BAB V
STRUKTUR SEKUNDER

5.1 Perencanaan Pembebanan Pelat Atap

1. Beban Mati

• Beban Sendiri Pelat	= 0,12 x 2400 kg/m^3	= 288	kg/m^2	
• *Plumbing*		= 10	kg/m^2	
• *Plafond*		= 18	kg/m^2	
• *Ducting AC*		= 20	kg/m^2	
• Aspal		= 14	kg/m^2	
• Spesi 2 cm	= 0,2 x 2100 kg/m^2	= 42	kg/m^2	+
Beban Mati Pelat Atap		**= 392**	**kg/m^2**	

2. Beban Hidup
   - Beban Hidup Lantai Atap = 100 kg/m^2
3. Beban Air Hujan = 50 kg/m^2

Beban *Ultimate*

Qu = 1,2 (D) + 1,6 (L) + 0,5 (R)

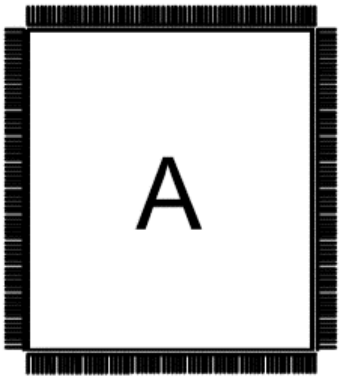
Qu = 1,2 (392) + 1,6 (100) + 0,5 (50)

Qu = 655,4 kg/m^2

5.1.1 Momen Pelat Atap

Ly/lx = 4500/4000 (Tipe A) = 1,13 ≤ 2 (*Two Way Slab)*

Kemudian didapatkan koefisien C pada PBI 1971



Gambar 5.1 Pelat Atap A yang Ditinjau

Tabel 5.1 Koefisien Pelat Atap

C Mlx	25
C Mly	21
C Mtx	59
C Mty	54

Perhitungan Momen Pelat Atap A

Mlx = $0{,}001qlx^2.C$ = 0,001 x 655,4 x 4^2 x 25 = 110,72 kgm

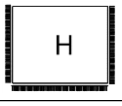
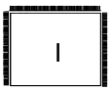
Mly = $0{,}001qlx^2.C$ = 0,001 x 655,4 x 4^2 x 21 = 110,72 kgm

Mtx = $-0{,}001qlx^2$ C =-0,001 x 655,4 x 4^2 x 59 =-274,54 kgm

Mty = $-0{,}001qlx^2$ C =-0,001 x 655,4 x 4^2 x 54 =-274,54 kgm

5.1.2 Tabel Perhitungan Pelat Atap

Tabel 5.2 Penulangan Pelat Atap

Tipe Pelat	Ukuran Pelat (m)	ly/lx	Keterangan	Mlx (kgm)	Mly (kgm)	Mtx (kgm)	Mty (kgm)	Gambar Pelat	Penulangan
A	4,5 x 4	1,13	Two Way Slab	262,16	220,2144	-618,6976	-566,2656		Arah X = D10 - 350 mm, Arah Y = D10 - 350 mm
B	4 x 4	1,00	Two Way Slab	220,2144	220,2144	-545,2928	-545,2928		Arah X = D10 - 350 mm, Arah Y = D10 - 350 mm
C	4 x 3,2	1,25	Two Way Slab	208,050176	127,514624	-463,079424	-382,543872		Arah X = D10 - 350 mm, Arah Y = D10 - 400 mm
D	4 x 3,1	1,29	Two Way Slab	195,250214	119,669486	-434,589186	-359,008458		Arah X = D10 - 350 mm, Arah Y = D10 - 400 mm
E	4 x 3	1,33	Two Way Slab	182,8566	112,0734	-407,0034	-336,2202		Arah X = D10 - 400 mm, Arah Y = D10 - 400 mm
F	3,1 x 3	1,03	Two Way Slab	123,8706	123,8706	-306,7272	-306,7272		Arah X = D10 - 400 mm, Arah Y = D10 - 400 mm
G	4 x 3,8	1,05	Two Way Slab	198,743496	198,743496	-492,126752	-492,126752		Arah X = D10 - 350 mm, Arah Y = D10 - 350 mm
H	3,1 x 2,5	1,24	Two Way Slab	114,695	81,925	-262,16	-229,39		Arah X = D10 - 450 mm, Arah Y = D10 - 450 mm
I	4 x 2,5	1,60	Two Way Slab	151,56125	65,54	-323,60375	-233,48625		Arah X = D10 - 400 mm, Arah Y = D10 - 450 mm

5.1.3 Syarat Batas Penulangan Pelat Atap

Perhitungan syarat batas penulangan pelat atap dengan menggunakan standar SNI 2847-2019.

$$\beta 1 = 0{,}85 - \frac{0{,}05(fc' - 28)}{7} = 0{,}85 - \frac{0{,}05\ (35 - 28)}{7} = 0{,}8$$

$$\rho b = \frac{0{,}85\ .\ fc'.\beta 1}{fy}\left(\frac{600}{600 + fy}\right) = \frac{0{,}85\ .35\ .\ 0{,}8}{420}\left(\frac{600}{600 + 420}\right) = 0{,}033$$

$$\rho \max = 0{,}75\ .\ \rho b\ \ = 0{,}75\ .\ 0{,}033 = 0{,}025$$

$$\rho \min = \frac{0{,}0018\ .\ 420}{fy} = \frac{0{,}0018\ .\ 420}{420} = 0{,}0018$$

5.1.4 Penulangan pada pelat atap

Data Perencanaan penulangan pelat atap arah X dan arah Y, sebagai berikut :

Tebal pelat (h) = 120 mm

Selimut beton (s) = 20 mm

Tulangan diamater ($\boldsymbol{\phi}$) = 10 mm

Tulangan Arah X

Tinggi efektif (dx) = $h - s - \frac{1}{2}x$ ϕ tulangan arah x

= $120 - 20 - \frac{1}{2}.10$

= $95\ mm$

Momen Mu = Mtx = 618,6976 kgm = 6.186.976 Nmm

$$Mn = \frac{Mu}{\phi} = \frac{6.186.976}{0{,}8} = 7.733.720\ Nmm$$

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

$$Rn = \frac{Mn}{b\ x\ dx} = \frac{7.733.720}{1000\ x\ 95} = 0{,}86$$

$$\rho\ perlu = \frac{1}{m}\ x\ \left(1 - \sqrt{1 - \left(\frac{2\ x\ m\ x\ Rn}{fy}\right)}\right) = \frac{1}{14{,}12}\ x\ \left(1 - \sqrt{1 - \left(\frac{2\ x\ 14{,}12\ x\ 0{,}86}{420}\right)}\right) = 0{,}0020$$

$\rho \min < \ \rho < \ \rho \max = 0{,}0018 < \ 0{,}0020 < \ 0{,}025$, dipakai $\rho = 0{,}0020$

Tulangan perlu arah X

$As_{perlu}\ = \rho\ x\ b\ x\ d = 0{,}0020\ x\ 1000\ x\ 95 = 190\ mm^2$

Digunakan tulangan $\boldsymbol{\phi}$ 10-350 mm (224,3 mm^2)

Tulangan Susut arah X

As_{perlu} = 0,002 x b x h= 0,002 x 1000 x 120 = 240 mm^2

Digunakan tulangan $\boldsymbol{\phi}$ 8 – 200 mm (Ass = 251,2 mm^2)

Tulangan Arah Y

Tinggi efektif (dy) $= h - s\frac{1}{2}x$ ϕ tulangan arah x − ϕ tulangan arah y

$= 120 - 20\ \frac{1}{2}10 - 10$

$= 85\ mm$

Momen Mu = Mtx = 566,2656 kgm = 5.662.656 Nmm

$$Mn = \frac{Mu}{\phi} = \frac{5.662.656}{0,8} = 7.078.320\ Nmm$$

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

$$Rn = \frac{Mn}{b\ x\ dy} = \frac{7.078.320}{1000\ x\ 85} = 0,98$$

$$\rho\ perlu = \frac{1}{m}\ x\ \left(1 - \sqrt{1 - \left(\frac{2\ x\ m\ x\ Rn}{fy}\right)}\right) = \frac{1}{14,12}\ x\ \left(1 - \sqrt{1 - \left(\frac{2\ x\ 14,12\ x\ 0,98}{420}\right)}\right) = 0,0023$$

ρ min $<\ \rho <\ \rho$ max $= 0,0018 <\ 0,0023 <\ 0,025$, dipakai $\rho = 0,0023$

Tulangan perlu arah Y

As_{perlu} $= \rho\ x\ b\ x\ d = 0,0023\ x\ 1000\ x\ 95 = 218,5\ mm^2$

Digunakan tulangan $\boldsymbol{\phi}$ 10-350 mm (224,3 mm^2)

Tulangan Susut arah Y

As_{perlu} = 0,002 x b x h= 0,002 x 1000 x 120 = 240 mm^2

Digunakan tulangan $\boldsymbol{\phi}$ 8 – 200 mm (Ass = 251,2 mm^2)

5.1.5 Kontrol Kekuatan

Kontrol Tulangan Arah X

$$\rho = \frac{As\ pakai}{b\ .dx} = \frac{224,3}{1000\ .95} = 0,002$$

$$a = \frac{As\ .fy}{0,85\ .fc'.b} = \frac{224,3\ .420}{0,85\ .35\ .1000} = 3,16\ \text{mm}$$

$$Mn = As\ .\ fy\ .\left(d - \frac{a}{2}\right) = 224,3\ .420\ \left(95 - \frac{3,16}{2}\right) = 8.800.724,52\ Nmm$$

Mn struktur 8.800.724,52 Nmm = > Mn Beban = 7.733.720 Nmm **(OK)**

Jarak tulangan ≤ 3 x tebal pelat = 300 mm ≤ 3.120 (360 mm) **(OK)**

Tulangan Susut :

As pakai $= \frac{1}{4}.\phi^2.\ \pi\ .\frac{b}{s} = \frac{1}{4}\ .10^2.3,14\ .\frac{1000}{300} = 262\ mm^2 \geq Ass\ pakai$ $(\boldsymbol{OK})$

Kontrol Tulangan Arah Y

$\rho = \frac{As\ pakai}{b\ .dy} = \frac{224{,}3}{1000\ .85} = 0{,}002$

$a = \frac{As\ .fy}{0{,}85\ .fc'.b} = \frac{224{,}3\ .420}{0{,}85\ .35\ .1000} = 3{,}16$ mm

$Mn = As\ .fy\ .\left(d - \frac{a}{2}\right) = 224{,}3\ .420\ \left(85 - \frac{3{,}16}{2}\right) = 7.858.664{,}52\ Nmm$

Mn struktur $7.858.664{,}52\ Nmm$ > Mn Beban = $7.078.320\ Nmm$ **(OK)**

Jarak tulangan ≤ 3 x tebal pelat = 300 mm ≤ 3.120 (360 mm) **(OK)**

Tulangan Susut :

As pakai = $\frac{1}{4}.\phi^2.\ \pi\ .\frac{b}{s} = \frac{1}{4}\ .10^2.3{,}14\ .\frac{1000}{300} = 262\ mm^2 \geq Ass\ pakai\ (\boldsymbol{OK})$

5.1.6 Kontrol Retak

$Z = fs\ .(dc.A)^{\frac{1}{3}} \leq Mn/m$

$fs = 60\%\ .fy = 60\%.420 = 252\ Mpa$

$dc = s + \frac{1}{2}\ .\phi = 20 + \frac{1}{2}.10 = 25\ mm$

$A = 2\ .dc\ .h = 2.25\ .120 = 6000\ mm^2$

$Z = \ fs\ .(dc.A)^{\frac{1}{3}} = \ 252\ .(25\ .6000)^{\frac{1}{3}} = 13{,}398{,}497\ \frac{MN}{m} \leq 25\ \frac{MN}{m}\ (Memenuhi)$

5.2 Perencanaan Pembebanan Pelat Lantai

1. Beban Mati
   - Beban Sendiri Pelat = 0,12 x 2400 kg/m^3 = 288 kg/m^2
   - *Plumbing* = 10 kg/m^2
   - *Plafond* = 18 kg/m^2
   - *Ducting AC* = 20 kg/m^2
   - Keramik = 24 kg/m^2
   - Spesi 2 cm = 0,2 x 2100 kg/m^2 = 42 kg/m^2 +

     Beban Mati Pelat Lantai **= 402 kg/m^2**
2. Beban Hidup
   - Beban Hidup Pelat Lantai = 250 kg/m^2

Beban *Ultimate*

Qu = 1,2 (D) + 1,6 (L)

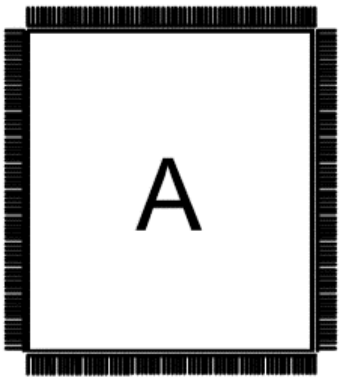
Qu = 1,2 (402) + 1,6 (250)

Qu = 882,4 kg/m^2

5.2.1 Momen Pelat Lantai

Ly/lx = 4500/4000 (Tipe A) = 1,13 ≤ 2 (*Two Way Slab)*

Kemudian didapatkan koefisien C pada PBI 1971



Gambar 5.2 Pelat Lantai A yang Ditinjau

Tabel 5.3 Koefisien Pelat Lantai

C Mlx	25
C Mly	21
C Mtx	59
C Mty	54

Perhitungan Momen Pelat Lantai A :

Mlx = 0,001qlx^2.C = 0,001 x 882,4 x 4^2 x 25 = -832,98 kgm

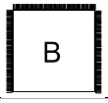
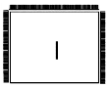
Mly = 0,001qlx^2.C = 0,001 x 882,4 x 4^2 x 21 = -762,39 kgm

Mtx =-0,001qlx^2 C =-0,001 x 882,4 x 4^2 x 59 = 352,96 kgm

Mty = -0,001qlx^2 C =-0,001 x 882,4 x 4^2 x 54 = 296,48 kgm

5.2.2 Tabel Perhitungan Pelat Lantai

Tabel 5.4 Penulangan Pelat Lantai

Tipe Pelat	Ukuran Pelat (m)	ly/lx	Keterangan	Mlx (kgm)	Mly (kgm)	Mtx (kgm)	Mty (kgm)	Gambar Pelat	Penulangan
A	4,5 x 4	1,13	Two Way Slab	352,96	296,4864	-832,9856	-762,3936		Arah X = D10 - 250 mm, Arah Y = D10 - 250 mm
B	4 x 4	1,00	Two Way Slab	296,4864	296,4864	-734,1568	-734,1568		Arah X = D10 - 250 mm, Arah Y = D10 - 250 mm
C	4 x 3,2	1,25	Two Way Slab	280,109056	171,679744	-623,468544	-515,039232		Arah X = D10 - 250 mm, Arah Y = D10 - 300 mm
D	4 x 3,1	1,29	Two Way Slab	262,875784	161,117416	-585,110616	-483,352248		Arah X = D10 - 250 mm, Arah Y = D10 - 300 mm
E	4 x 3	1,33	Two Way Slab	246,1896	150,8904	-547,9704	-452,6712		Arah X = D10 - 250 mm, Arah Y = D10 - 300 mm
F	3,1 x 3	1,03	Two Way Slab	166,7736	166,7736	-412,9632	-412,9632		Arah X = D10 - 350 mm, Arah Y = D10 - 350 mm
G	4 x 3,8	1,05	Two Way Slab	267,578976	267,578976	-662,576512	-662,576512		Arah X = D10 - 250 mm, Arah Y = D10 - 250 mm
H	3,1 x 2,5	1,24	Two Way Slab	154,42	110,3	-352,96	-308,84		Arah X = D10 - 400 mm, Arah Y = D10 - 400 mm
I	4 x 2,5	1,60	Two Way Slab	204,055	88,24	-435,685	-314,355		Arah X = D10 - 350 mm, Arah Y = D10 - 400 mm
J	5 x 3	1,67	Two Way Slab	293,8392	127,0656	-627,3864	-452,6712		Arah X = D10 - 250 mm, Arah Y = D10 - 350 mm

5.2.3 Syarat Batas Penulangan Pelat Lantai

Perhitungan syarat batas penulangan pelat lantai dengan menggunakan standar SNI 2847-2019.

$$\beta 1 = 0{,}85 - \frac{0{,}05(fc' - 28)}{7} = 0{,}85 - \frac{0{,}05\ (35 - 28)}{7} = 0{,}8$$

$$\rho b = \frac{0{,}85\ .\ fc'.\beta 1}{fy}\left(\frac{600}{600 + fy}\right) = \frac{0{,}85\ .35\ .\ 0{,}8}{420}\left(\frac{600}{600 + 420}\right) = 0{,}033$$

$$\rho \max = 0{,}75\ .\ \rho b\ \ = 0{,}75\ .\ 0{,}033 = 0{,}025$$

$$\rho \min = \frac{0{,}0018\ .\ 420}{fy} = \frac{0{,}0018\ .\ 420}{420} = 0{,}0018$$

5.2.4 Penulangan pada Pelat Lantai

Data Perencanaan penulangan pelat lantai arah X dan arah Y, sebagai berikut :

Tebal pelat (h) = 120 mm

Selimut beton (s) = 20 mm

Tulangan diamater ($\boldsymbol{\phi}$) = 10 mm

Tulangan Arah X

Tinggi efektif (dx) = $h - s\frac{1}{2}x$ ϕ tulangan arah x

= $120 - 20\ \frac{1}{2}10$

= $95\ mm$

Momen Mu = Mtx = 832,9856 kgm = 8.329.856 Nmm

$$Mn = \frac{Mu}{\phi} = \frac{8.329.856}{0{,}8} = 10.412.320\ Nmm$$

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

$$Rn = \frac{Mn}{b\ x\ dx} = \frac{10.412.320}{1000\ x\ 95} = 1{,}15$$

$$\rho\ perlu = \frac{1}{m}\ x\ \left(1 - \sqrt{1 - \left(\frac{2\ x\ m\ x\ Rn}{fy}\right)}\right) = \frac{1}{14{,}12}\ x\ \left(1 - \sqrt{1 - \left(\frac{2\ x\ 14{,}12\ x\ 1{,}15}{420}\right)}\right) = 0{,}0028$$

ρ min $<\ \rho <\ \rho$ max $= 0{,}0018 <\ 0{,}0028 <\ 0{,}025$, dipakai $\rho = 0{,}0028$

Tulangan perlu arah X

As_{perlu} = $\rho\ x\ b\ x\ d = 0{,}0028\ x\ 1000\ x\ 95 = 266\ mm^2$

Digunakan tulangan $\boldsymbol{\phi}$ 10 – 250 mm = 314 mm^2

Tulangan Susut arah X

As_{perlu} = 0,002 x b x h = 0,002 x 1000 x 120 = 240 mm^2

Digunakan tulangan $\boldsymbol{\phi}$ 8 – 200 mm (Ass = 251,2 mm^2)

Tulangan Arah Y

Tinggi efektif (dy) = $h - s\frac{1}{2}x$ ϕ tulangan arah x − ϕ tulangan arah y

= $120 - 20\ \frac{1}{2}10 - 10$

= $85\ mm$

Momen Mu = Mty = 762,3936 kgm = 7.623.936 Nmm

$$Mn = \frac{Mu}{\phi} = \frac{7.623.936}{0{,}8} = 9.529.920\ Nmm$$

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

$$Rn = \frac{Mn}{b\ x\ dy} = \frac{9.529.920}{1000\ x\ 85} = 1{,}31$$

$$\rho\ perlu = \frac{1}{m}\ x\ \left(1 - \sqrt{1 - \left(\frac{2\ x\ m\ x\ Rn}{fy}\right)}\right) = \frac{1}{14{,}12}\ x\ \left(1 - \sqrt{1 - \left(\frac{2\ x\ 14{,}12\ x\ 1{,}31}{420}\right)}\right) = 0{,}0032$$

$\rho \min < \rho < \rho \max = 0{,}0018 < 0{,}0032 < 0{,}025$, dipakai $\rho = 0{,}0032$

Tulangan perlu arah Y

$As_{perlu} = \rho\ x\ b\ x\ d = 0{,}0032\ x\ 1000\ x\ 85 = 272\ mm^2$

Digunakan tulangan $\boldsymbol{\phi}$ 10 – 250 mm = 314 mm^2

Tulangan Susut arah Y

As_{perlu} = 0,002 x b x h= 0,002 x 1000 x 120 = 240 mm^2

Digunakan tulangan $\boldsymbol{\phi}$ 8 – 200 mm (Ass = 251,2 mm^2)

5.2.5 Kontrol Kekuatan

Kontrol Tulangan Arah X

$$\rho = \frac{As\ pakai}{b\ .dx} = \frac{314}{1000\ .95} = 0{,}003$$

$$a = \frac{As\ .fy}{0{,}85\ .fc'.b} = \frac{314\ .420}{0{,}85\ .35\ .1000} = 4{,}43 \text{ mm}$$

$$Mn = As\ .\ fy\ .\left(d - \frac{a}{2}\right) = 314\ .420\ \left(95 - \frac{4{,}43}{2}\right) = 12.236.485{,}8\ Nmm$$

Mn struktur 12.236.485,8 Nmm => Mn Beban = 10.412.320 Nmm **(OK)**

Jarak tulangan ≤ 3 x tebal pelat = 300 mm ≤ 3.120 (360 mm) **(OK)**

Tulangan Susut :

As pakai = $\frac{1}{4}.\phi^2.\ \pi\ .\frac{b}{s} = \frac{1}{4}\ .10^2.3{,}14\ .\frac{1000}{300} = 262\ mm^2 \geq Ass\ pakai$ $(\boldsymbol{OK})$

Kontrol Tulangan Arah Y

$$\rho = \frac{As\ pakai}{b\ .dy} = \frac{314}{1000\ .85} = 0{,}003$$

$$a = \frac{As\ .fy}{0{,}85\ .fc'.b} = \frac{314\ .\ 420}{0{,}85\ .35\ .1000} = 4{,}43 \text{ mm}$$

$$Mn = As\ .\ fy\ .\left(d - \frac{a}{2}\right) = 314\ .420\ \left(85 - \frac{4{,}43}{2}\right) = 10.917.685{,}8\ Nmm$$

Mn struktur 10.917.685,8 Nmm => Mn Beban = 9.529.920Nmm **(OK)**

Jarak tulangan ≤ 3 x tebal pelat = 300 mm ≤ 3.120 (360 mm) **(OK)**

Tulangan Susut :

As pakai = $\frac{1}{4}.\phi^2.\ \pi\ .\frac{b}{s} = \frac{1}{4}\ .10^2.3{,}14\ .\frac{1000}{300} = 262\ mm^2 \geq Ass\ pakai$ $(\boldsymbol{OK})$

5.2.6 Kontrol Retak

$Z = fs\,.(dc.A)^{\frac{1}{3}} \leq Mn/m$

$fs = 60\%\,.fy = 60\%.420 = 252\ Mpa$

$dc = s + \frac{1}{2}\,.\phi = 20 + \frac{1}{2}.10 = 25\ mm$

$A = 2\,.dc\,.h = 2.25\,.120 = 6000\ mm^2$

$Z = \ fs\,.(dc.A)^{\frac{1}{3}} = \ 252\,.(25\,.6000)^{\frac{1}{3}} = 13{,}398{,}497\,\frac{MN}{m} \leq 25\,\frac{MN}{m}\ (Memenuhi)$

5.3 Perencanaan Tangga

Data tangga :

Beda tinggi lantai	= 400 cm
Elevasi Bordes	= 200 cm
Panjang Bordes	= 300 cm
Lebar Bordes	= 200 cm
Mutu Baja (fy)	= 420 MPa
Mutu Beton (fc')	= 35 MPa
Tinggi Injakan	= 20 cm
Lebar Injakan	= 40 cm
Jumlah injakan tangga	$= \frac{Elevasi\ bordes}{tinggi\ injakan} = \frac{200}{20} = 10\ buah$
Jumlah injakan	= 10 -1 = 9 buah
Kemiringan pada tangga	$= Arctan\ \left(\frac{200}{400}\right) = 26{,}5°$
Lebar Miring	= 150 cm
Panjang miring	$= \sqrt{400^2\ +\ 200^2}$ = 447,2 cm
R	$= \frac{1}{2}\,.h\,.\cos\alpha = \frac{1}{2}\,.20\,.\cos 26{,}5 = 8{,}9\ cm$

5.3.1 Pembebanan Tangga

Beban Pelat pada Tangga Miring

1. Beban Mati

Berat Sendiri	= 0,12 x 2400 x $\frac{1}{\cos 26{,}5}$	= 321,81 kg/m^2
Beban anak tangga	= 0,089 x 2400	= 213,60 kg/m^2
Spesi (2 cm)		= 42 kg/m^2
Keramik (1 cm)		= 24 kg/m^2

Railing = 30 kg/m^2 +

Total Qd = 631,41kg/m^2

2. Beban Hidup

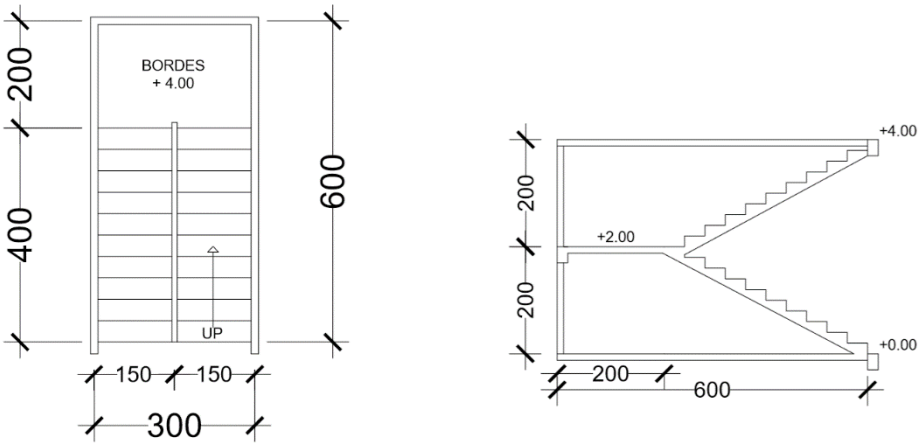
Beban hidup pelat tangga miring (QL) = 300kg/m^2

Beban Ultimate

Qu = 1,2 D + 1,6 L

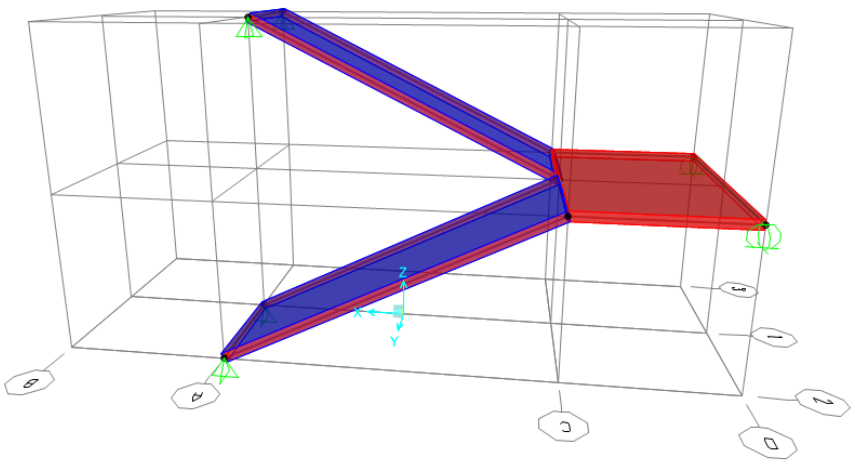
= 1,2 . (613,41) + 1,6 . (300)

= 1237,69 kg/m



Gambar 5.3 Perencanaan Tangga

Permodelan Struktur Tangga di Program Struktur :



Gambar 5.2 Desain Tangga di Aplikasi Perhitungan Struktur

Beban Pelat Bordes

1. Beban Mati

Berat Sendiri	= 0,12 x 2400	= 288	kg/m^2
Spesi (2 cm)		= 42	kg/m^2
Keramik (1 cm)		= 24	kg/m^2
Railing		= 30	kg/m^2 +
	Total Qd	= 417,81	kg/m^2

2. Beban Hidup

Beban hidup pelat bordes (QL) = 300kg/m^2

Beban Ultimate

Qu = 1,2 D + 1,6 L

= 1,2 . (417,81) + 1,6 . (300)

= 981,4 kg/m^2

5.3.2 Syarat Batas Penulangan Tangga

Perhitungan syarat batas penulangan tangga dengan menggunakan standar SNI 2847-2019.

$$\beta 1 = 0{,}85 - \frac{0{,}05(fc' - 28)}{7} = 0{,}85 - \frac{0{,}05\ (35 - 28)}{7} = 0{,}8$$

$$\rho b = \frac{0{,}85\ .\ fc'.\beta 1}{fy}\left(\frac{600}{600 + fy}\right) = \frac{0{,}85\ .35\ .\ 0{,}8}{420}\ \left(\frac{600}{600 + 420}\right) = 0{,}033$$

$$\rho \max = 0{,}75\ .\ \rho b\ \ = 0{,}75\ .\ 0{,}033 = 0{,}025$$

$$\rho \min = \frac{0{,}0018\ .\ 420}{fy} = \frac{0{,}0018\ .\ 420}{420} = 0{,}0018$$

5.3.3 Perencanaan Pelat Bordes Tangga

Mutu Baja (fy) = 420 MPa

Mutu Beton (fc') = 35 MPa

Tebal Pelat Bordes = 120 mm

Selimut Beton (s) = 20 mm (SNI 2847 2019 pasal 20.6.1.3.1)

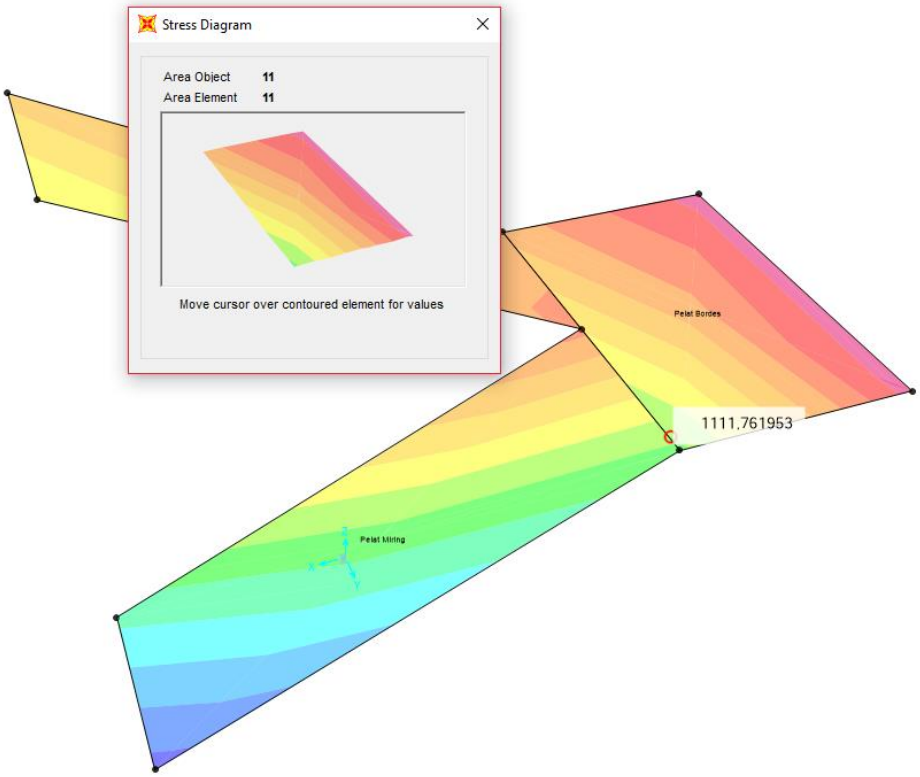
Tulangan diameter(ϕ) = 13 mm

5.3.4 Penulangan Pelat Bordes Tangga

Tinggi efektif (dx) $= h - s\frac{1}{-2}x\ \phi$ tulangan arah x

$= 120 - 20 - \frac{1}{2}13$

$= 93{,}5\ mm$



Gambar 5.3 Gaya Dalam Momen Momen Pelat Bordes Tangga

Momen Mu = Mtx = 1111,76 kgm = 11.117.600 Nmm

$$Mn = \frac{Mu}{\phi} = \frac{11.117.600}{0{,}8} = 13.897.000\ Nmm$$

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

$$Rn = \frac{Mn}{b\ x\ dx} = \frac{13.897.000}{1000\ x\ 93.5^2} = 1.59$$

Gambar 5.3 Gaya Dalam (M) Bordes Tangga

$$\rho\ perlu = \frac{1}{m}\ x\ \left(1 - \sqrt{1 - \left(\frac{2\ x\ m\ x\ Rn}{fy}\right)}\right) = \frac{1}{14{,}12}\ x\ \left(1 - \sqrt{1 - \left(\frac{2\ x\ 14{,}12\ x\ 1.59}{420}\right)}\right) = 0{,}0038$$

$\rho\ \min > \rho < \rho\ \max = 0{,}0018 < 0{,}0038 < 0{,}025$, dipakai $\rho = 0{,}0038$

Tulangan perlu arah X

$As_{perlu} = \rho\ x\ b\ x\ d = 0{,}0038\ x\ 1000\ x\ 93{,}5 = 355{,}3\ mm^2$

Digunakan tulangan D13 – 350 mm = 379 mm^2

Tulangan Susut arah X

As_{perlu} = 0,002 x b x h= 0,002 x 1000 x 120 = 240 mm^2

Digunakan tulangan D13 – 400 mm = 331,7 mm^2

Tulangan Arah Y

Tinggi efektif (dy) $= h - s - \frac{1}{2}x$ ϕ tulangan arah x − ϕ tulangan arah y

$= 120 - 20 - \frac{1}{2}13 - 13$

$= 80{,}5\ mm$

Momen Mu = Mty = 1111,76 kgm = 11.117.600 Nmm

$$Mn = \frac{Mu}{\phi} = \frac{11.117.600}{0{,}8} = 13.897.000\ Nmm$$

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

$$Rn = \frac{Mn}{b\ x\ dy} = \frac{13.897.000}{1000\ x\ 80{,}5^2} = 2{,}14$$

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

$$= 0{,}0053$$

ρ min $>\ \rho <\ \rho$ max = 0,0018 $<$ 0,0053 $<$ 0,025, dipakai $\rho = 0{,}0053$

Tulangan perlu arah Y

As_{perlu} $= \rho\ x\ b\ x\ d = 0{,}0053\ x\ 1000\ x\ 80{,}5 = 426{,}65\ mm^2$

Digunakan tulangan D13 – 300 mm = 442,2 mm^2

Tulangan Susut arah Y

As_{perlu} = 0,002 x b x h= 0,002 x 1000 x 120 = 240 mm^2

Digunakan tulangan D13 – 400 mm = 331,7 mm^2

5.3.5 Kontrol Kekuatan Pelat Bordes Tangga

Kontrol Tulangan Arah X

$$\rho = \frac{As\ pakai}{b\ .dx} = \frac{379}{1000\ .93{,}5} = 0{,}0040$$

$$a = \frac{As\ .fy}{0{,}85\ .fc'.b} = \frac{379\ .\ 420}{0{,}85\ .35\ .1000} = 5{,}35\ \text{mm}$$

$$Mn = As\ .\ fy\ .\left(d - \frac{a}{2}\right) = 379\ .420\ \left(93{,}5 - \frac{5{,}35}{2}\right) = 14.457.523\ Nmm$$

Mn struktur 14.457.523 Nmm = > Mn Beban = 11.117.600 Nmm **(OK)**

Jarak tulangan ≤ 3 x tebal pelat = 350 mm ≤ 3.120 (360 mm) **(OK)**

Tulangan Susut :

As pakai = $\frac{1}{4}.\phi^2.\ \pi.\frac{b}{s} = \frac{1}{4}.13^2.3{,}14.\frac{1000}{400} = 331{,}7\ mm^2 \geq Ass\ pakai\ (\boldsymbol{OK})$

Kontrol Tulangan Arah Y

$\rho = \frac{As\ pakai}{b.dy} = \frac{442{,}2}{1000.80{,}5} = 0{,}005$

$a = \frac{As.fy}{0{,}85.fc'.b} = \frac{442{,}2\ .\ 420}{0{,}85.35.1000} = 6{,}24$ mm

$Mn = As.fy.\left(d - \frac{a}{2}\right) = 442{,}2.420\ \left(80{,}5 - \frac{6{,}24}{2}\right) = 14.371.323{,}12\ Nmm$

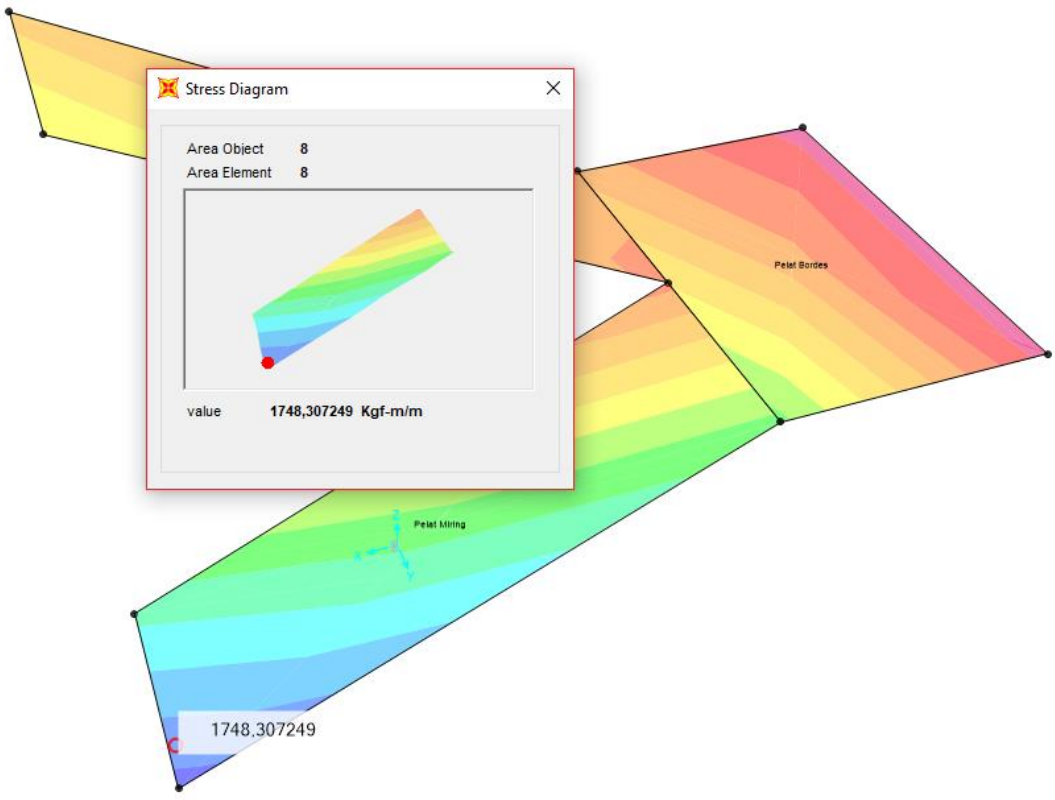
Mn struktur 14.371.323,12 Nmm = > Mn Beban = 11.117.600 Nmm **(OK)**

Jarak tulangan ≤ 3 x tebal pelat = 300 mm ≤ 3.120 (360 mm) **(OK)**

Tulangan Susut :

As pakai = $\frac{1}{4}.\phi^2.\ \pi.\frac{b}{s} = \frac{1}{4}.13^2.3{,}14.\frac{1000}{400} = 331{,}7\ mm^2 \geq Ass\ pakai\ (\boldsymbol{OK})$

5.4 Penulangan Pelat Miring Tangga



Gambar 5.4 Gaya Dalam (M) Miring Tangga

Tinggi efektif (dx) $= h - s - \frac{1}{2}x$ ϕ tulangan arah x

$= 120 - 20 - \frac{1}{2}.13$

$= 93{,}5\ mm$

Momen Mu = Mtx = 1748,307 kgm = 17.483.070 Nmm

$$Mn = \frac{Mu}{\phi} = \frac{17.483.070}{0{,}8} = 21.853.873{,}5\ Nmm$$

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

$$Rn = \frac{Mn}{b\ x\ dx} = \frac{21.853.873{,}5}{1000\ x\ 93{,}5} = 2{,}49$$

$$\rho\ perlu = \frac{1}{m}\ x\ \left(1 - \sqrt{1 - \left(\frac{2\ x\ m\ x\ Rn}{fy}\right)}\right) = \frac{1}{14{,}12}\ x\ \left(1 - \sqrt{1 - \left(\frac{2\ x\ 14{,}12\ x\ 2{,}49}{420}\right)}\right) = 0{,}0061$$

$\rho\ \text{min} < \rho < \rho\ \text{max} = 0{,}0018 < 0{,}0061 < 0{,}025$, dipakai $\rho = 0{,}0061$

Tulangan perlu arah X

$As_{perlu} = \rho\ x\ b\ x\ d = 0{,}0061\ x\ 1000\ x\ 93{,}5 = 570{,}35\ mm^2$

Digunakan tulangan D13 – 200 mm = 663,3 mm^2

Tulangan Susut arah X

As_{perlu} = 0,002 x b x h= 0,002 x 1000 x 120 = 240 mm^2

Digunakan tulangan D13 – 400 mm = 331,7 mm^2

Tulangan Arah Y

Tinggi efektif (dy) $= h - s\frac{1}{2}x$ ϕ tulangan arah x $-$ ϕ tulangan arah y

$= 120 - 20 - \frac{1}{2}13 - 13$

$= 80{,}5\ mm$

Momen Mu = Mty = 1748,307 kgm = 17.483.070 Nmm

$$Mn = \frac{Mu}{\phi} = \frac{17.483.070}{0{,}8} = 21.853.873{,}5\ Nmm$$

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

$$Rn = \frac{Mn}{b\ x\ dx} = \frac{21.853.873{,}5}{1000\ x\ 80{,}5} = 3{,}37$$

$$\rho\ perlu = \frac{1}{m}\ x\ \left(1 - \sqrt{1 - \left(\frac{2\ x\ m\ x\ Rn}{fy}\right)}\right) = \frac{1}{14{,}12}\ x\ \left(1 - \sqrt{1 - \left(\frac{2\ x\ 14{,}12\ x\ 3{,}37}{420}\right)}\right) = 0{,}0085$$

$\rho\ \text{min} < \rho < \rho\ \text{max} = 0{,}0018 < 0{,}0085 < 0{,}025$, dipakai $\rho = 0{,}0085$

Tulangan perlu arah Y

$As_{perlu} = \rho\ x\ b\ x\ d = 0{,}0085\ x\ 1000\ x\ 80{,}5 = 684{,}25\ mm^2$

Digunakan tulangan D13 – 150 mm = 884.4 mm^2

Tulangan Susut arah Y

As_{perlu} = 0,002 x b x h= 0,002 x 1000 x 120 = 240 mm^2

Digunakan tulangan D13 – 400 mm = 331,7 mm^2

5.4.1 Kontrol Kekuatan Pelat Miring

Kontrol Tulangan Arah X

$\rho = \frac{As\ pakai}{b\ .dx} = \frac{663{,}3}{1000\ .80{,}5} = 0{,}008$

$a = \frac{As\ .fy}{0{,}85\ .fc'.b} = \frac{663{,}3\ .\ 420}{0{,}85\ .35\ .1000} = 9{,}36$ mm

$Mn = As\ .\ fy\ .\left(d - \frac{a}{2}\right) = 663{,}3\ .420\ \left(80.5 - \frac{9{,}36}{2}\right) = 21.112.390{,}52\ Nmm$

Mn struktur 21.112.390,52 Nmm => Mn Beban = 17.483.070 Nmm **(OK)**

Jarak tulangan ≤ 3 x tebal pelat = 200 mm ≤ 3.120 (360 mm) **(OK)**

Tulangan Susut :

As pakai = $\frac{1}{4}.\phi^2.\ \pi\ .\frac{b}{s} = \frac{1}{4}\ .13^2.3{,}14\ .\frac{1000}{400} = 331{,}7\ mm^2 \geq Ass\ pakai\ (\boldsymbol{OK})$

Kontrol Tulangan Arah Y

$\rho = \frac{As\ pakai}{b\ .dy} = \frac{884{,}4}{1000\ .80{,}5} = 0{,}010$

$a = \frac{As\ .fy}{0{,}85\ .fc'.b} = \frac{884{,}4\ .\ 420}{0{,}85\ .35\ .1000} = 12{,}48$ mm

$Mn = As\ .\ fy\ .\left(d - \frac{a}{2}\right) = 884{,}4\ .420\ \left(85 - \frac{12{,}48}{2}\right) = 48.742.848\ Nmm$

Mn struktur 27.583.728,48 Nmm => Mn Beban = 17.483.070 Nmm **(OK)**

Jarak tulangan ≤ 3 x tebal pelat = 300 mm ≤ 3.120 (360 mm) **(OK)**

Tulangan Susut :

As pakai = $\frac{1}{4}.\phi^2.\ \pi\ .\frac{b}{s} = \frac{1}{4}\ .13^2.3{,}14\ .\frac{1000}{400} = 331{,}7\ mm^2 \geq Ass\ pakai\ (\boldsymbol{OK})$

5.5 Perencanaan Balok Bordes

Dimensi Balok H = $\frac{l}{16} = \frac{300}{16} = 18{,}75\ cm,\quad dipakai = 25\ cm$

B = $\frac{2}{3}\ h = \frac{2}{3}\ .25 = 16{,}67\ cm,\ dipakai = 20\ cm$

Diameter Tulangan = D-12

Diameter Sengkang = D-8

Mutu Beton (fc') = 35 MPa

Mutu Baja (fy) = 420 MPa

Selimut Beton = 20 mm

Pembebanan Balok Bordes

Berat Sendiri Balok	=	0,25 m x 0,2 m x 2400 kg/m^3	= 120	kg/m^3	
Beban Pelat Bordes	=		= 981,4	kg/m^2	+
	Total	= Qu	= 1101,4	kg/m^2	

5.5.1 Perhitungan Gaya Dalam

Momen $_{Tumpuan}$ $= \frac{l}{11}\ x\ Qu\ x\ l^2 = \frac{1}{11} x\ 1101{,}4\ x\ (3)^2 = 901{,}14\ kgm$

Momen $_{Lapangan}$ $= \frac{l}{16}\ x\ Qu\ x\ l^2 = \frac{1}{16} x\ 1101{,}4\ x\ (3)^2 = 619{,}53\ kgm$

$V_1 = V_2$ $= \frac{l}{2}\ x\ Qu\ x\ l = \frac{1}{2} x\ 1101{,}4\ x\ 3 = 1652{,}1\ kgm$

5.5.2 Syarat Batas Penulangan Balok Bordes

Perhitungan syarat batas penulangan Balok Bordes dengan menggunakan standar SNI 2847-2019.

$$\beta 1 = 0{,}85 - \frac{0{,}05(fc' - 28)}{7} = 0{,}85 - \frac{0{,}05\ (35 - 28)}{7} = 0{,}8$$

$$\rho b = \frac{0{,}85\ .\ fc'.\ \beta 1}{fy}\left(\frac{600}{600 + fy}\right) = \frac{0{,}85\ .35\ .\ 0{,}8}{420}\left(\frac{600}{600 + 420}\right) = 0{,}033$$

$$\rho \max = 0{,}75\ .\ \rho b\ = 0{,}75\ .\ 0{,}033 = 0{,}025$$

$$\rho \min = \frac{0{,}0018\ .\ 420}{fy} = \frac{0{,}0018\ .\ 420}{420} = 0{,}0018$$

5.5.3 Penulangan Lentur Balok Bordes

Daerah Tumpuan :

Momen $_{Tumpuan}$ $= 19.661{,}44\ kgm$ = 196.614.400 Nmm

d_{eff} = h – s - ϕ tulangan sengkang + ½ ϕ tulangan utama

= 250 – 20 – 8 + (1/2) . 12

= 228 mm

Mn $= \frac{196.614.400}{0{,}8} = 245.768.000\ Nmm$

Xmin = d' = s + ϕ tulangan sengkang + ½ ϕ tulangan utama = 20 + 8 +6 = 34 mm

Xmax $= 0{,}75\frac{600\,.228}{600+420} = 100{,}58\,mm$

Xpakai = 72,5 mm

$$Asc = \frac{0{,}85.fc'.\beta.b.x}{fy} = \frac{0{,}85\,.\,35\,.\,0{,}85\,.\,200\,.\,72{,}5}{420} = 873{,}02\,mm$$

$$Mnc = Asc\,.fy\,.\left(d - \frac{\beta x}{2}\right) = 873{,}02\,.\,420\,.\left(228 - \frac{0{,}85\,.72{,}5}{2}\right) = 723.024.250 \text{ Nmm}$$

$Mns = Mn - Mnc = 245.768.000 - 723.024.250$ = -47.737.655,42 Nmm (tidak memerlukan tulangan tekan)

$$m = \frac{fy}{0{,}85\,fc'} = \frac{420}{0{,}85\,.35} = 14{,}11$$

$$Rn = \frac{Mn}{b.d^2} = \frac{245.768.000}{200\,.\,228^2} = 23{,}6$$

$$\rho perlu = \frac{1}{m}.\left(1 - \sqrt{1 - \frac{2\,.m\,.Rn}{fy}}\right) = \frac{1}{14{,}11}\left(1 - \sqrt{1 - \frac{2\,.14{,}11\,.23{,}6}{420}}\right) = 0{,}070$$

$\rho \min < \rho < \rho \max = 0{,}0018 < 0{,}070 > 0{,}025$, dipakai $\rho = 0{,}0018$

Tulangan Tarik (atas)

$As = p\ x\ b\ x\ d = 0{,}0018\ x\ 200\ x\ 228 = 82{,}08$ mm^2

Digunakan Tulangan 3D12 (As = 339 mm^2)

Tulangan Tekan (Bawah)

As = δ x As = 0,5 x 339 = 169,5 mm^2

Digunakan Tulangan 2D12 (As = 226 mm^2)

Kontrol Kekuatan

$$\rho = \frac{As}{b.d} = \frac{339}{200\,.\,228} = 0{,}007$$

$$a = \frac{As\,.fy}{0{,}85\,.fc'.b} = \frac{339\,.420}{0{,}85\,.35\,.200} = 23{,}92$$

$Mn = As.fy\left(d - \frac{a}{2}\right)$ = 339 . 420 . (228 – 23,92/2) = 293.441.367 Nmm > 245.768.000 Nmm (**Memenuhi)**

Daerah Lapangan :

Momen $_{\text{Tumpuan}} = 13.517{,}24\ kgm$ = 135.172.400 Nmm

deff = h – s - ϕ tulangan sengkang + ½ ϕ tulangan utama

= 250 – 20 – 8 + (1/2) . 12

= 228 mm

Mn $= \frac{135.172.400}{0,8} = 168.965.500\ Nmm$

Xmin = d' = s + ϕ tulangan sengkang + ½ ϕ tulangan utama = 20 + 8 +6 = 34 mm

Xmax $= 0,75\frac{600\ .228}{600+420} = 100,58\ mm$

Xpakai = 45,5 mm

$$Asc = \frac{0,85.fc'.\beta.b.x}{fy} = \frac{0,85\ .\ 35\ .\ 0,85\ .\ 200\ .\ 45,5}{420} = 547,89\ mm$$

$$Mnc = Asc\ .fy\ .\left(d - \frac{\beta x}{2}\right) = 547,89\ .\ 420\ .\left(228 - \frac{0,85\ .45,5}{2}\right) = 164.379.040,35 \text{ Nmm}$$

$Mns = Mn - Mnc =$ 168.965.500 − 164.379.040,35 = -7.737.655,42 Nmm (tidak memerlukan tulangan tekan)

$$m = \frac{fy}{0,85\ fc'} = \frac{420}{0,85\ .35} = 14,11$$

$$Rn = \frac{Mn}{b.d^2} = \frac{168.965.500}{200\ .\ 358^2} = 16,29$$

$$\rho perlu = \frac{1}{m}.\left(1 - \sqrt{1 - \frac{2\ .m\ .Rn}{fy}}\right) = \frac{1}{14,11}\left(1 - \sqrt{1 - \frac{2\ .14,11\ .16,29}{420}}\right) = 0,050$$

ρ min $<$ ρ $<$ ρ max $= 0,0018 <$ 0,050 $>$ 0,025, dipakai $\rho = 0,025$

Tulangan Tarik (atas)

$As = p\ x\ b\ x\ d =$ 0,0018 x 200 x 228 = 82,08 mm^2

Digunakan Tulangan 3D12 (As = 339 mm^2)

Tulangan Tekan (Bawah)

As = δ x As = 0,5 x 339 = 169,5 mm^2

Digunakan Tulangan 2D12 (As = 226 mm^2)

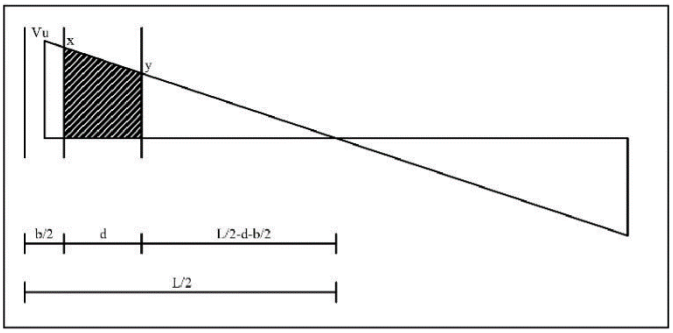
Kontrol Kekuatan

$$\rho = \frac{As}{b.d} = \frac{339}{200\ .\ 228} = 0,007$$

$$a = \frac{As\ .fy}{0,85\ .fc'.b} = \frac{339\ .420}{0,85\ .35\ .200} = 23,92$$

$Mn = As.fy\ \left(d - \frac{a}{2}\right)$ = 339 . 420 . (228 – 23,92/2) = 175.579.404 Nmm > 168.965.500 Nmm (**Memenuhi)**

Penulangan Geser Balok Bordes



Gambar 5.5 Diagram Geser Balok Bordes

Daerah Tumpuan

Beban geser terfaktor : Vu : 13.517,24 $kg = 135.172{,}4\ N$

$$Vc = \frac{1}{6}\sqrt{fc}.bw\,.\,d = \frac{1}{6}\sqrt{35}\,.\,200\,.\,228 = 44.962{,}21\ N$$

Kategori Desain :

1) $\frac{1}{2}$. φ . Vc	= $\frac{1}{2}$. 0,6 . 44.962,21	= 44.548,08 N
2) φ . Vc	= 0,6 . 148.493,60	= 13.488,66 N
3) φ . Vc+ minφ . Vs	= 13.488,66 + 0,6 . . $\frac{1}{3}$. 200 . 228	= 17.213,20 N
4) φ + Vc . $\frac{1}{3}\sqrt{fc}$. bw . d	= 13.488,66 + 0,6 . $\frac{1}{3}$.√35 . 200 . 228	= 67.443,31 N
5) φ .+ Vc . $\frac{2}{3}\sqrt{fc}$. bw . d	= 13.488,66 +0,6 . $\frac{2}{3}$.√35 . 200 . 228	= 121.397,9 N

Nilai φ . Vc+minφ . Vs < Vu < φ + Vc . $\frac{1}{3}\sqrt{fc}$. bw . d. Maka termasuk pada kategori desain 4. Jadi, tulangan geser maksimum dengan sengkang yang diperlukan :

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

$$= \frac{228}{2} \leq 600\ mm$$

$$= 114 \leq 600\ mm$$

Dicoba menggunakan jarak sengkang (s) sebesar 100 mm

$$Av = \frac{1}{4}\ x\ 3{,}14\ x\ d^2\ x\ n = \frac{1}{4}\ x\ 3{,}14\ x\ 10^2\ x\ 2 = 235{,}5\ mm^2$$

$$\emptyset Vs = \frac{\emptyset\,.\,Av\,.\,fy\,.\,d}{s} = \frac{0{,}6\,.\,235{,}5\,.\,420\,.\,200}{100} = 125.692\ N$$

$$\emptyset Vs = \emptyset Vs + \emptyset Vc = 125.692 + 13.488{,}66 = 139.180{,}66\ N > 135.172{,}4\ N$$

Jadi dapat digunakan sengkang 2D8 − 100 mm

Mencari nilai y :

$$\frac{Vu}{\frac{1}{2}L} = \frac{y}{\frac{1}{2}L - \frac{b}{2} - d}$$

$$\frac{135.172,4}{\frac{1}{2}3000} = \frac{y}{\frac{1}{2}3000 - \frac{200}{2} - 228}$$

$$y = 105.614,38\ N$$

$$Vc = \frac{1}{6}\sqrt{fc}.bw\ .\ d = \frac{1}{6}\sqrt{35}\ .\ 200\ .\ 228 = 44.962,21\ N$$

Kategori Desain :

1) $\frac{1}{2}$. φ . Vc	= $\frac{1}{2}$. 0,6 . 44.962,21	= 44.548,08 N
2) φ . Vc	= 0,6 . 148.493,60	= 13.488,66 N
3) φ . Vc+ minφ . Vs	= 13.488,66 + 0,6 . . $\frac{1}{3}$. 200 . 228	= 17.213,20 N
4) φ + Vc . $\frac{1}{3}$ $\sqrt{fc}$' . bw . d	= 13.488,66 + 0,6 . $\frac{1}{3}$.√35 . 200 . 228	= 67.443,31 N
5) φ .+ Vc . $\frac{2}{3}\sqrt{fc}$. bw . d	= 13.488,66 +0,6 . $\frac{2}{3}$.√35 . 200 . 228	= 121.397,9 N

Nilai φ . Vc+minφ . Vs < Vu < φ + Vc . $\frac{1}{3}$ √fc' . bw . d. Maka termasuk pada kategori desain 4. Jadi, tulangan geser maksimum dengan sengkang yang diperlukan :

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

$$= \frac{228}{2} \leq 600\ mm$$

$$= 114 \leq 600\ mm$$

Dicoba menggunakan jarak sengkang (s) sebesar 100 mm

Digunakan sengkang 2D8 – 150 mm

5.6 Perencanaan Balok Anak Atap

Dimensi Balok

Bentang (L) = 400 cm

h = $\frac{L}{16} = \frac{400}{16}$ = 25 cm, dipakai h = 30 cm

b = $\frac{2}{3}h = \frac{2}{3}\ x\ 30 = 20\ cm$, dipakai b = 20 cm

Jadi, digunakan dimensi Balok BA adalah 20/30 cm

Diameter Tulangan = D-12

Diameter Sengkang = D-8

Mutu Beton (fc') = 35 MPa

Mutu Baja (fy) = 420 MPa

Selimut Beton = 40 mm **(SNI 2847 2019 pasal 20.6.1.3.1)**

5.6.1 Pembebanan Balok Anak Atap

1) Beban Mati

Beban sendiri Pelat	= 0,12 x 2400 kg/$m3$	= 288 kg/m^2
Plumbing		= 10 kg/m^2
Plafond		= 18 kg/m^2
Aspal		= 14 kg/m^2
Ducting AC		= 20 kg/m^2
Spesi 2 cm	= 0,2 x 2100 kg/$m2$	= 42 kg/m^2
Finishing		= 21 kg/m^2 +
Beban mati pelat atap		= 412 kg/m^2

2) Beban Hidup

Beban hidup Pelat atap = 100 kg/m^2

3) Beban Air Hujan = 500 kg/m^2

Pembebanan Trapesium

1) Beban Mati

Berat Sendiri Balok = 0,2 m x 0,3 m x 2400 kg/m^3 = 144 kg/m

Beban Ekuivalen $= \frac{1}{2}\ x\ Qd\ x \frac{lx}{2}\ x\ \left(1 - \frac{1}{3}\ x\ \left(\frac{lx}{\frac{2}{ly}}\right)^2\right) x\ 2$

$= \frac{1}{2}\ x\ 412\ x \frac{4}{2}\ x\ \left(1 - \frac{1}{3}\ x\ \left(\frac{4}{\frac{2}{4}}\right)^2\right) x\ 2$ = 755,3 kg/m

Total Beban Mati = 889,3 kg/m

2) Beban Hidup $= \frac{1}{2}\ x\ Ql\ x \frac{lx}{2}\ x\ \left(1 - \frac{1}{3}\ x\ \left(\frac{lx}{\frac{2}{ly}}\right)^2\right) x\ 2$

$= \frac{1}{2}\ x\ 100\ x \frac{4}{2}\ x\ \left(1 - \frac{1}{3}\ x\ \left(\frac{4}{\frac{2}{4}}\right)^2\right) x\ 2$ = 183,3 kg/m

Total Beban Hidup = 183,3 kg/m

3) Beban Hujan $= \frac{1}{2}\ x\ R\ x \frac{lx}{2}\ x\ \left(1 - \frac{1}{3}\ x\ \left(\frac{lx}{\frac{2}{ly}}\right)^2\right) x\ 2$

$= \frac{1}{2}\ x\ 50\ x \frac{4}{2}\ x\ \left(1 - \frac{1}{3}\ x\ \left(\frac{4}{\frac{2}{4}}\right)^2\right) x\ 2$ = 183,3 kg/m

Total Beban Hujan = 91,6 kg/m

Beban Ultimate :

Qu = 1,2 D + 1,6 L + 0,5 R

= 1,2 (889,3) + 1,6 (183,3) + 0,5 (91,6)

= 1067,16 + 293,28 + 45,8

= 1.406,24 kg/m

5.6.2 Perhitungan Gaya Dalam

Momen $_{\text{Tumpuan}} = \frac{l}{11}\ x\ Qu\ x\ l^2 = \frac{1}{11} x\ 1.406{,}24 \quad x\ (4)^2 = 2045{,}44\ kgm$

Momen $_{\text{Lapangan}} = \frac{l}{16}\ x\ Qu\ x\ l^2 = \frac{1}{16} x\ 1.406{,}24 \quad x\ (4)^2 = 1.406{,}24\ kgm$

$V_1 = V_2 = \frac{l}{2}\ x\ Qu\ x\ l = \frac{1}{2} x\ 1.406{,}24 \quad x\ 4 = 2.812{,}48\ kgm$

5.6.3 Syarat Batas Penulangan Balok Anak Atap

Perhitungan syarat batas penulangan Balok Anak Atap dengan menggunakan standar SNI 2847-2019.

$$\beta 1 = 0{,}85 - \frac{0{,}05(fc' - 28)}{7} = 0{,}85 - \frac{0{,}05\ (35 - 28)}{7} = 0{,}8$$

$$\rho b = \frac{0{,}85\ .\ fc'.\ \beta 1}{fy}\left(\frac{600}{600 + fy}\right) = \frac{0{,}85\ .35\ .\ 0{,}8}{420}\ \left(\frac{600}{600 + 420}\right) = 0{,}033$$

$$\rho \max = 0{,}75\ .\ \rho b\ = 0{,}75\ .\ 0{,}033 = 0{,}025$$

$$\rho \min = \frac{0{,}0018\ .\ 420}{fy} = \frac{0{,}0018\ .\ 420}{420} = 0{,}0018$$

5.6.4 Penulangan Lentur Balok Anak Atap

Daerah Tumpuan :

Momen $_{\text{Tumpuan}} = 2.045{,}44\ \ kgm$ = 20.454.400 Nmm

D = h – s - ϕ tulangan sengkang + ½ ϕ tulangan utama

= 400 – 20 – 8 + (1/2) . 12

= 358 mm

Mn $= \frac{20.454.400}{0{,}8} = 25.568.000\ Nmm$

Xmin = d' = s + ϕ tulangan sengkang + ½ ϕ tulangan utama = 40 + 8 +6 = 54 mm

Xmax = $0{,}75\frac{600\,.358}{600+420} = 210\ mm$

Xpakai = 54 mm

$$Asc = \frac{0{,}85.fc'.\beta.b.x}{fy} = \frac{0{,}85\,.\,35\,.\,0{,}85\,.\,200\,.\,54}{420} = 650{,}25\ mm$$

$$Mnc = Asc\,.fy\,.\left(d - \frac{\beta x}{2}\right) = 650{,}25\,.\,420\,.\left(358 - \frac{0{,}85\,.54}{2}\right) = 91.503.830{,}25 \text{ Nmm}$$

$Mns = Mn - Mnc =$ 25.568.000 − 91.503.830,25= (tidak memerlukan tulangan tekan)

$$m = \frac{fy}{0{,}85\ fc'} = \frac{420}{0{,}85\,.35} = 14{,}11$$

$$Rn = \frac{Mn}{b.d^2} = \frac{25.568.000}{200\,.\,358^2} = 1$$

$$\rho perlu = \frac{1}{m}.\left(1 - \sqrt{1 - \frac{2\,.m\,.Rn}{fy}}\right) = \frac{1}{14{,}11}\left(1 - \sqrt{1 - \frac{2\,.14{,}11\,.1}{420}}\right) = 0{,}0024$$

ρ min $<$ ρ $<$ ρ max $= 0{,}0018 <$ 0,0024 $<$ 0,025, dipakai $\rho = 0{,}0024$

Tulangan Tarik (atas)

$As = p\ x\ b\ x\ d = 0{,}0024x\ 200\ x358 = 173{,}44$ mm^2

Digunakan Tulangan 3D12 (As = 339 mm^2)

Tulangan Tekan (Bawah)

As = δ x As = 0,5 x 339 = 169,5 mm^2

Digunakan Tulangan 2D12 (As = 226,1 mm^2)

Kontrol Kekuatan

$$\rho = \frac{As}{b.d} = \frac{339}{200\,.\,358} = 0{,}0031$$

$$a = \frac{As\,.fy}{0{,}85\,.fc'.b} = \frac{339\,.420}{0{,}85\,.\,35\,.\,200} = 15{,}96$$

$Mn = As.fy\ \left(d - \frac{a}{2}\right)$ = 339 . 420 . (358 – 15,96/2) = 33.238.599,24 Nmm > 25.568.000 Nmm (**Memenuhi)**

Daerah Lapangan :

Momen $_{\text{Tumpuan}} = 1.406{,}24\ kgm$ = 14.062.400 Nmm

D = h – s - ϕ tulangan sengkang + ½ ϕ tulangan utama

= 400 – 20 – 8 + (1/2) . 12

= 358 mm

Mn = $\frac{14.062.400}{0,8} = 17.578.000\ Nmm$

Xmin = d' = s + ϕ tulangan sengkang + ½ ϕ tulangan utama = 40 + 10 +6 = 56 mm

Xmax = $0,75\frac{600\ .358}{600+420} = 210\ mm$

Xpakai = 54 mm

$Asc = \frac{0,85.fc'.\beta.b.x}{fy} = \frac{0,85\ .\ 35\ .\ 0,85\ .\ 200\ .\ 54}{420} = 650,25\ mm$

$Mnc = Asc\ .fy\ .\left(d - \frac{\beta x}{2}\right) = 650,25\ .\ 420\ .\left(358 - \frac{0,85\ .54}{2}\right)$ = 91.503.830,25 Nmm

$Mns = Mn - Mnc =$ 17.578.000 − 91.503.830,12 Nmm (tidak memerlukan tulangan tekan)

$m = \frac{fy}{0,85\ fc'} = \frac{420}{0,85\ .35}$ = 14,11

$Rn = \frac{Mn}{b.d^2} = \frac{17.578.000}{200\ .358^2} = 0,67$

$\rho perlu = \frac{1}{m}.\left(1 - \sqrt{1} - \frac{2\ .m\ .Rn}{fy}\right) = \frac{1}{14,11}\left(1 - \sqrt{1} - \frac{2\ .14,11\ .0,87}{420}\right) = 0,0021$

ρ min $<$ $\rho <$ ρ max $= 0,0018 <$ $0,0021 <$ $0,025$, dipakai $\rho = 0,0021$

Tulangan Tarik (atas)

$As = p\ x\ b\ x\ d = 0,0021\ x\ 200\ x358 =$ 150,36 mm^2

Digunakan Tulangan 3D12 (As = 339 mm^2)

Tulangan Tekan (Bawah)

As = δ x As = 0,5 x 339 = 169,5 mm^2

Digunakan Tulangan 2D12 (As = 226,1 mm^2)

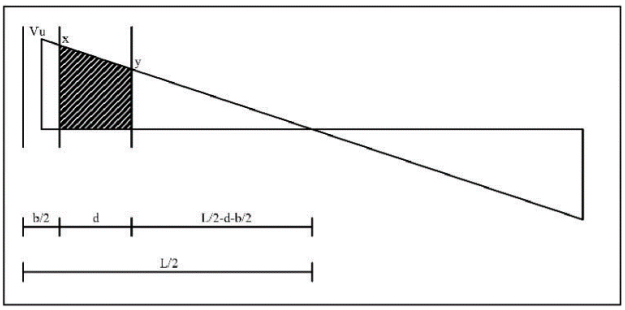
Kontrol Kekuatan

$\rho = \frac{As}{b.d} = \frac{339}{200\ .\ 358} = 0,0031$

$a = \frac{As\ .fy}{0,85\ .fc'.b} = \frac{339\ .420}{0,85\ .35\ .200} = 15,96$

$Mn = As.fy\ \left(d - \frac{a}{2}\right)$ = 339 . 420 . (358 – 15,96/2) = 33.238.599,24 Nmm > 25.568.000 Nmm (**Memenuhi)**

5.6.5 Penulangan Geser Balok Anak Atap



Gambar 5.6 Diagram Geser Balok Anak Atap

Daerah Tumpuan

Beban geser terfaktor : Vu : 2.812,48 $kg = 28.124{,}8\ N$

$$Vc = \frac{1}{6}\sqrt{fc}.bw\,.d = \frac{1}{6}\sqrt{35}\,.200\,.376{,}5 = 68.429{,}32\ N$$

Kategori Desain :

1) $\frac{1}{2}$. φ . Vc = $\frac{1}{2}$. 0,6 . 68.429,32 = 20.528,796 N

2) φ . Vc = 0,6 . 68.429,32 = 41.057,592 N

3) φ . Vc+ minφ . Vs = 41.057,592 + 0,6 . . $\frac{1}{3}$. 200 . 376,5 = 56.117,592 N

4) φ + Vc . $\frac{1}{3}\sqrt{fc}$. bw . d = 41.057,592 + 0,6 . $\frac{1}{3}$.√35 . 200 . 376,5 = 130.153,753 N

5) φ .+ Vc . $\frac{2}{3}\sqrt{fc}$. bw . d = 41.057,592 +0,6 . $\frac{2}{3}$.√35 . 200 . 376,5 = 219.249,915 N

Nilai φ . Vc+minφ . Vs < Vu < φ + Vc . $\frac{1}{3}\sqrt{fc}$. bw . d. Maka termasuk pada kategori desain 4. Jadi, tulangan geser maksimum dengan sengkang yang diperlukan :

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

$$= \frac{376{,}5}{2} \leq 600\ mm$$

$$= 188.5 \leq 600\ mm$$

$$Jadi\ dapat\ digunakan\ sengkang\ 2D8 - 100\ mm$$

Daerah Lapangan

Mencari nilai y :

$$\frac{Vu}{\frac{1}{2}L} = \frac{y}{\frac{1}{2}L - \frac{b}{2} - d}$$

$$\frac{35.809,6}{\frac{1}{2}4000} = \frac{y}{\frac{1}{2}4000 - \frac{200}{2} - 376,5}$$

$y = 27.277,96\ N$

$Vc = \frac{1}{6}\sqrt{fc}bw\ .\ d = \frac{1}{6}\sqrt{35}\ .\ 200\ .\ 376,5 = 68.429,32\ N$

Kategori Desain :

1) $\frac{1}{2}$. φ . Vc = $\frac{1}{2}$. 0,6 . 68.429,32 = 20.528,796 N

2) φ . Vc = 0,6 . 68.429,32 = 41.057,592 N

3) φ . Vc+ minφ . Vs = 41.057,592 + 0,6 . . $\frac{1}{3}$. 200 . 376,5 = 56.117,592 N

4) φ + Vc . $\frac{1}{3}\sqrt{fc}$. bw . d = 41.057,592 + 0,6 . $\frac{1}{3}$.√35 . 200 . 376,5 = 130.153,753 N

5) φ .+ Vc . $\frac{2}{3}\sqrt{fc}$. bw . d = 41.057,592 +0,6 . $\frac{2}{3}$.√35 . 200 . 376,5 = 219.249,915 N

Nilai φ . Vc+minφ . Vs < Vu < φ + Vc . $\frac{1}{3}\sqrt{fc}$. bw . d. Maka termasuk pada kategori desain 4. Jadi, tulangan geser maksimum dengan sengkang yang diperlukan :

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

$= \frac{376,5}{2} \leq 600\ mm$

$= 188.5 \leq 600\ mm$

Digunakan sengkang 2D8 – 150 mm

5.7 Perencanaan Balok Anak Lantai

Dimensi Balok

Bentang (L) = 400 cm

h = $\frac{L}{16} = \frac{400}{16}$ = 25 cm, dipakai h = 30 cm

b = $\frac{2}{3}h = \frac{2}{3}\ x\ 30 = 20\ cm$, dipakai b = 20 cm

Jadi, digunakan dimensi Balok BA adalah 20/30 cm

Diameter Tulangan = D-12

Diameter Sengkang = D-8

Mutu Beton (fc') = 35 MPa

Mutu Baja (fy) = 420 MPa

Selimut Beton = 40 mm **(SNI 2847 2019 pasal 20.6.1.3.1)**

5.7.1 Pembebanan Balok Anak Lantai

1) Beban Mati

Beban sendiri Pelat	= 0,12 x 2400 kg/$m3$	= 288	kg/m^2
Plumbing		= 10	kg/m^2
Plafond		= 18	kg/m^2
Keramik		= 24	kg/m^2
Ducting AC		= 20	kg/m^2
Spesi 2 cm	= 0,2 x 2100 kg/$m2$	= 42	kg/m^2 +
Beban mati pelat atap		= 402	kg/m^2

2) Beban Hidup

Beban hidup Pelat Lantai = 250 kg/m^2

Pembebanan Trapesium

1) Beban Mati

Berat Sendiri Balok = 0,2 m x 0,3 m x 2400 kg/m^3 = 144 kg/m

Beban Ekuivalen $= \frac{1}{2}\ x\ Qd\ x \frac{lx}{2}\ x\ \left(1 - \frac{1}{3}\ x\ \left(\frac{lx}{\frac{2}{ly}}\right)^2\right) x\ 2$

$= \frac{1}{2}\ x\ 402\ x \frac{4}{2}\ x\ \left(1 - \frac{1}{3}\ x\ \left(\frac{4}{\frac{2}{4}}\right)^2\right) x\ 2$ = 737 kg/m

Total Beban Mati = 881 kg/m

2) Beban Hidup $= \frac{1}{2}\ x\ Ql\ x \frac{lx}{2}\ x\ \left(1 - \frac{1}{3}\ x\ \left(\frac{lx}{\frac{2}{ly}}\right)^2\right) x\ 2$

$= \frac{1}{2}\ x\ 250\ x \frac{4}{2}\ x\ \left(1 - \frac{1}{3}\ x\ \left(\frac{4}{\frac{2}{4}}\right)^2\right) x\ 2$ = 458,3 kg/m

Total Beban Hidup = 458,3 kg/m

Beban Ultimate :

Qu = 1,2 D + 1,6 L

= 1,2 (881) + 1,6 (458,3)

= 1057,2 + 733,28

= 1.790,48 kg/m

5.7.2 Perhitungan Gaya Dalam

Momen $_{Tumpuan}$ $= \frac{l}{11}\ x\ Qu\ x\ l^2 = \frac{1}{11} x\ 1.790{,}48\ \ x\ (4)^2 = 2.604{,}33\ kgm$

Momen $_{Lapangan}$ $= \frac{l}{16}\ x\ Qu\ x\ l^2 = \frac{1}{16} x\ 1.790{,}48\ \ x\ (4)^2 = 1.790{,}48\ kgm$

$V_1 = V_2$ $= \frac{l}{2}\ x\ Qu\ x\ l = \frac{1}{2} x\ 1.790{,}48\ \ x\ 4 = 3.580{,}96\ kgm$

5.7.3 Syarat Batas Penulangan Balok Anak Lantai

Perhitungan syarat batas penulangan Balok Bordes dengan menggunakan standar SNI 2847-2019.

$$\beta 1 = 0{,}85 - \frac{0{,}05(fc' - 28)}{7} = 0{,}85 - \frac{0{,}05\ (35 - 28)}{7} = 0{,}8$$

$$\rho b = \frac{0{,}85\ .\ fc'.\ \beta 1}{fy}\left(\frac{600}{600 + fy}\right) = \frac{0{,}85\ .35\ .\ 0{,}8}{420}\ \left(\frac{600}{600 + 420}\right) = 0{,}033$$

$$\rho \max = 0{,}75\ .\ \rho b\ \ = 0{,}75\ .\ 0{,}033 = 0{,}025$$

$$\rho \min = \frac{0{,}0018\ .\ 420}{fy} = \frac{0{,}0018\ .\ 420}{420} = 0{,}0018$$

5.7.4 Penulangan Lentur Balok Anak Lantai

Daerah Tumpuan :

Momen $_{Tumpuan}$ $= 2.604{,}33\ \ kgm$ = 26.043.300 Nmm

D = h – s - ϕ tulangan sengkang + ½ ϕ tulangan utama

= 400 – 20 – 8 + (1/2) . 12

= 358 mm

Mn $= \frac{26.043.300}{0{,}8} = 32.554.125\ Nmm$

Xmin = d’ = s + ϕ tulangan sengkang + ½ ϕ tulangan utama = 40 + 8 +6 = 54 mm

Xmax $= 0{,}75 \frac{600\ .358}{600+420} = 210\ mm$

Xpakai = 58 mm

$$Asc = \frac{0{,}85.\ fc'.\ \beta.\ b.\ x}{fy} = \frac{0{,}85\ .\ 35\ .\ 0{,}85\ .\ 200\ .\ 58}{420} = 698{,}42\ mm$$

$$Mnc = Asc\ .\ fy\ .\left(d - \frac{\beta x}{2}\right) = 698{,}42\ .\ 420\ .\left(358 - \frac{0{,}85\ .58}{2}\right) = 97.783.688{,}94 \text{ Nmm}$$

$Mns = Mn - Mnc = \ 32.554.125 - \ 97.783.688{,}94\ =$ (tidak memerlukan tulangan tekan)

$$m = \frac{fy}{0{,}85\ fc'} = \frac{420}{0{,}85\ .35} = 14{,}11$$

$$Rn = \frac{Mn}{b.\ d^2} = \frac{32.554.125}{200\ .\ 358^2} = 1{,}27$$

$$\rho perlu = \frac{1}{m}.\left(1 - \sqrt{1} - \frac{2\,.\,m\,.\,Rn}{fy}\right) = \frac{1}{14{,}11}\left(1 - \sqrt{1} - \frac{2\,.\,14{,}11\,.\,1{,}27}{420}\right) = 0{,}0031$$

$\rho \min < \rho < \rho \max = 0{,}0018 < 0{,}0031 < 0{,}025$, dipakai $\rho = 0{,}0031$

Tulangan Tarik (atas)

$As = p\ x\ b\ x\ d = 0{,}0031\ x\ 200\ x358 = 221{,}96$ mm^2

Digunakan Tulangan 3D12 (As = 339,1 mm^2)

Tulangan Tekan (Bawah)

As = δ x As = 0,5 x 221,96 = 110,98 mm^2

Digunakan Tulangan 2D12 (As = 226,1 mm^2)

Kontrol Kekuatan

$$\rho = \frac{As}{b.d} = \frac{339{,}1}{200\,.\,358} = 0{,}0047$$

$$a = \frac{As\,.\,fy}{0{,}85\,.\,fc'.\,b} = \frac{339{,}1\,.\,420}{0{,}85\,.\,35\,.\,200} = 23{,}97$$

$Mn = As.fy\ \left(d - \frac{a}{2}\right)$ = 339,1 . 420 . (358 – 23,97/2) = 611.080.105,86Nmm >

32.554.125 Nmm (**Memenuhi)**

Daerah Lapangan :

Momen $_{\text{Tumpuan}} = 1.790{,}48\ kgm$ = 17.904.800 Nmm

D = h – s - ϕ tulangan sengkang + ½ ϕ tulangan utama

= 400 – 20 – 8 + (1/2) . 12

= 358 mm

Mn = $\frac{17.904.800}{0{,}8} = 22.381.000\ Nmm$

Xmin = d’ = s + ϕ tulangan sengkang + ½ ϕ tulangan utama = 40 + 10 +6 = 56 mm

Xmax = $0{,}75\frac{600\,.358}{600+420} = 210\ mm$

Xpakai = 56 mm

$$Asc = \frac{0{,}85.fc'.\beta.b.x}{fy} = \frac{0{,}85\,.\,35\,.\,0{,}85\,.\,200\,.\,56}{420} = 674{,}33\ mm$$

$Mnc = Asc\,.fy\,.\left(d - \frac{\beta x}{2}\right) = 674{,}33\,.\,420\,.\left(358 - \frac{0{,}85\,.56}{2}\right) = 94.651.656{,}12$ Nmm

$Mns = Mn - Mnc =$ 22.381.000 − 94.651.656,12 Nmm (tidak memerlukan tulangan tekan)

$m = \frac{fy}{0{,}85\ fc'} = \frac{420}{0{,}85\ .35} = 14{,}11$

$Rn = \frac{Mn}{b.d^2} = \frac{22.381.000}{200\ .358^2} = 0{,}87$

$\rho perlu = \frac{1}{m}.\left(1 - \sqrt{1} - \frac{2\ .m\ .Rn}{fy}\right) = \frac{1}{14{,}11}\left(1 - \sqrt{1} - \frac{2\ .14{,}11\ .0{,}87}{420}\right) = 0{,}0026$

$\rho\,\text{min} < \rho < \rho\,\text{max} = 0{,}0018 < 0{,}0026 < 0{,}025$, dipakai $\rho = 0{,}0026$

Tulangan Tarik (atas)

$As = p\ x\ b\ x\ d = 0{,}0026\ x\ 200\ x358 = 186{,}16$ mm^2

Digunakan Tulangan 2D12 (As = 226,1 mm^2)

Tulangan Tekan (Bawah)

As = δ x As = 0,5 x 186,16 = 93,08 mm^2

Digunakan Tulangan 1D12 (As = 113 mm^2)

Kontrol Kekuatan

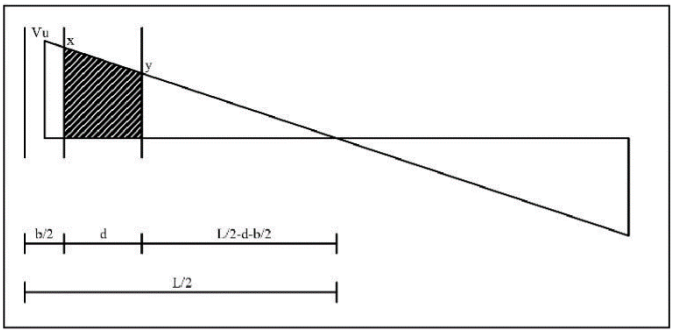
$\rho = \frac{As}{b.d} = \frac{186{,}16}{200\ .358} = 0{,}0026$

$a = \frac{As\ .fy}{0{,}85\ .fc'.b} = \frac{186{,}16\ .420}{0{,}85\ .35\ .200} = 13{,}14$

$Mn = As.fy\ \left(d - \frac{a}{2}\right) = 186{,}16\ .\ 420\ .\ (358 - 13{,}14/2) = 27.439.015{,}968 Nmm >$

$22.381.000\ \ Nmm$ (**Memenuhi)**

5.7.5 Penulangan Geser Balok Anak Lantai



Gambar 5.7 Diagram Geser Balok Anak Lantai

Daerah Tumpuan

Beban geser terfaktor : Vu : 3.580,96 $kg = 35.809{,}6\ N$

$Vc = \frac{1}{6}\sqrt{fc}bw\ .d = \frac{1}{6}\sqrt{35}\ .200\ .376{,}5 = 68.429{,}32\ N$

Kategori Desain :

1) $\frac{1}{2}$. φ . Vc $= \frac{1}{2}$. 0,6 . 68.429,32 = 20.528,796 N

2) φ . Vc = 0,6 . 68.429,32 = 41.057,592 N

3) φ . Vc+ minφ . Vs = 41.057,592 + 0,6 . . $\frac{1}{3}$. 200 . 376,5 = 56.117,592 N

4) φ + Vc . $\frac{1}{3}\sqrt{fc}$. bw . d = 41.057,592 + 0,6 . $\frac{1}{3}$.√35 . 200 . 376,5 = 130.153,753 N

5) φ .+ Vc . $\frac{2}{3}\sqrt{fc}$. bw . d = 41.057,592 +0,6 . $\frac{2}{3}$.√35 . 200 . 376,5 = 219.249,915 N

Nilai φ . Vc+minφ . Vs < Vu < φ + Vc . $\frac{1}{3}\sqrt{fc}$. bw . d. Maka termasuk pada kategori desain 4. Jadi, tulangan geser maksimum dengan sengkang yang diperlukan :

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

$$= \frac{376,5}{2} \leq 600\ mm$$

$$= 188.5 \leq 600\ mm$$

$$Jadi\ dapat\ digunakan\ sengkang\ 2D8 - 100\ mm$$

Daerah Lapangan

Mencari nilai y :

$$\frac{Vu}{\frac{1}{2}L} = \frac{y}{\frac{1}{2}L - \frac{b}{2} - d}$$

$$\frac{35.809,6}{\frac{1}{2}4000} = \frac{y}{\frac{1}{2}4000 - \frac{200}{2} - 376,5}$$

$$y = 27.277,96\ N$$

$$Vc = \frac{1}{6}\sqrt{fc}.bw\ .d = \frac{1}{6}\sqrt{35}\ .200\ .376,5 = 68.429,32\ N$$

Kategori Desain :

1) $\frac{1}{2}$. φ . Vc = $\frac{1}{2}$. 0,6 . 68.429,32 = 20.528,796 N

2) φ . Vc = 0,6 . 68.429,32 = 41.057,592 N

3) φ . Vc+ minφ . Vs = 41.057,592 + 0,6 . . $\frac{1}{3}$. 200 . 376,5 = 56.117,592 N

4) φ + Vc . $\frac{1}{3}\sqrt{fc'}$. bw . d = 41.057,592 + 0,6 . $\frac{1}{3}$.√35 . 200 . 376,5 = 130.153,753 N

5) φ .+ Vc . $\frac{2}{3}\sqrt{fc}$. bw . d = 41.057,592 +0,6 . $\frac{2}{3}$.√35 . 200 . 376,5 = 219.249,915 N

Nilai φ . Vc+minφ . Vs < Vu < φ + Vc . $\frac{1}{3}$ √fc' . bw . d. Maka termasuk pada kategori desain 4. Jadi, tulangan geser maksimum dengan sengkang yang diperlukan :

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

$$= \frac{376{,}5}{2} \leq 600\ mm$$

$$= 188.5 \leq 600\ mm$$

Digunakan sengkang 2D8 – 150 mm

5.8 Perencanaan Balok Penggantung *Lift*

Perencanaan balok penggantung lt ini meggunakan *Lift* penuMPang dengan data sebagai berikut :

Merk	= Abtech	
Kecepatan	= 90 mm/menit	
Kapasitas	= 8 orang (600 kg)	
Lebar pintu (open width)	= 1000 mm	
Dimensi balok *Lift*	= 30 m x 40 m	
Dimensi sangkar (carsize)	= Clear Opening	= 800 x 2100 mm^2
	= Car inside	= 1400 x 1100 mm^2
Dimensi ruang luncur (hoistway)		= 1800 x 1750 mm^2
Dimensi ruang mesin (Machine)		= 2400 x 3600 mm^2

Beban reaksi pada ruang mesin (Reaction Load) =

R1 = 3700 kg (berat mesin penggerak *Lift* + beban kereta + perlengkapan)

R2 = 2700 kg (berat bandul pemberat + perlengkapan)

5.8.1 Beban Hidup Koefisien Kejut yang diakibakaoleh Keran

Ψ = (1 + k1+ k2+V) ≥ 1,15

= (1 + 0,6+ 1,3+1) ≥1,15

= 1,78 ≥ 1,15

Dimana :

Ψ = Koefisien kejut yang diakibatkan oleh keran

$k1$ = koefisien oleh kekuatan keran induk, umumnya diambil 0,6 untuk struktur rangka $k2$ = 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 = R1 x Ψ = 3700 x 1,78 = 6.586 kg

Pu_2 = R2 x Ψ = 2700 x 1,78 = 4.806 kg

P = $Pu_1 + Pu_2$ = 6.586 + 4.806 = 11.392 kg

5.8.2 Pembebanan Balok Penggantung *Lift* :

1. Beban Terpusat

   Beban Terpusat *Lift* = 11.392 kg/m

   Beban Kapasitas Elevator = 600 kg/m +

   Total = 11.992 kg/m

2. Beban Merata

   Beban Sendiri Balok = 0,3 x 0,4 x 2400 = 288 kg/m

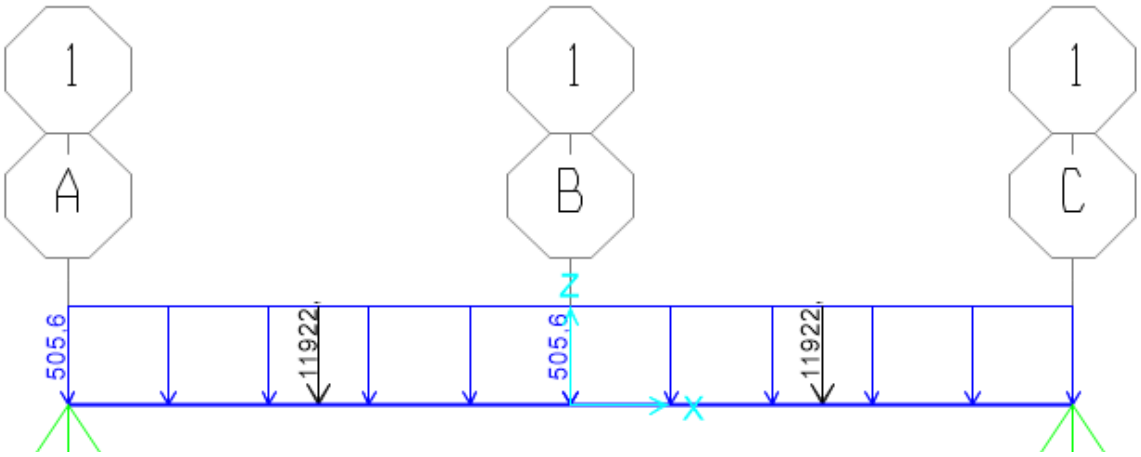
   Beban Pekerja = = 100 kg/m +

   Total = 388 kg/m

3. Kombinasi Beban

   1,2 D + 1,6 L = 1,2 (288) + 1,6 (100)

   = 505,6 kg/m



Gambar 5.8 Beban Balok Penggantung Lift

Gaya geser pada balok penggantung *Lift* :

$V_{terpusat}$ = 11.992 kg/m

V_{merata} = 505,6 kg/m

V_{total} = (505,6 x 3) + 11.992 = 13.508 kg/m

5.8.3 Penulangan Lentur Balok Penggantung *Lift*

Diameter Tulangan = D-12

Diameter Sengkang = D-8

Mutu Beton (fc') = 35 MPa

Mutu Baja (fy) = 420 MPa

Selimut Beton = 40 mm (SNI 2847 2019 pasal 20.6.1.3.1)

5.8.4 Syarat Batas Penulangan Balok Penggantung *Lift*

Perhitungan syarat batas penulangan Balok Bordes dengan menggunakan standar SNI 2847-2019.

$$\beta 1 = 0{,}85 - \frac{0{,}05(fc' - 28)}{7} = 0{,}85 - \frac{0{,}05\ (35 - 28)}{7} = 0{,}8$$

$$\rho b = \frac{0{,}85\ .\ fc'.\beta 1}{fy}\left(\frac{600}{600 + fy}\right) = \frac{0{,}85\ .35\ .\ 0{,}8}{420}\ \left(\frac{600}{600 + 420}\right) = 0{,}033$$

$$\rho \max = 0{,}75\ .\ \rho b\ \ = 0{,}75\ .\ 0{,}033 = 0{,}025$$

$$\rho \min = \frac{0{,}0018\ .\ 420}{fy} = \frac{0{,}0018\ .\ 420}{420} = 0{,}0018$$

5.8.5 Penulangan Lentur Balok Penggantung *Lift*

Daerah Tumpuan :

Momen $_{\text{Tumpuan}}$ $= 2.247\ \ kgm$ = 22.470.000 Nmm

D = h – s - ϕ tulangan sengkang + ½ ϕ tulangan utama

= 400 – 40 – 8 + (1/2) . 12

= 356 mm

Mn = $\frac{22.470.000}{0{,}8} = 28.087.500\ Nmm$

Xmin = d' = s + ϕ tulangan sengkang + ½ ϕ tulangan utama = 40 + 8 +6 = 54 mm

Xmax = $0{,}75\frac{600\ .358}{600+420} = 210\ mm$

Xpakai = 54 mm

$$Asc = \frac{0{,}85.\ fc'.\beta.b.x}{fy} = \frac{0{,}85\ .\ 35\ .\ 0{,}85\ .\ 300\ .\ 54}{420} = 975{,}38\ mm$$

$$Mnc = Asc\ .\ fy\ .\left(d - \frac{\beta x}{2}\right) = 975{,}38\ .\ 420\ .\left(356 - \frac{0{,}85\ .54}{2}\right) = 136.437.129{,}78\ \text{Nmm}$$

$Mns = Mn - Mnc =\ 28.087.500\ -\ 136.437.129{,}78 =$ (tidak memerlukan tulangan tekan)

$m = \frac{fy}{0{,}85\ fc'} = \frac{420}{0{,}85\ .35} = 14{,}11$

$Rn = \frac{Mn}{b.d^2} = \frac{28.087.500}{300\ .356} = 0{,}73$

$\rho perlu = \frac{1}{m}.\left(1 - \sqrt{1 - \frac{2\ .m\ .Rn}{fy}}\right) = \frac{1}{14{,}11}\left(1 - \sqrt{1 - \frac{2\ .14{,}11\ .0{,}73}{420}}\right) = 0{,}0017$

$\rho \min < \rho < \rho \max = 0{,}0018 < 0{,}0017 < 0{,}025$, dipakai $\rho = 0{,}0017$

Tulangan Tarik (atas)

$As = p\ x\ b\ x\ d = 0{,}0017\ x\ 300\ x356 = 181{,}56$ mm^2

Digunakan Tulangan 3D12 (As = 339,1 mm^2)

Tulangan Tekan (Bawah)

As = δ x As = 0,5 x 181,56 = 90,78 mm^2

Digunakan Tulangan 3D12 (As = 339,1 mm^2)

Kontrol Kekuatan

$\rho = \frac{As}{b.d} = \frac{339{,}1}{300\ .356} = 0{,}0035$

$a = \frac{As\ .fy}{0{,}85\ .fc'.b} = \frac{339{,}1\ .420}{0{,}85\ .35\ .300} = 15{,}96$

$Mn = As.fy\ \left(d - \frac{a}{2}\right)$ = 339,1 . 420 . (358 – 15,96/2) = 49.850.548,44 Nmm >

28.087.500 Nmm (**Memenuhi)**

Daerah Lapangan :

Momen $_{\text{Tumpuan}}$ $= 3589{,}19\ kgm$ = 35.891.900 Nmm

D = h – s - ϕ tulangan sengkang + ½ ϕ tulangan utama

= 400 – 40 – 8 + (1/2) . 12

= 356 mm

Mn = $\frac{35.891.900}{0{,}8} = 44.864.875\ Nmm$

Xmin = d’ = s + ϕ tulangan sengkang + ½ ϕ tulangan utama = 40 + 8 +6 = 54 mm

Xmax = $0{,}75\frac{600\ .356}{600+420} = 210\ mm$

Xpakai = 54 mm

$Asc = \frac{0{,}85.fc'.\beta.b.x}{fy} = \frac{0{,}85\ .35\ .0{,}85\ .300\ .54}{420} = 975{,}38\ mm$

$Mnc = Asc\ .fy\ .\left(d - \frac{\beta x}{2}\right) = 975{,}38\ .420\ .\left(358 - \frac{0{,}85\ .54}{2}\right) = 136.437.129{,}78$ Nmm

$Mns = Mn - Mnc =$ 35.891.900 − 136.437.129,78 Nmm (tidak memerlukan tulangan tekan)

$m = \frac{fy}{0{,}85\ fc'} = \frac{420}{0{,}85\ .35}$ = 14,11

$Rn = \frac{Mn}{b.d^2} = \frac{44.864.875}{300\ .358^2} = 1{,}18$

$\rho perlu = \frac{1}{m}.\left(1 - 1 - \sqrt{1 - \frac{2\ .m\ .Rn}{fy}}\right) = \frac{1}{14{,}11}\left(1 - \sqrt{1 - \frac{2\ .14{,}11\ .1{,}18}{420}}\right)$

$= 0{,}0028$

ρ min $< \rho <$ ρ max $= 0{,}0018 < 0{,}0028 < 0{,}025$, dipakai $\rho = 0{,}0028$

Tulangan Tarik (atas)

$As = p\ x\ b\ x\ d = 0{,}0028\ x\ 300\ x358 = 300{,}7$ mm^2

Digunakan Tulangan 3D12 (As = 339 mm^2)

Tulangan Tekan (Bawah)

As = δ x As = 0,5 x 300,7 = 150,35 mm^2

Digunakan Tulangan 3D12 (As = 339,1 mm^2)

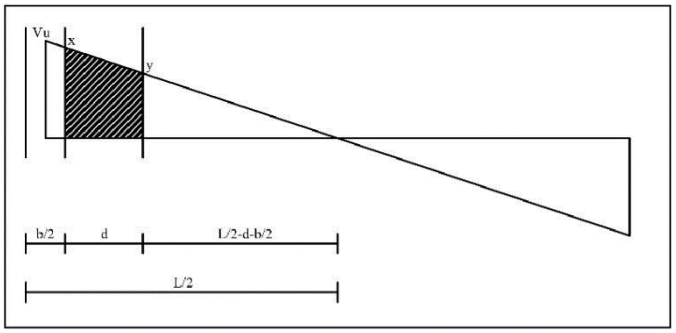
Kontrol Kekuatan

$\rho = \frac{As}{b.d} = \frac{339}{300\ .356} = 0{,}0035$

$a = \frac{As\ .fy}{0{,}85\ .fc'.b} = \frac{339{,}1\ .420}{0{,}85\ .35\ .300} = 15{,}96$

$Mn = As.fy\ \left(d - \frac{a}{2}\right)$ = 339 . 420 . (358 – 15,96/2) = 49.850.548,44 Nmm > 44.864.875 Nmm (**Memenuhi)**

5.8.6 Penulangan Geser Balok Penggantung *Lift*



Gambar 5.9 Diagram Geser Balok Penggantung Lift

Daerah Tumpuan

Beban geser terfaktor : Vu : 13.508,8 $kg = 135.088\ N$

$Vc = \frac{1}{6}\sqrt{fc}.bw\ .d = \frac{1}{6}\sqrt{35}\ .300\ .376 = 102.971{,}84\ \ N$

Kategori Desain :

1) $\frac{1}{2}$. φ . Vc	= $\frac{1}{2}$. 0,6 . 102.971,84	= 30.891,55 N
2) φ . Vc	= 0,6 . 102.971,84	= 61.783,1 N
3) φ . Vc+ minφ . Vs	= 61.783,1 + 0,6 . . $\frac{1}{3}$. 300 . 376,5	= 84.343 N
4) φ + Vc . $\frac{1}{3}\sqrt{fc'}$. bw . d	= 61.783,1 + 0,6 . $\frac{1}{3}$.√35 . 300 . 376,5	= 185.349,2 N
5) φ .+ Vc . $\frac{2}{3}\sqrt{fc}$. bw . d	= 5017,91 +0,6 . $\frac{2}{3}$.√35 . 300 . 376,5	= 308.915,41 N

Nilai φ . Vc+minφ . Vs < Vu < φ + Vc . $\frac{1}{3}\sqrt{fc}$. bw . d. Maka termasuk pada kategori desain 4. Jadi, tulangan geser maksimum dengan sengkang yang diperlukan :

$$Max\ s = \frac{d}{2} \leq 300\ mm$$
$$= \frac{376{,}5}{2} \leq 300\ mm$$
$$= 188.5 \leq 300\ mm$$

$Jadi\ dapat\ digunakan\ sengkang\ 3D8 - 100\ mm$

Daerah Lapangan

Mencari nilai y :

$$\frac{Vu}{\frac{1}{2}L} = \frac{y}{\frac{1}{2}L - \frac{b}{2} - d}$$

$$\frac{135.088}{\frac{1}{2}3000} = \frac{y}{\frac{1}{2}3000 - \frac{300}{2} - 376{,}5}$$

$y = 87.717{,}14\ N$

$Vc = \frac{1}{6}\sqrt{fc}.bw\ .d = \frac{1}{6}\sqrt{35}\ .300\ .376{,}5 = 102.971{,}84\ N$

Kategori Desain :

1) $\frac{1}{2}$. φ . Vc	= $\frac{1}{2}$. 0,6 . 102.971,84	= 30.891,55 N
2) φ . Vc	= 0,6 . 102.971,84	= 61.783,1 N
3) φ . Vc+ minφ . Vs	= 61.783,1 + 0,6 . . $\frac{1}{3}$. 300 . 376,5	= 84.343 N
4) φ + Vc . $\frac{1}{3}\sqrt{fc}$. bw . d	= 61.783,1 + 0,6 . $\frac{1}{3}$.√35 . 300 . 376,5	= 185.349,2 N

5) φ .+ Vc . $\frac{2}{3}\sqrt{fc}$. bw . d = 5017,91 +0,6 . $\frac{2}{3}$.√35 . 300 . 376,5 = 308.915,41 N

Nilai φ . Vc+minφ . Vs < Vu < φ + Vc . $\frac{1}{3}\sqrt{fc}$. bw . d. Maka termasuk pada kategori desain 4. Jadi, tulangan geser maksimum dengan sengkang yang diperlukan :

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

$$= \frac{347}{2} \leq 600\ mm$$

$$= 173{,}5 \leq 600\ mm$$

Digunakan sengkang 3D8 – 150 mm