BAB V
ANALISIS DAN DESAIN STRUKTUR

5.1 Data Perencanaan

Data perencanaan memuat data-data yang diperlukan dalam proses analisis.

5.1.1 Parameter Bahan

- fy = kuat leleh baja karakteristik = 400 MPa.
- $f'c$ (kuat desak beton karakteristik) untuk kolom yang digunakan adalah 20 MPa, 30 MPa, 40 MPa dan 50 MPa, sedangkan untuk balok dan pelat adalah 30 MPa.
- E = modulus elastisitas beton = $4700\sqrt{f'c}$

5.1.2 Asumsi yang digunakan

a. Tebal pelat atap = 100 mm.
b. Tebal pelat lantai = 120 mm.
c. Dimensi kolom = 500 x 750 mm^2.
d. Dimensi balok induk = 300 x 500 mm^2.
e. Tinggi antar tingkat = 4,5 meter.
f. Berat volume beton = 24 kN/m^3.
g. Tata guna ruang sebagai perkantoran dengan beban hidup lantai 2,5 kN/m^2 dan beban hidup atap 1 kN/m^2.

5.2 Perhitungan Gaya-Gaya Yang Bekerja Pada Struktur

5.2.1 Perhitungan Beban Akibat Beban Gravitasi

Pada bab ini dilakukan perhitungan terhadap portal arah X dan Y.

5.2.1.1 Beban Pelat

A. Pembebanan Pada Balok Atap

1) Beban mati pelat atap (w_D)

- Pelat Atap (100mm) $= 0{,}10 \text{ m} \times 24 \text{ kN/m}^3 = 2{,}40 \text{ kN/m}^2$
- Lapisan kedap air (20mm) $= 0{,}02 \text{ m} \times 21 \text{ kN/m}^3 = 0{,}42 \text{ kN/m}^2$
- Gantungan+Plafon $= (0{,}11 + 0{,}07) \text{ kN/m}^2 = 0{,}18 \text{ kN/m}^2$

$w_D = 3{,}00 \text{ kN/m}^2$

- Berat sendiri balok induk dihitung langsung dengan SAP 2000.

2) Beban hidup pelat atap (w_L)

$w_L = 1{,}00 \text{ kN/m}^2$

B. Pembebanan Pada Balok Lantai

1) Beban mati pelat lantai (w_D)

- Pelat Lantai (120mm) $= 0{,}12 \text{ m} \times 24 \text{ kN/m}^3 = 2{,}88 \text{ kN/m}^2$
- Pasir (5cm) $= 0{,}05 \text{ m} \times 18 \text{ kN/m}^3 = 0{,}90 \text{ kN/m}^2$
- Keramik (1cm) $= 1{,}00 \times 0{,}24 \text{ kN/m}^2 = 0{,}24 \text{ kN/m}^2$
- Spesi (2cm) $= 2{,}00 \times 0{,}24 \text{ kN/m}^2 = 0{,}48 \text{ kN/m}^2$
- Gantungan+Plafon $= (0{,}11 + 0{,}07) \text{ kN/m}^2 = 0{,}18 \text{ kN/m}^2$

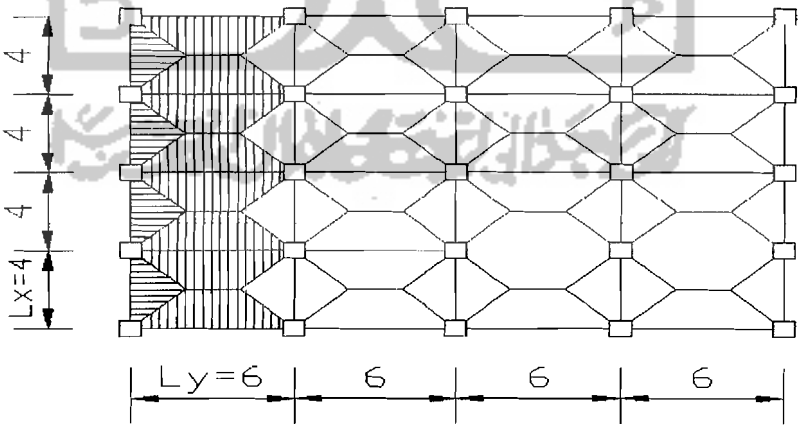
$w_D = 4{,}68 \text{ kN/m}^2$

- Berat sendiri balok induk dihitung langsung dengan SAP 2000.

2) Beban hidup pelat lantai (w_L)

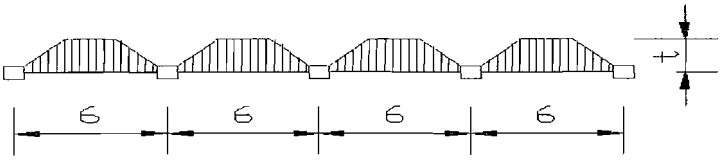
$w_L = 2{,}50 \text{ kN/m}^2$ (Untuk Perkantoran)

5.2.1.2 Distribusi Beban Pelat



Gambar 5.1 Distribusi Beban Pelat

a. Perhitungan beban trapesium



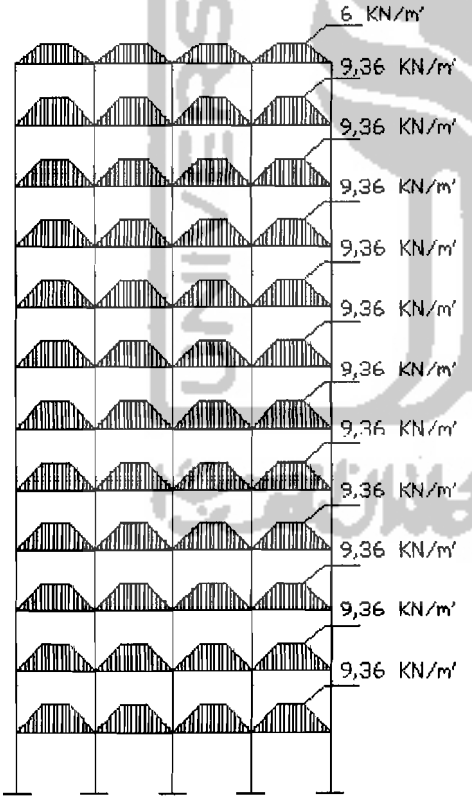
Gambar 5.2 Beban Trapesium

Untuk Atap :

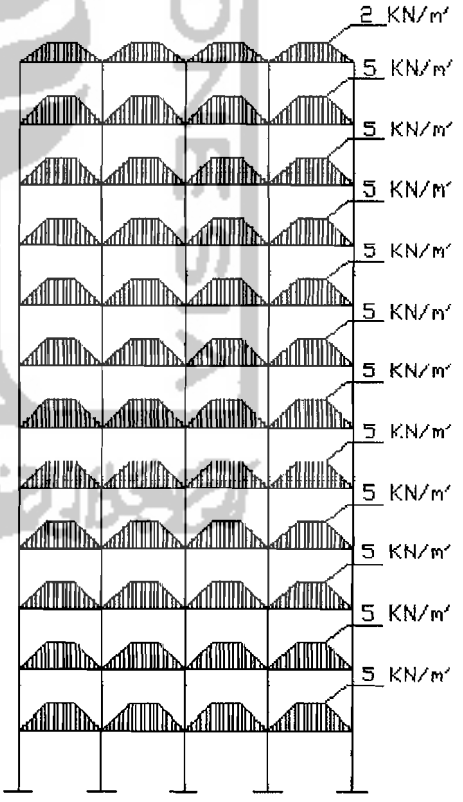
- $t = ½ \times Lx = ½ \times 4 = 2$ m.
- $q_D = t \times w_D = 2 \times 3 = 6$ kN/m.
- $q_L = t \times w_L = 2 \times 1 = 2$ kN/m.

Untuk Lantai :

- $t = ½ \times Lx = ½ \times 4 = 2$ m.
- $q_D = t \times w_D = 2 \times 4{,}68 = 9{,}36$ kN/m.
- $q_L = t \times w_L = 2 \times 2{,}5 = 5$ kN/m.

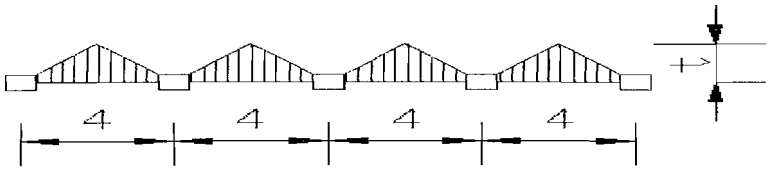


Gambar 5.3 Beban Mati Trapesium



Gambar 5.4 Beban Hidup Trapesium

b. Perhitungan beban segitiga



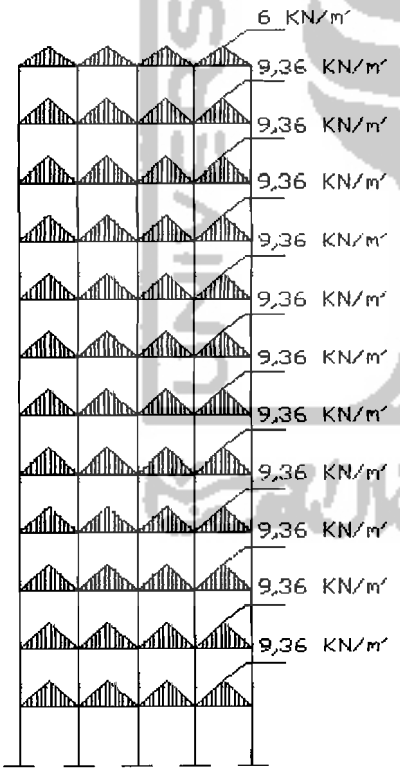
Gambar 5.5 Beban Segitiga

Untuk Atap :

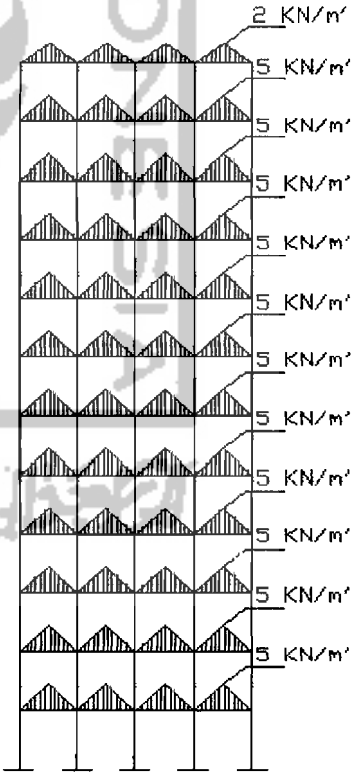
- $t = ½ \times Lx = ½ \times 4 = 2$ m.
- $q_D = t \times w_D = 2 \times 3 = 6$ kN/m.
- $q_L = t \times w_L = 2 \times 1 = 2$ kN/m.

Untuk Lantai :

- $t = ½ \times Lx = ½ \times 4 = 2$ m.
- $q_D = t \times w_D = 2 \times 4{,}68 = 9{,}36$ kN/m.
- $q_L = t \times w_L = 2 \times 2{,}5 = 5$ kN/m.



Gambar 5.6 Beban Mati Segitiga



Gambar 5.7 Beban Hidup Segitiga

5.2.2 Perhitungan Beban Akibat Beban Gempa

Perhitungan distribusi gaya geser horizontal akibat beban gempa (Fi) diawali dengan menghitung berat total bangunan (wt), menentukan waktu getar bangunan (T), koefisien gempa dasar (C), faktor keutamaan (I), faktor jenis struktur (K), dan gaya geser dasar (V).

5.2.2.1 Berat Total Bangunan

1. Atap

- Pelat Atap = P.L.w_D atap.jumlah = 6×4×3×16 = 1152 kN
- Kolom = b.h.t.bj.jumlah = 0,75×0,5×2,25×24×25 = 506,25 kN
- Balok Induk= b.h.bj.panjang = 0,3×0,5×24×200 = 720 kN
- Beban berguna tereduksi (untuk kantor = 0,3) :
  =P×L×w_L atap×jumlah×reduksi = 6×4×1×16×0,3 = 115,2 kN

  Jumlah = 2493,45 kN

2. Untuk Lantai 3 sampai 12

- Pelat Lantai = P.L.w_D lantai.jumlah = 6×4×4,68×16 = 1797,12 kN
- Kolom = b.h.t.bj.jumlah = 0,75×0,5×4,5×24×25 = 1012,5 kN
- Balok Induk= b.h.bj.panjang = 0,3×0,5×24×200 = 720 kN
- Tembok = (H_T-H_B).panjang.w_T = (4,5-0,5)×200×2,5 = 2000 kN
- Beban berguna tereduksi (untuk kantor = 0,3) :
  =P×L×w_L lantai×jumlah×reduksi = 6×4×2,5×16×0,3 = 288 kN

  Jumlah = 5817,62 kN

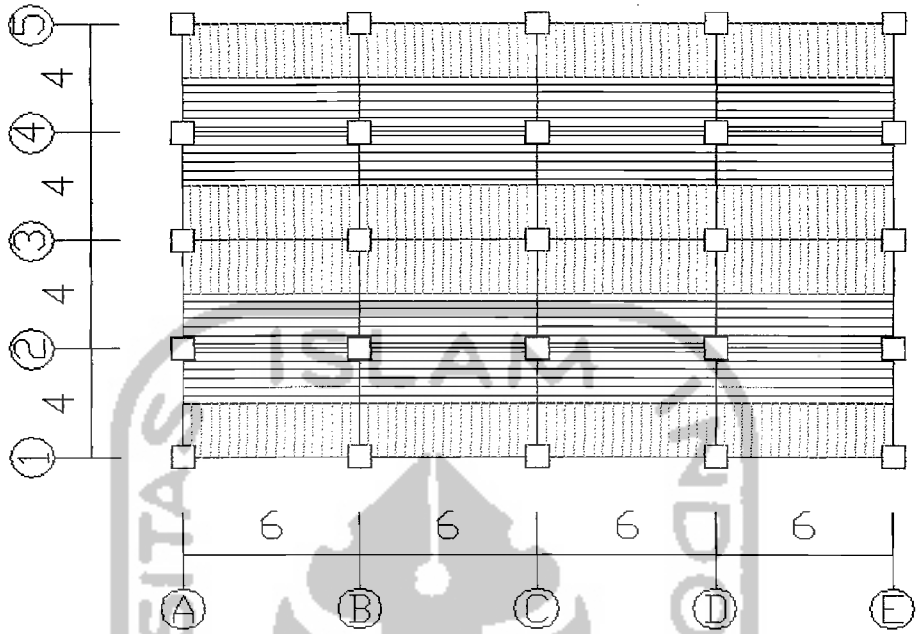
3. Lantai 2

- Pelat Lantai = P.L.w_D lantai.jumlah = 6×4×4,68×16 = 1797,12 kN
- Kolom = b.h.t.bj.jumlah = 0,75×0,5×6,75×24×25 = 1518,75 kN
- Balok Induk= b.h.bj.panjang = 0,3×0,5×24×200 = 720 kN
- Tembok = (H_T-H_B).panjang.w_T = (4,5-0,5)×200×2,5 = 2000 kN
- Beban berguna tereduksi (untuk kantor = 0,3) :
  =P×L×w_L lantai×jumlah×reduksi = 6×4×2,5×16×0,3 = 288 kN

  Jumlah = 6323,87 kN

Distribusi Gaya Geser Horizontal per Luasan

Portal Arah X

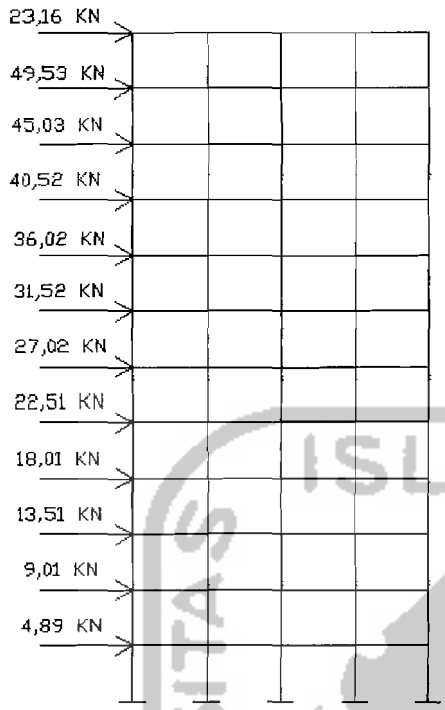


Gambar 5.9 Distribusi Luasan Arah X

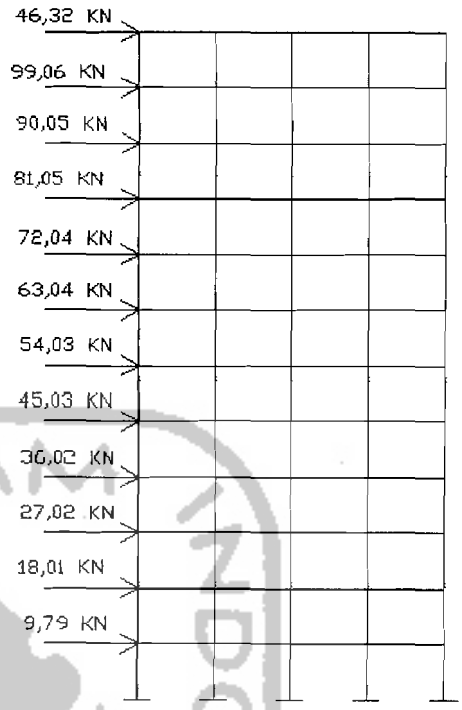
Tabel 5.2 Hasil Hitungan Distribusi Gaya Geser per Luasan Arah X

As	Luas	Atap kN	Lt-12 kN	Lt-11 kN	Lt-10 kN	Lt-9 kN	Lt-8 kN
1	48	23.16	49.53	45.03	40.52	36.02	31.52
2	96	46.32	99.06	90.05	81.05	72.04	63.04
3	96	46.32	99.06	90.05	81.05	72.04	63.04
4	96	46.32	99.06	90.05	81.05	72.04	63.04
5	48	23.16	49.53	45.03	40.52	36.02	31.52
Σ	384	185	396	360	324	288	252

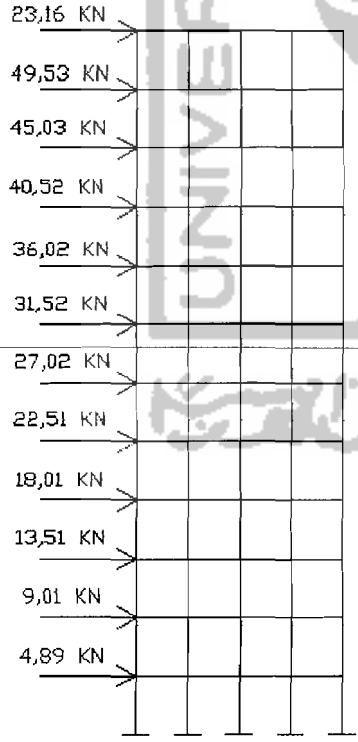
As	Lt-7 kN	Lt-6 kN	Lt-5 kN	Lt-4 kN	Lt-3 kN	Lt-2 kN	Total kN
1	27.02	22.51	18.01	13.51	9.01	4.89	
2	54.03	45.03	36.02	27.02	18.01	9.79	
3	54.03	45.03	36.02	27.02	18.01	9.79	
4	54.03	45.03	36.02	27.02	18.01	9.79	
5	27.02	22.51	18.01	13.51	9.01	4.89	
Σ	216	180	144	108	72	39	2566



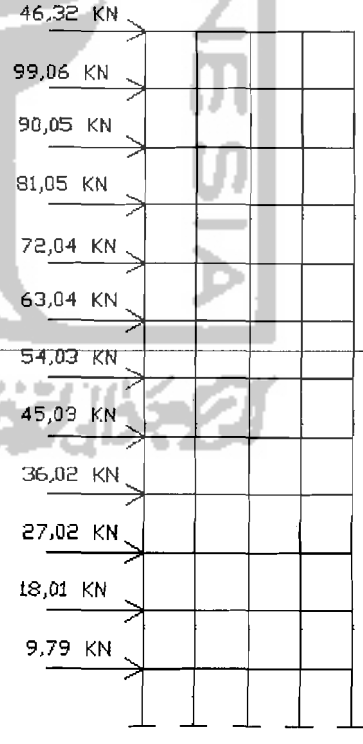
Gambar 5.11 Bagian Tepi Arah X



Gambar 5.12 Bagian Tengah Arah X



Gambar 5.13 Bagian Tepi Arah Y



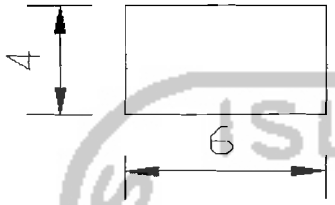
Gambar 5.14 Bagian Tengah Arah Y

5.3 Perencanaan

Dalam perencanaan hanya diambil salah satu perwakilan dari beberapa elemen bangunan yang dihitung. Sedangkan data-data perencanaan diambil dari data-data analisis SAP2000.

5.3.1 Perencanaan Pelat

Contoh perencanaan memakai perencanaan pelat lantai.



Lx = 4 m.

Ly = 6 m.

Tebal pelat lantai = 120 mm.

wD Lantai = 4,68 KN/m^2 ; wL Lantai = 2,5 kN/m^2

q_u lantai = $1,2 \times w_D + 1,6 \times w_L$

$= 1,2 \times 4,68 + 1,6 \times 2,5$

q_u lantai = 9,616 kN/m^2

$\frac{ly}{lx} = \frac{6}{4} = 1,5 < 2$ tulangan dua arah

Berdasarkan PBI 71, dari Tabel 13.3.1 (terjepit penuh) hal 202 didapat:

- Clx = 36 - Ctx = 76
- Cly = 17 - Cty = 57

- Mtx $= -0,001 \times q_u$ lantai $\times Lx^2 \times Ctx$
  $= -0,001 \times 9,616 \times 4^2 \times 76 = -11,6931$ kNm
- Mty $= -0,001 \times q_u$ lantai $\times Lx^2 \times Cty$
  $= -0,001 \times 9,616 \times 4^2 \times 57 = -8,7698$ kNm
- Mlx $= 0,001 \times q_u$ lantai $\times Lx^2 \times Clx$
  $= 0,001 \times 9,616 \times 4^2 \times 36 = 5,5388$ kNm
- Mly $= 0,001 \times q_u$ lantai $\times Lx^2 \times Cly$
  $= 0,001 \times 9,616 \times 4^2 \times 17 = 2,6156$ kNm

- dlx = h – pb – ½.Øtul = 120 – 20 – ½.10 = 95 mm
- dly = h – pb – 1½.Øtul = 120 – 20 – 1½.10 = 85 mm
- dtx = dty = dlx = 95 mm

$$\rho_b = \frac{0{,}85 \times fc' \times \beta_1}{fy} \times \left(\frac{600}{600 + fy} \right)$$

$$= \frac{0{,}85 \times 30 \times 0{,}85}{300} \times \left(\frac{600}{600 + 300} \right)$$

$$= 0{,}0482$$

$$\rho_{mak} = 0{,}75 \cdot \rho_b = 0{,}0361$$

$$\rho_{min} = \frac{1{,}4}{fy} = \frac{1{,}4}{300} = 0{,}0047$$

a. Tulangan Lx

$$Rn = \frac{Mu/\phi}{b.d^2} = \frac{5{,}5388.10^6 / 0{,}8}{1000.95^2} = 0{,}7671 \text{ MPa}$$

$$m = \frac{fy}{0{,}85.fc'} = \frac{300}{0{,}85.30} = 11{,}7647$$

$$\rho_{perlu} = \frac{1}{m} \times \left(1 - \sqrt{1 - \frac{2 \times m \times Rn}{fy}} \right)$$

$$= \frac{1}{11{,}7647} \times \left(1 - \sqrt{1 - \frac{2 \times 11{,}7647 \times 0{,}7671}{300}} \right)$$

$$= 0{,}002597$$

$$1{,}33.\rho_{perlu} = 1{,}33 \cdot 0{,}002597 = 0{,}003454$$

Karena $\rho_{perlu} < \rho_{min} = 0{,}0047$ dan $1{,}33.\rho_{perlu} < \rho_{min}$, maka $\rho_{pakai} = 0{,}003454$

$$As_{perlu} = \rho_{perlu} \times b \times d = 0{,}003454 \times 1000 \times 95 = 328{,}101 \text{ mm}^2$$

$$As_{susut} = 0{,}002 \times b \times h = 0{,}002 \times 1000 \times 120 = 240 \text{ mm}^2$$

$As_{perlu} > As_{susut}$ → **Ok**

Dipakai tulangan Ø 10 mm.

$A_1Ø = 0{,}25 \times \pi \times Ø_{tul}{}^2 = 0{,}25 \times \pi \times 10^2 = 78{,}5 \text{ mm}^2$

$S \leq \frac{A_1\phi . b}{As} = \frac{78{,}5.1000}{328{,}101} = 239{,}47 \text{ mm}$

$S \leq 2 . h = 2 . 120 = 240 \text{ mm}$

$S \leq 250 \text{ mm}$

Maka dipakai tulangan P_{10} – 200 mm

Kontrol Kapasitas :

$As_{ada} = \frac{A_1\phi . b}{S} = \frac{78{,}5.1000}{200} = 392{,}857 \text{ mm}^2$

$a = \frac{As_{ada} . fy}{0{,}85 . fc' . b} = \frac{392{,}857.300}{0{,}85.30.1000} = 4{,}622 \text{ mm}$

$Mn = As_{ada} . fy . \left(d - \frac{a}{2}\right)$

$= 392{,}857 . 300 . \left(95 - \frac{4{,}622}{2}\right)$

$= 10{,}924 \text{ kNm} > Mu/\phi = 6{,}924 \text{ kNm} \rightarrow$ **Ok**

b. Tulangan tx

$Rn = \frac{Mu/\phi}{b.d^2} = \frac{11{,}6931.10^6 / 0{,}8}{1000.95^2} = 1{,}6195 \text{ MPa}$

$m = \frac{fy}{0{,}85 . fc'} = \frac{300}{0{,}85.30} = 11{,}7647$

$\rho_{ada} = \frac{1}{m} \times \left(1 - \sqrt{1 - \frac{2 \times m \times Rn}{fy}}\right)$

$= \frac{1}{11{,}7647} \times \left(1 - \sqrt{1 - \frac{2 \times 11{,}7647 \times 1{,}6195}{300}}\right)$

$= 0{,}0056$

$1{,}33.\rho_{perlu} = 1{,}33 . 0{,}0056 = 0{,}007424$

Karena $\rho_{perlu} > \rho_{min} = 0{,}0047$ dan $\rho_{perlu} < \rho_{max} = 0{,}0361$, maka $\rho_{pakai} = 0{,}0056$

$As_{perlu} = \rho_{perlu} \times b \times d = 0{,}0056 \times 1000 \times 95 = 530{,}264\ mm^2$

$As_{susut} = 0{,}002 \times b \times h = 0{,}002 \times 1000 \times 120 = 240\ mm^2$

$As_{perlu} > As_{susut} \rightarrow$ **Ok**

Dipakai tulangan Ø 10 mm.

$A_1Ø = 0{,}25 \times \pi \times Ø_{tul}^2 = 0{,}25 \times \pi \times 10^2 = 78{,}5\ mm^2$

$S \leq \frac{A_1\phi . b}{As} = \frac{78{,}5.1000}{530{,}264} = 148{,}17\ mm$

$S \leq 2 . h = 2 . 120 = 240\ mm$

$S \leq 250\ mm$

Maka dipakai tulangan P_{10} – 140 mm

Kontrol Kapasitas :

$As_{ada} = \frac{A_1\phi . b}{S} = \frac{78{,}5.1000}{140} = 561{,}225\ mm^2$

$a = \frac{As_{ada} . fy}{0{,}85 . fc' . b} = \frac{561{,}225.300}{0{,}85.30.1000} = 6{,}603\ mm$

$Mn = As_{ada} . fy . \left(d - \frac{a}{2}\right)$

$= 561{,}225 . 300 . \left(95 - \frac{6{,}603}{2}\right)$

$= 15{,}439\ kNm > Mu/\phi = 14{,}616\ kNm \rightarrow$ **Ok**

Tulangan Susut

$AS_{SUSUT} = 0{,}002 \times b \times h = 0{,}002 \times 1000 \times 120 = 240 mm^2$

Pakai D_{tul} $Ø8 \rightarrow A_{1Ø} = 1/4 \times \pi \times 8^2 = 50{,}265 mm^2$

$S = \frac{A_{1Ø} \times b}{As_{susut}} = \frac{50{,}265 \times 1000}{240} = 209{,}438 mm \ \rangle\ 200 mm$

S_{Pakai} =200mm→ **P_8 – 200**

Kontrol:

$$AS_{ada} = \frac{A_{1\varnothing} \times b}{S_{pakai}} = \frac{50{,}265 \times 1000}{200} = 251{,}33mm^2 \rangle AS_{SUSUT} = 240mm^2 \rightarrow \text{AMAN}$$

c. Tulangan Ly

$$\text{Rn} = \frac{Mu/\phi}{b.d^2} = \frac{2{,}6156.10^6/0{,}8}{1000.85^2} = 0{,}4525 \text{ MPa}$$

$$\text{m} = \frac{fy}{0{,}85.fc'} = \frac{300}{0{,}85.30} = 11{,}7647$$

$$\rho_{\text{porlu}} = \frac{1}{m} \times \left(1 - \sqrt{1 - \frac{2 \times m \times Rn}{fy}}\right)$$

$$= \frac{1}{11{,}7647} \times \left(1 - \sqrt{1 - \frac{2 \times 11{,}7647 \times 0{,}4525}{300}}\right)$$

$$= 0{,}0015$$

$$1{,}33.\rho_{\text{perlu}} = 1{,}33 \;.\; 0{,}0015 = 0{,}002024$$

Karena $\rho_{perlu} < \rho_{min} = 0{,}0047$ dan $1{,}33.\rho_{perlu} < \rho_{min}$, maka $\rho_{pakai} = 0{,}002024$

$As_{perlu} = \rho_{perlu} \times b \times d = 0{,}002024 \times 1000 \times 85 = 172{,}064 \text{ mm}^2$

$As_{susut} = 0{,}002 \times b \times h = 0{,}002 \times 1000 \times 120 = 240 \text{ mm}^2$

$As_{perlu} > As_{susut} \rightarrow$ **Ok**

Dipakai tulangan Ø 10 mm.

$A_1Ø = 0{,}25 \times \pi \times Ø_{tul}^2 = 0{,}25 \times \pi \times 10^2 = 78{,}5 \text{ mm}^2$

$$S \leq \frac{A_1\phi.b}{As} = \frac{78{,}5.1000}{172{,}064} = 456{,}64 \text{ mm}$$

$S \leq 2 \;.\; h = 2 \;.120 = 240 \text{ mm}$

$S \leq 250 \text{ mm}$

Maka dipakai tulangan P_{10} – 200 mm

Kontrol Kapasitas :

$$As_{ada} = \frac{A_1\phi \;.b}{S} = \frac{78{,}5.1000}{200} = 392{,}857 \text{ mm}^2$$

$$a = \frac{As_{ada} \cdot fy}{0{,}85 \cdot fc' \cdot b} = \frac{392{,}857 \cdot 300}{0{,}85 \cdot 30 \cdot 1000} = 4{,}622 \text{ mm}$$

$$Mn = As_{ada} \cdot fy \cdot \left(d - \frac{a}{2}\right)$$

$$= 392{,}857 \cdot 300 \cdot \left(85 - \frac{4{,}622}{2}\right)$$

$$= 9{,}7455 \text{ kNm} > Mu/\phi = 3{,}2694 \text{ kNm} \rightarrow \textbf{Ok}$$

d. Tulangan ty

$$Rn = \frac{Mu/\phi}{b \cdot d^2} = \frac{8{,}7698.10^6 / 0{,}8}{1000 \cdot 95^2} = 1{,}2147 \text{ MPa}$$

$$m = \frac{fy}{0{,}85 \cdot fc'} = \frac{300}{0{,}85 \cdot 30} = 11{,}7647$$

$$\rho_{ada} = \frac{1}{m} \times \left(1 - \sqrt{1 - \frac{2 \times m \times Rn}{fy}}\right)$$

$$= \frac{1}{11{,}7647} \times \left(1 - \sqrt{1 - \frac{2 \times 11{,}7647 \times 1{,}2147}{300}}\right)$$

$$= 0{,}0042$$

$$1{,}33\ \rho_{perlu} = 1{,}33 \cdot 0{,}0042 = 0{,}00552$$

Karena $\rho_{perlu} < \rho_{min} = 0{,}0047$ dan $1{,}33 \cdot \rho_{perlu} > \rho_{min}$, maka $\rho_{pakai} = 0{,}0047$

$$As_{perlu} = \rho_{perlu} \times b \times d = 0{,}0047 \times 1000 \times 95 = 443{,}33 \text{ mm}^2$$

$$As_{susut} = 0{,}002 \times b \times h = 0{,}002 \times 1000 \times 120 = 240 \text{ mm}^2$$

$As_{perlu} > As_{susut} \rightarrow$ **Ok**

Dipakai tulangan Ø 10 mm.

$$A_1Ø = 0{,}25 \times \pi \times Ø_{tul}^2 = 0{,}25 \times \pi \times 10^2 = 78{,}5 \text{ mm}^2$$

$$S \leq \frac{A_1 \phi \cdot b}{As} = \frac{78{,}5 \cdot 1000}{530{,}264} = 177{,}23 \text{ mm}$$

$$S \leq 2 \cdot h = 2 \cdot 120 = 240 \text{ mm}$$

$$S \leq 250 \text{ mm}$$

Maka dipakai tulangan P_{10} – 170 mm

Kontrol Kapasitas :

$$As_{ada} = \frac{A_1\phi \ .b}{S} = \frac{78,5.1000}{170} = 462,185 \text{ mm}^2$$

$$a = \frac{As_{ada}.fy}{0,85.fc'.b} = \frac{462,185.300}{0,85.30.1000} = 5,4375 \text{ mm}$$

$$Mn = As_{ada}.fy.\left(d - \frac{a}{2}\right)$$

$$= 462,185 \ . \ 300 \ . \left(95 - \frac{5,4375}{2}\right)$$

$$= 12,795 \text{ kNm} > Mu/\phi = 10,962 \text{ kNm} \rightarrow \textbf{Ok}$$

Tulangan Susut

$$AS_{SUSUT} = 0,002 \times b \times h = 0,002 \times 1000 \times 120 = 240mm^2$$

Pakai D_{tul} $\emptyset 8 \rightarrow A_{1\emptyset} = 1/4 \times \pi \times 8^2 = 50,265mm^2$

$$S = \frac{A_{1\emptyset} \times b}{As_{susut}} = \frac{50,265 \times 1000}{240} = 209,438mm \ \rangle \ 200mm$$

S_{Pakai} =200mm→ **P_8– 200**

Kontrol:

$$AS_{ada} = \frac{A_{1\emptyset} \times b}{S_{pakai}} = \frac{50,265 \times 1000}{200} = 251,33mm^2 \rangle AS_{SUSUT} = 240mm^2 \rightarrow \text{AMAN}$$

Tabel 5.4 Hasil Hitungan penulangan pelat

	Lapangan X	Tumpuan X	Lapangan Y	Tumpuan Y
Atap	P_8 – 200	P_8 – 140	P_8 – 200	P_8 – 140
Lantai	P_{10} – 200	P_{10} – 140	P_{10} – 200	P_{10} – 170
Tul.Susut		P_8 – 200		P_8 – 200

5.3.2 Perencanaan Balok Induk

a. Desain Balok

Contoh analisa diambil dari perhitungan SAP2000 dari lantai 3

Mu = 319,88 kNm

$$\rho_b = \frac{0,85 \times fc' \times \beta_1}{fy} \times \left(\frac{600}{600 + fy} \right)$$

$$= \frac{0,85 \times 30 \times 0,85}{400} \times \left(\frac{600}{600 + 400} \right)$$

$$= 0,0325$$

$\rho_{mak} = 0,75 \cdot \rho_b = 0,0244$

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

ρ pakai $= 0,75.\rho_{mak} = 0,75.0,0244 = 0,0183$

$$m = \frac{fy}{0,85.fc'} = \frac{400}{0,85.30} = 15,686$$

$$Rn = \rho.fy.\left(1 - \tfrac{1}{2}.\rho.m\right) = 0,0183.400\left(1 - \tfrac{1}{2}.0.0244.15,686\right)$$

$$= 6,27 \text{ MPa}$$

$$\frac{Mu}{0,8} = \frac{319,88}{0,8} = 399,85 \text{ kNm}$$

$$bd^2 = \frac{Mu/\varphi}{Rn} = \frac{399,85\ 10^6}{6,27} = 63812591,11 \text{ mm}$$

b	250	350	400
d	505,22	426,9	399,41

Dipakai : b = 250 mm ; h = 450.

d = (h – ds)

= 450 – 80 = 370 mm < 505,22 mm ----- Tulangan Rangkap

$$c = \frac{600}{600 + fy}.d = \frac{600}{600 + 400}.370 = 222 \text{ mm}$$

a = c. β = 222 x 0,85 = 188,7 mm

As_1 = ρ.b.d = 0.0183.250.370 = 1691,67 mm^2

Ts_1 = $As_1.fy$ = 2225,07. 400 = 676666,41 Nmm

Mn_1 = $As_1.fy$ (d – $\frac{a}{2}$)

$$= 1691,67.400.\left(370-\frac{188,7}{2}\right).10^{6}$$

$$= 186,52 \text{ kNm} < \frac{Mu}{\varphi} = 399,85 \text{ kNm}$$

Mn_2 = $\frac{Mu}{\varphi}$ - Mn 1 = 399,85 – 186,52 = 213,33 kNm

T_2 = Cs = $\left(\frac{Mn_2}{d-d'}\right).=\left(\frac{213,33}{370-60}\right).1000 = 688,15$ kNm

$\varepsilon_{s'}$ = $\left(\frac{c-d'}{c}\right).\varepsilon_{cu}=\left(\frac{222-60}{222}\right).0.003 = 0,0022$

ε_y = $\frac{fy}{Es}=\frac{400}{200000}=0.002$

ε_s = $\left(\frac{d-c}{d}\right).\varepsilon_{cu}=\left(\frac{365-85}{365}\right).0,003=0.002$

Tulangan Desak

~~Karena $\varepsilon_{s'} > \varepsilon_y$, maka $f's = fy$ = 400 Mpa.~~

As' = $\frac{Cs}{f's}=\frac{688,15.10^3}{400}=1720,39$ mm^2

As_2 = $\frac{T_2}{fy}=\frac{688,15.10^3}{400}=1720,39$ mm^2

Coba Tulangan D 22 → $A_1Ø$ = 380,133 mm^2

N = $\frac{As'}{A_1\theta}=\frac{1720,39}{380,133}=4,52 \approx 5$ batang ---- **5 D22**

Tulangan Tarik

As $= As_1 + As_2 = 1691,67 + 1720,39 = 3412,05\ mm^2$

Coba Tulangan D 22 $\rightarrow$ $A_1Ø = 380,133\ mm^2$

$$N = \frac{As}{A_1\theta} = \frac{3412,05}{380,133} = 8,96 \approx 9 \text{ batang ---- } \mathbf{9\ D22}$$

Cek Kontrol :

As ada = n . $A_1Ø$ $= 9 . 380,133 = 3421,2\ mm^2$

As' ada = n . $A_1Ø$ $= 5 . 380,133 = 1900,67\ mm^2$

As_{baru} = As ada – As' ada = 3421,2 – 1900,67 = 1520,53 mm^2

$$\rho = \frac{As_{baru}}{b.d} = \frac{1520,53}{250.370} = 0,0167$$

Kontrol Kapasitas

Cc/a $= 0,85 . f'c . b$

$= 0,85 . 30 . 250 = 6375$

Cs $= As' (fy - 0,85.f'c) = 1900,67\ (400 - 0,85.30) = 711,8\ N$

T $= As . fy = 3421,20 .400 = 1368,5\ N$

$$a = \frac{T - Cs}{Cc} = \frac{(1368,5 - 711,8).10^3}{6375} = 103,00\ mm$$

Cc $= 6375 . 103,00 / 1000 = 656,68\ N$

$$Mn = Cc.\left(d - \frac{a}{2}\right) = 656,68.\left(370 - \frac{103,00}{2}\right)$$

$= 429,81\ kNm > Mu/\theta = 399,85\ kNm$

$$\text{Rasio} = \frac{Mn.\phi}{Mu} = 429,81.0,8\ /319,88 = 1,07$$ **AMAN**

b. Momen Kapasitas

Dari hasil hitungan desain balok diatas didapat :

Es = 200000 Mpa ; εcu = 0,003

b = 250 mm.

h = 450 mm.

d = 370 mm.

d' = 60 mm.

Momen Kapasitas Negatif (dianggap tulangan desak sudah luluh)

- D tulangan Tarik = 22 mm

  Jumlah tulangan = 9 batang

  $As = n \times A_1\text{Ø} = 9 \times (¼ \times \pi \times 22^2) = 3421{,}20 \text{ mm}^2$

- D tulangan desak = 22 mm

  Jumlah tulangan = 5 batang

  $As' = n \times A_1\text{Ø} = 5 \times (¼ \times \pi \times 22^2) = 1900{,}66 \text{ mm}^2$

$$cb = \left(\frac{600}{600+fy}\right) \times d$$

$$= \left(\frac{600}{600+400}\right) \times 370$$

$$= 222$$

$$ab = 0{,}85 \times cb = 0{,}85 \times 222 = 188{,}7$$

$$Asb = \frac{0{,}85 \times fc' \times b \times ab}{fy} = \frac{0{,}85 \times 30 \times 250 \times 188{,}7}{400} = 3007{,}41 \text{ mm}^2$$

$0{,}75 \times Asb = 0{,}75 \times 3007{,}41 = 2255{,}55 \text{ mm}^2$

$As - As' = 3421{,}20 - 1900{,}66 = 1520{,}53 \text{ mm}^2 < 0{,}75 \times Asb = 2255{,}55 \text{ mm}^2$ **OK**

$$a = \left(\frac{As - As'}{0{,}85 \times fc' \times b}\right) \times fy = \left(\frac{1520{,}53}{0{,}85 \times 30 \times 250}\right) \times 400$$

$$= 95{,}41 \text{ mm}$$

$$c = \frac{a}{0{,}85} = \frac{95{,}41}{0{,}85} = 112{,}24 \text{ mm}$$

$$\varepsilon's = \left(\frac{c-d'}{c}\right) \times \varepsilon_{cu} = \left(\frac{112{,}24-60}{112{,}24}\right) \times 0{,}003 = 0{,}0014$$

$f's$ $= \varepsilon's \times Es = 0{,}0014 \times 200000$

$= 279{,}26$ MPa $< fy = 400$ MPa, maka baja belum luluh

Dengan Pers.Keseimbangan: cc + cs – Ts = 0

$0{,}85.f'c.0{,}85.b.c^2 + (As'.600 - As.fy).c + 600.As'.d' = 0$

$0{,}85.30.0{,}85.250.c^2 + (1900{,}66.600 - 3421{,}20.400).c + 600.1900{,}66.60 = 0$

$5418{,}75.c^2 - 228084.c + 68423760 = 0$

Didapat : c1 = 152,5 dan c2 = -110,41

Dpakai : c = 152,5

a $= 0{,}85 \times c = 0{,}85 \times 152{,}5 = 129{,}62$ mm

$$f's = \left(\frac{c-d'}{c}\right) \times 600 = \left(\frac{152{,}5 - 60}{152{,}5}\right) \times 600$$

$= 285{,}24$ MPa $< fy = 400$ MPa, maka dipakai $f's$

M nak$^-$ $= 0{,}85.f'c.a.b.(d - a/2) + As'.f's.(d - d')$

$= 0{,}85.30.129{,}62.250.(370 - 129{,}62/2) + 1900{,}66.285{,}24.(370 - 60)$

$= 409409980$ Nmm $= 409{,}41$ kNm.

M Kap$^-$ $= 1{,}25 \times$ M nak$^- = 1{,}25 \times 409{,}41 = 511{,}76$ kNm

Momen Kapasitas Positif

- D tulangan Tarik = D tulangan desak = 22 mm
- Jumlah tulangan tarik = Jumlah tulangan desak = 5 batang

  $As' = As = n \times A_1\text{Ø} = 5 \times (¼ \times \pi \times 22^2) = 1900{,}66$ mm^2

Dengan Pers.Keseimbangan: cc + cs – Ts = 0

$0{,}85.f'c.0{,}85.b.c^2 + (As'.600 - As.fy).c + 600.As'.d' = 0$

$0{,}85.30.0{,}85.250.c^2 + (1900{,}66.600 - 1900{,}66.400).c + 600.1900{,}66.60 = 0$

$5418{,}75.c^2 + 380132.c + 68423760 = 0$

Didapat : c1 = 77,30 dan c2 = -147,45

Dpakai : c = 77,30

a $= 0{,}85 \times c = 0{,}85 \times 77{,}30 = 65{,}70$ mm

$$f's = \left(\frac{c-d'}{c}\right) \times 600 = \left(\frac{77{,}30 - 60}{77{,}30}\right) \times 600$$

$= 134{,}25$ MPa $< fy = 400$ MPa, maka dipakai $f's$

$M\ nak^{+}$ $= 0{,}85.f'c.a.b.(d - a/2) + As'.f's.(d - d')$

$= 0{,}85.30.65{,}7.250.(370 - 65{,}7/2) + 2280{,}80.134{,}25.(370 - 60)$

$= 221592177$ Nmm $= 221{,}60$ kNm.

$M\ Kap^{+}$ $= 1{,}25 \times M\ nak^{+} = 1{,}25 \times 221{,}60 = 277{,}00$ kNm

c. Tulangan geser balok.

ln $= 5{,}25$ m

VD $= 75{,}358$ kN

VL $= 20{,}645$ kN

VE $= 142{,}07$ kN

$M\ Kap^{-}$ $= 511{,}76$ kNm

$M\ Kap^{+}$ $= 277$ kNm

Vg $= VD + VL = 75{,}358 + 20{,}645 = 95{,}82$ kN

$$Vu = \frac{0{,}7.(Mkap^{+} + Mkap^{-})}{ln} + 1{,}05.Vg$$

$$= \frac{0\ ,7.(511{,}76 + 277)}{5{,}25} + 1{,}05.95{,}82$$

$= 205{,}78$ kN

Vu max $= 1{,}05\ .\ (VD + VL + 4/k\ .\ VE)$

$= 1{,}05\ (75{,}358 + 20{,}645 + 4/1\ .\ 142{,}07)$

$= 697{,}308$ KN

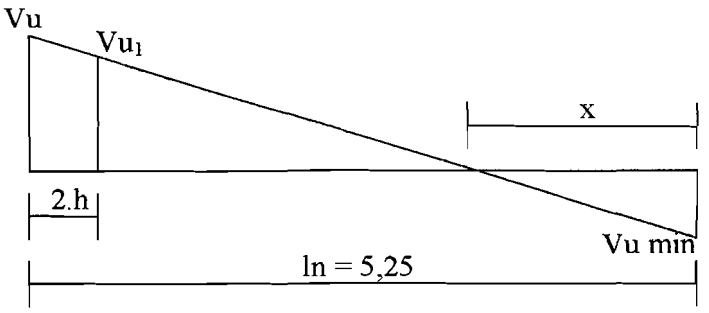
Vu $= 205{,}78$ kN $<$ Vu max $= 697{,}308$ kN

Jadi Vu pakai = Vu = 205,78 kN

$$Vu\ min = \frac{0{,}7.(Mkap^{+} + Mkap^{-})}{ln} - 1{,}05.Vg$$

$$= \frac{0\ ,7.(511{,}76 + 277)}{5{,}25} - 1{,}05.95{,}82$$

$= -4{,}55$ kN



$$x = \frac{Vu\ \min}{Vu\ \min + Vu_{pakai}} . \ln = \frac{4,55}{4,55 + 205,78} . 5,25 = 0,114m$$

Penulangan pada daerah sendi plastis :

$$Vs_1 = \frac{Vu}{\phi} = \frac{205,78}{0,6} = 342,97 \text{ kN}$$

Ø sengkang = 12 mm

jumlah kaki = 2

$Av = 2 . ¼ . \pi . 12^2 = 226,195 \text{ mm}^2$

$$S = \frac{Av.fy.d}{Vs_1} = \frac{226,195 . 300 . 370}{342,97 . 10^3} = 73,21 \text{ mm}$$

Pakai **P12–70**

Penulangan di luar sendi plastis :

$Vc = 1/6 . \sqrt{fc1} . b . d$

$= 1/6 . \sqrt{30} . 250 . 370.10^{-3}$

$= 84,44$ kN

$$Vu_1 = \frac{Vu.(ln - 2.h - x)}{(ln - x)} = \frac{205,78.(5,25 - 2.0,45 - 0,114)}{(5,25 - 0,114)} = 169,73 \text{ kN}$$

$$Vs_2 = \frac{Vu_1}{\phi} - Vc = \frac{169,73}{0,6} - 84,44 = 198,44 \text{ kN}$$

Ø sengkang = 12 mm

jumlah kaki = 2

$Av = 2 . ¼ . \pi . 12^2 = 226,195 \text{ mm}^2$

$$S = \frac{Av.fy.d}{Vs_1} = \frac{226,195 . 300 . 370}{198,44 . 10^3} = 126,53 \text{ mm}$$

Pakai **P12–120**

5.3.3 Perencanaan Kolom

a. Perhitungan Momen Rencana Kolom.

Arah X

M_{kap+} = 277,0 kNm

M_{kap-} = 511,76 kNm

ha = 4,5 m

hb = 4,5 m

b_{kolom} = 0,5 m

h_{kolom} = 0,75 m

h_{balok} = 0,45 m

l = 6 m

Ka $= \frac{1}{ha}$

$= \frac{1}{4,5}$

$= 0,222$

Kb $= \frac{1}{hb}$

$= \frac{1}{4,5}$

$= 0,222$

αa $= \frac{ka}{ka+kb}$

$= \frac{0,222}{0,222+0,222}$

$= 0,5$

αb $= \frac{kb}{ka+kb}$

$= \frac{0,222}{0,222+0,222}$

$= 0,5$

hn $= h - h_{balok}$

$= 4,5 - 0,45$

$= 4,05$ m

$ln = l - h_{kolom}$

$= 6 - 0,75$

$= 5,25$ m

Muk ax $= \frac{hn}{h} . \alpha_a . \omega_d . 0,7 . \left(\frac{l}{\ln} . M_{kap^+} + \frac{l}{\ln} M_{kap^-} \right)$

$= \frac{4,05}{4,5} . 0,5 . 1,3 . 0,7 . \left(\frac{6}{5,25} . 277,0 + \frac{6}{5,25} . 511,76 \right)$

$= 369,14$ kNm

Md = 5,592 kNm

Ml = 1,667 kNm

Me = 284,34 kNm

K = 1

$M_{mak} = 1{,}05 \cdot \left(Md + Ml + \left(\frac{4}{K} \cdot Me \right) \right)$

$= 1{,}05 \cdot \left(5{,}592 + 1{,}667 + \left(\frac{4}{1} \cdot 284{,}34 \right) \right)$

$= 1202{,}25$ kNm

Muk ax < M_{mak} maka Mu pakai adalah **Muk ax = 369,14 kNm**

Muk bx $= \frac{hn}{h} \cdot \alpha_a \cdot \omega_d \cdot 0{,}7 \cdot \left(\frac{l}{\ln} \cdot M_{kap^+} + \frac{l}{\ln} M_{kap^-} \right)$

$= \frac{4{,}05}{4{,}5} \cdot 0{,}5 \cdot 1{,}3 \cdot 0{,}7 \cdot \left(\frac{6}{5{,}25} \cdot 277{,}0 + \frac{6}{5{,}25} \cdot 511{,}76 \right)$

$= 369{,}14$ kNm

Md $= 5{,}592$ kNm

Ml $= 1{,}667$ kNm

Me $= 284{,}34$ kNm

K $= 1$

$M_{mak} = 1{,}05 \cdot \left(Md + Ml + \left(\frac{4}{K} \cdot Me \right) \right)$

$= 1{,}05 \cdot \left(5{,}592 + 1{,}667 + \left(\frac{4}{1} \cdot 284{,}34 \right) \right)$

$= 1202{,}25$ kNm

Muk ax < M_{mak} maka Mu pakai adalah **Muk ax = 369,14 kNm**

Antara Muk ax dan Muk bx diambil yang terbesar, maka Muk x = 369,14 kNm.

- Pengambilan nilai Mn :

  Mn1 = (100% × Muk x) + (30% × Muk y)

  = (100% × 369,14) + (30% × 378,86) = 482,80 kNm.

  Mn2 = (30% × Muk x) + (100% × Muk y)

  = (30% × 369,14) + (100% × 378,86) = 489,60 kNm.

Diambil nilai Mn yang terbesar = $489{,}60 / 0{,}65 = 753{,}24$ kNm.

b. Perhitungan Gaya aksial rencana kolom

Arah X

Pd = 2516,82 kN M_{Kap}^{-} = 511,76 kNm

Pl = 495,15 kN M_{Kap}^{+} = 277,0 kNm

Pe = 127,84 kN l = 6 m

K = 1

Pg = Pd + Pl = 2516,82 + 495,15 = 3011,97 kN

$\Sigma M = M_{Kap}^{-} + M_{Kap}^{+} = 511,76 + 277,0 = 788,75$ kNm

Pu x $= \left\{0,7 \,.\, K \,.\, \left(\frac{\sum M}{l}\right)\right\} + (1,05 \,.\, Pg)$

$= \left\{0,7 \,.\, 1 \,.\, \left(\frac{788,75}{6}\right)\right\} + (1,05 \,.\, 3011,97)$

= 3254,59 kN

Arah Y

Pd = 2516,82 kN M_{Kap}^{-} = 532,55 kNm

Pl = 495,15 kN M_{Kap}^{+} = 277,0 kNm

Pe = 127,84 kN l = 4 m

K = 1

Pg = Pd + Pl = 2516,82 + 495,15 = 3011,97 kN

$\Sigma M = M_{Kap}^{-} + M_{Kap}^{+} = 510,42 + 399,90 = 809,54$ kNm

Pu y $= \left\{0,7 \,.\, K \,.\, \left(\frac{\sum M}{l}\right)\right\} + (1,05 \,.\, Pg)$

$= \left\{0,7 \,.\, 1 \,.\, \left(\frac{809,54}{4}\right)\right\} + (1,05 \,.\, 3011,97)$

= 3304,24 kN

Antara Pu x dan Pu y ambil yang terbesar yaitu 3304,24 kN

$Pu_{max} = 1,05 \,.\, \left(Pd + Pl + \left(\frac{4}{K} \,.\, Pe\right)\right)$

$= 1,05 \,.\, \left(2516,82 + 495,15 + \left(\frac{4}{1} \,.\, 127,84\right)\right)$

= 3699,49 kN

Pu_{max} > Pu = 3304,24 kN, maka Pu_{pakai} = 3304,24 kN

- Pengambilan nilai Pn :

  Pn = Pu/0,65

  = 3304,24/0,65 = 5083,44 kN.

c. Perhitungan Grafik Mn dan Pn.

f'c = 20 MPa

fy = 400 MPa

d' = 60 mm

b = 500 mm

h = 750 mm

Ag = b . h = 500 . 750 = 375000 mm²

Ast = misal 1% Ag = 1% . 375000 = 3750 mm²

As = As'= Ast/2 = 3750/2 = 1875 mm²

Dalam Keadaan Desak Aksial (Mn = 0)

Mn = 0

Pn = $0{,}85.f'c.(Ag - Ast) + Ast.fy$

$- 0{,}85.20.(375000 - 3750) + 3750.400$

= 7811250 N – 7811,25 kN

Dalam Keadaan Seimbang (*fs* = *fy*)

d = h – d' = 750 – 60 = 690 mm

$$xb = \left(\frac{600}{600+fy}\right)\times d = \left(\frac{600}{600+400}\right)\times 690$$

= 414 mm

a = 0,85 . xb = 0,85 . 414 = 351,9 mm

$$f's = \left(\frac{x-d'}{x}\right).600 = \left(\frac{414-60}{414}\right).600$$

= 513,04 MPa > *fy* = 400 MPa

$f's_{pakai}$ = *fy* = 400 Mpa

$fs = \left(\frac{d-x}{x}\right).600 = \left(\frac{690-414}{414}\right).600$

$= 400$ MPa

$fs = fy = 400$ MPa

Cc $= 0{,}85 \,.\, f'c$ a. b

$= 0{,}85 \,.\, 20 \,.\, 351{,}9 \,.\, 500 \,.1/1000$

$= 2991{,}15$ kN

Cs $=$ As' $(f's - 0{,}85 \,.\, f'c)$

$= 1875\ (400 - 0{,}85.20)/1000$

$= 718{,}125$ kN

Ts $=$ As $.\ fs$

$= 1875 \,.\, 400\ /1000$

$= 750$ kN

Pn $=$ Cc + Cs – Ts

$= 2991{,}15 + 718{,}125 - 750$

$= 2959{,}275$ kN

Mn $=$ Cc (h/2 – a/2) + Cs (h/2 – d') + Ts (d – h/2)

$= 2991{,}15\left(\frac{750}{2} - \frac{351{,}9}{2}\right) + 718{,}125\left(\frac{750}{2} - 60\right) + 750\left(690 - \frac{750}{2}\right)$

$= 1057848$ kNmm $= 1057{,}85$ kNm

e $= \frac{Mn}{Pn} = \frac{1057{,}85}{2959{,}275}$

$= 0{,}357$

Dalam Keadaan Patah Desak

x $= 1{,}5 \,.xb = 1{,}5.414$

$= 621$ mm

a $= 0{,}85 \,.\, x = 0{,}85 \,.\, 936 = 527{,}85$ mm

$f's = \left(\frac{x-d'}{x}\right).600 = \left(\frac{621-60}{621}\right).600$

$= 542{,}03$ MPa $> fy = 400$ MPa

$f's$ $= fy = 400$ MPa

fs $= \left(\frac{d-x}{x}\right).600 = \left(\frac{690-621}{621}\right).600 = 66{,}667$ Mpa $< fy = 400$ MPa

fs $= fs = 66{,}667$ MPa

Cc $= 0{,}85 \,.\, f'c$ a b

$= 0{,}85 \,.\, 20 \,.\, 527{,}85 \,.\, 500 \,.1/1000$

$= 4486{,}725$ kN

Cs $=$ As' $(f's - 0{,}85 \,.\, f'c)$

$= 1875\ (400 - 0{,}85.20)/1000$

$= 718{,}125$ kN

Ts $=$ As $.\ fs$

$= 1875 \,.\, 66{,}667\ /1000$

$= 125$ kN

Pn $=$ Cc + Cs – Ts

$= 4486{,}725 + 718{,}125 - 125$

$= 5079{,}85$ kN

Mn $=$ Cc (h/2 – a/2) + Cs (h/2 – d') + Ts (d – h/2)

$= 4486{,}725\left(\frac{750}{2} - \frac{527{,}85}{2}\right) + 718{,}125\left(\frac{750}{2} - 60\right) + 125\left(690 - \frac{750}{2}\right)$

$= 763947$ kNmm $= 763{,}95$ kNm

e $= \frac{Mn}{Pn} = \frac{763{,}95}{5079{,}85}$

$= 0{,}15 < eb = 0{,}357$ **ok**

Dalam Keadaan Patah Tarik

x $= 0{,}5$ .xb $= 0{,}5. 414$

$= 207$ mm

a $= 0{,}85 \,.\, x = 0{,}85 \,.\, 207 = 175{,}95$ mm

$f's$ $= \left(\frac{x-d'}{x}\right).600 = \left(\frac{207-60}{207}\right).600$

$= 426{,}09$ MPa $> fy = 400$ MPa

$f's$ $= fy = 400$ MPa

fs $= \left(\frac{d-x}{x}\right).600 = \left(\frac{690-207}{207}\right).600$

$= 1400$ MPa $> fy = 400$ MPa

fs $= fs = 400$ MPa

Cc $= 0{,}85 \,.\, f'c$ a b

$= 0{,}85 \,.\, 20 \,.\, 175{,}95 \,.\, 500 \,.1/1000$

$= 1495{,}575$ kN

Cs $=$ As' $(f's - 0{,}85 \,.\, f'c)$

$= 1875\ (400 - 0{,}85.20)/1000$

$= 718{,}125$ kN

Ts $=$ As $.\ fs$

$= 1875 \,.\, 400\ /1000$

$= 750$ kN

Pn $=$ Cc + Cs – Ts

$= 1495{,}575 + 718{,}125 - 750$

$= 1463{,}7$ kN

Mn $=$ Cc (h/2 – a/2) + Cs (h/2 – d') + Ts (d – h/2)

$= 1495{,}575\left(\frac{750}{2} - \frac{175{,}95}{2}\right) + 718{,}125\left(\frac{750}{2} - 60\right) + 750\left(690 - \frac{750}{2}\right)$

$= 891727$ kNmm $= 891{,}727$ kNm

e $= \frac{Mn}{Pn} = \frac{891{,}727}{1463{,}7}$

$= 0{,}61 >$ eb $= 0{,}357$ **ok**

Dalam Keadaan Lentur Murni (Pn = 0)

a $= \frac{As.fy}{0{,}85.f'c.b} = \frac{1875.400}{0{,}85.20.500} = 88{,}24$ mm

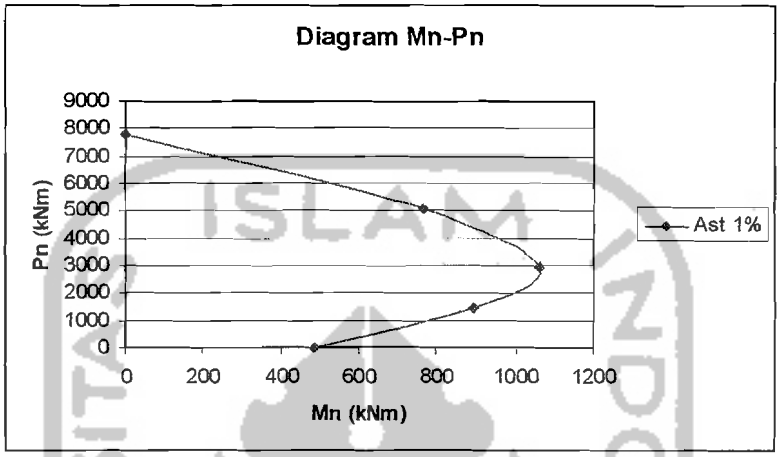
Pn $= 0$

Mn $= As.fy.(d - a/2) = 1875.400.(690 - 88{,}24/2)$

$= 484{,}41.10^6$ Nmm $= 484{,}41$ kNm

Tabel 5.5 Perhitungan grafik Mn-Pn dengan Ast 1%

	Desak Aksial	Patah Desak	Balance	Patah Tarik	Lentur Murni
Pn (kN)	7811,25	5079,85	2959,275	1463,7	0
Mn (kNm)	0	763,95	1057,85	891,727	484,41



Gambar 5.15 Grafik Mn-Pn

d. Penulangan geser kolom.

VD = 21,08 kN.

VL = 20,47 kN.

VE = 122,69 kN.

$f'c$ = 20 MPa, fy = 400 MPa

b kolom = 500 mm, h kolom = 750 mm

d = 750 – 60 = 690 mm

$$Vuk = \frac{\text{Mu.k atas pakai} + \text{Mu.k bawah pakai}}{hn}$$

$$= \frac{753,24 + 815,09}{4,05}$$

= 387,24 kN.

Vuk maks = 1,05 (VD + VL +(4/K).VE)

= 1,05 (21,08+ 20,47 + (4/K).122,69)

= 558,91 kN.

Vu_{max} > Vuk, maka Vuk_{pakai} = 387,24 kN

- **Dalam Sendi Plastis**

Vuk = 387,24 kN

$$Vs_1 = \frac{Vuk}{0,6} = \frac{387,24}{0,6} = 645,4 \text{ kN}$$

Pakai Tulangan Sengkang D = 12 mm → $A_{1\emptyset}$ = 113,1 mm^2

Pakai Kaki Sengkang = 2 buah

$$S = \frac{n.A_{1\emptyset}.fy.d}{Vs_1} = \frac{2.113,1.400.690}{645,4.10^3} = 96,73 \text{ mm}$$

S pakai = 90 mm

Pakai Tulangan **P12–90**

- **Luar Sendi Plastis**

Puk = 5083,44 kN

Ag = 500 . 750 = 375000 mm^2

$$Vc = \left(1+\frac{Puk}{14.Ag}\right).\left(\frac{1}{6}\right).\sqrt{f'c}.b.d$$

$$= \left(1+\frac{5083,44.1000}{14.375000}\right).\left(\frac{1}{6}\right).\sqrt{20}.500.690$$

– 257396 N = 257,396 kN

$$Vs = \frac{Vuk}{0,6} - Vc = \frac{387,24}{0,6} - 257,396 = 388,00 \text{ kN}$$

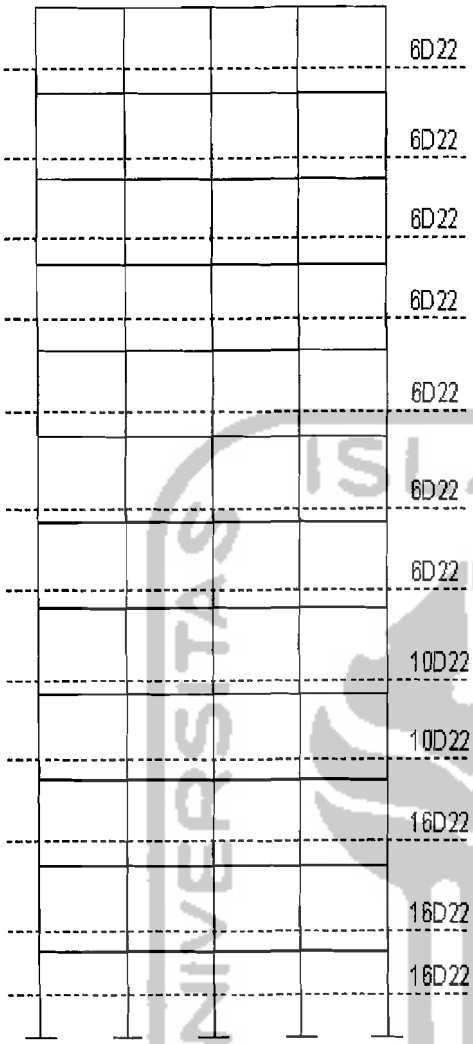
Pakai Tulangan Sengkang D = 12 mm → $A_{1\emptyset}$ = 113,1 mm^2

Pakai Kaki Sengkang = 2 buah

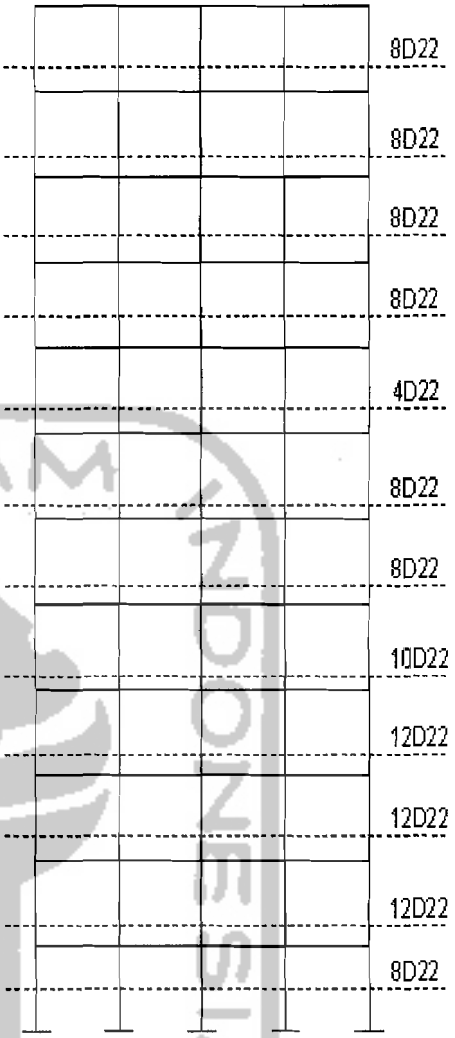
$$S = \frac{n.A_{1\emptyset}.fy.d}{Vs_1} = \frac{2.113,1.400.690}{388.10^3} = 160,9 \text{ mm}$$

S pakai = 160 mm

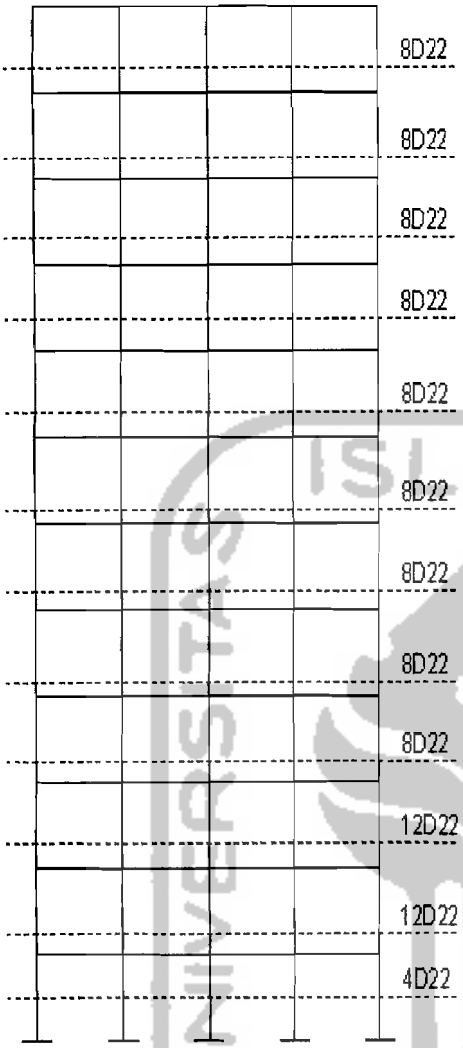
Pakai Tulangan **P12–160**



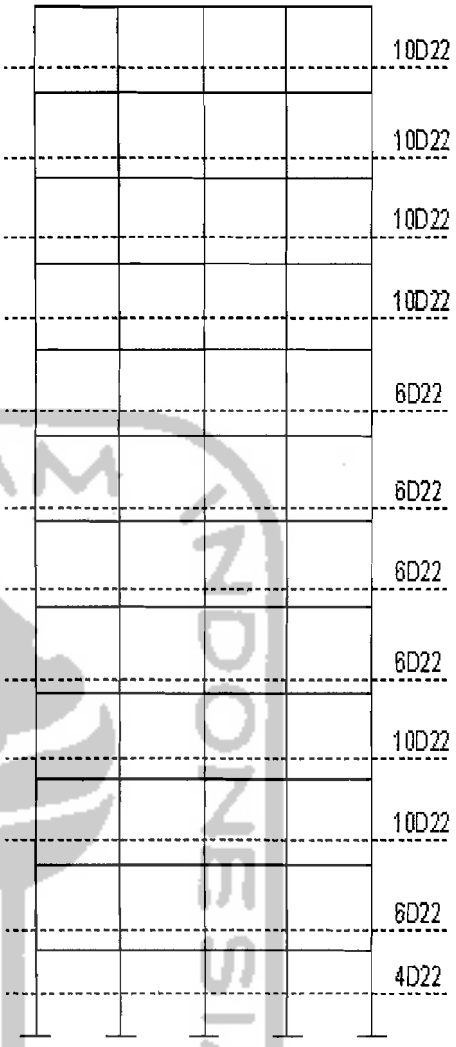
Gambar 5.16 Kebutuhan tulangan kolom 500x750mm



Gambar 5.17 Kebutuhan tulangan kolom 440x660mm



Gambar 5.18 Kebutuhan tulangan kolom 410x620mm



Gambar 5.19 Kebutuhan tulangan kolom 390x580mm