0{,}85\cdot 35} = 14{,}12$$

$$\rho = \frac{1}{m}\cdot\left(1 - \sqrt{1 - \frac{2\cdot m\cdot Rn}{fy}}\right) = \frac{1}{14{,}12}\cdot\left(1 - \sqrt{1 - \frac{2\cdot 14{,}12\cdot 3{,}2}{420}}\right)$$

$$\rho = 0{,}008$$

Luas Tulangan Tarik

$As = \rho \cdot b \cdot d = 0{,}008 \cdot 200 \cdot 244 = 390\ mm^2$

Dipakai 4D12 (452 mm^2)

Luas Tulangan Tekan

$As' = 0{,}5 \cdot As = 0{,}5 \cdot 390 = 195\ mm^2$

Dipakai 2D12 (226 mm^2)

Kontrol Kekuatan

$\rho = \frac{As\ pakai}{b \cdot d} = \frac{452}{200 \cdot 244} = 0{,}009$

$\rho_{min} < \rho < \rho_{max}$ (OK)

$a = \frac{As \cdot fy}{0{,}85 \cdot fc' \cdot b} = \frac{452 \cdot 420}{0{,}85 \cdot 35 \cdot 200} = 31{,}9\ mm$

$Mn = As \cdot fy \cdot \left(d - \frac{a}{2}\right) = 452 \cdot 420 \cdot \left(244 - \frac{31{,}9}{2}\right)$

$Mn = 43.102.614$ Nmm

Mn > Mn Beban (OK)

Daerah Lapangan

Penulangan

Tinggi Balok Bordes (h) = 300 mm

Tebal Selimut Beton (s) = 40 mm (SNI 2847:2019 Tabel 20.6.1.3.1)

Diameter Tulangan Utama (D) = D12 mm

Diameter Tulangan Sengkang (∅) = ∅10 mm

d = h – s – D – ½∅ = 300 – 40 – 10 – ½12 = 244 mm

d' = h – d = 300 – 244 = 56 mm

$Momen_{lapangan} = 2.057{,}8$ Kgm = 20.578.000 Nmm

$Mn = \frac{Mu}{\emptyset} = \frac{20.578.000}{0{,}8} = 25.722.500$ Nmm

Xmin = d` = 56 mm

$Xmax = 0{,}75 \cdot \left(\frac{600 \cdot d}{600 + fy}\right) = 0{,}75 \cdot \left(\frac{600 \cdot 244}{600 + 420}\right) = 107{,}2\ mm$

Digunakan X = 60 mm

$Asc = \frac{0{,}85 \cdot fc' \cdot \beta \cdot b \cdot X}{fy} = \frac{0{,}85 \cdot 35 \cdot 0{,}85 \cdot 200 \cdot 60}{420} = 722{,}5\ mm^2$

$Mnc = Asc \cdot fy \cdot \left(d - \frac{\beta - X}{2}\right) = 722{,}5 \cdot 420 \cdot \left(244 - \frac{0{,}85 - 60}{2}\right) = 112.450.984$ Nmm

$Mnc > Mn$ (OK)

Mns = Mn – Mnc = 25.722.500 – $112.450.984 = -86.728.484$ Nmm

Karena, Mn – Mnc < 0, maka tidak perlu tulangan tekan. Sehingga didesain dengan menggunakan tulangan tunggal.

$$\text{Rn} = \frac{\text{Mn}}{\text{b}\cdot\text{d}^2} = \frac{25.722.500}{200\cdot 244^2} = 2{,}2$$

$$\text{m} = \frac{\text{fy}}{0{,}85\cdot\text{fc}} = \frac{420}{0{,}85\cdot 35} = 14{,}12$$

$$\rho = \frac{1}{\text{m}}\cdot\left(1 - \sqrt{1 - \frac{2\cdot\text{m}\cdot\text{Rn}}{\text{fy}}}\right) = \frac{1}{14{,}12}\cdot\left(1 - \sqrt{1 - \frac{2\cdot 14{,}12\cdot 2{,}2}{420}}\right)$$

$$\rho = 0{,}005$$

Luas Tulangan Tarik

$$\text{As} = \rho\cdot\text{b}\cdot\text{d} = 0{,}005\cdot 200\cdot 244 = 244\ \text{mm}^2$$

Dipakai 3D12 (339 mm^2)

Luas Tulangan Tekan

$$\text{As}' = 0{,}5\cdot\text{As} = 0{,}5\cdot 244 = 122\ \text{mm}^2$$

Dipakai 2D12 (226 mm^2)

Kontrol Kekuatan

$$\rho = \frac{\text{As pakai}}{\text{b}\cdot\text{d}} = \frac{262}{200\cdot 244} = 0{,}007$$

$\rho_{\text{min}} < \rho < \rho_{\text{max}}$ (OK)

$$\text{a} = \frac{\text{As}\cdot\text{fy}}{0{,}85\cdot\text{fc}'\cdot\text{b}} = \frac{262\cdot 420}{0{,}85\cdot 35\cdot 200} = 23{,}9\ \text{mm}$$

$$\text{Mn} = \text{As}\cdot\text{fy}\cdot\left(\text{d} - \frac{\text{a}}{2}\right) = 262\cdot 420\cdot\left(243 - \frac{23{,}9}{2}\right)$$

$$\text{Mn} = 32.894.805\ \text{Nmm}$$

Mn > Mn Beban (OK)

5.7.5 Penulangan Geser Balok Bordes Tangga

Daerah Tumpuan

Beban Geser Terfaktor (Vu) = 5.487,6 Kg = 54.876 N

Kekuatan Geser Beton (Vc) $= \frac{1}{6}\cdot\sqrt{\text{fc}'}\cdot\text{bw}\cdot\text{d} = \frac{1}{6}\cdot\sqrt{35}\cdot 200\cdot 243 = 47.920{,}2$ N

Kategori Desain

$\frac{1}{2}\cdot\varphi\cdot\text{Vc}$	$= \frac{1}{2}\cdot 0{,}6\cdot 47.920{,}2$	= 14.376 N
$\varphi\cdot\text{Vc}$	$= 0{,}6\cdot 47.920{,}2$	= 28.752 N
$\varphi\cdot\text{Vc} + \varphi\text{min}\cdot\text{Vs}$	$= 28.752 + \left(0{,}6\cdot\frac{1}{3}\cdot 200\cdot 243\right)$	= 38.472 N
$\varphi\cdot\text{Vc} + \varphi\cdot\frac{1}{3}\cdot\sqrt{\text{fc}'}\cdot\text{bw}\cdot\text{d}$	$= 28.752 + \left(0{,}6\cdot\frac{1}{3}\cdot\sqrt{35}\cdot 200\cdot 243\right)$	= 86.256 N

$\varphi \cdot Vc + \varphi \cdot \frac{2}{3} \cdot \sqrt{fc'} \cdot bw \cdot d$ $= 28.752 + \left(0{,}6 \cdot \frac{2}{3} \cdot \sqrt{35} \cdot 200 \cdot 243\right)$ $= 143.761$ N

Berdasarkan perhitungan di atas, maka masuk ke dalam Kategori Desain 5

$$\left(\varphi \cdot Vc + \varphi \cdot \frac{1}{3} \cdot \sqrt{fc'} \cdot bw \cdot d\right) < Vu < \left(\varphi \cdot Vc + \varphi \cdot \frac{2}{3} \cdot \sqrt{fc'} \cdot bw \cdot d\right)$$

Dicoba menggunakan sengkang 2 kaki (∅10-50)

$s \leq \frac{d}{4} \leq 300$ mm

$50 \text{ mm} \leq \frac{243}{4} \leq 300$ mm

$50 \text{ mm} \leq 60{,}75 \text{ mm} \leq 300$ mm (OK)

Digunakan Sengkang 2 kaki ∅10-50

Daerah Lapangan

Beban Geser Terfaktor (Vu) = 5.487,6 Kg = 54.876 N

Nilai y = $\frac{Vu \cdot \left(\frac{L}{2} - \frac{b}{2} - d\right)}{\frac{L}{2}} = \frac{54.876 \times \left(\frac{3.000}{2} - \frac{200}{2} - 243\right)}{\frac{3.000}{2}} = 42.327{,}7$ N

Kekuatan Geser Beton (Vc) $= \frac{1}{6} \cdot \sqrt{fc'} \cdot bw \cdot d = \frac{1}{6} \cdot \sqrt{35} \cdot 200 \cdot 243 = 47.920{,}2$ N

Kategori Desain

$\frac{1}{2} \cdot \varphi \cdot Vc$ $= \frac{1}{2} \cdot 0{,}6 \cdot 47.920{,}2$ $= 14.376$ N

$\varphi \cdot Vc$ $= 0{,}6 \cdot 47.920{,}2$ $= 28.752$ N

$\varphi \cdot Vc + \varphi min \cdot Vs$ $= 28.752 + \left(0{,}6 \cdot \frac{1}{3} \cdot 200 \cdot 243\right)$ $= 38.472$ N

$\varphi \cdot Vc + \varphi \cdot \frac{1}{3} \cdot \sqrt{fc'} \cdot bw \cdot d$ $= 28.752 + \left(0{,}6 \cdot \frac{1}{3} \cdot \sqrt{35} \cdot 200 \cdot 243\right)$ $= 86.256$ N

$\varphi \cdot Vc + \varphi \cdot \frac{2}{3} \cdot \sqrt{fc'} \cdot bw \cdot d$ $= 28.752 + \left(0{,}6 \cdot \frac{2}{3} \cdot \sqrt{35} \cdot 200 \cdot 243\right)$ $= 143.761$ N

Berdasarkan perhitungan di atas, maka masuk ke dalam Kategori Desain 5

$$\left(\varphi \cdot Vc + \varphi \cdot \frac{1}{3} \cdot \sqrt{fc'} \cdot bw \cdot d\right) < Vu < \left(\varphi \cdot Vc + \varphi \cdot \frac{2}{3} \cdot \sqrt{fc'} \cdot bw \cdot d\right)$$

Dicoba menggunakan sengkang 2 kaki (∅10-50)

$s \leq \frac{d}{4} \leq 300$ mm

$50 \text{ mm} \leq \frac{243}{4} \leq 300$ mm

$50 \text{ mm} \leq 60{,}75 \text{ mm} \leq 300$ mm (OK)

Digunakan Sengkang 2 kaki ∅10-50

5.8 Balok Penggantung Lift

Perencanaan Balok Penggantung Lift pada sub-bab ini menggunakan lift penumpang duplex dengan data sebagai berikut:

Dimensi Balok Lift : 30 cm x 40 cm

Panjang Bentang : 6 Meter

Kapasitas : 17 Orang (1.150 Kg)

Kecepatan : 90 mm/menit

Lebar Pintu (*Open Width*) : 1.000 mm

Dimensi Sangkar (*Car Size*) *Outside* : 1.890 x 1.685 mm^2

Dimensi Sangkar (*Car Size*) *Indise* : 1.800 x 1.500 mm^2

Dimensi Ruang Luncur (*Hoistway*) : 2.200 x 4.950 mm^2

Dimensi Ruang Mesin (*Machine*) : 4.000 x 5.300 mm^2

Beban Reaksi Ruang Mesin :

R_1 = 7.750 Kg (Berat mesin penggerak lift + beban kereta + perlengkapan)

R_2 = 9.400 Kg (Berat bandul pemberat + perlengkapan)

5.8.1 Koefisien Kejut Beban Hidup oleh Keran

Balok Penggantung Lift memikul beban keran yang ditambah dengan berat pada muatan yang diangkat. Perhitungan beban rencana Balok Penggantung Lift perlu ditambahkan beban keran dengan koefisien seperti rumus di bawah:

$\Psi = (1 + k_1 + k_2 + V)$ $\geq 1{,}15$

$\Psi = (1 + 0{,}6 + 1{,}3 + 1)$ $\geq 1{,}15$

$\Psi = 1{,}78$ $\geq 1{,}15$

Keterangan:

Ψ = Koefisien kejut yang diakibatkan oleh keran, nilainya tidak boleh kurang dari 1,15

k_1 = Koefisien oleh kekuatan keran induk, umumnya diambil 0,6 untuk struktur rangka

k_2 = Koefisien pada sifat-sifat mesin angkat pada keran angkat, umumnya diambil 1,3

V = Kecepatan angkat maksimum yang nilainya tidak perlu lebih dari 1 m/det

Beban yang bekerja pada balok penggantung lift:

Pu_1 $= R_1 \times \Psi$ $= 7.750 \times 1{,}78$ $= 13.795$ Kg

Pu_2 $= R_2 \times \Psi$ $= 9.400 \times 1{,}78$ $= 16.732$ Kg

P $= Pu_1 + Pu_2$ $= 13.795 + 16.732$ $= 30.527$ Kg

5.8.2 Pembebanan Balok Penggantung Lift

Beban Terpusat

Beban Terpusat Lift	= 30.527	Kg/m`	
Kapasitas Lift	= 1.150	Kg/m`	
Total Beban Terpusat	= 31.677	Kg/m`	+

Beban Merata

Berat Sendiri Balok (DL): 0,3 x 0,4 x 2.400 = 288 Kg/m`

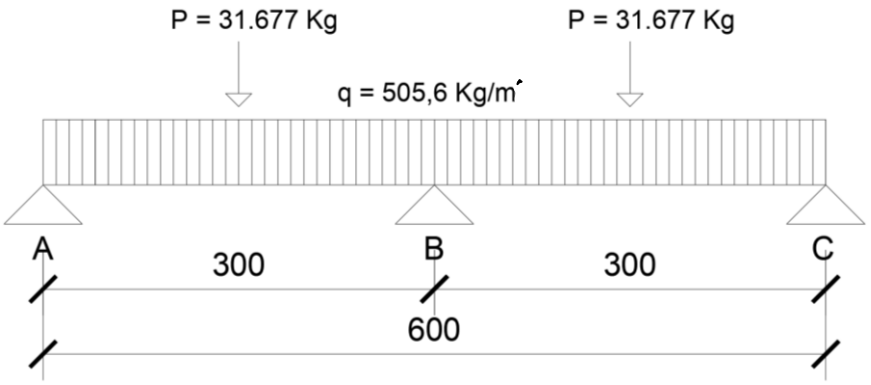
Beban Hidup Pekerja (LL) = 100 Kg/m`

Beban Ultimate (Qu)

Qu = 1,2DL + 1,6LL

Qu = (1,2 x 288) + (1,6 x 100)

Qu = 505,6 Kg/m`



Gambar 5.10 Analisa Statika Balok Penggantung Lift

5.8.3 Syarat Batas Penulangan Balok Penggantung Lift

Reduksi Kuat Tekan Beton berdasarkan SNI 2847:2019 Tabel 22.2.2.4.3, karena fc' > 28 MPa, maka:

$$\beta_1 = 0{,}85 - \left(\frac{0{,}05\cdot(fc'-28)}{7}\right) = 0{,}85 - \left(\frac{0{,}05\cdot(35-28)}{7}\right) = 0{,}8$$

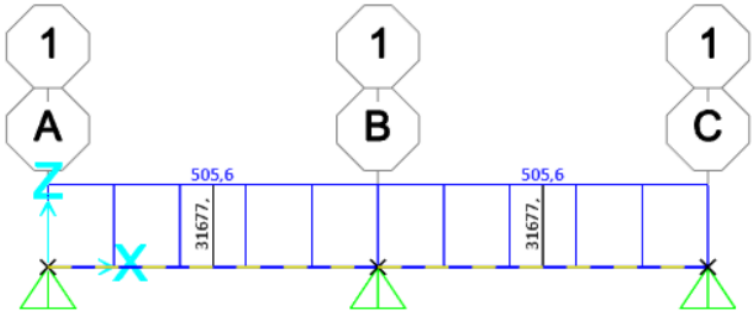
$$\rho_b = \frac{0{,}85\cdot fc\cdot\beta_1}{fy}\left(\frac{600}{600+fy}\right) = \frac{0{,}85\cdot 35\cdot 0{,}8}{420}\left(\frac{600}{600+420}\right) = 0{,}033$$

$$\rho_{max} = \rho_b \cdot 0{,}75 = 0{,}033 \cdot 0{,}75 = 0{,}025$$

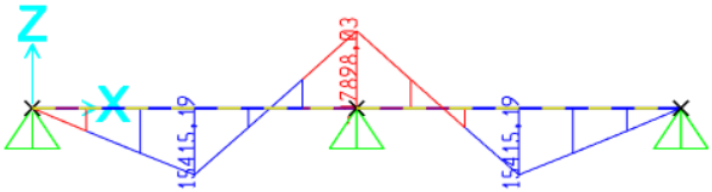
Berdasarkan SNI 2847:2019 Pasal 9.6.1.2, nilai ρ_{min} adalah:

$$\rho_{min} = \frac{0{,}25\cdot\sqrt{fc'}}{fy} = \frac{0{,}25\cdot\sqrt{35}}{420} = 0{,}0035$$

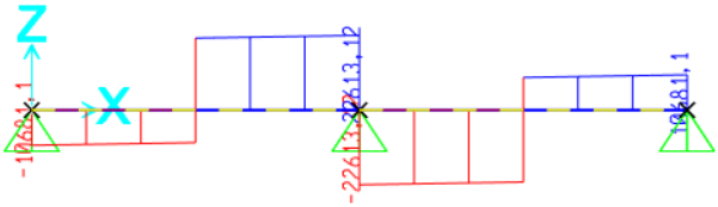
5.8.4 Gaya Dalam Balok Penggantung Lift



Gambar 5.11 Pembebanan Balok Penggantung Lift



Gambar 5.12 Gaya Momen Balok Penggantung Lift



Gambar 5.13 Gaya Geser Balok Penggantung Lift

5.8.5 Penulangan Lentur Balok Penggantung Lift

Daerah Tumpuan

Penulangan

Tinggi Balok Penggantung Lift (h) = 400 mm

Tebal Selimut Beton (s) = 40 mm (SNI 2847:2019 Tabel 20.6.1.3.1)

Diameter Tulangan Utama (D) = D22 mm

Diameter Tulangan Sengkang (∅) = ∅16 mm

d = h – s – D – ½∅ = 400 – 40 – 16 – ½22 = 333 mm

d' = h – d = 400 – 333 = 67 mm

$\text{Momen}_{\text{tumpuan}}$ = 17.898,03 Kgm = 178.980.300 Nmm

$$\text{Mn} = \frac{\text{Mu}}{\emptyset} = \frac{178.980.300}{0,8} = 223.725.375 \text{ Nmm}$$

Xmin = d` = 67 mm

$$\text{Xmax} = 0{,}75 \cdot \left(\frac{600 \cdot \text{d}}{600+\text{fy}}\right) = 0{,}75 \cdot \left(\frac{600 \cdot 333}{600+420}\right) = 145{,}6 \text{ mm}$$

Digunakan X = 80 mm

$$\text{Asc} = \frac{0{,}85 \cdot \text{fc}' \cdot \beta \cdot \text{b} \cdot \text{X}}{\text{fy}} = \frac{0{,}85 \cdot 35 \cdot 0{,}85 \cdot 300 \cdot 80}{420} = 1.445 \text{ mm}^2$$

$$\text{Mnc} = \text{Asc} \cdot \text{fy} \cdot \left(\text{d} - \frac{\beta - \text{X}}{2}\right) = 1.445 \cdot 420 \cdot \left(333 - \frac{0{,}85-80}{2}\right) = 224.295.068 \text{ Nmm}$$

$$\text{Mnc} > \text{Mn (OK)}$$

Mns = Mn – Mnc = 223.725.375 – 224.295.068 = −569.692 Nmm

Karena, Mn – Mnc < 0, maka tidak perlu tulangan tekan. Sehingga didesain dengan menggunakan tulangan tunggal.

$$\text{Rn} = \frac{\text{Mn}}{\text{b} \cdot \text{d}^2} = \frac{223.725.375}{300 \cdot 333^2} = 6{,}8$$

$$\text{m} = \frac{\text{fy}}{0{,}85 \cdot \text{fc}} = \frac{420}{0{,}85 \cdot 35} = 14{,}12$$

$$\rho = \frac{1}{\text{m}} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot \text{m} \cdot \text{Rn}}{\text{fy}}}\right) = \frac{1}{14{,}12} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 14{,}12 \cdot 6{,}8}{420}}\right)$$

$$\rho = 0{,}019$$

Luas Tulangan Tarik

$$\text{As} = \rho \cdot \text{b} \cdot \text{d} = 0{,}019 \cdot 300 \cdot 333 = 1.898 \text{ mm}^2$$

Dipakai 5D22 (1.901mm^2)

Luas Tulangan Tekan

$$\text{As}' = 0{,}5 \cdot \text{As} = 0{,}5 \cdot 1.898 = 949 \text{ mm}^2$$

Dipakai 3D22 (1.140 mm^2)

Kontrol Kekuatan

$$\rho = \frac{\text{As pakai}}{\text{b} \cdot \text{d}} = \frac{1.901}{300 \cdot 330} = 0{,}019$$

$$\rho_{\text{min}} < \rho < \rho_{\text{max}} \text{ (OK)}$$

$$\text{a} = \frac{\text{As} \cdot \text{fy}}{0{,}85 \cdot \text{fc}' \cdot \text{b}} = \frac{1.901 \cdot 420}{0{,}85 \cdot 35 \cdot 300} = 89{,}5 \text{ mm}$$

$$\text{Mn} = \text{As} \cdot \text{fy} \cdot \left(\text{d} - \frac{\text{a}}{2}\right) = 1.901 \cdot 420 \cdot \left(333 - \frac{89{,}5}{2}\right)$$

$$\text{Mn} = 227.765.743 \text{ Nmm}$$

Mn > Mn Beban (OK)

Daerah Lapangan

Penulangan

Tinggi Balok Bordes (h) = 300 mm

Tebal Selimut Beton (s) = 40 mm (SNI 2847:2019 Tabel 20.6.1.3.1)

Diameter Tulangan Utama (D) = D22 mm

Diameter Tulangan Sengkang (∅) = ∅16 mm

d = h – s – D – ½∅ = 300 – 40 – 16 – ½22 = 333 mm

d' = h – d = 300 – 333 = 67 mm

$\text{Momen}_{\text{lapangan}} = 15.415{,}19$ Kgm = 154.151.900 Nmm

$\text{Mn} = \frac{\text{Mu}}{\emptyset} = \frac{154.151.900}{0{,}8} = 192.689.875$ Nmm

Xmin = d` = 67 mm

$\text{Xmax} = 0{,}75 \cdot \left(\frac{600 \cdot \text{d}}{600+\text{fy}}\right) = 0{,}75 \cdot \left(\frac{600 \cdot 333}{600+420}\right) = 145{,}6$ mm

Digunakan X = 80 mm

$\text{Asc} = \frac{0{,}85 \cdot \text{fc}' \cdot \beta \cdot \text{b} \cdot \text{X}}{\text{fy}} = \frac{0{,}85 \cdot 35 \cdot 0{,}85 \cdot 300 \cdot 80}{420} = 1.445 \text{ mm}^2$

$\text{Mnc} = \text{Asc} \cdot \text{fy} \cdot \left(\text{d} - \frac{\beta - \text{X}}{2}\right) = 1.445 \cdot 420 \cdot \left(333 - \frac{0{,}85-80}{2}\right) = 224.295.068$ Nmm

$\text{Mnc} > \text{Mn}$ (OK)

Mns = Mn – Mnc = 192.689.875 – 224.295.068 = $-31.605.192$ Nmm

Karena, Mn – Mnc < 0, maka tidak perlu tulangan tekan. Sehingga didesain dengan menggunakan tulangan tunggal.

$\text{Rn} = \frac{\text{Mn}}{\text{b} \cdot \text{d}^2} = \frac{192.689.875}{300 \cdot 333^2} = 5{,}9$

$\text{m} = \frac{\text{fy}}{0{,}85 \cdot \text{fc}} = \frac{420}{0{,}85 \cdot 35} = 14{,}12$

$\rho = \frac{1}{\text{m}} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot \text{m} \cdot \text{Rn}}{\text{fy}}}\right) = \frac{1}{14{,}12} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot 14{,}12 \cdot 5{,}9}{420}}\right)$

$\rho = 0{,}016$

Luas Tulangan Tarik

$\text{As} = \rho \cdot \text{b} \cdot \text{d} = 0{,}016 \cdot 300 \cdot 333 = 1.565 \text{ mm}^2$

Dipakai 5D22 (1.901 mm^2)

Luas Tulangan Tekan

$\text{As}' = 0{,}5 \cdot \text{As} = 0{,}5 \cdot 1.565 = 782 \text{ mm}^2$

Dipakai 3D22 (1.140 mm^2)

Kontrol Kekuatan

$\rho = \frac{\text{As pakai}}{\text{b} \cdot \text{d}} = \frac{1.901}{300 \cdot 333} = 0{,}019$

$\rho_{\text{min}} < \rho < \rho_{\text{max}}$ (OK)

$\text{a} = \frac{\text{As} \cdot \text{fy}}{0{,}85 \cdot \text{fc}' \cdot \text{b}} = \frac{1.901 \cdot 420}{0{,}85 \cdot 35 \cdot 300} = 89{,}5$ mm

$$Mn = As \cdot fy \cdot \left(d - \frac{a}{2}\right) = 1.901 \cdot 420 \cdot \left(333 - \frac{89,5}{2}\right)$$

$$Mn = 227.765.743 \text{ Nmm}$$

Mn > Mn Beban (OK)

5.8.6 Penulangan Geser Balok Penggantung Lift

Daerah Tumpuan

Beban Geser Terfaktor (Vu) = 10.681,1 Kg = 106.811 N

Kekuatan Geser Beton (Vc) $= \frac{1}{6} \cdot \sqrt{fc'} \cdot bw \cdot d = \frac{1}{6} \cdot \sqrt{35} \cdot 300 \cdot 330 = 97.615$ N

Kategori Desain

$\frac{1}{2} \cdot \varphi \cdot Vc$	$= \frac{1}{2} \cdot 0,6 \cdot 97.615$	= 29.285 N
$\varphi \cdot Vc$	$= 0,6 \cdot 97.615$	= 58.569 N
$\varphi \cdot Vc + \varphi min \cdot Vs$	$= 58.569 + \left(0,6 \cdot \frac{1}{3} \cdot 300 \cdot 330\right)$	= 78.369 N
$\varphi \cdot Vc + \varphi \cdot \frac{1}{3} \cdot \sqrt{fc'} \cdot bw \cdot d$	$= 58.569 + \left(0,6 \cdot \frac{1}{3} \cdot \sqrt{35} \cdot 300 \cdot 330\right)$	= 175.708 N
$\varphi \cdot Vc + \varphi \cdot \frac{2}{3} \cdot \sqrt{fc'} \cdot bw \cdot d$	$= 58.569 + \left(0,6 \cdot \frac{2}{3} \cdot \sqrt{35} \cdot 300 \cdot 330\right)$	= 292.846 N

Berdasarkan perhitungan di atas, maka masuk ke dalam Kategori Desain 4

$$(\varphi \cdot Vc + \varphi min \cdot Vs) < Vu < \left(\varphi \cdot Vc + \varphi \cdot \frac{1}{3} \cdot \sqrt{fc'} \cdot bw \cdot d\right)$$

Dipakai sengkang 2 kaki (∅16-100)

$$s \leq \frac{d}{2} \leq 600 \text{ mm}$$

$$100 \text{ mm} \leq \frac{330}{2} \leq 600 \text{ mm}$$

$$100 \text{ mm} \leq 165 \text{ mm} \leq 600 \text{ mm (OK)}$$

Daerah Lapangan

Beban Geser Terfaktor (Vu) = 22.613,12 Kg = 226.131,2 N

Nilai y $= \frac{Vu \cdot \left(\frac{L}{2} - \frac{b}{2} - d\right)}{\frac{L}{2}} = \frac{226.131,2 \times \left(\frac{3.000}{2} - \frac{300}{2} - 330\right)}{\frac{3.000}{2}} = 153.769$ N

Kekuatan Geser Beton (Vc) $= \frac{1}{6} \cdot \sqrt{fc'} \cdot bw \cdot d = \frac{1}{6} \cdot \sqrt{35} \cdot 300 \cdot 330 = 97.615$ N

Kategori Desain

$\frac{1}{2} \cdot \varphi \cdot Vc$	$= \frac{1}{2} \cdot 0,6 \cdot 97.615$	= 29.285 N
$\varphi \cdot Vc$	$= 0,6 \cdot 97.615$	= 58.569 N
$\varphi \cdot Vc + \varphi min \cdot Vs$	$= 58.569 + \left(0,6 \cdot \frac{1}{3} \cdot 300 \cdot 330\right)$	= 78.369 N

$\varphi \cdot Vc + \varphi \cdot \frac{1}{3} \cdot \sqrt{fc'} \cdot bw \cdot d = 58.569 + \left(0{,}6 \cdot \frac{1}{3} \cdot \sqrt{35} \cdot 300 \cdot 330\right) = 175.708$ N

$\varphi \cdot Vc + \varphi \cdot \frac{2}{3} \cdot \sqrt{fc'} \cdot bw \cdot d = 58.569 + \left(0{,}6 \cdot \frac{2}{3} \cdot \sqrt{35} \cdot 300 \cdot 330\right) = 292.846$ N

Berdasarkan perhitungan di atas, maka masuk ke dalam Kategori Desain 5

$$\left(\varphi \cdot Vc + \varphi \cdot \frac{1}{3} \cdot \sqrt{fc'} \cdot bw \cdot d\right) < Vu < \left(\varphi \cdot Vc + \varphi \cdot \frac{2}{3} \cdot \sqrt{fc'} \cdot bw \cdot d\right)$$

Dipakai sengkang 2 kaki (∅16-50)

$s \leq \frac{d}{4} \leq 300$ mm

$50 \text{ mm} \leq \frac{330}{4} \leq 300$ mm

$50 \text{ mm} \leq 82{,}5 \text{ mm} \leq 300 \text{ mm}$ (OK)