BAB III

ANALISIS DAN PERENCANAAN

3.1 Data Perencanaan

1. Jarak gelagar memanjang : 1.5 m dan 2.0 m
2. jarak gelagar melintang : 5.0 m
3. Mutu beton : K-350
4. Tegangan ijin beton : 35 Mpa
5. Mutu baja : U-32
6. Tegangan leleh baja : 320 Mpa
7. Tebal plat beton : 25 cm
8. Tebal aspal : 3 cm
9. Genangan air hujan : 5 cm
10. Berat jenis beton : 2,5 t/m^3
11. Berat jenis aspal : 2,3 t/m^3
12. Berat jenis air : 1,0 t/m^3

3.2 Perencanaan Plat Lantai Kendaraan

3.2.1 Analisis Pembebanan

1. Beban mati (untuk lebar 1 meter)

Beban aspal : 0,03 . 1 . 2,3 = 0,069 t/m

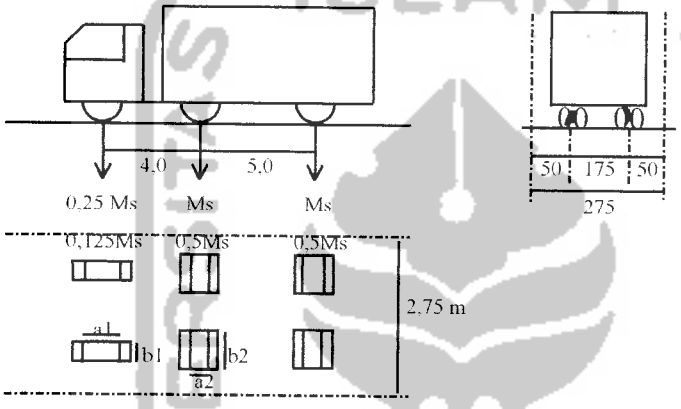
Beban slab beton : 0,25 . 1 . 2,5 = 0,625 t/m

Beban air hujan : 0,05 . 1 . 1,0 = 0,05 t/m +

q_d = 0,744 t/m

2. Beban hidup

untuk perhitungan kekuatan lantai kendaraan menggunakan beban "T". Beban "T" adalah merupakan beban kendaraan truk yang mempunyai beban roda ganda (dual wheel load) sebesar 10 ton dengan ukuran-ukuran serta kedudukan seperti pada gambar 3.1.



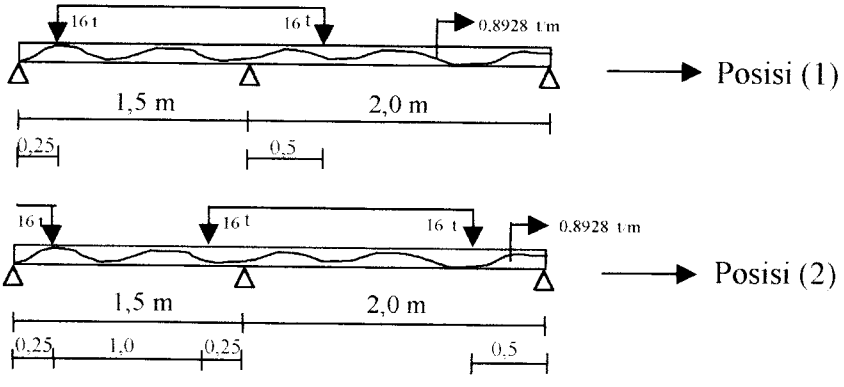
Keterangan: a1 = a2 = 30,0 cm
b1 = 12,5 cm
b2 = 50,0 cm
Ms= muatan rencana sumbu = 20 Ton

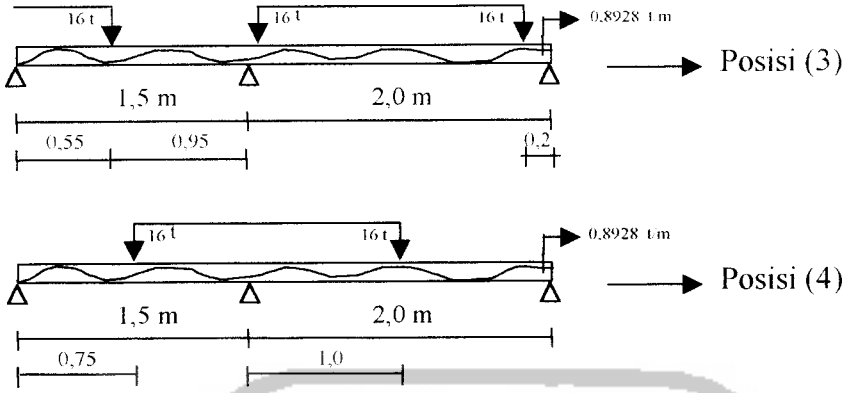
Gambar 3.1. Kedudukan dan ukuran-ukuran pembebanan

Jadi $q_{d\ ult} = 1,2 \cdot 0,744 = 0,8928$ t/m

$q_{l\ ult} = 1,6 \cdot 10 = 16$ t

3. Posisi-posisi pembebanan





Gambar 3.2. Posisi-posisi pembebanan

Untuk menghitung momen maksimum (baik momen lapangan maupun momen tumpuan dan reaksi-reaksi yang terjadi digunakan program "Microfeaf " yang dapat dilihat pada lampiran 1.

Modulus elastisitas = $4700 \sqrt{f'c}$

$= 4700 \sqrt{35} = 2{,}8 \cdot 10^4$ MPa

$= 2{,}8 \cdot 10^6$ t/m^2

Inersia plat = $1/12 \cdot b \cdot h^3$

$= 1/12 \cdot 100 \cdot 25^3 = 1{,}3 \cdot 10^{-3}$ m^4

3.2.2 Perhitungan Penulangan

1. Penulangan daerah lapangan

a. Arah X

d = ht – pb – ½ D

= 250 – 40 - ½.16 = 202 mm

Mu = 5,5865 tm

Mn = Mu/∅ = 5,5865 / 0,8 = 69, 831 KNm

Rasio penulangan (ρ)

$$\rho b = \frac{0,85 \cdot f'c \cdot \beta_1}{fy}\left(\frac{600}{600 + fy}\right)$$

$$\beta_1 = 0,85 - 0,008\ (\ f'c - 30\ )$$

$$= 0,85 - 0,008\ (\ 35 - 30\ ) = 0,81$$

$$\rho b = \frac{0,85 \cdot 35 \cdot 0,81}{320}\left(\frac{600}{600 + 320}\right) = 0,049$$

$$\rho_{maks} = 0,75 \cdot 0,049 = 0,037$$

$$\rho_{min} = 1,4 / fy = 1,4 / 320 = 0,0044$$

$$m = fy / (0,85 \cdot f'c) = 320 / (0,85 \cdot 35) = 10,756$$

$$Rn = Mn / (b \cdot d^2) = 69,831 \cdot 10^6 / (1000 \cdot 202^2) = 1,711\ N/m^2$$

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

$$\rho_{perlu} = \frac{1}{10,756}\left(1 - \sqrt{1 - \frac{2 \cdot 10,756 \cdot 1,711}{320}}\right)$$

$\rho_{min} < \rho_{perlu} < \rho_{maks} \longrightarrow$ dipakai ρ_{perlu}

$$As_{perlu} = \rho_{perlu} \cdot b \cdot d$$

$$= 0,0055 \cdot 1000 \cdot 202 = 1111\ mm^2$$

$$A_1\varnothing_{16} = 201,062\ mm^2$$

Jarak tulangan $S \leq \frac{A_1\varnothing_{16} \cdot b}{As_{perlu}}$

$$= \frac{201,062 \cdot 1000}{1111}$$

$$= 180,97\ mm$$

dipakai $\varnothing_{16} - 180$

Jumlah tulangan permeter (n) = 1000 / 180 = 5,6 ≅ 6 buah

Kontrol kapasitas

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

$= 0{,}85 \cdot 35 \cdot 1000 \cdot a = 29750\ a$ N/mm

$Ts = A_1\varnothing \cdot n \cdot fy$

$= 201{,}062 \cdot 6 \cdot 320 = 386039{,}04$ N

$Cc = Ts$

$29750\ a = 386039{,}04$

$a = 12{,}98$ mm

$Mn_{total} = Ts\ (d - \frac{1}{2}\ a)$

$= 386039{,}04\ (202 - (\frac{1}{2} \cdot 12{,}98)) \cdot 10^{-6}$

$= 75,4745$ KNm $>$ Mn $= 69{,}831$ KNm ⟶ Aman

b. Arah Y

$d = ht - pb - \frac{1}{2}\ D$

$= 250 - 40 - \frac{1}{2} \cdot 12 = 204$ mm

$Mu = 5{,}5865$ tm

$Mn = Mu/\varnothing = 5{,}5865 / 0{,}8 = 69,831$ KNm

Rasio penulangan (ρ)

$$\rho b = \frac{0{,}85 \cdot f'c \cdot \beta_1}{fy}\left(\frac{600}{600 + fy}\right)$$

$\beta_1 = 0{,}85 - 0{,}008\ (f'c - 30)$

$= 0{,}85 - 0{,}008\ (35 - 30) = 0{,}81$

$$\rho b = \frac{0{,}85 \cdot 35 \cdot 0{,}81}{320}\left(\frac{600}{600 + 320}\right) = 0{,}049$$

$\rho_{maks} = 0,75 \cdot 0,049 = 0,037$

$\rho_{min} = 1,4 / fy = 1,4 / 320 = 0,0044$

$m = fy / (0,85 \cdot f'c) = 320 / (0,85 \cdot 35) = 10,756$

$Rn = Mn / (b \cdot d^2) = 69,831 \cdot 10^6 / (1000 \cdot 204^2) = 1,678 \text{ N/m}^2$

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

$$\rho_{perlu} = \frac{1}{10,756}\left(1 - \sqrt{1 - \frac{2 \cdot 10,756 \cdot 1,678}{320}}\right) = 0,0054$$

$\rho_{min} < \rho_{perlu} < \rho_{maks} \longrightarrow$ dipakai ρ_{perlu}

$As_{perlu} = \rho_{perlu} \cdot b \cdot d$

$= 0,0054 \cdot 1000 \cdot 204 = 1101,6 \text{ mm}^2$

$A_1\varnothing_{12} = 113,098 \text{ mm}^2$

Jarak tulangan $S \leq \dfrac{A_1\varnothing_{12} \cdot b}{As_{perlu}}$

$= \dfrac{113,098 \cdot 1000}{1101,6}$

$= 102,67 \text{ mm}$

dipakai $\varnothing_{12-100}$

Jumlah tulangan permeter (n) = 1000 / 100 = 10 buah

Kontrol kapasitas

$Cc = 0,85 \cdot f'c \cdot b \cdot a$

$= 0,85 \cdot 35 \cdot 1000 \cdot a = 29750 \text{ a N/mm}$

$Ts = A_1\varnothing \cdot n \cdot fy$

$= 113,098 \cdot 10 \cdot 320 = 361913,6 \text{ N}$

Cc = Ts

29750 a = 361913,6

a = 12,165 mm

Mn_{total} = Ts (d – ½ a)

= 361913,6 (204 – (½ . 12,165)) . 10^{-6}

= 71,63 KNm > Mn = 69,831 KNm ⟶ Aman

2. Penulangan daerah tumpuan

a. Arah X

d = ht – pb – ½ D

= 250 – 40 - ½.16 = 202 mm

Mu = 5,7198 tm

Mn = Mu/∅ = 5,7198 / 0,8 = 71,9458 KNm

Rasio penulangan (ρ)

$$\rho b = \frac{0,85 \cdot f'c \cdot \beta_1}{fy}\left(\frac{600}{600 + fy}\right)$$

β_1 = 0,85 – 0,008 (f'c – 30)

= 0,85 – 0,008 (35 – 30) = 0,81

$$\rho b = \frac{0,85 \cdot 35 \cdot 0,81}{320}\left(\frac{600}{600 + 320}\right) = 0,049$$

ρ_{maks} = 0,75 . 0,049 = 0,037

ρ_{min} = 1,4 / fy = 1,4 / 320 = 0,0044

m = fy / (0,85 . f'c) = 320 / (0,85 . 35) = 10,756

Rn = Mn / (b . d^2) = 71,1498 . 10^6 / (1000 . 202^2) = 1,752 N/m^2

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

$$\rho_{perlu} = \frac{1}{10,756}\left(1 - \sqrt{1 - \frac{2 \cdot 10,756 \cdot 1,752}{320}}\right) = 0,00565$$

$\rho_{min} < \rho_{perlu} < \rho_{maks} \longrightarrow$ dipakai ρ_{perlu}

$As_{perlu} = \rho_{perlu} \cdot b \cdot d$

$= 0,00565 \cdot 1000 \cdot 202 = 1141,3 \text{ mm}^2$

$A_1\varnothing_{16} = 201,062 \text{ mm}^2$

Jarak tulangan $S \leq \frac{A_1\varnothing_{16} \cdot b}{As_{perlu}}$

$= \frac{201,062 \cdot 1000}{1141,3}$

$= 176,17 \text{ mm}$

dipakai $\varnothing_{16} - 170$

Jumlah tulangan permeter (n) = 1000 / 170 = 5,88 ≅ 6 buah

Kontrol kapasitas

$Cc = 0,85 \cdot f'c \cdot b \cdot a$

$= 0,85 \cdot 35 \cdot 1000 \cdot a = 29750 \text{ a N/mm}$

$Ts = A_1\varnothing \cdot n \cdot fy$

$= 201,062 \cdot 6 \cdot 320 = 386039,04 \text{ N}$

$Cc = Ts$

$29750 \text{ a} = 386039,04$

$a = 12,98 \text{ mm}$

$Mn_{total} = Ts\ (d - ½\ a)$

$= 386039{,}04\ (202 - (½ \cdot 12{,}98)) \cdot 10^{-6}$

$= 75,\ 4745\ KNm > Mn = 71{,}1498\ KNm \longrightarrow$ Aman

b. Arah Y

$d = ht - pb - ½\ D$

$= 250 - 40 - ½.12 = 204\ mm$

$Mu = 5{,}7198\ tm$

$Mn = Mu/\varnothing = 5{,}7198 / 0{,}8 = 71{,}1498\ KNm$

Rasio penulangan (ρ)

$$\rho b = \frac{0{,}85 \cdot f'c \cdot \beta_1}{fy}\left(\frac{600}{600 + fy}\right)$$

$\beta_1 = 0{,}85 - 0{,}008\ (f'c - 30)$

$= 0{,}85 - 0{,}008\ (35 - 30) = 0{,}81$

$$\rho b = \frac{0{,}85 \cdot 35 \cdot 0{,}81}{320}\left(\frac{600}{600 + 320}\right) = 0{,}049$$

$\rho_{maks} = 0{,}75 \cdot 0{,}049 = 0{,}037$

$\rho_{min} = 1{,}4 / fy = 1{,}4 / 320 = 0{,}0044$

$m = fy / (0{,}85 \cdot f'c) = 320 / (0{,}85 \cdot 35) = 10{,}756$

$Rn = Mn / (b \cdot d^2) = 71{,}1498 \cdot 10^6 / (1000 \cdot 204^2) = 1{,}718\ N/m^2$

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

$$\rho_{perlu} = \frac{1}{10{,}756}\left(1 - \sqrt{1 - \frac{2 \cdot 10{,}756 \cdot 1{,}718}{320}}\right) = 0{,}00553$$

$\rho_{min} < \rho_{perlu} < \rho_{maks} \longrightarrow$ dipakai ρ_{perlu}

$As_{perlu} = \rho_{perlu} . b . d$

$= 0{,}00553 . 1000 . 204 = 1128{,}82 \text{ mm}^2$

$A_1\varnothing_{12} = 113{,}098 \text{ mm}^2$

Jarak tulangan $S \leq \dfrac{A_1\varnothing_{12} . b}{As_{perlu}}$

$= \dfrac{113{,}098 . 1000}{1128{,}82}$

$= 100{,}191 \text{ mm}$

dipakai $\varnothing_{12} - _{100}$

Jumlah tulangan permeter (n) = 1000 / 100 = 10 buah

Kontrol kapasitas

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

$= 0{,}85 . 35 . 1000 . a = 29750 \text{ a N/mm}$

$Ts = A_1\varnothing . n . fy$

$= 113{,}098 . 10 . 320 = 361913{,}6 \text{ N}$

$Cc = Ts$

$29750 \text{ a} = 361913{,}6$

$a = 12{,}165 \text{ mm}$

$Mn_{total} = Ts (d - \frac{1}{2} a)$

$= 361913{,}6 (204 - (\frac{1}{2} . 12{,}165)) . 10^{-6}$

$= 71{,}63 \text{ KNm} > Mn = 71{,}1498 \text{ KNm} \longrightarrow$ Aman

3. Perhitungan tulangan susut

$$As = \frac{0{,}0018 \cdot 400 \cdot b \cdot ht}{fy}$$

$$= \frac{0{,}0018 \cdot 400 \cdot 1000 \cdot 250}{320} = 562{,}5 \text{ mm}^2$$

$A_1\varnothing_{12} = 113{,}098 \text{ mm}^2$

Jarak tulangan $S \leq \frac{A_1\varnothing_{12} \cdot b}{As_{perlu}}$

$$= \frac{113{,}098 \cdot 1000}{562{,}5}$$

$$= 201{,}06 \text{ mm}$$

dipakai $\varnothing_{12-200}$

Jumlah tulangan permeter (n) = 1000 / 200 = 5 buah

4. Perhitungan tulangan bagi

$As = 20\ \% \cdot A_{pokok}$

$= 20\ \% \cdot 1128{,}82 = 225{,}764 \text{ mm}^2$

$A_1\varnothing_{12} = 113{,}098 \text{ mm}^2$

Jarak tulangan $S \leq \frac{A_1\varnothing_{12} \cdot b}{As_{perlu}}$

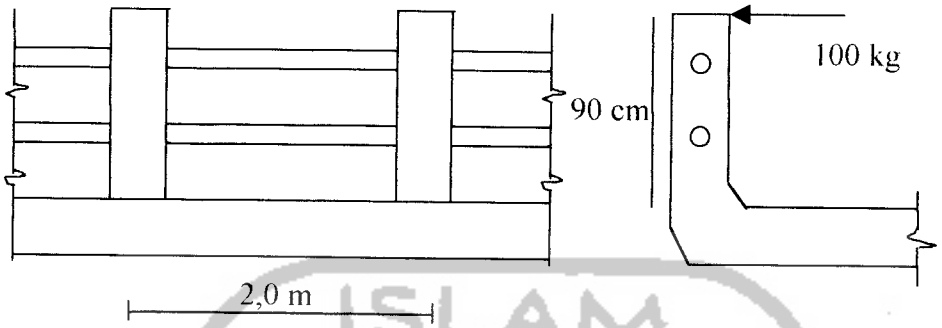
$$= \frac{113{,}098 \cdot 1000}{225{,}764}$$

$$= 500{,}95 \text{ mm}$$

dipakai $\varnothing_{12-250}$

Jumlah tulangan permeter (n) = 1000 / 250 = 4 buah

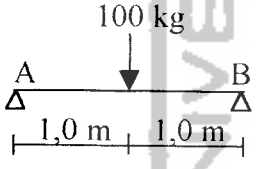
3.2.3 Perencanaan Tiang Sandaran



Gambar 3.3. Letak tiang sandaran dan beban horisontal

Tiang sandaran pada setiap tepi trotoar harus diperhitungkan untuk dapat menahan beban horisontal sebesar 100 kg/m yang bekerja pada tiang setinggi 90 cm di atas lantai trotoar (PPPJJR edisi revisi 1987, hal 10).

1. Pipa sandaran



$R_A = R_B = 50$ kg

$M_A = 50 \cdot 100 = 5000$ kg

Dipakai pipa baja ∅ 76,3 mm, tebal 2.8 mm diperoleh $W_X = 11{,}5$ cm^3 (Tabel profil konstruksi baja, Ir.Rudi Gunawan hal 64).

Tegangan yang terjadi (σ) = M / W_X

= 5000 / 11,5 = 434,78 kg/cm^2 < fy

2. Tiang sandaran

Dipakai ukuran :

Ht = 20 cm

D' = 3 cm

D = 20 - 3 = 17 cm

M = 100 . 90 = 9000 kg cm



$\rho_{min} = 0{,}0044$

Asumsi : (D – a/2) = γ . D = 0,9 D = 0,9 . 17 = 15,3 cm

As = M / (fy . (D – a/2)) = 9000 / (3200 . 15,3) = 0,18 cm^2

Cek ρ ⟶ ρ = As / (b . d) = 0,18 / (17 . 15) = 0,0007 < ρ_{min}

Dipakai ρ_{min}

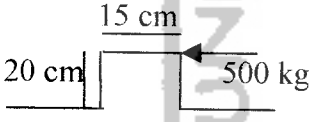
As = ρ_{min} . b . d = 0,0044 . 17 . 15 = 1,122 cm^2

Dipakai tulangan pokok $2\varnothing_{10}$ = 157 mm^2 > As = 112,2 mm^2

Dipakai tulangan sengkang minimum $\varnothing_{6-200}$

3.2.4 Perencanaan Kerb Jembatan

Kerb yang terdapat di tepi-tepi lantai kendaraan harus diperhitungkan untuk dapat menahan beban horisontal kearah melintang jembatan sebesar 500 kg/m yang bekerja pada puncak kerb yang bersangkutan atau pada tinggi 25 cm di atas permukaan lantai kendaraan apabila kerb yang bersangkutan lebih tinggi dari 25 cm (PPPJJR edisi revisi 1987 hal 10).



dipakai Ht = 15 cm , D' = 5 cm

D = 15 – 5 = 10 cm

M = 500 . 10 = 5000 kg cm

ρ_{min} = 0,0044

Asumsi: (D – a/2) = γ . D = 0,9 D = 0,9 . 10 = 9 cm

As = M / (fy . (D – a/2)) = 5000 / (3200 . 9) = 0,174 cm^2

Cek ρ ⟶ ρ = As / (b . d) = 0,174 / (20 . 10) = 0,00087 < ρ_{min}

Dipakai ρ_{min}

As = ρ_{min} . b . d = 0,0044 . 20 . 10 = 0,88 cm^2

Jarak tulangan (S) ≤ $\frac{113,1 \cdot 1000}{88}$ = 1285 mm

Dipakai jarak tulangan maksimum = 250 mm

Dipakai tulangan pokok $\varnothing_{12-250}$ = 452,4 mm^2 > As = 88 mm^2

Dipakai tulangan bagi $5\varnothing_{10}$ = 392,7 mm^2 > 20 % As

3.2.5 Perencanaan Lantai Trotoar

Konstruksi lantai trotoar diperhitungkan terhadap beban hidup sebesar 500 kg/m (PPPJJR edisi revisi 1987 hal 10).

Dipakai tebal trotoar 10 cm

Berat sendiri = 0,1 . 1,0 . 2,5 = 0,25 t/m^2 = 250 kg/m^2

Beban hidup = 500 kg/m^2

q_u = 1,2 D + 1,6 L

= (1,2 . 250) + (1,6 . 500) = 1100 kg/m^2

Mu = 1/8 . q_u . L^2 = 1/8 . 1100 . 1^2 = 137,5 kg m =13750 kg cm

ρ_{min} = 0,0044

Asumsi: (D – a/2) = γ . D = 0,9 D = 0,9 . 8 = 7,2 cm

As = M / (fy . (D – a/2)) = 13750 / (3200 . 7,2) = 0,597 cm^2

Cek ρ ⟶ ρ = As / (b . d) = 0,597 / (100 . 8) = 0,00075 < ρ_{min}

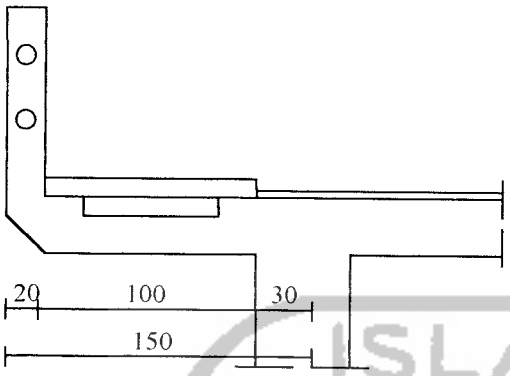
Dipakai ρ_{min}

As = ρ_{min} . b . d = 0,0044 . 100 . 8 = 3,52 cm^2

Dipakai tulangan pokok $\varnothing_{12-250}$ = 452,4 mm^2 > As = 352 mm^2

Dipakai tulangan bagi $\varnothing_{10-250}$ = 314 mm^2 > 20 % As

3.2.6 Perencanaan Plat Kantilever



Gambar 3.4. Struktur plat kantilever

Ditentukan :

Berat pipa sandaran = 5,08 kg/m

(Tabel profil baja Ir. Rudi Gunawan hal 64)

Berat jenis beton = 2500 kg/m^3

Berat jenis aspal = 2300 kg/m^3

Ditinjau 1 m tegak lurus bidang gambar :

Berat pipa sandaran = 2 . 5,08 . 2,0 = 20,32 kg

Berat tiang sandaran = (0,15 . 0,20) . 0,9 . 2500 = 67,5 kg

M_1 = (20,32 + 67,5) . 1,5 = 131,73 kgm

Berat lantai trotoar = 0,5 . 1100 . 1,0 = 550 kg

Berat pejalan (asumsi) = 200 . 1,0 = 200 kg

M_2 = (550 + 200) . (1,5 – 0,2 – 0,5) = 600 kgm

Berat kerb = 0,15 . 0,20 . 2500 = 75 kg/m

Berat aspal = 0,03 . 0,3 . 2300 = 20,7 kg/m

Berat plat = 0,25 . 1,5 . 2500 = 937,5 kg/m

M_3 = 0,5 . (75 + 20,7 + 937,5) . $1,5^2$ = 1162,35 kgm

$M_{total} = M_1 + M_2 + M_3$

$= 131,73 + 600 + 1162,35 = 1894,08$ kgm

Dipandang 1 meter tegak lurus bidang gambar

ht = 25 cm ; d' = 3 cm

d = 25 – 3 = 22 cm

Asumsi: $(D - a/2) = \gamma \cdot D = 0,9\ D = 0,9 \cdot 22 = 19,8$ cm

$As = Mt / (fy \cdot (D - a/2)) = (1894,08 \cdot 10^2) / (3200 \cdot 19,8) = 2,989\ cm^2$

Cek $\rho \longrightarrow \rho = As / (b \cdot d) = 2,989 / (100 \cdot 22) = 0,0014 < \rho_{min}$

Dipakai ρ_{min}

$As = \rho_{min} \cdot b \cdot d = 0,0044 \cdot 100 \cdot 22 = 9,68\ cm^2$

Jarak tulangan $(S) \leq \frac{201,06 \cdot 1000}{968} = 207.7$ mm

Dipakai jarak tulangan = 200 mm

Dipakai tulangan pokok $\varnothing_{16-200} = 1005,3\ mm^2 > As = 968\ mm^2$

20 % As = $0,2 \cdot 968 = 193,6\ mm^2$

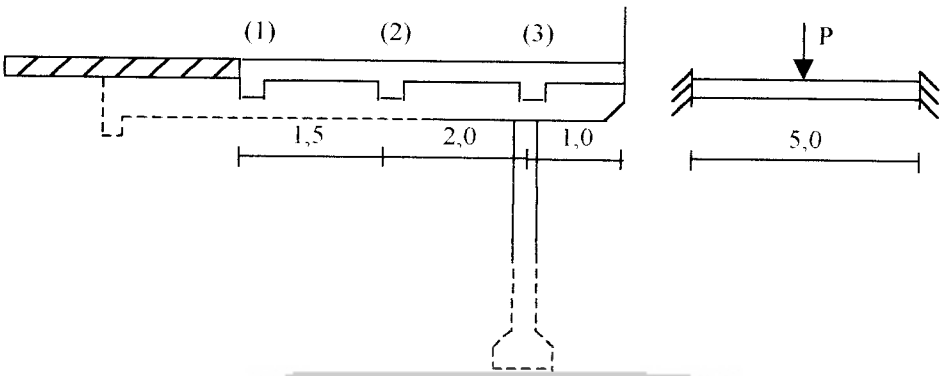
Jarak tulangan $(S) \leq \frac{113,1 \cdot 1000}{193,6} = 584,2$ mm

Dipakai jarak tulangan maksimum = 250 mm

Dipakai tulangan bagi $\varnothing_{12-250} = 452,4\ mm^2 > 20\ \%\ As = 193,6\ mm^2$

3.3 Perencanaan Gelagar Memanjang

Perencanaan gelagar memanjang ini, dirancang sebagai balok dengan asumsi tumpuan jepit-jepit, seperti pada gambar 3.5.



Gambar 3.5. Letak gelagar memanjang

3.3.1 Perhitungan Mekanika Gelagar Memanjang

1. Gelagar memanjang (1)

a. Beban mati

Berat aspal = 0,03 . 0,75 . 2,3 = 0,0518 t/m

Berat air = 0,05 . 0,75 . 1,0 = 0,0375 t/m

Berat slab beton = 0,25 . 0,75 . 2,5 = 0,4688 t/m +

q_d = 0,5580 t/m

b. Beban hidup

Beban hidup diambil sesuai dengan ketentuan dalam PPPJJR 1987 hal 7.

Beban garis (P) = 12 t

Panjang bentang (L) = 5m (L < 30m), maka q = 2,2 t/m

Faktor kejut (K) = $1 + \frac{20}{50 + L} = 1 + \frac{20}{50 + L} = 1{,}364$

Beban hidup (ql) = $\frac{2{,}2 \cdot 0{,}75}{2{,}75} = 0{,}6$ t/m

Beban garis (pl) = $\frac{12 \cdot 0{,}75 \cdot 1{,}364}{2.75} = 4{,}464$ t

qu = 1,2 qd + 1,6 ql

= 1,2 . 0,558 + 1,6 . 0,6 = 1,6296 t/m

pu = 1,6 pl

= 1,6 . 4,464 = 7,1424 t

c. Dimensi balok

Tinggi minimum balok menurut SK- SNI tabel 3.25

h_{min} = (L / 18,5) (0,4 + (fy / 700))

= (5000/18,5) . (0,4 + (320/700)) = 231,66 mm

diambil: ht = 40 cm

b = 20 cm

q_{balok} = b (ht_{balok} - ht_{plat}) γ_{beton}

= 0,2 (0,40 – 0,25) 2500 = 75 kg/m

qu_{balok} = 1,2 . 75 = 90 kg/m = 0,09 t/m

qu_{total} = 1,6296 + 0,09 = 1,7196 t/m

2. Gelagar memanjang (2)

a. Beban mati

Berat aspal	= 0,03 . 1,75 . 2,3 =	0,1208 t/m
Berat air	= 0,05 . 1,75 . 1,0 =	0,2188 t/m
Berat slab beton	= 0,25 . 1,75 . 2,5 =	1,0938 t/m +
	q_d =	1,4334 t/m

b. Beban hidup

Beban hidup diambil sesuai dengan ketentuan dalam PPPJJR 1987 hal 7.

Beban garis (P) = 12 t

Panjang bentang (L) = 5m (L < 30m), maka q = 2,2 t/m

Faktor kejut (K) = $1 + \frac{20}{50 + L} = 1 + \frac{20}{50 + L} = 1{,}364$

Beban hidup (ql) = $\frac{2{,}2 \,.\, 1{,}75}{2{,}75} = 1{,}4$ t/m

Beban garis (pl) = $\frac{12 \,.\, 1{,}75}{2.75} . 1{,}364 = 10{,}416$ t

qu = 1,2 qd + 1,6 ql

= 1,2 . 1,4334 + 1,6 . 1,4 = 3,9601 t/m

pu = 1,6 pl

= 1,6 . 10,416 = 16,6656 t

c. Dimensi balok

Tinggi minimum balok menurut SK- SNI tabel 3.25

$h_{min} = (L / 18{,}5) (0{,}4 + (fy / 700))$

= (5000/18,5) . (0,4 + (320/700)) = 231,66 mm

diambil: ht = 40 cm

b = 30 cm

$q_{balok} = b (ht_{balok} - ht_{plat}) \gamma_{beton}$

= 0,3 (0,40 – 0,25) 2500 = 112,5 kg/m

$qu_{balok} = 1{,}2 \,.\, 112{,}5 = 135$ kg/m = 0,135 t/m

$qu_{total} = 3{,}9601 + 0{,}135 = 4{,}0951$ t/m

3. Gelagar memanjang (3)

a. Beban mati

Berat aspal	= 0,03 . 1,3 . 2,3	= 0,0897 t/m
Berat air	= 0,05 . 1,3 . 1,0	= 0,065 t/m
Berat slab beton	= 0,25 . 2,0 . 2,5	= 1,25 t/m
Berat tiang sandaran + pipa	= 0,0203 + 0,0675	= 0,0878 t/m
Berat trotoar + kerb	= 0,5500 + 0,0750	= 0,6250 t/m +
	q_d	= 2,1462 t/m

b. Beban hidup

Beban hidup diambil sesuai dengan ketentuan dalam PPPJJR 1987 hal 7.

Beban garis (P) = 12 t

Panjang bentang (L) = 5m (L < 30m), maka q = 2,2 t/m

Faktor kejut (K) = $1 + \frac{20}{50 + L} = 1 + \frac{20}{50 + L} = 1{,}364$

Beban hidup (ql) = $\frac{2{,}2 \,.\, 2{,}0}{2{,}75} = 1{,}6$ t/m

Beban garis (pl) = $\frac{12 \,.\, 2{,}0}{2.75} \,.\, 1{,}364 = 11{,}904$ t

qu = 1,2 qd + 1,6 ql

= 1,2 . 2,1462 + 1,6 . 1,6 = 5,1354 t/m

pu = 1,6 pl

= 1,6 . 11,904 = 19,0464 t

c. Dimensi balok

Tinggi minimum balok menurut SK- SNI tabel 3.25

$h_{min} = (L / 18,5) (0,4 + (fy / 700))$

$= (5000/18,5) . (0,4 + (320/700)) = 231,66$ mm

diambil: ht = 40 cm

b = 30 cm

$q_{balok} = b (ht_{balok} - ht_{plat}) \gamma_{beton}$

$= 0,3 (0,40 - 0,25) 2500 = 112,5$ kg/m

$qu_{balok} = 1,2 . 112,5 = 135$ kg/m $= 0,135$ t/m

$qu_{total} = 5,1354 + 0,135 = 5,2704$ t/m

Untuk menghitung momen maksimum (baik momen lapangan maupun momen tumpuan dan reaksi-reaksi yang terjadi digunakan program "Microfeaf " yang dapat dilihat pada lampiran 2.

Modulus elastisitas $= 4700 \sqrt{f'c}$

$= 4700 \sqrt{35} = 2,8 . 10^4$ MPa

$= 2,8 . 10^6$ t/m^2

Inersia gelagar (1) $= 1/12 . b . h^3$

$= 1/12 . 200 . 400^3 = 1,07 . 10^{-3}$ m^4

Inersia gelagar (2) dan (3) $= 1/12 . b . h^3$

$= 1/12 . 300 . 400^3 = 1,6 . 10^{-3}$ m^4

3.3.2 Perhitungan Dimensi Gelagar Memanjang

1. Gelagar memanjang (1)

a. Perencanaan dimensi gelagar

h = 40 cm = 400 mm

b = 20 cm = 200 mm

digunakan: penutup beton (Pb) = 40 mm

tulangan berdiameter 19 mm

sengkang berdiameter 10 mm

$d = h - Pb - Ds - \frac{1}{2} D = 400 - 40 - 10 - \frac{1}{2} .19 = 340,5$ mm

$d' = Pb + Ds + \frac{1}{2} D = 40 + 10 + \frac{1}{2} .19 = 59,5$ mm

b. Kontrol terhadap geser

Vumaks = 7,8702 t ⟶ microfeap

$Vc = \sqrt{f'c} \cdot b \cdot d \cdot {}^{1}/_{6} = \sqrt{35} \cdot 200 \cdot 340,5 \cdot 10^{-4} \cdot {}^{1}/_{6} = 6,715$ t

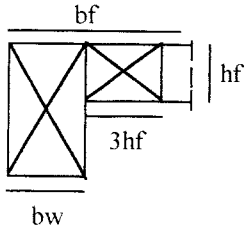
$Vs_1 = {}^{1}/_{3} \cdot \sqrt{f'c} \cdot b \cdot d = {}^{1}/_{3} \cdot \sqrt{35} \cdot 200 \cdot 340,5 \cdot 10^{-4} = 13,4295$ t

$\phi (Vc + Vs_1) = 0,6 (6,715 + 13,4295) = 12,0867$ t > Vumaks →O.K

c. Kontrol terhadap torsi

Tumaks = $1,1921 \cdot 10^{-4}$ tm ⟶ microfeap

Karena Tumaks mendekati 0 maka torsi boleh diabaikan.



hf = 250 mm ; Pb = 40 mm
bw = 200 mm ; 3hf = 750 mm
h = 400 mm ; L = S = 5000 mm

$bf \leq {}^{1}/_{12}\ L + bw = {}^{1}/_{12} \cdot 5000 + 200 = 616{,}67$ mm

$\leq bw + 16hf = 200 + 16 \cdot 250 = 4200$ mm

$\leq bw + {}^{S}/_{2} = 200 + {}^{5000}/_{2} = 2700$ mm $\rightarrow$ dipakai $bf = 616{,}67$ mm

d. Perencanaan tulangan tumpuan (M^-)

$Mu^- = 8{,}0465$ tm ⟶ microfeap

$$Mn = \frac{Mu^-}{\phi} = \frac{8{,}0465}{0{,}8} = 10{,}0581 \text{ tm}$$

1) Kontrol kapasitas total

$Mntotal = 0{,}85 \cdot f'c \cdot bw \cdot Hf\,(d - \tfrac{1}{2} hf)$

$= 0{,}85 \cdot 35 \cdot 200 \cdot 250\,(340{,}5 - \tfrac{1}{2} \cdot 250)\ 10^{-7}$

$= 32{,}0556$ tm $> Mn \rightarrow$ O.K

2) Perencanaan tulangan pokok

$$\rho b = \frac{0{,}85 \cdot f'c \cdot \beta \cdot 600}{fy\,(600 + fy)} \quad \rightarrow \beta = 0{,}85 - 0{,}008\,(f'c - 30)$$

$$= 0{,}85 - 0{,}008\,(35 - 30) = 0{,}81$$

$$= \frac{0{,}85 \cdot 35 \cdot 0{,}81 \cdot 600}{320\,(600 + 320)} = 0{,}049$$

$\rho maks = 0{,}75 \cdot \rho b = 0{,}75 \cdot 0{,}049 = 0{,}037$

$\rho min = 1{,}4/fy = 1{,}4/320 = 0{,}0044$

$m = fy/0{,}85 f'c = 320/(0{,}85 \cdot 35) = 10{,}756$

$$Rn = Mn/(bw \cdot d^2) = \frac{(10{,}0581 \cdot 10^7)}{(200 \cdot 340{,}5^2)} = 4{,}3376 \text{ Mpa}$$

$$\rho perlu = \frac{1}{m}\left[1 - \sqrt{1 - \frac{2 \cdot m \cdot Rn}{fy}}\right]$$

$$= \frac{1}{10{,}756}\left[1 - \sqrt{1 - \frac{2 \cdot 10{,}756 \cdot 4{,}3376}{320}}\right] = 0{,}0147$$

$\rho min < \rho perlu < \rho maks \rightarrow$ dipakai tulangan sebelah

$As = \rho perlu \cdot bw \cdot d = 0{,}0147 \cdot 200 \cdot 340{,}5 = 1001{,}07\ mm^2$

$A\varnothing_{19} = \frac{1}{4}\pi\ 19^2 = 283{,}53\ mm^2$

$N = As/A\varnothing_{19} = 1001{,}07/283{,}53 = 3{,}53 \cong 4$ buah

$Asb = N \cdot A\varnothing_{19} = 4 \cdot 283{,}53 = 1134{,}12\ mm^2$

$\rho aktual = Asb/(bw \cdot d) = 1134{,}12/(200 \cdot 340{,}5)$

$= 0{,}0167 < \rho maks \rightarrow$ O.K

3) Kontrol kapasitas

$Cc = 0{,}85 \cdot f'c \cdot bw \cdot a = 0{,}85 \cdot 35 \cdot 200 \cdot a = 5950\ a$

$Ts = fy \cdot Asb = 320 \cdot 1134{,}12 = 362918{,}4$

Syarat: $Cc = Ts$

$5950\ a = 362918{,}4 \rightarrow a = 362918{,}4/5950 = 60{,}9947$ mm

$Mntotal = Asb \cdot fy(d - {}^{a}/_{2}) = 1134{,}12 \cdot 320(340{,}5 - {}^{60{,}9947}/_{2})10^{-7}$

$= 11{,}2506$ tm $> Mn \rightarrow$ O.K

$c = a/\beta = 60{,}9947/0{,}81 = 75{,}3021\ mm < hf$

$\rightarrow$ pemisalan benar sebagai balok "T"

4) Kontrol jarak tulangan

$Y = h - 2Pb - 2Ds - 2D = 400 - (2 \cdot 40) - (2 \cdot 10) - (2 \cdot 19)$

$= 262\ mm < 300\ mm \rightarrow$ O.K

$X = (bw - 2Pb - 2Ds - N.D)/(N - 1)$

$= (200 - 80 - 20 - (4 \cdot 19))/(4 - 1) = 8\ mm < 25\ mm$

$\rightarrow$ dipakai jarak minimum = 25 mm

e. Perencanaan tulangan lapangan (M^+)

$Mu^+ = 6{,}2552$ tm ⟶ microfeap

$$Mn = \frac{Mu^+}{\phi} = \frac{6{,}2552}{0{,}8} = 7{,}819 \text{ tm}$$

1) Kontrol kapasitas total

$$Mntotal = 0{,}85 \cdot f'c \cdot bw \cdot Hf\,(d - \tfrac{1}{2} hf)$$

$$= 0{,}85 \cdot 35 \cdot 200 \cdot 250\,(340{,}5 - \tfrac{1}{2} \cdot 250)\,10^{-7}$$

$$= 32{,}0556 \text{ tm} > Mn \rightarrow \text{O.K}$$

2) Perencanaan tulangan pokok

$$\rho b = \frac{0{,}85 \cdot f'c \cdot \beta \cdot 600}{fy\,(600 + fy)} \qquad \beta = 0{,}85 - 0{,}008\,(f'c - 30)$$

$$= 0{,}85 - 0{,}008\,(35 - 30) = 0{,}81$$

$$= \frac{0{,}85 \cdot 35 \cdot 0{,}81 \cdot 600}{320\,(600 + 320)} = 0{,}049$$

$$\rho maks = 0{,}75 \cdot \rho b = 0{,}75 \cdot 0{,}049 = 0{,}037$$

$$\rho min = 1{,}4/fy = 1{,}4/320 = 0{,}0044$$

$$m = fy/0{,}85 f'c = 320/(0{,}85 \cdot 35) = 10{,}756$$

$$Rn = Mn/(bw \cdot d^2) = \frac{(7{,}819 \cdot 10^7)}{(200 \cdot 340{,}5^2)} = 3{,}372 \text{ Mpa}$$

$$\rho perlu = \frac{1}{m}\left[1 - \sqrt{1 - \frac{2 \cdot m \cdot Rn}{fy}}\right]$$

$$= \frac{1}{10{,}756}\left[1 - \sqrt{1 - \frac{2 \cdot 10{,}756 \cdot 3{,}372}{320}}\right] = 0{,}0112$$

$\rho min < \rho perlu < \rho maks \rightarrow$ dipakai tulangan sebelah

$As = \rho perlu \cdot bw \cdot d = 0{,}0112 \cdot 200 \cdot 340{,}5 = 763{,}658 \text{ mm}^2$

$A\varnothing_{19} = \frac{1}{4}\,\pi\,19^2 = 283{,}53 \text{ mm}^2$

$N = As/A\varnothing_{19} = 763,658/283,53 = 2,69 \cong 3$ buah

$Asb = N \cdot A\varnothing_{19} = 3 \cdot 283,53 = 850,59\ mm^2$

$\rho aktual = Asb/(bw \cdot d) = 850,59/(200 \cdot 340,5)$

$= 0,0125 < \rho maks \rightarrow$ O.K

3) Kontrol kapasitas

$Cc = 0,85 \cdot f'c \cdot bw \cdot a = 0,85 \cdot 35 \cdot 200 \cdot a = 5950\ a$

$Ts = fy \cdot Asb = 320 \cdot 850,59 = 272188,8$

Syarat: $Cc = Ts$

$5950\ a = 272188,8 \rightarrow a = 272188,8/5950 = 45,746$ mm

$Mntotal = Asb \cdot fy(d - {}^{a}/_{2}) = 850,59 \cdot 320(340,5 - {}^{45.746}/_{2})10^{-7}$

$= 8,6454$ tm $> Mn \rightarrow$ O.K

$c = a/\beta = 45,746/0,81 = 56,4765$ mm $< hf$

$\rightarrow$ pemisalan benar sebagai balok "T"

4) Kontrol jarak tulangan

$Y = h - 2Pb - 2Ds - 2D = 400 - (2 \cdot 40) - (2 \cdot 10) - (2 \cdot 19)$

$= 262$ mm < 300 mm $\rightarrow$ O.K

$X = (bw - 2Pb - 2Ds - N.D)/(N - 1)$

$= (200 - 80 - 20 - (3 \cdot 19))/(3 - 1) = 21,5$ mm < 25 mm

$\rightarrow$ dipakai jarak minimum = 25 mm

f. Perencanaan tulangan geser murni

Vumaks = 7,8702 t $\longrightarrow$ microfeap

$Vc = \sqrt{f'c}\ . b \cdot d \cdot {}^{1}/_{6} = \sqrt{35} \cdot 200 \cdot 340,5 \cdot 10^{-4} \cdot {}^{1}/_{6} = 6,715$ t

$\phi Vc = 4{,}0288$ t < Vumaks < ϕ (Vc + Vs_1) → perlu tulangan geser

Pada daerah dimana Vumaks > ϕVc spasi sengkang maksimum $^{d}/_{2}$ atau 600 mm, maka dicari titik dimana gaya geser = ϕVc = 4,0288 t

$x_1 = (4{,}0288/7{,}8702) \cdot 2500 = 1280$ mm dari tengah bentang,

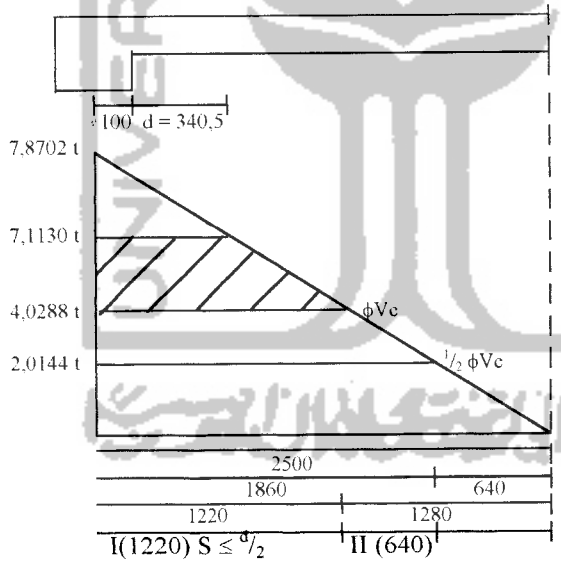
titik dimana gaya geser = $^{1}/_{2}$ ϕVc = 2,0144 t:

$x_2 = (2{,}0144/7{,}8702) \cdot 2500 = 640$ mm dari tengah bentang,

gaya geser pada penampang kritis, sejauh d dari perletakan:

$$Vu = \frac{^{1}/_{2}L - (d - {}^{1}/_{2}bw)}{^{1}/_{2}L} \cdot Vumaks$$

$$= \frac{2500 - (340{,}5 - 100)}{2500} \cdot 7{,}8702 = 7{,}113 \text{ t}$$



Gambar 3.6. Diagram tulangan geser

$S \leq {}^{d}/_{2} = {}^{340{,}5}/_{2} = 170{,}25$ mm < 600 mm

Digunakan sengkang $\varnothing_{10}$ → As = 2(¼ π 10^2) = 157,08 mm^2

Daerah I:

$\phi Vs = Vu - \phi Vc = 7{,}113 - 4{,}0288 = 3{,}0842$ t

Vs = 3,0842/0,6 = 5,1403 t

Jarak sengkang S = $\frac{As \,.fy\,.\,d}{Vs}$

$= \frac{157,08\,.\,320\,.\,340,5}{5,1403\,.\,10^{4}}$ = 332,97 mm > 170,25 mm

dipakai sengkang $\varnothing_{10-170\ mm}$

Daerah II:

Yaitu daerah tulangan geser minimum.

Jarak sengkang S = $\frac{3\ As\,.\,fy}{bw}$

$= \frac{3\,.\,157,08\,.\,320}{200}$ = 753,984 mm > 170,25 mm

dipakai sengkang $\varnothing_{10-170\ mm}$

2. Gelagar memanjang (2)

a. Perencanaan dimensi gelagar

h = 40 cm = 400 mm

b = 30 cm = 300 mm

digunakan: penutup beton (Pb) = 40 mm

tulangan berdiameter 19 mm

sengkang berdiameter 10 mm

d = h – Pb – Ds - ½ D = 400 – 40 – 10 - ½ .19 = 340,5 mm

d' = Pb + Ds + ½ D = 40 + 10 + ½ .19 = 59,5 mm

b. Kontrol terhadap geser

Vumaks = 18,517 t ⟶ microfeap

Vc = $\sqrt{f'c}$. b . d .$^{1}/_{6}$ = $\sqrt{35}$. 300 . 340,5 . 10^{-4} . $^{1}/_{6}$ = 10,0721 t

$Vs_1 = {}^1/_3 \cdot \sqrt{f'c} \cdot b \cdot d = {}^1/_3 \cdot \sqrt{35} \cdot 300 \cdot 340{,}5 \cdot 10^{-4} = 20{,}1442$ t

$\phi\,(Vc + Vs_1) = 0{,}6(10{,}0721 + 20{,}1442)$

$= 18{,}1298$ t $<$ Vumaks $\rightarrow$ Not O.K

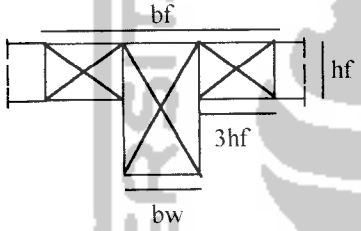
$Vs_2 = {}^2/_3 \cdot \sqrt{f'c} \cdot b \cdot d = {}^2/_3 \cdot \sqrt{35} \cdot 300 \cdot 340{,}5 \cdot 10^{-4} = 40{,}2885$ t

$\phi\,(Vc + Vs_2) = 0{,}6(10{,}0721 + 40{,}2885)$

$= 30{,}2164$ t $>$ Vumaks $\rightarrow$ O.K

c. Kontrol terhadap torsi

Tumaks $= Mtx_1 - Mtx_2 = 2{,}627 - 1{,}8519 = 0{,}7751$ tm $\rightarrow$ microfeap



hf = 250 mm ; Pb = 40 mm
bw = 300 mm ; 3hf = 750 mm
h = 400 mm ; L = S = 5000 mm

$bf \le {}^1/_4\, L = {}^1/_4 \cdot 5000 = 1250$ mm

$\le bw + 16hf = 300 + 16 \cdot 250 = 4300$ mm

$\le S = 5000$ mm $\rightarrow$ dipakai bf = 1250 mm

d. Perencanaan tulangan tumpuan (M^-)

$Mu^- = 18{,}947$ tm $\longrightarrow$ microfeap

$$Mn = \frac{Mu^-}{\phi} = \frac{18{,}947}{0{,}8} = 23{,}6837 \text{ tm}$$

1) Kontrol kapasitas total

$Mntotal = 0{,}85 \cdot f'c \cdot bw \cdot hf\,(d - \tfrac{1}{2}\, hf)$

$= 0{,}85 \cdot 35 \cdot 300 \cdot 250\,(340{,}5 - \tfrac{1}{2} \cdot 250)\, 10^{-7}$

$= 48{,}0834$ tm $>$ Mn $\rightarrow$ O.K

2) Perencanaan tulangan pokok

$$\rho b = \frac{0{,}85 \cdot f'c \cdot \beta \cdot 600}{fy\,(600 + fy)} \quad \rightarrow \beta = 0{,}85 - 0{,}008\,(f'c - 30)$$
$$= 0{,}85 - 0{,}008\,(35 - 30) = 0{,}81$$

$$= \frac{0{,}85 \cdot 35 \cdot 0{,}81 \cdot 600}{320\,(600 + 320)} = 0{,}049$$

$\rho maks = 0{,}75 \cdot \rho b = 0{,}75 \cdot 0{,}049 = 0{,}037$

$\rho min = 1{,}4/fy = 1{,}4/320 = 0{,}0044$

$m = fy/0{,}85f'c = 320/(0{,}85 \cdot 35) = 10{,}756$

$$Rn = Mn/(bw \cdot d^2) = \frac{(23{,}6837 \cdot 10^7)}{(300 \cdot 340{,}5^2)} = 6{,}8092 \text{ Mpa}$$

$$\rho perlu = \frac{1}{m}\left[1 - \sqrt{1 - \frac{2 \cdot m \cdot Rn}{fy}}\right]$$

$$= \frac{1}{10{,}756}\left[1 - \sqrt{1 - \frac{2 \cdot 10{,}756 \cdot 6{,}8092}{320}}\right] = 0{,}0245$$

$\rho min < \rho perlu < \rho maks \rightarrow$ dipakai tulangan sebelah

$As = \rho perlu \cdot bw \cdot d = 0{,}0245 \cdot 300 \cdot 340{,}5 = 2503{,}6238 \text{ mm}^2$

$A\varnothing_{19} = \frac{1}{4}\,\pi\,19^2 = 283{,}53 \text{ mm}^2$

$N = As/A\varnothing_{19} = 2503{,}6238/283{,}53 = 8{,}83 \cong 9$ buah

$Asb = N \cdot A\varnothing_{19} = 9 \cdot 283{,}53 = 2551{,}77 \text{ mm}^2$

$\rho aktual = Asb/(bw \cdot d) = 2551{,}77/(300 \cdot 340{,}5)$

$= 0{,}025 < \rho maks \rightarrow$ O.K

3) Kontrol kapasitas

$Cc = 0{,}85 \cdot f'c \cdot bw \cdot a = 0{,}85 \cdot 35 \cdot 300 \cdot a = 8925\,a$

$Ts = fy \cdot Asb = 320 \cdot 2551{,}77 = 816566{,}4$

Syarat: Cc = Ts

$8925\ a = 816566{,}4 \rightarrow a = 816566{,}4/8925 = 91{,}492$ mm

$Mntotal = Asb \cdot fy(d - {}^{a}/_{2}) = 2552{,}77 \cdot 320(340{,}5 - {}^{91.492}/_{2})10^{-7}$

$= 24{,}0686$ tm $> Mn \rightarrow$ O.K

$c = a/\beta = 91{,}492/0{,}81 = 112{,}953$ mm $< hf$

$\rightarrow$ pemisalan benar sebagai balok "T"

4) Kontrol jarak tulangan

$Y = h - 2Pb - 2Ds - 2D = 400 - (2 \cdot 40) - (2 \cdot 10) - (2 \cdot 19)$

$= 262$ mm < 300 mm $\rightarrow$ O.K

$X = (bw - 2Pb - 2Ds - N.D)/(N - 1)$

$= (300 - 80 - 20 - (9 \cdot 19))/(9 - 1) = 3{,}625$ mm < 25 mm

$\rightarrow$ dipakai jarak minimum = 25 mm

e. Perencanaan tulangan lapangan (M^{+})

$Mu^{+} = 14{,}682$ tm $\longrightarrow$ microfeap

$$Mn = \frac{Mu^{-}}{\phi} = \frac{14{,}682}{0{,}8} = 18{,}3525 \text{ tm}$$

1) Kontrol kapasitas total

$Mntotal = 0{,}85 \cdot f'c \cdot bw \cdot Hf\,(d - \frac{1}{2} hf)$

$= 0{,}85 \cdot 35 \cdot 300 \cdot 250\,(340{,}5 - \frac{1}{2} \cdot 250)\ 10^{-7}$

$= 48{,}0834$ tm $> Mn \rightarrow$O.K

2) Perencanaan tulangan pokok

$$\rho b = \frac{0{,}85 \cdot f'c \cdot \beta \cdot 600}{fy\,(600 + fy)} \qquad \rightarrow \beta = 0{,}85 - 0{,}008\,(f'c - 30)$$

$= 0{,}85 - 0{,}008\,(35 - 30) = 0{,}81$

$$= \frac{0,85 \cdot 35 \cdot 0,81 \cdot 600}{320\,(600 + 320)} = 0,049$$

$\rho maks = 0,75 \cdot \rho b = 0,75 \cdot 0,049 = 0,037$

$\rho min = 1,4/fy = 1,4/320 = 0,0044$

$m = fy/0,85f'c = 320/(0,85 \cdot 35) = 10,756$

$$Rn = Mn/(bw \cdot d^2) = \frac{(18,3525 \cdot 10^7)}{(300 \cdot 340,5^2)} = 5,2764 \text{ Mpa}$$

$$\rho perlu = \frac{1}{m}\left[1 - \sqrt{1 - \frac{2 \cdot m \cdot Rn}{fy}}\right]$$

$$= \frac{1}{10,756}\left[1 - \sqrt{1 - \frac{2 \cdot 10,756 \cdot 5,2764}{320}}\right] = 0,0183$$

$\rho min < \rho perlu < \rho maks \rightarrow$ dipakai tulangan sebelah

$As = \rho perlu \cdot bw \cdot d = 0,0183 \cdot 300 \cdot 340,5 = 1869,345 \text{ mm}^2$

$A\varnothing_{19} = \frac{1}{4}\pi\, 19^2 = 283,53 \text{ mm}^2$

$N = As/A\varnothing_{19} = 1869,345/283,53 = 6,59 \cong 7$ buah

$Asb = N \cdot A\varnothing_{19} = 7 \cdot 283,53 = 1984,71 \text{ mm}^2$

$\rho aktual = Asb/(bw \cdot d) = 1984,71/(300 \cdot 340,5)$

$= 0,0194 < \rho maks \rightarrow$ O.K

3) Kontrol kapasitas

$Cc = 0,85 \cdot f'c \cdot bw \cdot a = 0,85 \cdot 35 \cdot 300 \cdot a = 8925\,a$

$Ts = fy \cdot Asb = 320 \cdot 1984,71 = 635107,2$

Syarat: $Cc = Ts$

$8925\,a = 635107,2 \rightarrow a = 635107,2/8925 = 71,1605$ mm

Mntotal = Asb . fy(d – $^{a}/_{2}$) = 1984,71 . 320(340,5 – $^{71,1605}/_{2}$)10^{-7}

= 19,3657 tm > Mn → O.K

c = a/β = 71,1605/0,81 = 87,8525 mm < hf

→ pemisalan benar sebagai balok "T"

4) Kontrol jarak tulangan

Y = h – 2Pb – 2Ds – 2D = 400 – (2 . 40) – (2 . 10) – (2 . 19)

= 262 mm < 300 mm → O.K

X = (bw – 2Pb – 2Ds – N.D)/(N – 1)

= (300 – 80 – 20 – (7 . 19))/(7 – 1) = 11,17 mm < 25 mm

→ dipakai jarak minimum = 25 mm

f. Perencanaan tulangan geser murni

Vumaks = 18,571 t ⟶ microfeap

Vc = $\sqrt{f'c}$. b . d . $^{1}/_{6}$ = $\sqrt{35}$. 300 . 340,5 . 10^{-4} . $^{1}/_{6}$ = 10,0721 t

Ternyata: ϕVc = 6,0433 t < Vumaks

ϕ (Vc + Vs_1) < Vumaks < ϕ (Vc + Vs_2), berarti ukuran penampang dapat dipakai, tetap perlu tulangan geser.

Pada daerah dimana Vumaks > ϕ (Vc + Vs_1) spasi sengkang maksimum $^{d}/_{4}$ atau 300 mm, maka dicari titik dimana Vumaks = ϕ (Vc + Vs_1) = 18,1298 t

x_1 = (18,1298/18,571) . 2500 = 2441 mm dari tengah bentang,

sedang didaerah dimana Vu > ϕVc spasi sengkang maksimum $^{d}/_{2}$ atau 600 mm, maka dicari titik dimana Vumaks = ϕVc = 6,0433 t

x_2 = (6,0433/18,571) . 2500 = 814 mm dari tengah bentang,

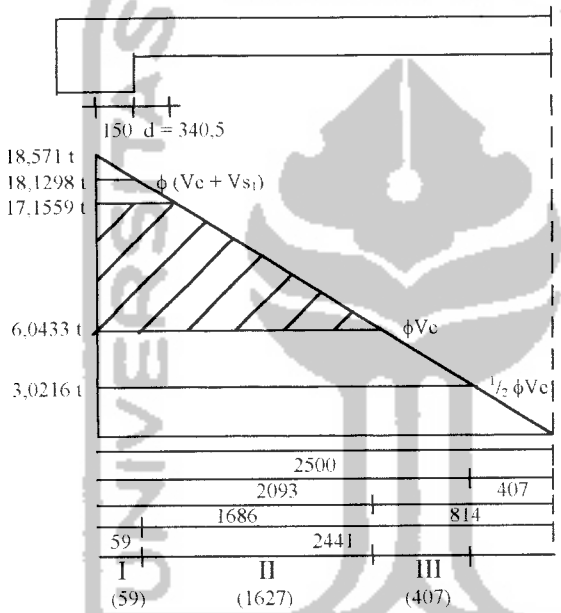
titik dimana gaya geser = $^1/_2$ ϕVc = 3,0216 t

x_3 = (3,0216/18,571) . 2500 = 407 mm dari tengah bentang,

gaya geser pada penampang kritis, sejauh d dari perletakan:

Vu = (($^1/_2$L – (d - $^1/_2$bw)) / $^1/_2$L) . Vumaks

= ((2500 – (340,5 – 150)) / 2500) . 18,571 = 17,1559 t



Gambar 3.7. Diagram tulangan geser

S ≤ $^d/_4$ = $^{340,5}/_4$ = 85,125 mm < 300 mm

S ≤ $^d/_2$ = $^{340,5}/_2$ = 170,25 mm < 600 mm

Digunakan sengkang ∅$_{10}$ → As = 2(¼ π 10^2) = 157,08 mm²

Daerah I:

ϕVs = Vu - ϕVc = 17,1559 – 6,0433 = 11,1126 t

Vs = 11,1126/0,6 = 18,521 t

Jarak sengkang S = $\frac{As \,.fy\,.\,d}{Vs}$

$$= \frac{157{,}08 \cdot 320 \cdot 340{,}5}{18{,}521 \cdot 10^4} = 92{,}411 \text{ mm} > 85{,}125 \text{ mm}$$

dipakai sengkang $\varnothing_{10-85\text{ mm}}$

Daerah II:

Dibagi menjadi dua bagian dengan lebar daerah 800 dan 827 mm.

Daerah Iia, lebar 800 mm dengan Vu = 17,1559 t

$\phi Vs = Vu - \phi Vc = 17{,}1559 - 6{,}0433 = 11{,}1126$ t

$Vs = 11{,}1126/0{,}6 = 18{,}521$ t

Jarak sengkang $S = \frac{As \cdot fy \cdot d}{Vs}$

$$= \frac{157{,}08 \cdot 320 \cdot 340{,}5}{18{,}521 \cdot 10^4} = 92{,}411 \text{ mm} < 170{,}25 \text{ mm}$$

dipakai sengkang $\varnothing_{10-90\text{ mm}}$

Daerah Iib, lebar 827 mm dengan $Vu = \frac{2500 - (59 + 800)}{2500} \cdot 18{,}571$

$= 12{,}19$ t

$\phi Vs = Vu - \phi Vc = 12{,}19 - 6{,}0433 = 6{,}1467$ t

$Vs = 6{,}1467/0{,}6 = 10{,}2445$ t

Jarak sengkang $S = \frac{As \cdot fy \cdot d}{Vs}$

$$= \frac{157{,}08 \cdot 320 \cdot 340{,}5}{10{,}2445 \cdot 10^4} = 167{,}1 \text{ mm} < 170{,}25 \text{ mm}$$

dipakai sengkang $\varnothing_{10-165\text{ mm}}$

Daerah III:

Yaitu daerah tulangan geser minimum.

Jarak sengkang $S = \frac{3\ As \cdot fy}{bw}$

$$= \frac{3 \cdot 157{,}08 \cdot 320}{300} = 502{,}656 \text{ mm} > 170{,}25 \text{ mm}$$

dipakai sengkang $\varnothing_{10-170\text{ mm}}$

3. Gelagar memanjang (3)

a. Perencanaan dimensi gelagar

h = 40 cm = 400 mm

b = 30 cm = 300 mm

digunakan: penutup beton (Pb) = 40 mm

tulangan berdiameter 19 mm

sengkang berdiameter 10 mm

d = h – Pb – Ds - ½ D = 400 – 40 – 10 - ½ .19 = 340,5 mm

d' = Pb + Ds + ½ D = 40 + 10 + ½ .19 = 59,5 mm

b. Kontrol terhadap geser

Vumaks = 23,002 t ⟶ microfeap

$Vc = \sqrt{f'c} \cdot b \cdot d \cdot {}^{1}/_{6} = \sqrt{35} \cdot 300 \cdot 340{,}5 \cdot 10^{-4} \cdot {}^{1}/_{6} = 10{,}0721$ t

$Vs_1 = {}^{1}/_{3} \cdot \sqrt{f'c} \cdot b \cdot d = {}^{1}/_{3} \cdot \sqrt{35} \cdot 300 \cdot 340{,}5 \cdot 10^{-4} = 20{,}1442$ t

$\phi (Vc + Vs_1) = 0{,}6(10{,}0721 + 20{,}1442)$

$= 18{,}1298$ t < Vumaks → Not O.K

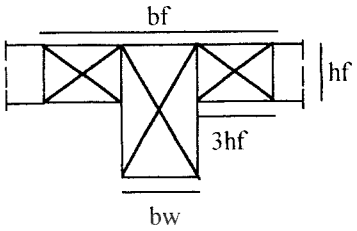
$Vs_2 = {}^{2}/_{3} \cdot \sqrt{f'c} \cdot b \cdot d = {}^{2}/_{3} \cdot \sqrt{35} \cdot 300 \cdot 340{,}5 \cdot 10^{-4} = 40{,}2885$ t

$\phi (Vc + Vs_2) = 0{,}6(10{,}0721 + 40{,}2885)$

$= 30{,}2164$ t > Vumaks → O.K

c. Kontrol terhadap torsi

Tumaks = 1,8941 tm → perencanaan plat cantilever



hf = 250 mm ; Pb = 40 mm
bw = 300 mm ; 3hf = 750 mm
h = 400 mm ; L = S = 5000 mm

$bf \leq {}^1/_4\, L = {}^1/_4 \,.\, 5000 = 1250$ mm

$\leq bw + 16hf = 300 + 16 \,.\, 250 = 4300$ mm

$\leq S = 5000$ mm → dipakai bf = 1250 mm

$\Sigma x^2y = 300^2 \,.\, 400 + 2 \,.\, 250^2 \,.\, 750 = 129750000 \text{ mm}^3$

$$\frac{\phi \,.\, \sqrt{f'c} \,.\, \Sigma x^2y}{20} = \frac{0{,}6 \,.\, \sqrt{35} \,.\, 129750000 \,.\, 10^{-7}}{20}$$

$= 2{,}3028$ tm > Tumaks

$$\frac{\phi \,.\, \sqrt{f'c} \,.\, \Sigma x^2y}{24} = \frac{0{,}6 \,.\, \sqrt{35} \,.\, 129750000 \,.\, 10^{-7}}{24}$$

$= 1{,}919$ tm > Tumaks

⟶ tidak perlu tulangan torsi

d. Perencanaan tulangan tumpuan (M^-)

$Mu^- = 23{,}137$ tm ⟶ microfeap

$$Mn = \frac{Mu^-}{\phi} = \frac{23{,}137}{0{,}8} = 28{,}9212 \text{ tm}$$

1) Kontrol kapasitas total

$Mntotal = 0{,}85 \,.\, f'c \,.\, bw. hf\,(d - \tfrac{1}{2} hf)$

$= 0{,}85 \,.\, 35 \,.\, 300 \,.\, 250\,(340{,}5 - \tfrac{1}{2} \,.\, 250)\, 10^{-7}$

$= 48{,}0834$ tm > Mn → O.K

2) Perencanaan tulangan pokok

$$\rho b = \frac{0{,}85 \,.\, f'c \,.\, \beta \,.600}{fy\,(600 + fy)} \quad \rightarrow \beta = 0{,}85 - 0{,}008\,(f'c - 30)$$

$= 0{,}85 - 0{,}008\,(35 - 30) = 0{,}81$

$$= \frac{0,85 \cdot 35 \cdot 0,81 \cdot 600}{320\,(600 + 320)} = 0,049$$

$\rho maks = 0,75 \cdot \rho b = 0,75 \cdot 0,049 = 0,037$

$\rho min = 1,4/fy = 1,4/320 = 0,0044$

$m = fy/0,85f'c = 320/(0,85 \cdot 35) = 10,756$

$$Rn = Mn/(bw \cdot d^2) = \frac{(28,9212 \cdot 10^7)}{(300 \cdot 340,5^2)} = 8,315 \text{ Mpa}$$

$$\rho perlu = \frac{1}{m}\left[1 - \sqrt{1 - \frac{2 \cdot m \cdot Rn}{fy}}\right]$$

$$= \frac{1}{10,756}\left[1 - \sqrt{1 - \frac{2 \cdot 10,756 \cdot 8,315}{320}}\right] = 0,0312$$

$\rho min < \rho perlu < \rho maks \rightarrow$ dipakai tulangan sebelah

$As = \rho perlu \cdot bw \cdot d = 0,0312 \cdot 300 \cdot 340,5 = 3187,08 \text{ mm}^2$

$A\varnothing_{19} = \frac{1}{4}\pi\, 19^2 = 283,53 \text{ mm}^2$

$N = As/A\varnothing_{19} = 3187,08/283,53 = 11,24 \cong 12$ buah

$Asb = N \cdot A\varnothing_{19} = 12 \cdot 283,53 = 3402,36 \text{ mm}^2$

$\rho aktual = Asb/(bw \cdot d) = 3402,36/(300 \cdot 340,5)$

$= 0,0333 < \rho maks \rightarrow$ O.K

3) Kontrol kapasitas

$Cc = 0,85 \cdot f'c \cdot bw \cdot a = 0,85 \cdot 35 \cdot 300 \cdot a = 8925\, a$

$Ts = fy \cdot Asb = 320 \cdot 3402,36 = 1088755,2$

Syarat: $Cc = Ts$

$8925\, a = 1088755,2 \rightarrow a = 1088755,2/8925$

$= 121,9894$ mm

Mntotal = Asb . fy(d – $^{a}/_{2}$) = 3402,36 . 320(340,5 – $^{121,9894}/_{2}$)10^{-7}

= 30,4313 tm > Mn → O.K

c = a/β = 121,9894/0,81 = 150,604 mm < hf

→ pemisalan benar sebagai balok "T"

4) Kontrol jarak tulangan

Y = h – 2Pb – 2Ds – 2D = 400 – (2 . 40) – (2 . 10) – (2 . 19)

= 262 mm < 300 mm → O.K

X = (bw – 2Pb – 2Ds – N.D)/(N – 1)

= (300 – 80 – 20 – (12 . 19))/(12 – 1) = -2,54 mm < 25 mm

→ dipakai jarak minimum = 25 mm

e. Perencanaan tulangan lapangan (M^{+})

Mu^{+} = 17,52 tm ⟶ microfeap

$$Mn = \frac{Mu^{+}}{\phi} = \frac{17,52}{0,8} = 21,9 \text{ tm}$$

1) Kontrol kapasitas total

Mntotal = 0,85 . f'c . bw. Hf (d - ½ hf)

= 0,85 . 35 . 300 . 250 (340,5 - ½ . 250) 10^{-7}

= 48,0834 tm > Mn →O.K

2) Perencanaan tulangan pokok

$$\rho b = \frac{0,85 \cdot f'c \cdot \beta \cdot 600}{fy\,(600 + fy)} \quad \rightarrow \beta = 0,85 - 0,008\,(f'c - 30)$$

$$= 0,85 - 0,008\,(35 - 30) = 0,81$$

$$= \frac{0,85 \cdot 35 \cdot 0,81 \cdot 600}{320\,(600 + 320)} = 0,049$$

ρmaks = 0,75 . ρb = 0,75 . 0,049 = 0,037

$\rho min = 1,4/fy = 1,4/320 = 0,0044$

$m = fy/0,85f'c = 320/(0,85 \cdot 35) = 10,756$

$Rn = Mn/(bw \cdot d^2) = \frac{(21,9 \cdot 10^7)}{(300 \cdot 340,5^2)} = 6,2963$ Mpa

$$\rho perlu = \frac{1}{m}\left[1 - \sqrt{1 - \frac{2 \cdot m \cdot Rn}{fy}}\right]$$

$$= \frac{1}{10,756}\left[1 - \sqrt{1 - \frac{2 \cdot 10,756 \cdot 6,2963}{320}}\right] = 0,0224$$

$\rho min < \rho perlu < \rho maks \rightarrow$ dipakai tulangan sebelah

$As = \rho perlu \cdot bw \cdot d = 0,0224 \cdot 300 \cdot 340,5 = 2284,74\ mm^2$

$A\varnothing_{19} = \frac{1}{4}\pi\ 19^2 = 283,53\ mm^2$

$N = As/A\varnothing_{19} = 2284,74/283,53 = 8,06 \cong 9$ buah

$Asb = N \cdot A\varnothing_{19} = 9 \cdot 283,53 = 2551,77\ mm^2$

$\rho aktual = Asb/(bw \cdot d) = 2551,77/(300 \cdot 340,5)$

$= 0,025 < \rho maks \rightarrow$ O.K

3) Kontrol kapasitas

$Cc = 0,85 \cdot f'c \cdot bw \cdot a = 0,85 \cdot 35 \cdot 300 \cdot a = 8925\ a$

$Ts = fy \cdot Asb = 320 \cdot 2551,77 = 816566,4$

Syarat: $Cc = Ts$

$8925\ a = 816566,4 \rightarrow a = 816566,4/8925 = 91,492$ mm

$Mntotal = Asb \cdot fy(d - {}^{a}/_{2}) = 2551,77 \cdot 320(340,5 - {}^{91,492}/_{2})10^{-7}$

$= 24,0686$ tm $> Mn \rightarrow$ O.K

$c = a/\beta = 91,492/0,81 = 112,953$ mm $< hf$

$\rightarrow$ pemisalan benar sebagai balok "T"

4) Kontrol jarak tulangan

$Y = h - 2Pb - 2Ds - 2D = 400 - (2 . 40) - (2 . 10) - (2 . 19)$

$= 262 \text{ mm} < 300 \text{ mm} \rightarrow \text{O.K}$

$X = (bw - 2Pb - 2Ds - N.D)/(N - 1)$

$= (300 - 80 - 20 - (9 . 19))/(9 - 1) = 3{,}625 \text{ mm} < 25 \text{ mm}$

$\rightarrow$ dipakai jarak minimum = 25 mm

f. Perencanaan tulangan geser murni

Vumaks = 23,002 t $\longrightarrow$ microfeap

$Vc = \sqrt{f'c} \; . \; b \; . \; d \; . \; {}^{1}/_{6} = \sqrt{35} \; . \; 300 \; . \; 340{,}5 \; . \; 10^{-4} \; . \; {}^{1}/_{6} = 10{,}0721 \text{ t}$

Ternyata: $\phi Vc = 6{,}0433 \text{ t} < \text{Vumaks}$

$\phi \; (Vc + Vs_1) < \text{Vumaks} < \phi \; (Vc + Vs_2)$, berarti ukuran penampang dapat dipakai, tetap perlu tulangan geser.

Pada daerah dimana Vumaks $> \phi \; (Vc + Vs_1)$ spasi sengkang maksimum ${}^{d}/_{4}$ atau 300 mm, maka dicari titik dimana :

Vumaks = $\phi \; (Vc + Vs_1) = 18{,}1298 \text{ t}$

$x_1 = (18{,}1298/23{,}002) \; . \; 2500 = 1971 \text{ mm}$ dari tengah bentang,

sedang didaerah dimana Vu $> \phi Vc$ spasi sengkang maksimum ${}^{d}/_{2}$ atau 600 mm, maka dicari titik dimana Vumaks = $\phi Vc = 6{,}0433 \text{ t}$

$x_2 = (6{,}0433/23{,}002) \; . \; 2500 = 657 \text{ mm}$ dari tengah bentang,

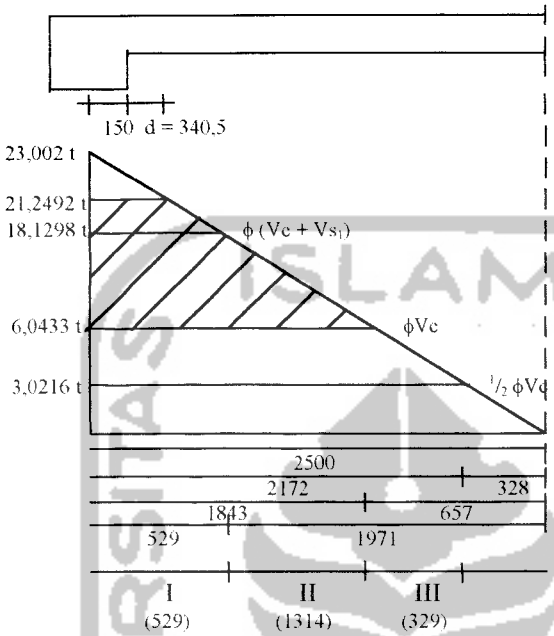
titik dimana gaya geser = ${}^{1}/_{2} \; \phi Vc = 3{,}0216 \text{ t}$

$x_3 = (3{,}0216/23{,}002) \; . \; 2500 = 328 \text{ mm}$ dari tengah bentang,

gaya geser pada penampang kritis, sejauh d dari perletakan:

$$Vu = \frac{{}^1/_2L - (d - {}^1/_2bw)}{{}^1/_2L} \cdot Vumaks$$

$$= 2500 - \frac{(340{,}5 - 150)}{2500} \cdot 23{,}002 = 21{,}2492 \text{ t}$$



Gambar 3.8. Diagram tulangan geser

$S \leq {}^d/_4 = {}^{340{,}5}/_4 = 85{,}125$ mm < 300 mm

$S \leq {}^d/_2 = {}^{340{,}5}/_2 = 170{,}25$ mm < 600 mm

Digunakan sengkang $\varnothing_{10} \rightarrow As = 2(\frac{1}{4}\,\pi\,10^2) = 157{,}08$ mm²

Daerah I:

$\phi Vs = Vu - \phi Vc = 21{,}2492 - 6{,}0433 = 15{,}2059$ t

$Vs = 15{,}2059/0{,}6 = 25{,}3432$ t

Jarak sengkang $S = \frac{As \,.fy\,.\,d}{Vs}$

$$= \frac{157{,}08\,.\,320\,.\,340{,}5}{25{,}3432\,.\,10^4} = 67{,}53 \text{ mm} < 85{,}125 \text{ mm}$$

dipakai sengkang $\varnothing_{10-65\,mm}$

Daerah II:

Dibagi menjadi dua bagian dengan lebar daerah 650 dan 664 mm.

Daerah IIa, lebar 650 mm dengan Vu = 21,2492 t

$\phi Vs = Vu - \phi Vc = 21,2492 - 6,0433 = 15,2059$ t

$Vs = 15,2059/0,6 = 25,3432$ t

Jarak sengkang $S = \frac{As \,.fy\,.\,d}{Vs}$

$= \frac{157,08\,.\,320\,.\,340,5}{25,3432\,.\,10^4} = 67,53$ mm < 170,25 mm

dipakai sengkang $\varnothing_{10-65\ mm}$

Daerah IIb, lebar 664 mm dengan $Vu = \frac{2500 - (529+650)}{2500}\,.\,23,002$

$= 12,1543$ t

$\phi Vs = Vu - \phi Vc = 12,1543 - 6,0433 = 6,111$ t

$Vs = 6,111/0,6 = 10,1849$ t

Jarak sengkang $S = \frac{As\,.fy\,.\,d}{Vs}$

$= \frac{157,08\,.\,320\,.\,340,5}{10,1849\,.\,10^4} = 168,05$ mm < 170,25 mm

dipakai sengkang $\varnothing_{10-165\ mm}$

Daerah III:

Yaitu daerah tulangan geser minimum.

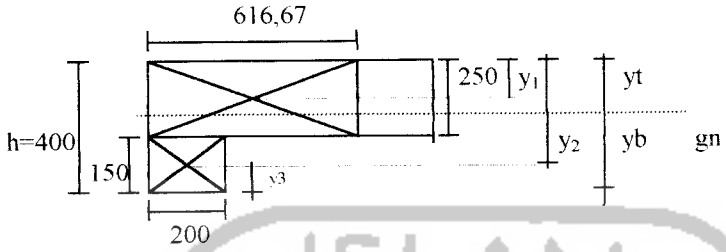
Jarak sengkang $S = \frac{3\ As\,.\,fy}{bw}$

$= \frac{3\,.\,157,08\,.\,320}{300} = 502,656$ mm > 170,25 mm

dipakai sengkang $\varnothing_{10-170\ mm}$

3.3.3 Kontrol Terhadap Kombinasi Beban

1. Gelagar memanjang (1)



Statis momen terhadap sisi atas

$A_I = 250 \cdot 616{,}67 \cdot = 154.167{,}5\ mm^2$ $\quad Y_1 = 125$ mm

$A_{II} = 200 \cdot 150 = 30.000\ mm^2$ $\quad Y_2 = 325$ mm

$A_{tot} = A_I + A_{II} = 184.167{,}5\ mm^2$ $\quad Y_3 = 75$ mm

$$Y_t = \frac{(A_I . Y_1)+(A_{II} . Y_2)}{A_{tot}} = \frac{(154.167,5 \cdot 125)+(30.000 \cdot 325)}{184.167,5} = 157{,}6 \text{ mm}$$

$Y_b = h - Y_t = 400 - 157{,}6 = 242{,}4$ mm

$I = (1/12 \cdot b \cdot h^3 + A_I \cdot (Y_t - Y_1)^2) + (1/12 \cdot b \cdot h^3 + A_{II} \cdot (Y_b - Y_3)^2)$

$= (1/12 \cdot 616{,}67 \cdot 250^3 + 154.167{,}5 \cdot (32{,}6)^2)$

$+ (1/12 \cdot 200 \cdot 150^3 + 30.000 \cdot (167{,}4)^2) = 0{,}0019\ m^4$

$Sb = I/Y_b = 0{,}0019/0{,}2424 = 0{,}0077\ m^3$

Menentukan tegangan ijin yang terjadi :

$\bar{\sigma} = E \cdot \varepsilon \longrightarrow$ dengan : $\bar{\sigma}$ = tegangan ijin

E = modulus elastisitas

ε = regangan

$= 2{,}8 \cdot 10^6 \cdot 0{,}003 = 8400\ t/m^2$

a. Beban mati (M)

qd = 0,558 t/m ; L = 5 m

$M = 1/12 . qd . L^2 = 1/12 . 0,558 . 5^2 = 1,1625$ tm

$\sigma = M/S = 1,1625/0,0077 = 151,2$ t/m^2

b. Beban hidup (H + K)

$q_{LL} = 0,6$ t/m ; $p_{LL} = 4,464$ t

$M = 1/12 . q_{LL} . L^2 + p .a .b^2/L^2$

$= 1/12 . 0,6 . 5^2 + 4,464 . 2,5 . 2,5^2/5^2$

$= 4,04$ tm

$\sigma = M/S = 4,04/0,0077 = 525,449$ t/m^2

c. Gaya rem dan traksi (Rm)

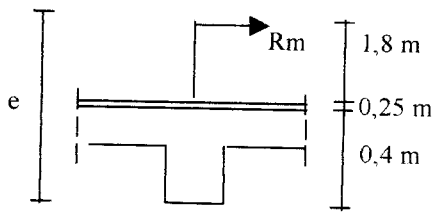
Pengaruh gaya rem dan traksi sebesar 5 % dari beban "D" tanpa koefisien kejut.

$D = P_{LL} + q_{LL}$

$= \frac{12 . 0,75}{2,75} + \frac{1,364 . 0,75}{2,75} = 3,873$ t

Rm = 5 % . D

= 5 % . 3,873 = 0,1936 t



e = 1,8 + 0,25 + 0,4 = 2,45 m

M = R . e = 0,1936 . 2,45 = 0,4744 tm

$\sigma = M/S = 0,4744/0,0077 = 61,701$ t/m^2

d. Gaya akibat perbedaan suhu (Tm)

$Tm = E \cdot \varepsilon \cdot t$ ⟶ dengan : $E = 2{,}8 \cdot 10^{6}$ t/m^2

$\varepsilon = 10 \cdot 10^{-6}$

$t = 15\ ^{\circ}$

(Dari tabel IV PMJJR 1987 hal 14)

$Tm = 2{,}8 \cdot 10^{6} \cdot 10 \cdot 10^{-6} \cdot 15\ ^{\circ} = 420$ t/m^2

e. Gaya rangkak atau susut (SR)

Besarnya gaya rangkak dan susut dianggap sama dengan gaya yang timbul atau bekerja, akibat perbedaan suhu 15 °.

(Dari PMJJR 1987 hal 14)

SR = 420 t/m^2

f. Gaya akibat gempa bumi (Gh)

$K = E \cdot G$ ⟶ dengan : E = 0,05 (Bandung Termasuk daerah gempa III)

G = L (qd)

= 5 (0,558) = 2,79 t

$K = 0{,}05 \cdot 2{,}79 = 0{,}1395$ t

$Mg = \frac{1}{4} \cdot K \cdot L = \frac{1}{4} \cdot 0{,}1395 \cdot 5 = 0{,}1744$ tm

$\sigma = Mg / S = 0{,}1744/0{,}007 = 22{,}6461$ t/m^2

g. Gaya sentrifugal

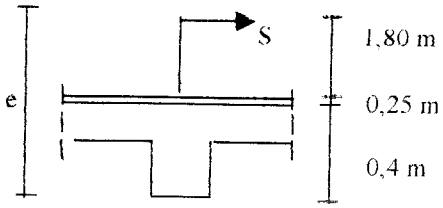
$Ks = 0{,}79\ Vr^2/R$ ⟶ dengan : Vr = 80 km/jam

R = 250 m

$Ks = 0{,}79 \cdot 80^2/250 = 20{,}224$ %

S = Ks . D

= 20,224 % . 3,873 = 0,7833 t



e = 1,8 + 0,25 + 0,4 = 2,45 m

Ms = S . e

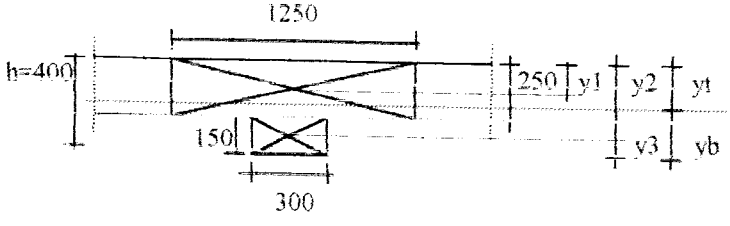
= 0,7833 . 2,45 = 1,919 tm

σ = Ms/S = 1,919/0,0077 = 249,22 t/m^2

Tabel 3.1 Kombinasi pembebanan dan gaya gelagar (1)

No	Kombinasi pembebanan dan gaya	Tegangan yang terjadi (t/m^2)
I	M + (H + K)	151,2 + 525,49 = 676,649 < 100 %$\bar{\sigma}$ = 8400
II	M + SR + Tm	151,2 + 420 + 420 = 991,2 <125 % $\bar{\sigma}$ = 10500
III	M+(H+K)+Rm+SR+Tm +S	151,2+525,449+61,701+420 +420+249,22 = 1827,57 < 140 % σ =,11760
IV	(M + Gh)	151,2 + 22,6461 = 173,8461 < 150 %$\bar{\sigma}$ = 12600
V	M + (H+K) + S	151,2+525,49+249,22 = 925,869 < 150 %$\bar{\sigma}$ – 12600

2. Gelagar memanjang (2)



Statis momen terhadap sisi atas

$A_I = 1250 \cdot 250 = 312.500 \text{ mm}^2$ $\quad Y_1 = 125 \text{ mm}$

$A_{II} = 150 \cdot 300 = 45.000 \text{ mm}^2$ $\quad Y_2 = 325 \text{ mm}$

$A_{tot} = A_I + A_{II} = 357.500 \text{ mm}^2$ $\quad Y_3 = 75 \text{ mm}$

$$Y_t = \frac{(A_I . Y_1) + (A_{II} . Y_2)}{A_{tot}} = \frac{(312.500.125) + (45.000.325)}{357.000} = 150,175 \text{ mm}$$

$Y_b = h - Y_t = 400 - 150,175 = 249,825 \text{ mm}$

$I = (1/12 \cdot b \cdot h^3 + A_I \cdot (Y_t - Y_1)^2) + (1/12 \cdot b \cdot h^3 + A_{II} \cdot (Y_b - Y_3)^2)$

$= (1/12 \cdot 1250 \cdot 250^3 + 312.500 \cdot (25,175)^2)$

$+ (1/12 \cdot 300 \cdot 150^3 + 45.000 \cdot (174,825)^2) = 0,0033 \text{ m}^4$

$Sb = I/Y_b = 0,0033/0,2498 = 0,01315 \text{ m}^3$

Menentukan tegangan ijin yang terjadi :

$\bar{\sigma} = E \cdot \varepsilon \longrightarrow$ dengan : $\bar{\sigma}$ = tegangan ijin

E = modulus elastisitas

ε = regangan

$= 2,8 \cdot 10^6 \cdot 0,003 = 8400 \text{ t/m}^2$

a. Beban mati (M)

qd = 1,4334 t/m ; L = 5 m

$M = 1/12 \cdot qd \cdot L^2 = 1/12 \cdot 1,4334 \cdot 5^2 = 2,98625 \text{ tm}$

$\sigma = M/S = 2,98625/0,01315 = 227,091 \text{ t/m}^2$

b. Beban hidup (H + K)

$q_{LL} = 1,4 \text{ t/m}$; $p_{LL} = 10,416 \text{ t}$

$M = 1/12 \cdot q_{LL} \cdot L^2 + p_{LL} \cdot a \cdot b^2/L^2$

$= 1/12 \cdot 1{,}4 \cdot 5^2 + 10{,}416 \cdot 2{,}5 \cdot 2{,}5^2/5^2$

$= 9{,}4267$ tm

$\sigma = M/S = 9{,}4267/0{,}01315 = 716{,}8568$ t/m^2

c. Gaya rem dan traksi (Rm)

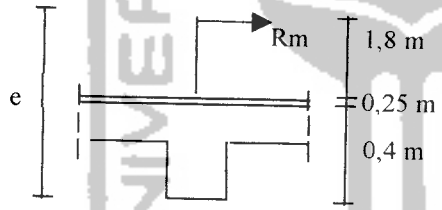
Pengaruh gaya rem dan traksi sebesar 5 % dari beban "D" tanpa koefisien kejut.

$D = P_{LL} + q_{LL}$

$= \frac{12 \cdot 1{,}75}{2{,}75} + \frac{1{,}364 \cdot 1{,}75}{2{,}75} = 9{,}0364$ t

$Rm = 5\,\% \cdot D$

$= 5\,\% \cdot 9{,}0364 = 0{,}4518$ t



$e = 1{,}8 + 0{,}25 + 0{,}4 = 2{,}45$ m

$M = R \cdot e = 0{,}4518 \cdot 2{,}45 = 1{,}107$ tm

$\sigma = M/S = 1{,}107/0{,}01315 = 84{,}1825$ t/m^2

d. Gaya akibat perbedaan suhu (Tm)

$Tm = E \cdot \varepsilon \cdot t \longrightarrow$ dengan : $E = 2{,}8 \cdot 10^6$ t/m^2

$\varepsilon = 10 \cdot 10^{-6}$

$t = 15\,°$

(Dari tabel IV PMJJR 1987 hal 14)

$Tm = 2{,}8 \cdot 10^6 \cdot 10 \cdot 10^{-6} \cdot 15\,° = 420$ t/m^2

e. Gaya rangkak atau susut (SR)

Besarnya gaya rangkak dan susut dianggap sama dengan gaya yang timbul atau bekerja, akibat perbedaan suhu 15 °.

(Dari PMJJR 1987 hal 14)

SR = 420 t/m^2

f Gaya akibat gempa bumi (Gh)

K = E . G ⟶ dengan : E = 0,05 (Bandung Termasuk daerah gempa III)

G = L (qd)

= 5 (1,4334) = 7,167 t

K = 0,05 . 7,167 = 0,3583 t

Mg = ¼ . K . L = ¼ . 0,3583 . 5 = 0,4479 tm

σ = Mg/S = 0,4479/0,01315 = 34,0589 t/m^2

g. Gaya sentrifugal

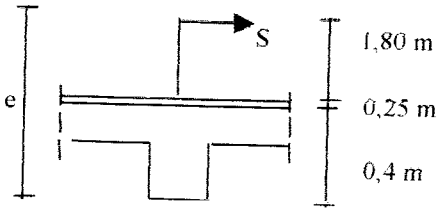
Ks = 0,79 Vr^2/R ⟶ dengan : Vr = 80 km/jam

R = 250 m

Ks = 0,79 . 80^2/250 = 20, 224 %

S = Ks . D

= 20,224 % . 9,0364 = 1,8275 t



e = 1,8 + 0,25 + 0,4 = 2,45 m

Ms = S . e

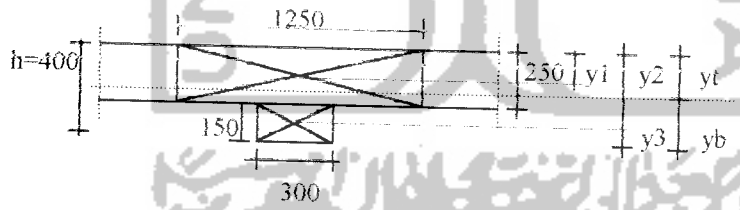
= 1,8275 . 2,45 = 4,4774 tm

σ = Ms/S = 4,4774/0,01315 = 340,489 t/m^2

Tabel 3.2. Kombinasi pembebanan dan gaya gelagar (2)

No	Kombinasi pembebanan dan gaya	Tegangan yang terjadi (t / m^2)
I	M + (H + K)	227,091+716,8568 = 943,9478 < 100 % $\bar{\sigma}$ = 8400
II	M + SR + Tm	227,091+420+420 = 1067,091 <125 % $\bar{\sigma}$ = 10500
III	M+(H+K)+Rm+SR+Tm +S	227,091+716,8568+84,1825 +420+420+340,489 = 2208,6193 < 140 % $\bar{\sigma}$ =11760
IV	(M + Gh)	227,091 + 34,0589 = 261,1499 < 150 %$\bar{\sigma}$ = 12600
V	M + (H+K) + S	227,091+716,8568+340,489 = 1284,4368 < 150 %$\bar{\sigma}$ = 12600

3. Gelagar memanjang (3)



Statis momen terhadap sisi atas

A_I = 1250 . 250 = 312.500 mm^2 Y_1 = 125 mm

A_{II} = 150 . 300 = 45.000 mm^2 Y_2 = 325 mm

$A_{tot} = A_I + A_{II}$ = 357.500 mm^2 Y_3 = 75 mm

$$Y_t = \frac{(A_I.Y_1)+(A_{II}.Y_2)}{A_{tot}} = \frac{(312.500.125)+(45.000.325)}{357.000} = 150,175 \text{ mm}$$

$Y_b = h - Y_t = 400 - 150,175 = 249,825$ mm

$I = (1/12 \cdot b \cdot h^3 + A_I \cdot (Y_t - Y_1)^2) + (1/12 \cdot b \cdot h^3 + A_{II} \cdot (Y_b - Y_3)^2)$

$= (1/12 \cdot 1250 \cdot 250^3 + 312.500 \cdot (25{,}175)^2)$

$+ (1/12 \cdot 300 \cdot 150^3 + 45.000 \cdot (174{,}825)^2) = 0{,}0033\ m^4$

$Sb = I / Y_b = 0{,}0033 / 0{,}2498 = 0{,}01315\ m^3$

Menentukan tegangan ijin yang terjadi :

$\bar{\sigma} = E \cdot \varepsilon$ ⟶ dengan : $\bar{\sigma}$ = tegangan ijin

E = modulus elastisitas

ε = regangan

$= 2{,}8 \cdot 10^6 \cdot 0{,}003 = 8400\ t/m^2$

a. Beban mati (M)

qd = 2,2472 t/m ; L = 5 m

$M = 1/12 \cdot qd \cdot L^2 = 1/12 \cdot 2{,}2472 \cdot 5^2 = 4{,}6817$ tm

$\sigma = M/S = 4{,}6817/0{,}01315 = 356{,}0203\ t/m^2$

b. Beban hidup (H + K)

$q_{LL} = 1{,}6$ t/m ; $p_{LL} = 11{,}904$ t

$M = 1/12 \cdot q_{LL} \cdot L^2 + p_{LL} \cdot a \cdot b^2/L^2$

$= 1/12 \cdot 1{,}6 \cdot 5^2 + 11{,}904 \cdot 2{,}5 \cdot 2{,}5^2/5^2$

$= 10{,}7733$ tm

$\sigma = M/S = 10{,}7733/0{,}01315 = 819{,}2649\ t/m^2$

c. Gaya rem dan traksi (Rm)

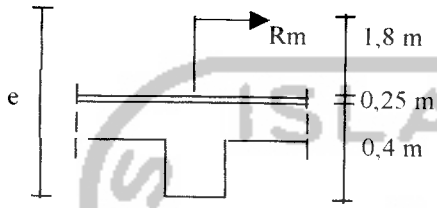
Pengaruh gaya rem dan traksi sebesar 5 % dari beban "D" tanpa koefisien kejut.

$D = P_{LL} + q_{LL}$

$= \frac{12 \,.\, 2{,}00}{2{,}75} + \frac{1{,}364 \,.\, 2{,}00}{2{,}75} = 10{,}3273$ t

$Rm = 5\,\% \,.\, D$

$= 5\,\% \,.\, 10{,}3273 = 0{,}5164$ t



$e = 1{,}8 + 0{,}25 + 0{,}4 = 2{,}45$ m

$M = R \,.\, e = 0{,}5164 \,.\, 2{,}45 = 1{,}2651$ tm

$\sigma = M/S = 1{,}2651/0{,}01315 = 96{,}2053$ t/m^2

d. Gaya akibat perbedaan suhu (Tm)

$Tm = E \,.\, \varepsilon \,.\, t$ ⟶ dengan : $E = 2{,}8 \,.\, 10^{6}$ t/m^2

$\varepsilon = 10 \,.\, 10^{-6}$

$t = 15\,°$

(Dari tabel IV PMJJR 1987 hal 14)

$Tm = 2{,}8 \,.\, 10^{6} \,.\, 10 \,.\, 10^{-6} \,.\, 15\,° = 420$ t/m^2

e. Gaya rangkak atau susut (SR)

Besarnya gaya rangkak dan susut dianggap sama dengan gaya yang timbul atau bekerja, akibat perbedaan suhu 15 °.

(Dari PMJJR 1987 hal 14)

$SR = 420$ t/m^2

f. Gaya akibat gempa bumi (Gh)

K = E . G ⟶ dengan : E = 0,05 (Bandung Termasuk daerah gempa III)

G = L (qd)

= 5 (2,2472) = 11,236 t

K = 0,05 . 11,236 = 0,5618 t

Mg = ¼ . K . L = ¼ . 0,5618 . 5 =0,70225 tm

σ = Mg/S = 0,70225/0,01315 = 53,4030 t/m^2

g. Gaya sentrifugal

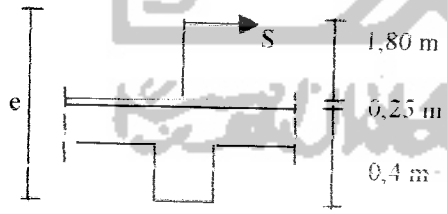
Ks = 0,79 Vr^2/R ⟶ dengan : Vr = 80 km/jam

R = 250 m

Ks = 0,79 . 80^2/250 = 20,224 %

S = Ks . D

= 20,224 % . 10,3273 = 2,0886 t



e = 1,8 + 0,25 + 0,4 = 2,45 m

Ms = S . e

= 2,0886 . 2,45 = 5,1171 tm

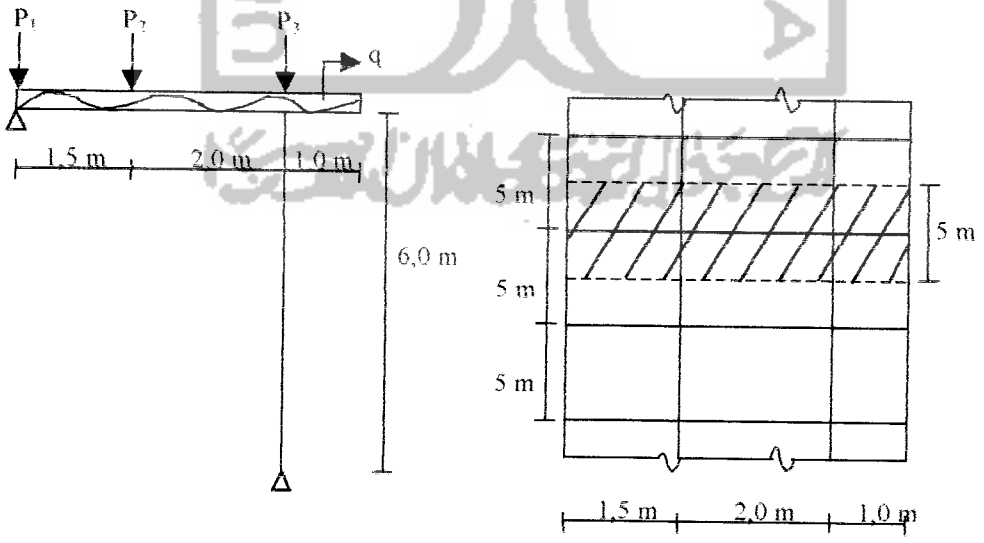
σ = Ms/S = 5,1171/0,01315 = 389,1295 t/m^2

Tabel 3.3. Kombinasi pembebanan dan gaya gelagar (3)

No	Kombinasi pembebanan dan gaya	Tegangan yang terjadi (t / m^2)
I	M + (H + K)	356,0203+819,2649= 1125,2852 < 100 % $\overline{\sigma}$ = 8400
II	M + SR + Tm	356,0203+420+420 = 1196,0203 <125 % $\overline{\sigma}$ – 10500
III	M+(H+K)+Rm+SR+Tm +S	356,0203+819,2649+96,205 +420+420+389,130= 2111,491 < 140 % $\overline{\sigma}$ =11760
IV	(M + Gh)	356,0203 + 53,4030 = 409,4233 < 150 %$\overline{\sigma}$ = 12600 = 1609,5742
V	M + (H+K) + S	356,0203+819,2649+389,130 < 150 %$\overline{\sigma}$ = 12600

3.4 Perencanaan Gelagar Melintang dan Kolom

Perencanaan gelagar melintang dan kolom ini, dirancang sebagai konstruksi portal dengan tumpuan sendi-sendi dan beban-beban yang bekerja seperti yang terlihat pada gambar 3.9.



Gambar 3.9. Struktur portal dan posisi pembebanannya

3.4.1 Perhitungan Mekanika Gelagar Melintang dan Kolom

1. Gelagar melintang

a. Beban-beban yang terjadi pada gelagar (P_1)

qd = 0,558 t/m

ql = 0,6 t/m

pl = 4,464 t

1) Beban mati

P_1 = qd . L = 0,558 . 5 = 2,79 t

2) Beban hidup

P_1 = pl + (ql . L) = 4,464 + (0,6 . 5) = 7,464 t

$P_{1\ total}$ = 2,79 + 7,464 = 10,254 t

b. Beban-beban yang terjadi pada gelagar (P_2)

qd = 1,4334 t/m

ql = 1,4 t/m

pl = 10,416 t

1) Beban mati

P_2 = qd . L = 1,4334 . 5 = 7,167 t

2) Beban hidup

P_2 = pl + (ql . L) = 10,416 + (1,4 . 5) = 17,416 t

$P_{2\ total}$ = 7,167 + 17,416 = 24,583 t

c. Beban-beban yang terjadi pada gelagar (P_3)

qd = 2,1462 t/m

ql = 1,6 t/m

pl = 11,904 t

1) Beban mati

P_3 = qd . L = 2,1462 . 5 = 10,731 t

2) Beban hidup

P_3 = pl + (ql . L) = 11,904 + (1,6 . 5) = 19,904 t

$P_{3\ total}$ = 10,731 + 19,904 = 30,635 t

d. Dimensi balok

Tinggi minimum balok menurut SK- SNI tabel 3.25

h_{min} = (L / 18,5) (0,4 + (fy / 700))

= (4500/18,5) . (0,4 + (320/700)) = 208,5 mm

diambil: ht = 50 cm

b = 40 cm

q_{balok} = b (ht_{balok} - ht_{plat}) γ_{beton}

= 0,4 (0,50 – 0,25) 2500 = 250 kg/m

qu_{balok} = 1,2 . 250 = 300 kg/m = 0,3 t/m

2. Dimensi kolom

Beban yang terjadi pada kolom:

q_{balok} = (1,7 + 1,0) . 0,25 = 0,6875 t

P_2 = 0,5 . 24,583 = 12,2915 t

P_3 = 30,6350 t +

N = 43,6140 t

Luas yang diperlukan (Ag) = N/f`c = $(43{,}614 \cdot 10^4)/35 = 12461{,}14\ mm^2$

Dipakai b = 400 mm, maka:

h = Ag/b = 12461,14/400 = 31,1529 mm

⟶ dipakai dimensi kolom h = 500 mm dan b = 400 mm

Untuk menghitung momen maksimum (baik momen lapangan maupun momen tumpuan dan reaksi-reaksi yang terjadi digunakan program "Microfeaf " yang dapat dilihat pada lampiran 3.

Modulus elastisitas = $4700\ \sqrt{f`c}$

$= 4700\ \sqrt{35} = 2{,}8 \cdot 10^4\ MPa$

$= 2{,}8 \cdot 10^6\ t/m^2$

Inersia balok dan kolom = $1/12 \cdot b \cdot h^3$

$= 1/12 \cdot 400 \cdot 500^3 = 4{,}17 \cdot 10^{-3}\ m^4$

3.4.2 Perhitungan Dimensi Gelagar Melintang

1. Perencanaan dimensi gelagar

   h = 50 cm = 500 mm

   b = 40 cm = 400 mm

   Digunakan : penutup beton (pb) = 40 mm

   diameter tulangan (D) = 22 mm

   diameter sengkang(Ds) = 10 mm

   d = h – pb – Ds – 1/2D = 439 mm

   d'= pb + Ds +1/2D = 61 mm

2. Kontrol terhadap geser

   Vu_{maks} = 43,214 t ⟶ microfeaf

$Vc = 1/6 \cdot \sqrt{35} \cdot 400 \cdot 439 \cdot 10^{-4} = 17\,3144$ t

$Vs_1 = 1/3 \cdot \sqrt{35} \cdot 400 \cdot 439 \cdot 10^{-4} = 34{,}6288$ t

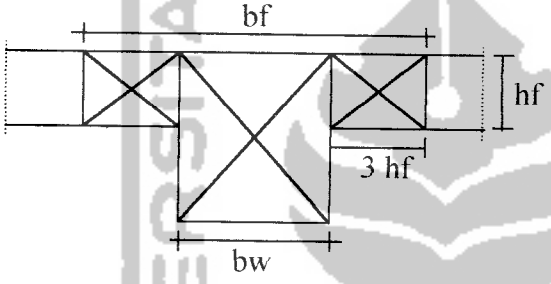
$\varnothing(Vc + Vs_1) = 0{,}6\,(17{,}3144 + 34{,}6288) = 31{,}1659$ t $< Vu_{maks}$

$Vs_2 = 2/3 \cdot \sqrt{35} \cdot 400 \cdot 439 \cdot 10^{-4} = 69{,}2576$ t

$\varnothing(Vc + Vs_2) = 0{,}6\,(17{,}3144 + 69{,}2576) = 51{,}9432$ t $> Vu_{maks} \rightarrow$ o.k

3. Kontrol terhadap torsi

$Tu_{maks} = Mtx_{1maks} - Mtx_{2maks} = 5{,}3146 - 0{,}15 = 5{,}1646$ tm (microfeaf)



hf = 250 mm pb = 40 mm

bw = 400 mm 3 hf = 750 mm

h = 500 mm L = S = 4500 mm

bf $\leq$ ¼ L = ¼ . 4500 = 1125 mm

$\leq$ bw + 16 hf = 400 + 16 . 250 = 4400 mm

$\leq$ S = 4500 mm $\longrightarrow$ dipakai bf = 1125 mm

$\Sigma x^2y = 400^2 \cdot 500 + 2 \cdot 250^2 \cdot 750 = 173.750.000$ mm^3

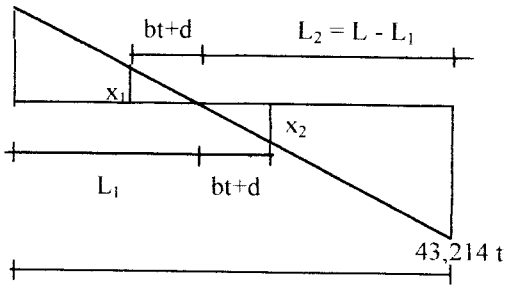
$$\frac{\varnothing \cdot \sqrt{f'c} \cdot \Sigma x^2y}{20} = \frac{0{,}6 \cdot \sqrt{35} \cdot 173.750.000 \cdot 10^{-7}}{20} = 3{,}0838 \text{ tm} < Tu_{maks}$$

$Ct = (bw \cdot d) / \Sigma x^2y = (400 \cdot 439) / 173.750.000 = 1{,}011 \cdot 10^{-3}$ / mm

$bt = bw - 2pb - 2Ds = 400 - 2 \cdot 40 - 2 \cdot 10 = 300$ mm

$bt + d = 300 + 439 = 739$ mm

23,308 t



L = 3500 mm

$23,308 / L_1 = 43,214 / 3500-L_1$
L_1 = 1226,3 mm
L_2 =3500–1226=2273,7 mm
$x_1 = (739/1226,3) \cdot 23,308$
= 14,046 t
$x_2 = (739/2273,7) \cdot 43,214$
= 14,045 t

$Vu_{maks} = 14,046$ t

$$Tc = \frac{\sqrt{f'c} \cdot \Sigma x^2 y}{15 \cdot \sqrt{(1 + (0,4Vu / Ct \cdot Tu)^2)}}$$

$$= \frac{\sqrt{35} \cdot 173.750.000 \cdot 10^{-4}}{15\sqrt{(1 + (0,4 \cdot 14,046 / 1,01.1\ 10^{-3} \cdot 5,1646)^2)}} = 4,665 \text{ tm}$$

$Ts = (Tu / \varnothing) - Tc = (5,1646 / 0,6) - 4,665 = 3,9427$ tm

$4Tc = 4 \cdot 4,665 = 18,66$ tm > $Ts = 3,9427$ tm ⟶ o.k

4. Perencanaan tulangan tumpuan (M^-)

$Mn^- = 5,3146$ tm

$Mn = Mn^- / \varnothing = 5,3146 / 0,8 = 6,6432$ tm

a. Kontrol kapasitas total

$Mn_{tot} = 0,85 \cdot f'c \cdot bw \cdot hf \cdot (d - ½\ hf)$

$= 0,85 \cdot 35 \cdot 400 \cdot 250 \cdot (439 - ½\ 250).10^{-7}$

$= 93,415$ tm > $Mn = 6,6432$ tm ⟶ o.k

b. Perencanaan tulangan pokok

$\rho_b = 0,049$; $\rho_{maks} = 0,037$; $\rho_{min} = 0,0044$; $m = 10,756$

$Rn = Mn / bw \cdot d^2 = 6,6432 \cdot 10^7 / 400 \cdot 439^2 = 0,8618$ Mpa

$$\rho_{perlu} = \frac{1}{10,756}\left[1 - \sqrt{1 - \frac{2 \,.\, 0,8618 \,.\, 10,256}{320}}\right] = 0,0027$$

$\rho_{min} > \rho_{perlu} \longrightarrow$ dipakai ρ_{min} (tulangan sebelah)

$As = \rho_{min} \,.\, bw \,.\, d = 0,0044 \,.\, 400 \,.\, 439 = 772,64 \text{ mm}^2$

$A\varnothing_{22} = \frac{1}{4} \,.\, \pi \,.\, 22^2 = 380,13 \text{ mm}^2$

$N = As / A\varnothing_{22} = 2,03 \approx 3$ buah

$Asb = N \,.\, A\varnothing_{22} = 3 \,.\, 380,13 = 1140,39 \text{ mm}^2$

$\rho_{aktual} = Asb / bw \,.\, d = 1140,39 / 400 \,.\, 439$

$= 0,0065 < \rho_{maks} = 0,037 \longrightarrow$ o.k

c. Kontrol kapasitas

$Cc = 0,85 \,.\, f'c \,.\, bw \,.\, a = 0,85 \,.\, 35 \,.\, 400 \,.\, a = 11.900\, a$

$Ts = fy \,.\, Asb = 320 \,.\, 1140,39 = 364.924,8 \text{ N}$

Syarat : $Cc = Ts$

$11.900\, a = 364.924,8 \longrightarrow a = 30,666 \text{ mm}$

$Mn_{tot} = Asb \,.\, fy \,.\, (d - \frac{1}{2} a)$

$= 1140,39 \,.\, 320 \,.\, (439 - \frac{1}{2} 30,666) \,.\, 10^{-7}$

$= 15,4607 \text{ tm} > Mn = 6,6432 \text{ tm} \longrightarrow$ o.k

$c = a / \beta_1 = 30,666 / 0,81 = 37\ 8593 \text{ mm} < hf = 250 \text{ mm}$

$\longrightarrow$ Asumsi sebagai balok "T" benar

d. Kontrol jarak tulangan

$Y = h - 2pb - 2Ds - 2D$

$= 500 - 2 \,.\, 40 - 2 \,.\, 10 - 2 \,.\, 22 = 356 \text{ mm} > 300 \text{ mm}$

$X = bw - 2pb - 2Ds - ND / (N-1)$

$= 400 - 2 \cdot 40 - 2 \cdot 10 - 3 \cdot 22 / 2 = 117 \text{ mm} > 25 \text{ mm}$

5. Perencanaan tulangan lapangan (M^+)

$Mn^+ = 16{,}239$ tm

$Mn = Mn^+ / \varnothing = 516{,}239 / 0{,}8 = 20{,}2987$ tm

a. Kontrol kapasitas total

$Mn_{tot} = 0{,}85 \cdot f'c \cdot bw \cdot hf \cdot (d - \frac{1}{2} hf)$

$= 0{,}85 \cdot 35 \cdot 400 \cdot 250 \cdot (439 - \frac{1}{2} 250).10^{-7}$

$= 93{,}415 \text{ tm} > Mn = 20{,}2987 \text{ tm} \longrightarrow$ o.k

b. Perencanaan tulangan pokok

$\rho_b = 0{,}049$; $\rho_{maks} = 0{,}037$; $\rho_{min} = 0{,}0044$; $m = 10{,}756$

$Rn = Mn / bw \cdot d^2 = 20{,}2987 \cdot 10^7 / 400 \cdot 439^2 = 2{,}6332$ Mpa

$$\rho_{perlu} = \frac{1}{10{,}756}\left[1 - \sqrt{1 - \frac{2 \cdot 2{,}6332 \cdot 10{,}256}{320}}\right] = 0{,}0086$$

$\rho_{min} < \rho_{perlu} < \rho_{maks} \longrightarrow$ dipakai tulangan sebelah

$As = \rho_{perlu} \cdot bw \cdot d = 0{,}0086 \cdot 400 \cdot 439 = 1515{,}27 \text{ mm}^2$

$A\varnothing_{22} = \frac{1}{4} \cdot \pi \cdot 22^2 = 380{,}13 \text{ mm}^2$

$N = As / A\varnothing_{22} = 1515{,}27 / 380{,}13 = 3{,}99 \approx 4$ buah

$Asb = N \cdot A\varnothing_{22} = 4 \cdot 380{,}13 = 1520{,}52 \text{ mm}^2$

$\rho_{aktual} = Asb / bw \cdot d = 1520{,}52 / 400 \cdot 439$

$= 0{,}0087 < \rho_{maks} = 0{,}037 \longrightarrow$ o.k

c. Kontrol kapasitas

$Cc = 0{,}85 \cdot f'c \cdot bw \cdot a = 0{,}85 \cdot 35 \cdot 400 \cdot a = 11.900\, a$

Ts = fy . Asb = 320 . 1520,52 = 486.566,4 N

Syarat : Cc = Ts

11.900 a = 486.566,4 ⟶ a = 40,8879 mm

Mn_{tot} = Asb . fy . (d – ½ a)

= 1520,52 . 320 . (439 – ½ 40,8879) . 10^{-7}

= 20,3655 tm > Mn = 20,2987 tm ⟶ o.k

c = a / β_1 = 40,8879 / 0,81 = 50,479 mm < hf = 250 mm

⟶ Asumsi sebagai balok "T" benar

d. Kontrol jarak tulangan

Y = h – 2pb – 2Ds – 2D = 500 – 2 . 40 – 2 . 10 – 2 . 22

= 356 mm > 300 mm

X = bw – 2pb – 2Ds – ND / (N-1)

= 400 – 2 . 40 – 2 . 10 – 4 . 22 / 3 = 70,67 mm > 25 mm

6. Perencanaan tulangan geser dan torsi

Tu_{maks} = 5,1646 tm

$$\frac{\varnothing \cdot \sqrt{f'c} \cdot \Sigma x^2 y}{24} = \frac{0{,}6 \cdot \sqrt{35} \cdot 173.750.000 \cdot 10^{-7}}{24} = 2{,}5698 \text{ tm} < Tu_{maks}$$

Luas tulangan tertutup minimal, harus dihitung sebesar :

Av + 2 . At = (bw . 5) / (3 . fy)

Syarat spasi tulangan :

X_1 = b – 2pb – Ds = 400 – 2 . 40 – 10 = 310 mm

Y_1 = h – 2pb – Ds = 500 – 2 . 40 – 10 = 410 mm

S_1 = ¼ (X_1 + Y_1) = ¼ (310 + 410) = 180 mm

S_2 = 300 mm ⟶ dipakai S_{min} = 180 mm

a. Kontrol terhadap geser torsi

$$Vc = \frac{\sqrt{f'c} \cdot b \cdot d}{6\sqrt{(1 + (2{,}5 \cdot Ct \cdot Tu / Vu)^2)}}$$

$$= \frac{\sqrt{35} \cdot 400 \cdot 439 \cdot 10^{-4}}{6\sqrt{(1 + (2{,}5 \cdot 1{,}011 \cdot 10^{-3} \cdot 5{,}1646 \cdot 10^{3} / 14{,}046)^2)}}$$

$= 12{,}683$ t

$\varnothing Vc = 0{,}6 \cdot 12{,}683 = 7{,}6098$ t $< Vu_{maks} = 14{,}046$ tm

⟶ perlu tulangan geser

$Vs = (Av \cdot fy \cdot d) / s$ ⟶ $Av / s = Vs / fy \cdot d$

$Av / s = ((Vu / \varnothing) - Vc) / fy \cdot d$

$= ((14{,}046 / 0{,}6) - 12{,}683) / 320 \cdot 439 \cdot 10^{-4}$

$= 0{,}7636$ mm

b. kontrol terhadap torsi

$Tc = 4{,}665$ tm

$\varnothing Tc = 0{,}6 \cdot 4{,}665 = 2{,}799$ tm $< Tu_{maks} = 5{,}1646$ tm

⟶ perlu tulangan torsi

$Ts = (At \cdot \alpha_t \cdot X_1 \cdot Y_1 \cdot fy) / S$; dengan :

$\alpha_t = 1/3 (2 + Y_1 / X_1)$

$= 1/3 (2 + 410 / 310)$

$= 1{,}11 < 1{,}5$

$At / s = Ts / \alpha_t \cdot X_1 \cdot Y_1 \cdot fy = (Tu / \varnothing - Tc) / \alpha_t \cdot X_1 \cdot Y_1 \cdot fy$

$= ((5{,}1646 / 0{,}6) - 4{,}665) \cdot 10^{7} / 1{,}11 \cdot 310 \cdot 410 \cdot 320$

$= 0{,}8733$ mm

Spasi sengkang :

$Sx = (Av / S) + (2 . At / S) = 0{,}7636 + 2 . 0{,}8733$ mm = 2,5102 mm

$Sx_{min} = b / 3 . fy = 400 / 3 . 320 = 0{,}4167$ mm

⟶ dipakai Sx = 2,5102 mm

Digunakan sengkang D10 ⟶ $A\varnothing_{10} = 78{,}54$ mm^2

$S = (Av + 2 . At) / Sx = (2 . A\varnothing_{10}) / Sx$

$= 2 . 78{,}54 / 2{,}5102 = 62{,}58$ mm $< S_{min} = 180$ mm

⟶ dipakai sengkang tertutup $\varnothing_{10 - 180}$

c. Analisis geser dan torsi

$((Av / S) + (2 . At / S))_{aktual} = 2 . 78{,}54 / 180$

$= 0{,}873$ mm $< Sx = 2{,}5102$ mm

dipakai S = 2,5102 mm

$Av' / Sx = (Av / S) . S / Sx = 0{,}7636 . 320 . 439 . 10^{-4} = 10{,}7271$ t

$\varnothing (Vc + Vs) = 0{,}6 (12{,}683 + 10{,}7271)$

$= 14{,}0463$ t $> Vu_{maks} = 14{,}046$ tm ⟶ O.K

3.4.3 Perhitungan Dimensi Kolom

1. Beban-beban yang bekerja

N melintang = 43,514 t ⟶ microfeaf

Berat sendiri kolom = 0,5 . 0,4 . 2,5 . 6 = 3 t

$N_{total} = 43{,}514 + 3 = 46{,}514$ t

Kolom dianggap jepit-sendi

K = 0,9 ; lk = 6,0 m

M melintang = 5,1646 tm ⟶ microfeaf

ht = 40 cm ; b = 50 cm

digunakan: penutup beton (Pb) 40 mm

diameter tulangan 25 mm

diameter sengkang 10 mm

$d = ht - Pb - Ds - 0{,}5\ D = 400 - 40 - 10 - 0{,}5 \cdot 25 = 337{,}5$ mm

$d' = Pb + Ds + 0{,}5\ .D = 40 + 10 + 0{,}5 \cdot 25 = 62{,}5$ mm

$A_k = 0{,}4 \cdot 05 = 0{,}2\ m^2$

$I_k = 1/12 \cdot 05 \cdot 0{,}4^3 = 2{,}67 \cdot 10^{-3}\ m^4$

$r = \sqrt{I_k / A_k} = \sqrt{2{,}67 \cdot 10^{-3} / 0{,}2} = 0{,}1155$

$K \cdot lk / r = 0{,}9 \cdot 0{,}6 / 0{,}1155 = 46{,}7654 < 100$ ⟶ kolom langsing

2. Pembesaran momen

$$Pc = \left(\frac{\pi^2(Ec \cdot Ik)}{(K \cdot lk)^2}\right) = \frac{\pi^2(4700 \cdot \sqrt{35} \cdot 2{,}67 \cdot 10^{-3} \cdot 10^{12})}{(0{,}9 \cdot 6 \cdot 10^3)^2} = 2512{,}7852\ t$$

$$\delta b = \frac{1}{\left(1 - \left(\frac{Pu}{\phi Pc}\right)\right)} = \frac{1}{\left(1 - \left(\frac{46{,}514}{0{,}8 \cdot 2512{,}7852}\right)\right)} = 1{,}0237$$

$Mc = \delta b \cdot Mu = 1{,}0237 \cdot 5{,}1646 = 5{,}2869$ tm

$Mn = Mc/\phi = 5{,}2869/0{,}8 = 6{,}6087$ tm

$e = Mn/Pn = 6{,}6087/(46{,}514/0{,}8) = 0{,}1137$ m = 113,7 mm

3. Perencanaan tulangan

$\rho = \rho' = As/(b \cdot d) = 0{,}01$

$As = As' = 0{,}01 \cdot 500 \cdot 337{,}5 = 1687{,}5\ mm^2$

Dicoba dengan $4D_{25}$ pada masing-masing sisi kolom (As = As' = 1963,5 mm^2)

$\rho b = Asb/(b \cdot d) = 1963,5/(500 \cdot 337,5) = 0,0116 > 0,01 \longrightarrow$ O.K

4. Kontrol kapasitas tampang

$$Cb = \frac{\varepsilon c}{(\varepsilon c/\varepsilon y)} = \frac{600d}{(600 + fy)} = \frac{600 \cdot 337,5}{(600 + 320)} = 220,1087 \text{ mm}$$

$$ab = \beta_1 \cdot Cb = 0,81 \cdot 220,1087 = 178,288 \text{ mm}$$

$$f'sb = \frac{600(Cb - d')}{Cb} = \frac{600(220,1087 - 62,5)}{220,1087} = 429,6296 \text{ Mpa} > fy$$

Maka digunakan f'sb = fy

$Pnb = (0,85 \cdot f'c \cdot ab \cdot b) + (As' \cdot fy) - (As \cdot fy) \longrightarrow As = As'$

$= 0,85 \cdot 35 \cdot 178,288 \cdot 500 \cdot 10^{-4} = 265,2034$ t

$Mnb = 0,85 \cdot f'c \cdot ab \cdot b(\frac{1}{2}h + \frac{1}{2}ab) + As' \cdot fy(\frac{1}{2}h - d) - As \cdot fy(d - \frac{1}{2}h)$

$= 0,85 \cdot 35 \cdot 178,288 \cdot 500(\frac{1}{2} \cdot 400 + \frac{1}{2} \cdot 178,288) + 1963,5 \cdot 320(\frac{1}{2} \cdot 400 - 337,5) - 1963,5 \cdot 320(337,5 - \frac{1}{2} \cdot 400)10^{-7}$

$= 59,4032$ tm

$eb = Mnb/Pnb = (59,4032 \cdot 10^3)/265,2034 = 223,991 \text{ mm} > e$

$\longrightarrow$ kolom akan mengalami hancur dengan diawali luluhnya tulangan desak.

5. Kontrol akibat patah desak dengan rumus Whitney

$$Pn = \left(\frac{As' \cdot fy}{\left(\frac{e}{d - d'}\right) + 0,5} \right) + \left(\frac{b \cdot h \cdot f'c}{\left(\frac{3h \cdot e}{d^2}\right) + 1,18} \right)$$

$$Pn = \left(\frac{1963{,}5 \;.\; 320}{\left(\frac{113{,}7}{337{,}5 - 62{,}5} \right) + 0{,}5} \right) + \left(\frac{500 \;.\; 400 \;.\; 35}{\left(\frac{3 \;.\; 400 \;.\; 113{,}7}{337{,}5^2} \right) + 1{,}18} \right) = 363{,}171 \text{ t}$$

$\phi Pn = 0{,}8 \;.\; 363{,}171 = 290{,}537 \text{ t} > Pu = 46{,}514 \text{ t} \longrightarrow$ O.K

$a = Pn/(0{,}85 \;.\; f'c \;.\; b) = (363{,}171 \;.\; 10^4)/(0{,}85 \;.\; 35 \;.\; 500) = 244{,}1489$ mm

$c = a/\beta_1 = 244{,}1489/0{,}81 = 301{,}4183$ mm

$f'sb = (600(c - d'))/c = (600(301{,}4183 - 62{,}5))/301{,}4183)$

$= 475{,}5883$ Mpa $>$ fy $= 320$ Mpa $\longrightarrow$ O.K

6. Kontrol jarak tulangan

$Y = h - 2Pb - 2Ds - 2D = 400 - (2 \;.\; 40) - (2 \;.\; 10) - (2 \;.\; 25)$

$= 250$ mm < 300 mm $\rightarrow$ O.K

$X = (bw - 2Pb - 2Ds - N.D)/(N - 1)$

$= (500 - 80 - 20 - (4 \;.\; 25))/(4 - 1) = 100$ mm > 25 mm $\rightarrow$ O.K

7. Perencanaan sengkang

Dengan diameter tulangan 10 mm, jarak spasi sengkang ditentukan dari nilai terkecil ketentuan berikut ini:

a. 16D (tulangan pokok D_{25}) = 400 mm

b. 48Ds (tulangan sengkang D_{10}) = 480 mm

c. Dimensi terkecil kolom = 400 mm

$\longrightarrow$ Digunakan tulangan sengkang D_{10-400}

3.5 Perencanaan Pondasi

1. Pembebanan

   Berat kolom = 0,4 . 0,5 . 2,5 . 6 = 3 t

   Reaksi kolom (dari microfeap) = 43,514 t +

   Pu = 46,514 t

   Daya dukung tanah (σ) = 4 kg/cm^2 = 40 t/m^2

   Berat jenis tanah = 2,0 t/m^3

   Ditaksir tebal pondasi = 300 mm

   qu = berat tanah + berat pondasi

   = (0,0 . 2,0) + (0,3 . 2,5) = 0,75 t/m^2

2. Menentukan lebar pondasi

   $\sigma_{netto} = \sigma - qu \geq Pu/A$

   $= 40 - 0,75 \geq 46,514/A \longrightarrow A \geq 46,514/39,25 = 1,18$ m^2

   A rencana = 1,5 m^2

   B = 1,225 m $\longrightarrow$ dipakai B = 1,5 m

   $\sigma = (P/A) + qu$

   $= (46,514/1,5^2) + 0,75 = 21,423$ t/m^2 < $\sigma_{netto} = 39,25$ t/m^2

3. Menentukan tebal plat

   $Vu = \phi \cdot \sqrt{f'c} \cdot b \cdot d/6 = 0,6 \cdot \sqrt{35} \cdot 1500 \cdot 10^{-4} \cdot d/6$

   $= 0,0887\ d$ .....(1)

   $Vc = \sigma (x - d) b$

   $= 21,423 \cdot 10^{-6}(300 - d)\ 1500 = 0,032\ (300 - d)$ .....(2)

Dari kedua persamaan didapat:

$0{,}0887\ d = 0{,}032\ (300 - d)$

$d = 9{,}64/(0{,}0887 + 0{,}032) = 79{,}87\ \text{mm} < 300\ \text{mm}$

dipakai t = 300 mm, maka d = 300 - 40 - (16 . 1,5) = 236 mm

4. Kontrol kuat geser

a. Gaya lintang

d = 236 mm

$a = \frac{1}{2}b - \frac{1}{2}bk - d$

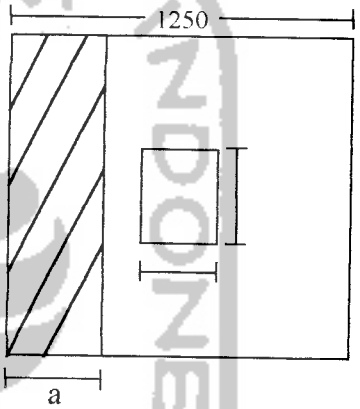
$= (\frac{1}{2} \cdot 1500) - (\frac{1}{2} \cdot 400) - 236$

= 314 mm

Uu = (P/A) . A arsir

= 20,673 . 0,314 . 1,5

= 9,737 t

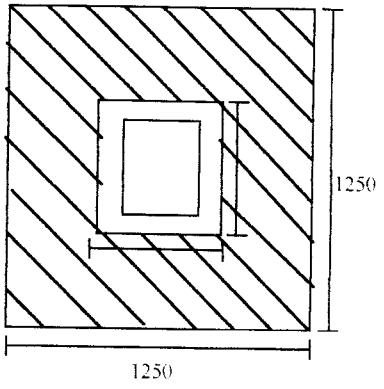


$Uc = \sqrt{f'c} \cdot b \cdot d/6$

$= \sqrt{35} \cdot 1500 \cdot 236 \cdot 10^{-4}/6 = 34{,}905\ t$

$\phi Uc = 0{,}6 \cdot 34{,}905 = 20{,}943\ t > Uu$

b. Gaya geser pondasi



$\beta = \frac{500}{400} = 1{,}25$

$Uc = (1 + {}^{2}/_{\beta})\sqrt{f'c} \cdot b \cdot d/6$

$= (1 + {}^{2}/_{1.25})\sqrt{35} \cdot 1500 \cdot 236/6$

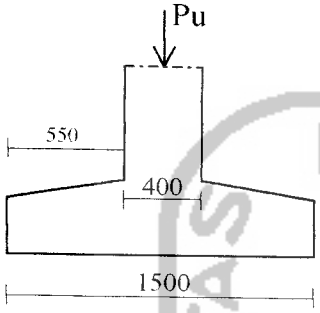
$= 907526{,}6 \cdot 10^{-4} = 90{,}7527\ t$

$Uu = (P/A)\ .\ A\ arsir$

$= 20{,}673\ (1{,}5^2 - (0{,}43\ .\ 0{,}53)) = 41{,}803\ t$

$\phi Uc = 0{,}6\ .\ 90{,}753 = 54{,}452\ t > Uu$

5. Perencanaan penulangan



$x = \frac{1}{2}(b - bk)$

$= \frac{1}{2}(1500 - 400) = 550\ mm$

$Mu = \frac{1}{2}(Pu/A)\ b\ .\ x^2$

$= \frac{1}{2}20{,}673\ .\ 1{,}5\ .\ 0{,}55^2 = 4{,}69\ tm$

$$\rho b = \frac{0{,}85\ .\ f'c\ .\ \beta}{fy}\ .\ \frac{600}{600 + fy}$$

$$= \frac{0{,}85\ .\ 35\ .\ 1{,}25}{320}\ .\ \frac{600}{600 + 320} = 0{,}0758$$

$\rho_{maks} = 0{,}75\ \rho b$

$= 0{,}75\ .\ 0{,}0758 = 0{,}0568$

$\rho_{min} = 1{,}4/fy = 1{,}4/320 = 0{,}0044$

$m = fy/(0{,}85\ .\ f'c) = 320/(0{,}85\ .\ 35) = 10{,}7563$

$Rn = Mu/(\phi b\ .\ d^2)$

$= (4{,}96\ .\ 10^7)/(0{,}6\ .\ 1500\ .\ 236^2) = 0{,}9895$

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

$$= \frac{1}{10{,}7563}\left(1 - \sqrt{1 - \frac{2\ .\ 0{,}9895\ .\ 10{,}7563}{320}}\right) = 0{,}003145$$

$\rho_{perlu} < \rho_{min} \longrightarrow$ dipakai $\rho_{min} = 0{,}0044$

$As = \rho_{min}\ .\ b\ .\ d = 0{,}0044\ .\ 1500\ .\ 236 = 1557{,}6\ mm^2$

$$\text{Jarak tulangan} = \frac{\frac{1}{4}\ .\ \pi\ 16^2\ .\ 1000}{1557{,}6} = 129{,}08\ mm$$

Dipakai tulangan $D_{16\ -\ 125\ mm}$

3.6 Perbandingan Dengan Analisis DPU Bina Marga

Dari analisis dan perencanaan di atas didapatkan hasil-hasil perhitungan yang akan dibandingkan dengan hasil perhitungan oleh DPU Bina Marga Prop. Jawa Barat yang menggunakan program komputer.

Perbandingan hasil perhitungannya dapat dilihat pada tabel 3.4.

Tabel 3.4. Perbandingan hasil perhitungan

No	Hasil perhitungan penulis	Hasil perhitungan dari PU
1	Pelat - Daerah lapangan a. Arah x D_{16-180} b. Arah y D_{10-100} - Daerah tumpuan a. Arah x D_{16-170} b. Arah y D_{12-100} Kerb jembatan - Tulangan pokok D_{12-250} - Tulangan bagi $5D_{10}$ Lantai trotoar - Tulangan pokok D_{12-250} - Tulangan bagi D_{10-250} Plat kantilever - Tulangan pokok D_{16-200} - Tulangan bagi D_{12-250}	Pelat - Daerah lapangan a. Arah x D_{16-150} b. Arah y D_{12-125} - Daerah tumpuan a. Arah x D_{16-300} b. Arah y D_{12-125} Kerb jembatan - Tulangan pokok D_{12-200} - Tulangan bagi $5D_{10}$ Lantai trotoar - Tulangan pokok D_{12-150} - Tulangan bagi D_{10-200} Plat kantilever - Tulangan pokok D_{16-300} - Tulangan bagi D_{12-150}
2	Gelagar memanjang a. Gelagar 1 - Dimensi 40/20 - Tul. Tumpuan $4D_{19}$ - Tul. Lapangan $3D_{19}$ - Tul. Sengkang D_{10-170} b. Gelagar 2 - Dimensi 40/30 - Tul. Tumpuan $9D_{19}$ - Tul. Lapangan $7D_{19}$ - Tul. Sengkang D_{10-85} c. Gelagar 3 - Dimensi 40/30 - Tul. Tumpuan $12D_{19}$ - Tul. Lapangan $9D_{19}$	Gelagar memanjang a. Gelagar 1 - Dimensi 50/20 - Tul. Tumpuan $5D_{19}$ - Tul. Lapangan $4D_{19}$ - Tul. Sengkang D_{10-150} c. Gelagar 2 - Dimensi 50/30 - Tul. Tumpuan $14D_{19}$ - Tul. Lapangan $10D_{19}$ - Tul. Sengkang D_{10-150} b. Gelagar 3 - Dimensi 50/30 - Tul. Tumpuan $14D_{19}$ - Tul. Lapangan $10D_{19}$

	- Tul. Sengkang D_{10-65}	- Tul. Sengkang D_{10-150}
3	Gelagar melintang - Dimensi 50/40 - Tul. Tumpuan $3D_{22}$ - Tul. Lapangan $4D_{22}$ - Tul. Sengkang tertutup D_{10-180}	Gelagar melintang - Dimensi 50/30 - Tul. Tumpuan $8D_{22}$ - Tul. Lapangan $12D_{22}$ - Tul. Sengkang tertutup D_{10-150}
4	Kolom - Dimensi 50/40 - Tul. Pokok $4D_{25}$ - Tul. Sengkang D_{10-400}	Kolom - Dimensi 60/50 - Tul. Pokok $5D_{25}$ - Tul. Sengkang D_{10-150}
5	Pondasi - Dimensi b = 1500 mm t = 300 mm - Tulangan D_{16-125}	Pondasi - Dimensi b = 1500 mm t = 300 mm - Tulangan D_{16-150}

Perhitungan dari DPU Bina Marga mengenai gelagar memanjang (2) dan (3) menjadi satu hitungan dipakai faktor beban yang terbesar, sedangkan perhitungan penulis sendiri-sendiri.

Dari hasil perbandingan di atas diperoleh perbedaan-perbedaan hasil perhitungan, hal ini dapat dikarenakan perbedaan pada asumsi pembebanan dan faktor teknik pelaksanaan di lapangan.