BAB IV

PERENCANAAN STRUKTUR

4.1 Rangka Atap Kuda-Kuda Baja

a. Data Konstruksi Rangka Atap

- Jarak antar kuda-kuda maksimum (b) : 3,5 m
- Panjang Bentang : 14,1 m
- Mutu baja profil (BJ36) :

  Tegangan leleh (fy) = 36 Ksi = 2400 kg/m^2

  Kuat tarik (Fu) = 3700 kg/cm^2
- Mutu baut A325× (non full drat) :

  Tegangan tarik (ft) = 36 Ksi = 2400 kg/cm^2

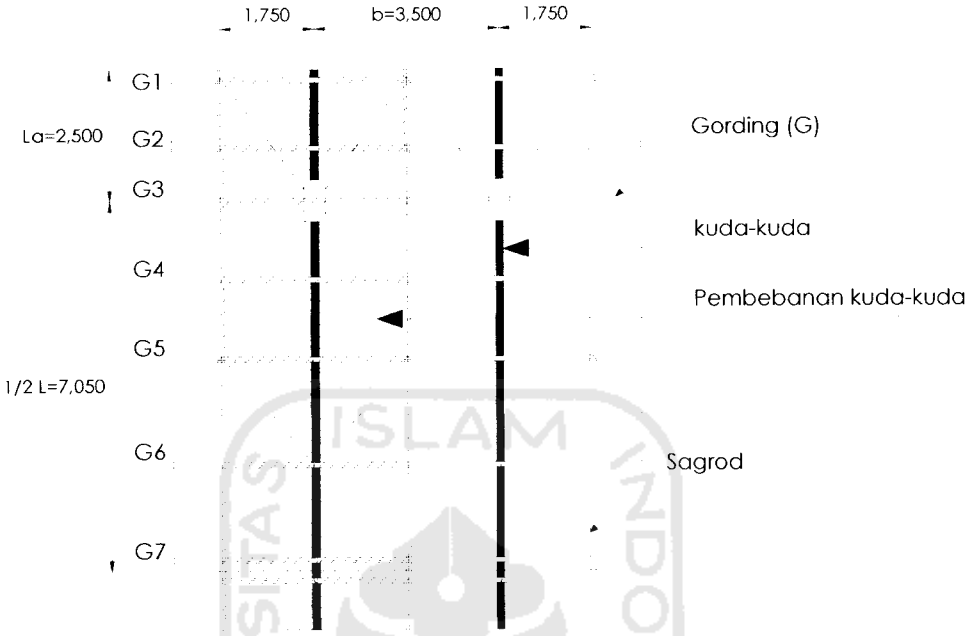
  Tegangan geser (Fv) = 24 Ksi = 1600 kg/cm^2
- Kemiringan atap genteng Beton : 35^o
- Usuk 5/7 dan reng 2/3 menggunakan bahan kayu
- Gording dipakai bahan baja jenis profil *Light Lip Channel*
- Jurai menggunakan menggunakan profil *Double Light Lip Channel*
- Rangka kuda-kuda menggunakan profil dua profil siku

b. Jumlah Dan Jarak Antar Gording

Jarak gording maksimum : 2,5 m

- Panjang sisi miring kuda-kuda (M) $= \frac{½.L}{\cos\alpha} = \frac{½ \times 14.1}{\cos 35} = 8{,}606$ m
- Jumlah gording ½ bentang (n) = 5 btg

- Jarak antar gording (Lg) $= \frac{2{,}013}{\cos 35} = 2{,}457 \ < 2{,}5$ m



Gambar 4.1 Pembebanan Atap (½ Bentang)

4.1.1 Perencanaan Gording

a. Pembebanan gording :

1. Beban Tetap :

- Berat genteng (tabel 2.1 PPIUG 83) = 50 x 2,457 = 122,85kg/m
- Beban hidup (Pasal 3.22.b PPIUG 83) = 20 x 2,457 = 49,14 kg/m
- Berat gording taksiran (7 s/d 10 kg/m^2) = 10 kg/m

Q_{total} = 181,99kg/m

Mekanika gording :

$q\perp = q_{total}.\cos\alpha = 181{,}99 \times \cos 35^o = 149{,}077$ kg/m'

$q// = q_{total}.\sin\alpha = 181{,}99 \times \sin 35^o = 104{,}385$ kg/m'

2. Beban angin

Wa = 25 kg/m^2 (pasal 4.2.1 PPIUG 83)

- Angin tekan (Wt)

C_1 = 0,02 α - 0,4 = 0,02 × 35^0 – 0,4 = + 0,3 (tekan)

Wt = C_1.Wa.Lg = 0,3 × 25 × 2,457 = + 18,43 Kg/m' (tekan)

- Angin hisap (Wh)

C_2 = -0,4

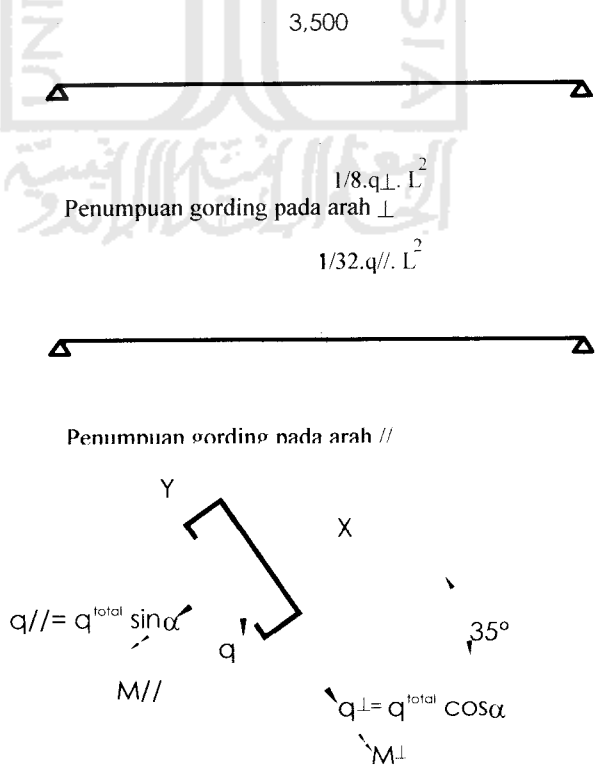
Wh = C_2.Wa.Lg = -0,4 × 25 × 2,457 = - 24,57Kg/m' (hisap)

W⊥ = + 18,43 kg/m (tekan)

W// = 0 (karena beban angin bekerja di atap, PPIUG 83)

b. Momen yang terjadi

1. Akibat beban mati (tetap)



Gambar 4.2 Penumpuan Gording

M⊥ maks $= \frac{1}{8}.q\perp.L^2 = \frac{1}{8} \times 149{,}077 \times 3{,}5^2 = 228{,}274$ kg.m'

M// maks $= \frac{1}{32}.q//.L^2 = \frac{1}{32} \times 104{,}385 \times 1{,}75^2 = 9{,}989$ kg.m'

2. Akibat beban angin

M⊥ maks $= \frac{1}{8}.q\perp.L^2 = \frac{1}{8} \times 18{,}43 \times 3{,}5^2 = 28{,}221$ kg.m'

c. Penentuan profil baja

Dicoba profil *Light Lip Channel* (Ir. Morisco hal. 46) 150x50x20x2,3

Sx $= 28{,}0$ cm^3 W $= 4{,}96$ kg/m

Sy $= 6{,}33$ cm^3 fy $= 2400$ kg/cm^2

Ix $= 210$ cm^4 E $= 2{,}1 \times 10^6$ kg/cm^2

Iy $= 21{,}9$ cm^4 Fu $= 3700$ kg/cm^2

d. Kontrol Penampang Kompak

$$\frac{bf}{2tf} \le \frac{65}{\sqrt{fy}} \rightarrow \frac{50}{2 \times 2{,}3} = 10{,}87 < 11{,}017 \text{ penampang kompak}$$

$$\frac{d}{tw} \le \frac{640}{\sqrt{fy}} \rightarrow \frac{150}{2{,}3} = 65{,}217 < 108{,}479$$

e. Kontrol Tegangan

fbx $= \frac{M \perp maks}{Sx} = \frac{(228{,}274 + 28{,}221)x100}{28{,}0} = 916{,}053$ kg/cm^2

fby $= \frac{M // maks}{Sy} = \frac{9{,}989x100}{6{,}33} = 157{,}804$ kg/cm^2

$\frac{fbx}{0{,}6\,fy} + \frac{fby}{0{,}75\,fy} = \frac{916{,}053}{0{,}6.2400} + \frac{157{,}804}{0{,}75.2400} = 0{,}66 < 1{,}00$ ...**(ok)**

f. Kontrol Lendutan

$$\delta\perp = \frac{5}{384}.\frac{q\perp L^4}{E.Ix} \qquad = \frac{5}{384}\times\frac{0{,}8\,(149{,}077+18{,}43)\,3{,}5^4.10^6}{2{,}1.10^6.210}$$

$$= 0{,}594 < \frac{L}{360} = \frac{350}{360} = 0{,}972 \text{ cm} \quad \text{.....(ok)}$$

$$\delta\perp = \frac{5}{384}.\frac{q\perp L^4}{E.Ix} \qquad = \frac{5}{384}\times\frac{1{,}00\,(149{,}077)\,3{,}5^4.10^6}{2{,}1.10^6.210}$$

$$= 0{,}661 < \frac{L}{360} = \frac{350}{360} = 0{,}972 \text{ cm} \quad \text{.....(ok)}$$

$$\delta// = \frac{5}{384}.\frac{q//\left(L/(a+1)\right)^4}{E.Iy} = \frac{5}{384}\times\frac{104{,}385\left(3{,}5/(1+1)\right)^4.10^6}{2{,}1.10^6.21{,}9}$$

$$= 0.277 \text{ cm} < \frac{L}{360} = \frac{350}{360} = 0{,}972 \quad \text{.....(ok)}$$

jadi profil Light Lip Channel 150x50x20x2,3 dapat dipakai

4.1.2 Perencanaan Sagrod dan Tierod

1. Sagrod

Beban sagrod dan tierod

- Berat penutup atap × sisi miring (M) = 50 × 8,606 = 430,300 kg/m'
- Beban hidup × sisi miring (M) = 20 × 8,606 = 172,12 kg/m'
- Berat gording × jumlah gording = 10 × 5 = 50 kg/m' +

P = 652,42 kg/m'

$$Ss = \frac{L}{2} = \frac{3{,}5}{2} = 1{,}75 \text{ m}$$

$P// = P.\sin\alpha.Ss = 652{,}42 \times \sin 35^o \times 1{,}75 = 654{,}872$ Kg

$$D = \sqrt{\frac{P//.4}{0{,}33.Fu.\pi}} = \sqrt{\frac{654{,}872.\ 4}{0{,}33.3700.3{,}14}} = 0{,}826 \text{ cm} = 8{,}26 \text{ mm}$$

dipakai sagrod = D + 3 = 8,26 + 3 = 11,26 mm

2. Tierod

Beban Tierod = T = P// . cosα= 652,42 . cos35 = 534,431

$$A_{tierod} = \frac{T}{0{,}33.Fu.\pi} = 1/4\ \pi\ D^2_{Tierod}$$

$$D = \sqrt{\frac{534{,}431.\ 4}{0{,}33.\ 3700.\ 3{,}14}} = 0{,}746 \text{ cm} = 7{,}46 \text{ mm}$$

Dipakai tierod = D+3 = 7,46 + 3 = 10,46 mm

Sagrod dan tierod dipakai diameter = 12 mm (P12)

4.1.3 Perencanaan Kuda – Kuda

4.1.3.1 Pembebanan kuda-kuda (KK1)

Beban mati (tetap)

- Jarak antar kuda-kuda (pj gording) = 3,5 m
- Sudut bt atas = 35^0
- Sudut bt bawah = 8^0
- $L_{bt\ kuda\text{-}kuda\ total}$ = 60,52 m
- $L_{bentang}$ = 14,1 m
- Berat gording (Tabel baja profil light Channel) = 4,96 kg/m'
- Berat eternit (tabel 2.1 PPIUG 83) = 11 kg/m^2
- Rangka eternit dari kayu (tabel 2.1 PPIUG 83) = 7 kg/m^2
- Berat atap genteng (tabel 2.1 PPIUG 83) = 50 kg/m^2
- Beban hidup (Pasal 3.2.(2)a PPIUG 83) = 20 kg/m^2
- Berat kuda-kuda taksiran :

Dari Tabel baja siku-siku sama kaki (Ir. Morisco, hal 36) ditaksir menggunakan profil **2L 65x65x7**

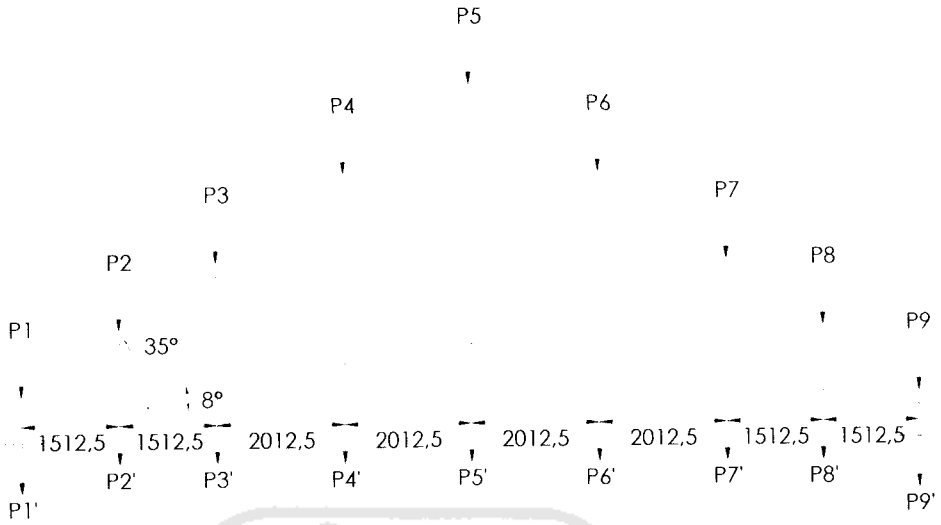
W = (2) × 6,83 = 13,66 kg/m'

$$\text{Berat kuda-kuda} = \frac{W \times L_{BT\ KUDA\text{-}KUDA\ TOTAL}}{L_{BENTANG}} = \frac{13{,}66.60{,}52}{14{,}1} = 58{,}631\ \text{kg/m}$$

Berat baut dan plat sambung = 20 % × berat kuda-kuda

= 0,2 × 58,631= 11,726 kg/m

berat total taksiran kuda-kuda = 58,631 + 11,726 = 70,357 kg/m



Gambar 4.3 Rangka atap akibat beban tetap

Beban-beban pada Joint :

a. $P_1 = P_9$

Beban gording = 4,96 × 3,5 = 17,36 kg

Berat penutup atap = $50 \times 3{,}5 \times \frac{1}{2} \left(\frac{1{,}5125}{Cos\,35} \right)$ = 161,508 kg

Beban mati (qD) = 178,868 kg

Beban hidup (qL) = $20 \times 3{,}5 \times \frac{1}{2} \left(\frac{(1{,}5125)}{Cos\,35} \right)$ = 64,603 kg

b. $P_2 = P_8$

Beban gording = 4,96 × 3,5 = 17,36 kg

Beban penutup atap =

$50 \times 3{,}5 \times \left\{ \frac{1}{2}(1{,}5125/\cos 35) + \frac{1}{2}(1{,}5125/\cos 35) \right\}$ = 323,017 kg

Beban mati (qD) = 340,377 kg

Beban hidup (qL) =

$20 \times 3{,}5 \times \left\{ \frac{1}{2}(1{,}5125/\cos 35) + \frac{1}{2}(1{,}5125/\cos 35) \right\}$ = 129,207 kg

c. $P_3 = P_7$

Beban gording $= 4{,}96 \times 3{,}5$ $= 17{,}36$ kg

Berat penutup atap =

$50 \times 3{,}5 \times \left\{\frac{1}{2}(1{,}5125/\cos 35) + \frac{1}{2}(2{,}0125/\cos 35)\right\}$ $= 376{,}479$ kg

Beban mati (qD) $= 393{,}839$ kg

Beban hidup (qL) =

$20 \times 3{,}5 \times \left\{\frac{1}{2}(1{,}5125/\cos 35) + \frac{1}{2}(2{,}0125/\cos 35)\right\}$ $= 150{,}592$ kg

d. $P_4 = P_6$

Beban gording $= 4{,}96 \times 3{,}5$ $= 17{,}36$ kg

Berat penutup atap =

$50 \times 3{,}5 \times \left\{\frac{1}{2}(2{,}0125/\cos 35) + \frac{1}{2}(2{,}0125/\cos 35)\right\}$ $= 429{,}942$ kg

Beban mati (qD) $= 447{,}302$ kg

Beban hidup (qL) =

$20 \times 3{,}5 \times \left\{\frac{1}{2}(2{,}0125/\cos 35) + \frac{1}{2}(2{,}0125/\cos 35)\right\}$ $= 171{,}977$ kg

e. P_5

Beban gording $= 4{,}96 \times 3{,}5$ $= 17{,}36$ kg

Berat penutup atap =

$50 \times 3{,}5 \times \left\{\frac{1}{2}(2{,}0125/\cos 35) + \frac{1}{2}(2{,}0125/\cos 35)\right\}$ $= 429{,}942$ kg

Beban mati (qD) $= 447{,}302$ kg

Beban hidup (qL) =

$20 \times 3{,}5 \times \left\{\frac{1}{2}(2{,}0125/\cos 35) + \frac{1}{2}(2{,}0125/\cos 35)\right\}$ $= 171{,}977$ kg

f. $P_1' = P_9'$

Berat eternit = 18 x 3,5 x (½)1,5125 = 47,644 kg

Berat kuda-kuda = $70{,}357 \times \frac{1}{2}\left(\frac{1{,}5125}{\cos 8}\right)$ = 96,775 kg

Beban mati (qD) = 144,419 kg

g. $P_2' = P_8'$

Berat eternit = 18 x 3,5 x (½.1,5125 + ½.1,5125) = 95,288 kg

Berat kuda-kuda =

$70{,}357 \times \left\{\frac{1}{2}(1{,}5125/\cos 8) + \frac{1}{2}(1{,}5125/\cos 8)\right\}$ = 193,550 kg

Beban mati (qD) = 282,838 kg

h. $P_3' = P_7'$

Berat eternit = 18 x 3,5 x (½.1,5125 + ½.2,0125) = 111,038 kg

Berat kuda-kuda =

$70{,}357 \times \left\{\frac{1}{2}(1{,}5125/\cos 8) + \frac{1}{2}(2{,}0125/\cos 8)\right\}$ = 225,542 kg

Beban mati (qD) = 336,580 kg

i. $P_4' = P_6'$

Berat eternit = 18 x 3,5 x (½.2,0125 + ½.2,0125) = 126,788 kg

Berat kuda-kuda =

$70{,}357 \times \left\{\frac{1}{2}(2{,}0125/\cos 8) + \frac{1}{2}(2{,}0125/\cos 8)\right\}$ = 257,534 kg

Beban mati (qD) = 384,321 kg

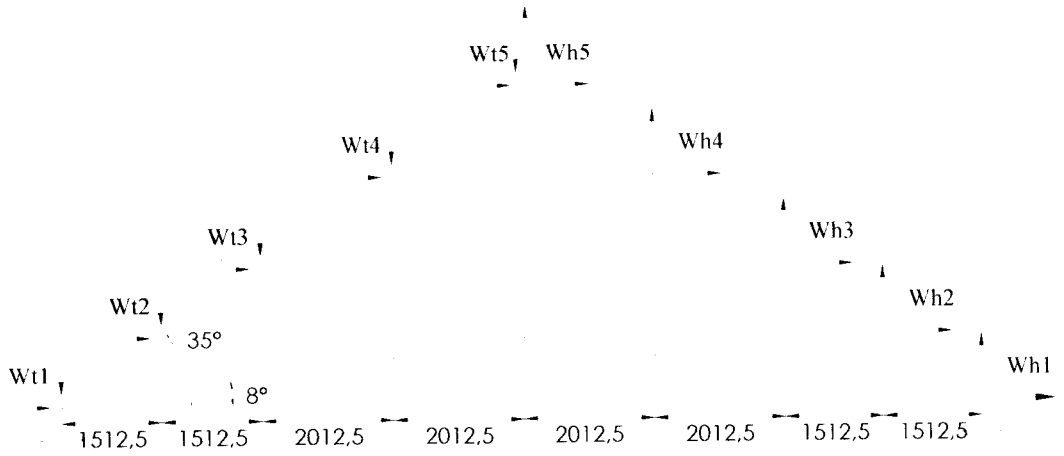
j. P_5'

Berat eternit = 18 x 3,5 x (½.2,0125 + ½.2,0125) = 126,788 kg

Berat kuda-kuda =

$70{,}357 \times \left\{\frac{1}{2}(2{,}0125/\cos 8) + \frac{1}{2}(2{,}0125/\cos 8)\right\}$ = 222,844 kg

Beban mati (qD) = 349,632 kg



Gambar 4.4 Rangka kuda-kuda akibat beban angin

Beban Angin

Wa = 25 kg/m^2 (pasal 4.2.1 PPIUG 83)

Koefisien angin :

- Angin tekan (Wt)

  C_1 = 0,02 sinα - 0,4 = + 0,3 (tekan)

- Angin hisap (Wh)

  C_2 = -0,4 (hisap)

Beban-beban angin :

Wt = C_1 x Wa = +0,3 × 25 = +7,5 kg/m^2 (tekan)

Wh = C_2 x Wa = -0,4 × 25 = -10 kg/m^2 (hisap)

a. Angin kiri

Akibat angin tekan :

$$Wt_1 = 7{,}5 \times 3{,}5 \times \tfrac{1}{2} \left(1{,}5125 / Cos\,35 \right) = +\,24{,}226 \text{ kg}$$

$$Wt_2 = 7{,}5 \times 3{,}5 \times \left\{ \tfrac{1}{2}(1{,}5125 / \cos 35) + \tfrac{1}{2}(1{,}5125 / \cos 35) \right\} = +\,48{,}453 \text{ kg}$$

$Wt_3 = 7{,}5 \times 3{,}5 \times \left\{\frac{1}{2}(1{,}5125/\cos 35) + \frac{1}{2}(2{,}0125/\cos 35)\right\} = +\ 56{,}472$ kg

$Wt_4 = 7{,}5 \times 3{,}5 \times \left\{\frac{1}{2}(2{,}0125/\cos 35) + \frac{1}{2}(2{,}0125/\cos 35)\right\} = +64{,}491$ kg

$Wt_5 = 7{,}5 \times 3{,}5 \times \frac{1}{2}\left(\frac{2{,}0125}{Cos\,35}\right) = +\ 32{,}246$ kg

Akibat angin hisap :

$Wh_1 = -10 \times 3{,}5 \times \frac{1}{2}\left(\frac{1{,}5125}{Cos\,35}\right) = -\ 32{,}302$ kg

$Wh_2 = -10 \times 3{,}5 \times \left\{\frac{1}{2}(1{,}5125/\cos 35) + \frac{1}{2}(1{,}5125/\cos 35)\right\} = -\ 64{,}603$ kg

$Wh_3 = -10 \times 3{,}5 \times \left\{\frac{1}{2}(1{,}5125/\cos 35) + \frac{1}{2}(2{,}0125/\cos 35)\right\} = -75{,}296$ kg

$Wh_4 = -10 \times 3{,}5 \times \left\{\frac{1}{2}(2{,}0125/\cos 35) + \frac{1}{2}(2{,}0125/\cos 35)\right\} = -85{,}988$ kg

$Wh_5 = -10 \times 3{,}5 \times \frac{1}{2}\left(\frac{2{,}0125}{Cos\,35}\right) = -42{,}944$ kg

4.1.3.2 Pembebanan kuda-kuda (KK2)

Beban mati (tetap)

- Jarak antar kuda-kuda (pj gording) = 3,5 m
- Sudut bt atas = 35^0
- Sudut bt bawah = 8^0
- $L_{bt\ kuda\text{-}kuda\ total}$ = 60,52 m
- $L_{bentang}$ = 14,1 m
- Berat gording = 4,96 kg/m'
- Berat eternit (tabel 2.1 PPIUG 83) = 11 kg/m^2
- Rangka eternit dari kayu = 7 kg/m^2

- Berat penutup atap (genteng) = 50 kg/m^2
- Beban hidup = 20 kg/m^2
- Berat kuda-kuda taksiran :

Dari Tabel baja siku-siku sama kaki (Ir. Morisco, hal 36) ditaksir menggunakan profil **2L 65x65x7**

W = 2 × 6,83 = 13,66 kg/m'

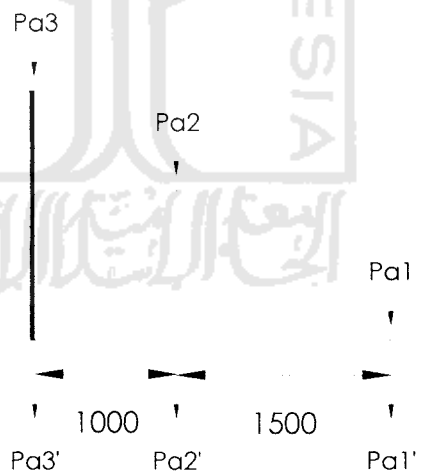
$$\text{Berat kuda-kuda} = \frac{W.L_{total}\ Kuda-kuda}{L_{kuda-kuda}} = \frac{13{,}66.\ 9{,}797}{2{,}5} = 53{,}531\ \text{kg/m}^2$$

Berat baut dan plat sambung = 20 % × berat kuda-kuda

= 0,2 × 53,531 = 10,706 kg/m'

berat total taksiran kuda-kuda = 46,320 + 9,264 = 64,237 kg/m'

Beban-beban pada Joint :



Gambar 4.5 Rangka kuda-kuda (KK2) akibat beban tetap

a. Pa_1

Beban gording = 4,96 × 3,5 = 17,36 kg

Berat penutup atap = 50 × 3,5 × ½ $\left(1{,}5/Cos\,35\right)$ = 160,227 kg

Beban Mati (qD) = 177,587 kg

Beban hidup (qL) $= 20 \times 3{,}5 \times \frac{1}{2} \left(\frac{(1{,}5)}{Cos\,35} \right)$ = 64,091 kg

b. Pa_2

Beban gording = $4{,}96 \times 3{,}5$ = 17,36 kg

Berat penutup atap =

$50 \times 3{,}5 \times \left\{ \frac{1}{2}(1{,}5/\cos 35) + \frac{1}{2}(1{,}0/\cos 35) \right\}$ = 267,044 kg

Beban Mati (qD) = 284,404 kg

Beban hidup (qL) =

$20 \times 3{,}5 \times \left\{ \frac{1}{2}(1{,}5/\cos 35) + \frac{1}{2}(1{,}0/\cos 35) \right\}$ = 106,818 kg

c. Pa_3

Beban gording = $4{,}96 \times 3{,}5$ = 17,36 kg

Berat penutup atap = $50 \times 3{,}5 \times \left\{ \frac{1}{2}(1{,}0/\cos 35) \right\}$ = 106,818 kg

Beban Mati (qD) = 124,178 kg

Beban hidup (qL) = $20 \times 3{,}5 \times \left\{ \frac{1}{2}(1{,}0/\cos 35) \right\}$ = 42,727 kg

d. Pa_1'

Berat eternit = 18 x 3,5 x (½.1,5) = 47,25 kg

Berat kuda-kuda = 64,237 x (½.1,5) = 48,178 kg

Beban mati (qD) = 95,428 kg

e. Pa_2'

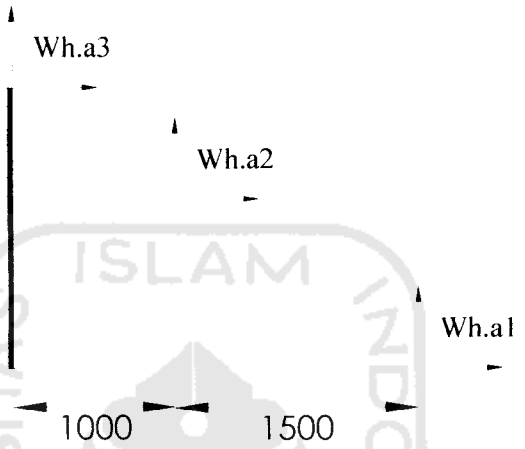
Berat eternit = 18 x 3,5 x (½.1,5 + ½.1,0) = 78,750 kg

Berat kuda-kuda = 64,237 x (½.1,5 + ½.1,0) = 80,296 kg

Beban mati (qD) = 159,046 kg

f. Pa_3'

Berat eternit	= 18 x 3,5 x (½.1,0)	= 31,500	kg
Berat kuda-kuda	= 64,237 x (½.1,0)	= 32,118	kg
	Beban mati (qD)	= 63,618	kg



Gambar 4.6 Rangka kuda-kuda (KK2) akibat beban angin

Beban Angin

Wa = 25 kg/m^2 (pasal 4.2.1 PPIUG 83)

Koefisien angin :

- Angin tekan (Wt)

  C_1 = 0,02 sinα - 0,4 = + 0,3 (tekan)

- Angin hisap (Wh)

  C_2 = -0,4 (hisap)

Beban-beban angin :

Wt = C_1 x Wa = +0,3 × 25 = +7,5 kg/m^2 (tekan)

Wh = C_2 x Wa = -0,4 × 25 = -10 kg/m^2 (hisap)

Akibat angin tekan :

$Wt.a_1 = 7{,}5 \times 3{,}5 \times ½ \left(1{,}5 / Cos\,35\right)$ = + 24,034 kg

$Wt.a_2 = 7{,}5 \times 3{,}5 \times \left\{½(1{,}5/Cos35) + ½(1{,}0/\cos 35)\right\}$ = + 40,057 kg

$Wt.a_3 = 7{,}5 \times 3{,}5 \times \left\{½(1{,}0/\cos 35)\right\}$ = + 16,023 kg

Akibat angin hisap :

$Wh.a_1 = -10 \times 3{,}5 \times ½ \left(1{,}5 / Cos\,35\right)$ = - 32,045 kg

$Wh.a_2 = -10 \times 3{,}5 \times \left\{½(1{,}5/Cos35) + ½(1{,}0/\cos 35)\right\}$ = - 53,409 kg

$Wh.a_3 = -10 \times 3{,}5 \times \left\{½(1{,}0/\cos 35)\right\}$ = -21,364 kg

4.1.3.2 Perhitungan Mekanika Rangka

Analisis mekanika rangka kuda-kuda menggunakan Program SAP2000 dan struktur dimodelkan dalam dua dimensi (2D). Beban rencana kuda-kuda (KK1 dan KK2) dapat dilihat pada tabel 4.5. sedangkan Hasil analisis terlampir pada lampiran 1.

Data profil yang digunakan :

Modulus of elasticity (Es) $= 2{,}1\times10^{5}$ Mpa $= 2{,}1\times10^{6}$ kg/cm^2 $= 2{,}1\ 10^{8}$ kN

Tegangan leleh profil (fy) = 240 Mpa = 2400 kg/cm^2 = 240000 kN

Asumsi PROFIL 2L 65×65×7, dengan :

T = 65 mm tf = 7 mm tw = 7 mm

1. Data-data pembebanan yang input ke SAP2000

   a. Akibat beban tetap (KK1)

Tabel 4.1 Gaya P_1 s/d P_9

Nama gaya	**Beban mati (qD) kg**	**Beban hidup (qL) kg**
$P_1 = P_9$	-178,868	-64,603
$P_2 = P_8$	-340,377	-129,207
$P_3 = P_7$	-393,839	-150,592
$P_4 = P_6$	-447,302	-171,977
P_5	-447,302	-171,977

Tabel 4.2 Gaya P'_1 sampai dengan P'_9

Nama gaya	Beban mati (qD) kg
$P'_1 = P'_9$	-144,419
$P'_2 = P'_8$	-288,838
$P'_3 = P'_7$	-336,580
$P'_4 = P'_6$	-384,321
P'_5	-384,321

Untuk pembebanan P'_1 s/d P'_9 pada analisis menggunakan SAP2000, berat sendiri kuda-kuda tidak lagi di input kedalam perhitungan

b. Akibat beban angin (KK1)

Tabel 4.3 Gaya angin tekan dan angin hisap kiri

Nama gaya	Gaya akibat beban angin kiri (W_{ki}) (Kg)	Gaya horizontal = Wki × cos α^o (Kg)	Gaya vertikal= Wki × sin α^o (Kg)
Wt_1	24,226	+19,842	-11,383
Wt_2	48,453	+39,690	-22,765
Wt_3	56,472	+46,259	-26,533
Wt_4	64,491	+52,828	-30,301
Wt_5	32,246	+26,414	-15,150
Wh_1	32,302	+26,460	+15,177
Wh_2	64,603	+52,920	+30,354
Wh_3	75,296	+61,679	+35,377
Wh_4	85,988	+70,438	+40,401
Wh_5	42,994	+35,219	+20,201

c. Akibat beban tetap (KK2)

Tabel 4.4 Gaya Pa_1 s/d Pa_3

Nama gaya	Beban mati (qD) kg	Beban hidup (qL) kg
Pa_1	-177,587	-64,091
Pa_2	-284,404	-106,818
Pa_3	-124,178	-42,727

Tabel 4.5 Gaya Pa'_1 sampai dengan Pa'_3

Nama gaya	Beban mati (qD) kg
Pa'_1	-95,428
Pa'_2	-159,046
Pa'_3	-63,618

Untuk pembebanan P'_1 s/d P'_3 pada analisis menggunakan SAP2000, berat kuda-kuda yang merupakan berat sendiri tidak lagi di input kedalan perhitungan

d. Akibat beban angin (KK2)

Tabel 4.6 Gaya angin tekan dan angin hisap kiri

Nama gaya	**Gaya akibat beban angin kiri (W_{ki}) (Kg)**	**Gaya horizontal = Wki × cos α^o (Kg)**	**Gaya vertikal= Wki × sin α^o (Kg)**
$Wt.a_1$	24,034	+19,688	-11,292
$Wt.a_2$	40,057	+32,813	-18,820
$Wt.a_3$	16,023	+13,125	-7,528
$Wh.a_1$	32,045	+26,250	+15,056
$Wh.a_2$	53,409	+43,750	+25,094
$Wh.a_3$	21,364	+17,500	+10,038

4.1.3.3 Perencanaan Profil Kuda-Kuda KK1

1. Batang Tekan (A_1 s/d A_8)

Gaya batang (tekan) maksimum = 6768 kg

Panjang = 1,85 m = 185 cm

Syarat $\frac{k.L}{r} < 200$ ➔ Ambil $\frac{k.L}{r} = 100$

$Cc = \frac{6440}{\sqrt{fy}} = \frac{6440}{\sqrt{2400}} = 131{,}456 > \frac{k.L}{r} = 100$, maka :

$$Fs = \frac{5}{3} + \frac{3}{8}\frac{k.L/r}{Cc} - \frac{1\left(k.L/r\right)^3}{8.Cc^3} = \frac{5}{3} + \frac{3}{8}\frac{100}{131{,}456} - \frac{1}{8}\frac{100^3}{131{,}456^3} = 1{,}897$$

$$Fa_{perlu} = \frac{fy}{Fs}\left(1 - 0{,}5\left(\frac{k.L/r}{Cc}\right)^2\right) = \frac{2400}{1{,}897}\left(1 - 0{,}5\left(\frac{100}{131{,}456}\right)^2\right) = 899{,}139 \text{ kg/cm}^2$$

$$A_{perlu} = \frac{P}{Fa_{perlu}} = \frac{6768}{899{,}139} = 7{,}527 \text{ cm}^2$$

Profil 2L 55x55x6 (dari tabel Profil baja Ir. Morisco), dengan :

A = 2 x 6,31 = 12,62 cm^2 2.Ix = 34,6 cm^4

Iy $_{Pergeseran}$ = 2. 17,3 + 6,31 $(1{,}56+0{,}5)^2$ + 6,31 $(1{,}56+0{,}5)^2$ = 86,59 cm^4

Iy > Ix ➔ dipakai Ix = 34,6 cm^4

$$r_{min} = \sqrt{\frac{Ix}{Atot}} = \sqrt{\frac{34{,}6}{12{,}62}} = 1{,}66 \text{ cm}$$

Kontrol Local Buckling :

$\frac{bf}{tf} - \leq \frac{76}{\sqrt{fy}}$ (fy dalam Ksi)

$\frac{55}{6} \leq \frac{76}{\sqrt{36}}$ ➔ 9,167 ≤ 12,667 (Ok!)

Kontrol Beban :

$$\frac{k.L}{r} = \frac{1.185}{1,66} \leq Cc = \frac{6440}{\sqrt{fy}} = \frac{6440}{\sqrt{2400}}$$

$= 111,446 \leq 131,456$ (terjadi tekuk elastis)

$$Fs = \frac{5}{3} + \frac{3}{8}\frac{k.L/r}{Cc} - \frac{1\left(k.L/r\right)^3}{8.Cc^3} = \frac{5}{3} + \frac{3}{8}\frac{111,446}{8.131,456} - \frac{1}{8}\frac{111,446^3}{131,456^3} = 1,909$$

$$Fa_{ada} = \frac{2400}{1,909}\left(1 - 0,5\left(\frac{111,446}{131,456}\right)^2\right) = 799,755 \text{ kg/cm}^2$$

$P_{ada} = Fa_{ada} \cdot A_{ada} \geq P_{tjd}$

$= 799,755 \cdot 12,62$

$= 10092,91 \text{ kg} \geq 6768 \text{ kg} \ldots\ldots\ldots$ (Ok!)

2. Batang Tekan (D_3)

Gaya batang (tekan) maksimum = 1431 kg

Panjang = 3,21 m = 321 cm

Syarat $\frac{k.L}{r} < 200$ ➔ Ambil $\frac{k.L}{r} = 200$

$$Cc = \frac{6440}{\sqrt{fy}} = \frac{6440}{\sqrt{2400}} = 131,456 < \frac{k.L}{r} = 200, \text{ maka :}$$

$$Fs = \frac{5}{3} + \frac{3}{8}\frac{k.L/r}{Cc} - \frac{1\left(k.L/r\right)^3}{8.Cc^3} = \frac{5}{3} + \frac{3}{8}\frac{200}{131,456} - \frac{1}{8}\frac{200^3}{131,456^3} = 1,797$$

$$Fa_{perlu} = \frac{12}{23}\left(\frac{\pi^2 \, E}{(k.L/r)^2}\right) = \frac{12}{23}\left(\frac{3,14^2 \times 2,1.10^6}{200^2}\right) = 270,067 \text{ kg/cm}^2$$

$$A_{perlu} = \frac{P}{Fa_{perlu}} = \frac{1431}{270,067} = 5,299 \text{ cm}^2$$

Profil 2L 55x55x6 (profil yang biasa digunakan di lapangan), dengan :

A = 2 x 6,31 = 13,62 cm^2

r_{min} = 1,66 cm (lihat hitungan r_{min} di halaman 102)

Kontrol Local Buckling :

$$\frac{bf}{tf} - \leq \frac{76}{\sqrt{fy}} \text{ (fy dalam Ksi)}$$

$$\frac{55}{6} \leq \frac{76}{\sqrt{36}}$$

9,167 ≤ 12,667 (Ok!)

Kontrol Beban :

$$\frac{k.L}{r} = \frac{1.321}{1,66} \leq Cc = \frac{6440}{\sqrt{fy}} = \frac{6440}{\sqrt{2400}}$$

$$= 193,374 > 131,456$$

$$Fs = \frac{5}{3} + \frac{3}{8}\frac{k.L/r}{Cc} - \frac{1\left(k.L/r\right)^3}{8.Cc^3} = \frac{5}{3} + \frac{3}{8}\frac{193,374}{8.131,456} - \frac{1}{8}\frac{193,374^3}{131,456^3} = 1,816$$

$$Fa_{ada} = \frac{12}{23}\left(\frac{\pi^2.E}{\left(\frac{k.L}{r}\right)^2}\right) = \frac{12}{23}\left(\frac{3,14^2.2,1.10^6}{193,374^2}\right) = 288,894 \text{ kg/cm}^2$$

$P_{ada} = Fa_{ada} . A_{ada} \geq P_{tjd}$

$= 288,894 . 13,62$

$= 3645,839 \text{ kg} \geq 1431 \text{ kg} \ldots\ldots\ldots$ (Ok!)

3. Batang Tarik (B_1, B_2, B_7, B_8)

$P_{tarik\ maks}$ = 4984 kg fy = 2400 kg/cm^2

Panjang = 1,53 m Fu = 3700 kg/cm^2

$$r_{min} = \frac{L}{240} = \frac{153}{240} = 0{,}638 \text{ cm}$$

● Untuk batang ada lubang

$\mu = 0{,}85$ (semua profil dengan jumlah baut ≥ 3 buah/baris)

$\mu = 0{,}75$ (jumlah baut 2 buah/baris)

$$A_{netto\ perlu} = \frac{P}{0{,}5.Fu.\mu} = \frac{4984}{0{,}5.3700.0{,}75} = 3{,}592 \text{ cm}^2$$

Dicoba profil 2L 55x55x6, dimana :

A = 2 x 6,31 = 12,62 cm^2

r_{min} = 1,66 cm (lihat hitungan r_{min} di halaman 102)

tw = 0,6 cm

d baut = ½ " = 1,27 cm

Kontrol kelangsingan (λ) :

$$\lambda_{ada} = \frac{k.L}{r_{ada}} = \frac{1.153}{1{,}66} = 92{,}41 \leq 240 \text{ (Ok!)}$$

Kontrol Tegangan :

● Untuk batang tidak ada lubang

$$fa = \frac{T}{A_{profil}} \leq 0{,}6\,fy$$

$$= \frac{4984}{12{,}62} = 394{,}929 \text{ kg/cm}^2 \leq 0{,}6.2400 = 1440 \text{ kg/cm}^2 \text{ (Ok!)}$$

● Untuk batang ada lubang

$A_{netto\ profil} = A_{profil} - (d_{baut} + 1/8") t_{pelat}$

$= 12{,}62 - (1{,}27 + 0{,}3175) . 0{,}6 . 2$

$= 10{,}715 \text{ cm}^2$

$A_{efektif} = A_{netto} \cdot \mu = 10{,}715 \cdot 0{,}75 = 8{,}036\ cm^2$

$$fa = \frac{T}{A_{efektif}} \leq 0{,}5\ Fu$$

$$= \frac{4984}{8{,}036} \leq 0{,}5.3700 = 620{,}19\ kg/cm^2 \leq 1850\ kg/cm^2\ (\text{Ok!})$$

4. Batang Tarik (V4)

$P_{tarik\ maks} = 3200$ kg fy = 2400 kg/cm^2

Panjang = 3,9 m Fu = 3700 kg/cm^2

$$r_{min} = \frac{L}{240} = \frac{390}{240} = 1{,}625\ cm$$

- Untuk batang ada lubang

$\mu = 0{,}85$ (semua profil dengan jumlah baut ≥ 3 buah/baris)

$\mu = 0{,}75$ (jumlah baut 2 buah/baris)

$$A_{netto\ perlu} = \frac{P}{0{,}5.Fu.\mu} = \frac{3200}{0{,}5.3700.0{,}75} = 2{,}306\ cm^2$$

Dicoba profil 2L 55x55x6, dimana :

A = 2 x 6,31 = 12,62 cm^2

r_{min} = 1,66 cm (lihat hitungan r_{min} di halaman 102)

tw = 0,6 cm

d baut = ½ " = 1,27 cm

Kontrol kelangsingan (λ) :

$$\lambda_{ada} = \frac{k.L}{r_{ada}} = \frac{1.390}{1{,}66} = 234{,}94 \leq 240\ (\text{Ok!})$$

Kontrol Tegangan :

- Untuk batang tidak ada lubang

$$fa = \frac{T}{A_{profil}} \leq 0{,}6\,fy$$

$$= \frac{3200}{12{,}62} = 253{,}566 \text{ kg/cm}^2 \leq 0{,}6.2400 = 1440 \text{ kg/cm}^2 \text{ (Ok!)}$$

- Untuk batang ada lubang

$$A_{netto\ profil} = A_{profil} - (d_{baut} + 1/8'')t_{pelat}$$

$$= 12{,}62 - (1{,}27 + 0{,}3175) . 0{,}6 . 2$$

$$= 10{,}715 \text{ cm}^2$$

$$A_{efektif} = A_{netto} . \mu = 10{,}715 . 0{,}75 = 8{,}036 \text{ cm}^2$$

$$fa = \frac{T}{A_{efektif}} \leq 0{,}5\,Fu$$

$$= \frac{3200}{8{,}036} \leq 0{,}5.3700 = 398{,}196 \text{ kg/cm}^2 \leq 1850 \text{ kg/cm}^2 \text{ (Ok!)}$$

Kontrol berat kuda-kuda :

- Berat total kuda-kuda (W_{total}) = L_{total} × berat profil

$$= 60{,}5 \text{ m} \times 2(4{,}95) \text{ kg/m} = 599{,}2 \text{ kg}$$

- Berat baut dan plat sambung = 20% x berat total kuda-kuda

$$= 0{,}2 \times 599{,}2 = 119{,}8 \text{ kg}$$

Jumlah (Σ) = W_{total} + 20% berat total kuda-kuda

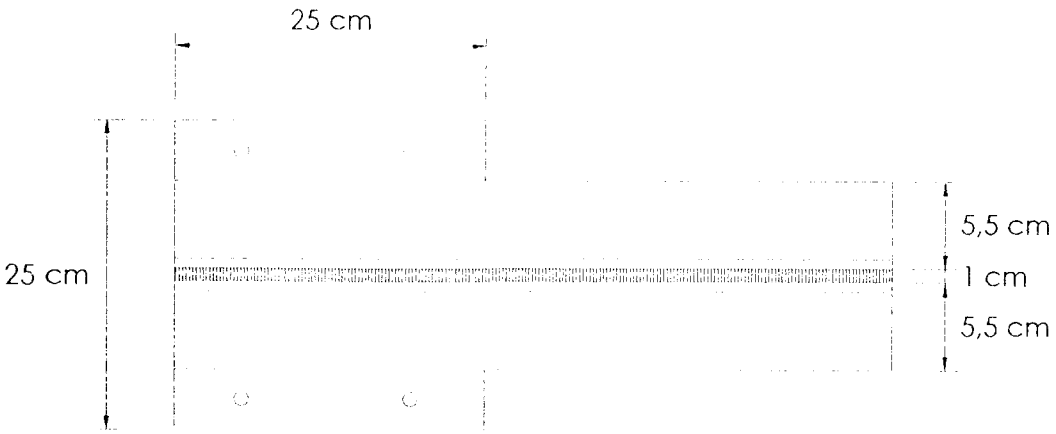
$$= 599{,}2 + 119{,}8 = 719 \text{ kg}$$

- Panjang bentang kuda-kuda (L) = 14,1 m

$$\frac{\Sigma}{L} \leq \text{ Berat taksiran } \rightarrow \quad \frac{719}{14{,}1} \leq {}^{kg}\!/_{m}$$

$$= 50{,}9 \text{ kg/m} \leq 70{,}357 \text{ kg/m (Ok!)}$$

4.1.3.4 Perencanaan Pelat Kuda-Kuda



Gambar 4.7 Pelat Kuda-kuda

Beban P diambil dari reaksi dukungan dari perhitungan SAP 2000 :

P_{maks} = 3814 kg $f'c$ = 22,5 Mpa = 225 kg/cm^2

$$A_{perlu} = \frac{P}{0{,}33.f'c} = \frac{3814}{0{,}33.225} = 51{,}367 \text{ cm}^2$$

Dipakai ukuran pelat = 25 cm x 25 cm = 625 cm^2 > A_{perlu} = 51,367 cm^2

$$q = \frac{P}{BxL} = \frac{3814}{25x25} = 6{,}1 \text{ kg/cm}^2$$

$$x = \frac{25 - (5{,}5 + 1 + 5{,}5)}{2} = 6{,}5 \text{ cm}$$

$M = ½ . q . x^2 = ½ . 6{,}1 . 6{,}5^2 = 128{,}86$ kg

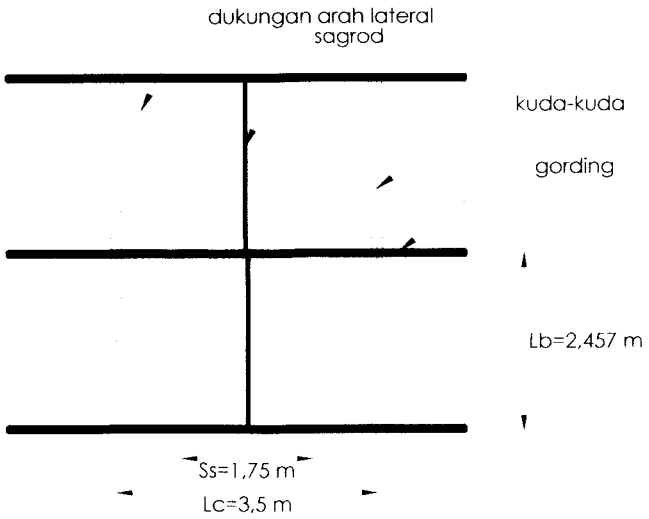
Syarat :

$$0{,}6 . Fy = \frac{M}{\frac{1}{6}.1.tp}$$

$$tp = \sqrt{\frac{10.M}{Fy}} = \sqrt{\frac{10.\ 128{,}86}{2400}} = 0{,}73\ cm \approx 1 \text{ cm}$$

Pelat kuda-kuda berukuran : 25 cm × 25 cm × 1 cm

4.1.4 Perencanaan Dukungan Lateral



Gambar 4.8 Dukungan Arah Lateral

Diketahui :

Lb = jarak antara gording = 2,457 m

Lc = jarak antar kuda-kuda = 3,5 m

$L = \sqrt{Lb^2 + Lc^2} = \sqrt{2{,}457^2 + 3{,}5^2} = 4{,}276$ m = 427,6 cm

Syarat :

L/refleks ≤ 300 , sehingga :

$r_{min} \geq \frac{L}{300} = \frac{427{,}6}{300} = 1{,}425$ cm = 14,25 mm

Keterangan :

- L ≤ 3 m, dipakai baja tulangan diameter 12 mm
- L ≥ 3 m, dipakai baja tulangan diameter 19 mm
- 3 m < L ≤ 5 m, dipakai baja tulangan diameter 16 mm

Karena L = 4,276 m, maka dukungan arah lateral dipakai baja tulangan diameter

16 mm > r_{min} = 14,25 mm

4.1.5 Perencanaan Sambungan

- Tebal pelat sambung = 1 cm, d_{baut} = ½" = 1,27 cm
- Mutu Baja Profil :

  Tegangan leleh (fy) = 36 Ksi = 2400 kg/cm^2

  Kuat tarik (Fu) = 3700 kg/cm^2

- Mutu Baut A325X (Non Full Drat) :

  Tegangan tarik (Ft) = 36 Ksi = 2400 kg/cm^2

  Tegangan Geser (Fv) = 24 Ksi = 1600 kg/cm^2

Tinjauan Tegangan Geser 1 Baut :

P_{geser} = ¼ . π . D^2_{baut} x Fv x jumlah bidang geser (n)

= ¼ . π . $1{,}27^2$. 1600 . 2

= 4051,605 kg

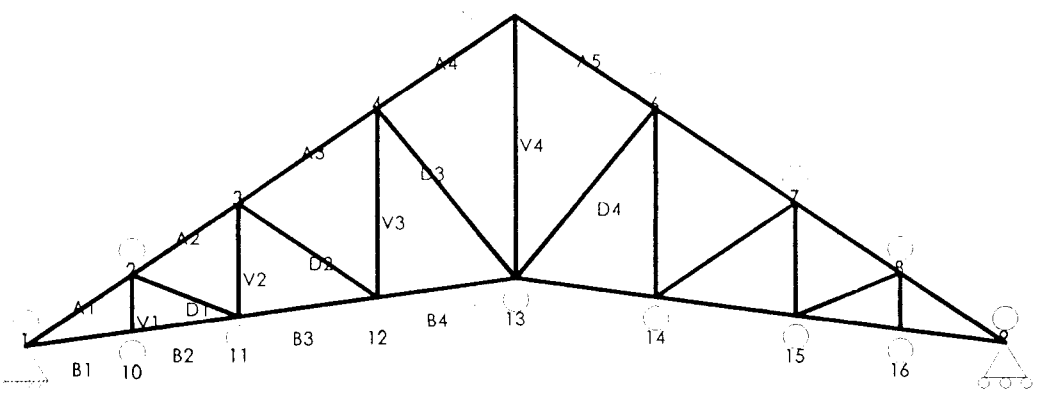
Tinjauan Tegangan Tumpu 1 baut :

P_{tumpu} = 1,2 . Fu . D_{baut} . t . jumlah tumpuan (n)

= 1,2 . 3700 . 1,27 . 1 . 1

= 5638,8 kg

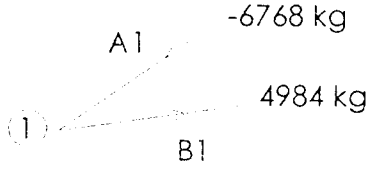
Jadi $P_{1\ baut}$ dipakai P_{geser} = 4051,605 kg



Gambar 4.9 Rangka Kuda-kuda (KK1)

$$\text{Jumlah Baut (N)} = \frac{P_{terjadi}}{P_{1baut}}$$

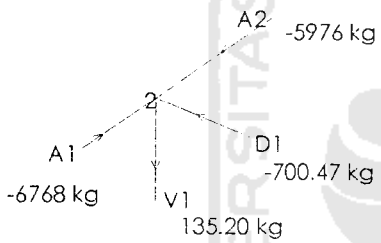
- Joint 1



$$n\ A1 = \frac{6768}{4051{,}605} = 1{,}67 \approx 2 \text{ buah}$$

$$n\ B1 = \frac{4984}{4051{,}605} = 1{,}23 \approx 2 \text{ buah}$$

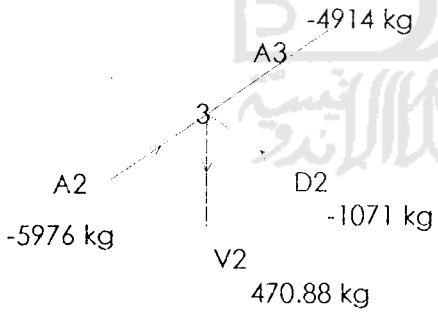
- Joint 2



$$n\ V1 = \frac{135{,}2}{4051{,}605} = 0{,}033 \approx 2 \text{ buah}$$

$$n\ D1 = \frac{700{,}47}{4051{,}605} = 0{,}173 \approx 2 \text{ buah}$$

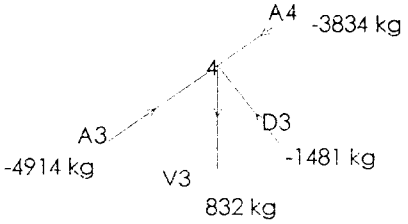
- Joint 3



$$n\ V2 = \frac{470{,}88}{4051{,}605} = 0{,}116 \approx 2 \text{ buah}$$

$$n\ D2 = \frac{1071}{4051{,}605} = 0{,}264 \approx 2 \text{ buah}$$

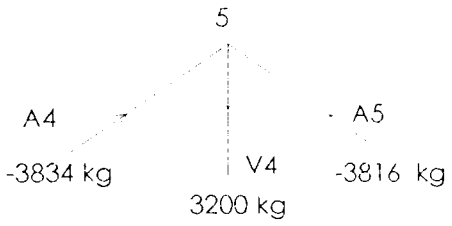
- Joint 4



$$n\ V3 = \frac{832}{4051{,}605} = 0{,}205 \approx 2 \text{ buah}$$

$$n\ D3 = \frac{1431}{4051{,}605} = 0{,}353 \approx 2 \text{ buah}$$

- Joint 5

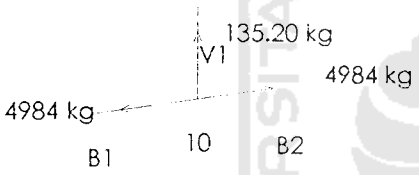


$$n\ A4 = \frac{3834}{4051{,}605} = 0{,}946 \approx 2 \text{ buah}$$

$$n\ A5 = \frac{3816}{4051{,}605} = 0{,}942 \approx 2 \text{ buah}$$

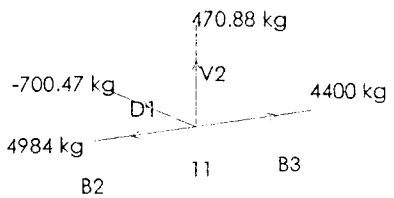
$$n\ V4 = \frac{3200}{4051{,}605} = 0{,}79 \approx 2 \text{ buah}$$

- Joint 10



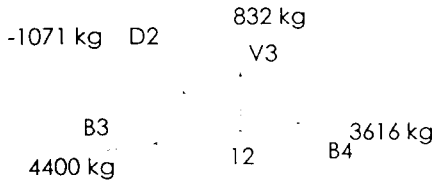
$$n\ B1 = B2 = \frac{4984}{4051{,}605} = 1{,}23 \approx 2$$

- Joint 11



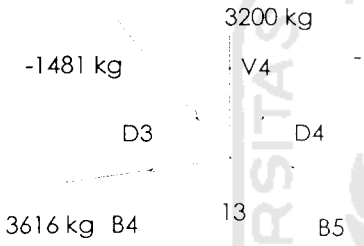
$$n\ B3 = \frac{4400}{4051{,}605} = 1{,}086 \approx 2 \text{ buah}$$

- Joint 12



$$n\ B4 = \frac{3616}{4051{,}605} = 0{,}892 \approx 2 \text{ buah}$$

- Joint 13



$$n\ B5 = \frac{3616}{4051{,}605} = 0{,}892 \approx 2 \text{ buah}$$

$$n\ D4 = \frac{1431}{4051{,}605} = 0{,}353 \approx 2 \text{ buah}$$

Tabel 4.6 Jumlah baut pada ½ bentang kuda-kuda KK1

Joint	Batang	Jumlah Baut (buah)
1	A1 ; B1	2
2	V1 ; D1	2
3	V2 ; D2	2
4	V3 ; D3	2
5	A4 ; A5 ; V4	2
10	B2	2
11	B3	2
12	B4	2
13	B5 ; D4	2

4.2 Perencanaan Pelat

Untuk perencanaan pelat terbagi atas dua yaitu :

- Perencanan pelat lantai
- Perencanaan pelat bak air

4.2.1 Perencanaan Pelat Lantai

a. Pembebanan Pelat Lantai

1. Beban mati pelat lantai (berdasarkan PPIUG 1983, Pasal 2.2, Tabel 2.1)

a. Berat sendiri pelat (tebal 12 cm)	: 0,12 x 24	= 2,88 kN/m^2
b. Pasir (tebal 5 cm)	: 0,05 x 16	= 0,80 kN/m^2
c. Spesi (tebal 2 cm)	: 0,02 x 21	= 0,42 kN/m^2
d. Ubin semen portland (tebal 2 cm)	: 0,02 x 24	= 0,48 kN/m^2
e. Eternit dan penggantung	:	= 0.18 kN/m^2
f. Mekanikal dan Elektrikal	:	= 0,12 kN/m^2
Beban mati total (qD)		= 4,88 kN/m^2

2. Beban hidup pelat lantai :

Gedung ini berfungsi sebagai rumah sakit, berdasarkan PPIUG, 1983, maka :

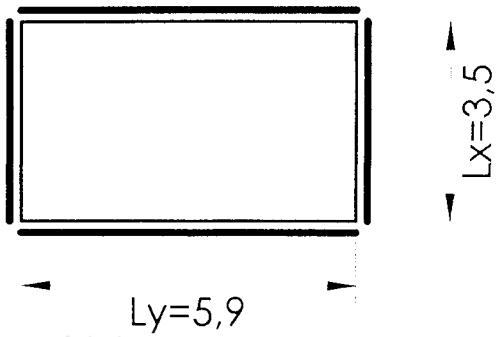
Beban hidup (qL) = 250 kg/m^2 = 2,5 kN/m^2 (tabel 3.1, hal 17)

Dengan Kombinasi pembebanan menurut SK SNI T-15-1991-03, Pasal 3.2.2 adalah:

$$qU = 1,2.qD + 1,6.qL = 1,2(4,88) + 1,6(2,5) = 9,9 \text{ kN/m}^2$$

b. Perencanaan Pelat Lantai Tipe PL1 (3,5x5,9)

Pelat dianggap terjepit elastis pada keempat sisinya



$\frac{ly}{lx} = \frac{5,9}{3,5} = 1,69$ dihitung sebagai pelat dua arah.

Koefisien momen (C) pada kondisi menerus atau terjepit elastis (lihat tabel 13.3.2 halaman 203 PBBI 1971 NI-2)

Koef. Momen Pelat (C)	1,6	1,7
Mlx = -Mtx	58	59
Mly = -Mty	36	36

Untuk nilai koefisien momen pelat (C) diantara yang tercantum pada tabel, maka nilainya diperoleh dengan cara interpolasi linier, yaitu sebagai berikut :

$$C = 58 + \left(\frac{1,69 - 1,6}{1,7 - 1,6} \times (59 - 58) \right) = 58,9$$

Diperkirakan balok tepi pelat mempunyai lebar, b = 250 mm, maka :

lnx = 3500 – ½ x 250 = 3375 mm

lny = 4000 – ½ x 350 = 5725 mm

perbandingan bentang bersih sisi panjang dan pendek :

$$\beta = \frac{\ln y}{\ln x} = \frac{5725}{3375} = 1,7$$

sehingga tebal pelat tidak boleh kurang dari :

$$h = \frac{\ln\left(0{,}8 + fy/1500\right)}{36 + 9.\beta} = \frac{5725\left(0{,}8 + 240/1500\right)}{36 + 9.1{,}7} = 107{,}204 \text{ mm}$$

tetapi tidak perlu lebih besar sama dengan dari :

$$h = \frac{\ln\left(0{,}8 + fy/1500\right)}{36} = \frac{5725\left(0{,}8 + 240/1500\right)}{36} = 152.687 \text{ mm}$$

Berdasarkan persyaratan PBBI 1971 bahwa tebal pelat tidak boleh kurang dari 70 mm untuk pelat atap dan 120 mm untuk pelat lantai, maka asumsi awal tebal pelat yang digunakan 120 mm., dengan :

- Tulangan pokok Ø 10 mm
- Penutup beton (Pb) digunakan 20 mm

Didapat, Tinggi manfaat tulangan pelat lantai :

- Arah x : dx $= h - Pb - \frac{1}{2} Ø_{tul.x}$

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

  $= 95$ mm

- Arah y : dy $= h - Pb - Ø_{tul.x} - \frac{1}{2} Ø_{tul.y}$

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

  $= 85$ mm

- Momen-momen yang bekerja pada pelat :

Mulx = -Mutx $= 0{,}001 \cdot qU \cdot lx^2 \cdot C$

$= 0{,}001 \cdot 9{,}856 \cdot 3{,}5^2 \cdot 58{,}9 = 7{,}111$ kNm

Muly = (-)Muty $= 0{,}001 \cdot 9{,}856 \cdot 3{,}5^2 \cdot 36 = 4{,}436$ kNm

1) Perencanaan Tulangan lx dan tx

Mulx = (-)Mutx = 7,111 kNm

$Mu/\phi = 7{,}111/0{,}8$ = 8,9 kNm

Rasio Tulangan (ρ)

$$\rho b = \frac{0{,}85.f'c.\beta_1}{fy}\left(\frac{600}{600+fy}\right) = \frac{0{,}85.\ 22{,}5.\ 0{,}85}{240}\left(\frac{600}{600+240}\right) = 0{,}0484$$

$$\rho_{min} = \frac{1{,}4}{fy} = \frac{1{,}4}{240} = 0{,}00583$$

$$\rho_{max} = 0{,}75\ .\ \rho b = 0{,}75\ .\ 0{,}0484 = 0{,}0363$$

$$m = \frac{fy}{0{,}85.f'c} = \frac{240}{0{,}85.22{,}5} = 12{,}5490$$

Koefisien ketahanan (Rn) :

$$Rn = \frac{Mu/\phi}{b.d^2} = \frac{8{,}9x1.10^6}{1000.95^2} = 0{,}9850 \text{ Mpa}$$

$$\rho ada = \frac{1}{m}\left(1-\sqrt{1-\frac{2m.Rn}{fy}}\right) = \frac{1}{12{,}549}\left(1-\sqrt{1-\frac{2.12{,}549.0{,}9850}{240}}\right)$$

$= 0{,}00422 < \rho_{max} = 0{,}0363$

$< \rho_{min} = 0{,}0058$

$1{,}33\ \rho = 1{,}333\ .\ 0{,}0042 = 0{,}00561 < \rho_{min} = 0{,}0058$, maka :

$\rho_{pakai} = 1{,}33\ \rho = 0{,}00561$

As_{ρ} $= \rho_{pakai} . b . d \geq 0{,}002 . b . h$

$= 0{,}00561 . 1000 . 95 \geq 0{,}002 . 1000 . 120$

$= 533{,}55\ mm^2 \geq 240\ mm^2$

digunakan tulangan pokok Ø 10 mm, sehingga :

$A_1 Ø = \frac{1}{4} . \pi . D^2 = \frac{1}{4} . \pi . 10^2 = 78{,}50\ mm^2$

Jarak tulangan (s) $= \frac{A_1 \phi . b}{As_{\rho}}$

$= \frac{78{,}5 . 1000}{532.6239}$

$= 147{,}126$ mm

dipakai s = 145 mm, maka Tulangan Pokok : P10 – 145

$As_{ada} = \frac{A_1 \phi . b}{s} = \frac{78{,}50.1000}{145} = 541{,}3793\ mm^2$

Kontrol Kapasitas Lentur Pelat (arah x) :

a $= \frac{As_{ada} . fy}{0{,}85 . f'c . b} = \frac{541{,}3793 . 240}{0{,}85.22{,}5.1000} = 6{,}7938$ mm

Mn $= As_{ada} . fy (d - \frac{a}{2}) \geq 1{,}33 . \frac{Mu}{\phi}$ (karena $\rho_{pakai} = 1{,}33\rho$)

$= 541{,}3793 . 240 (95 - \frac{6{,}7938}{2}) / 10^6$

$= 11{,}9021$ KNm $\geq 1{,}33 . 8{,}9 = 11{,}85$ kN m .....OK !

2) Perencanaan Tulangan ly dan ty

Muly = -Muty = 4,436 kN m

$\frac{Mu}{\phi} = \frac{4{,}346}{0{,}8} = 5{,}4$ kN m

Rasio Tulangan (ρ)

$$\rho b = \frac{0{,}85.f'c.\beta_1}{fy}\left(\frac{600}{600+fy}\right) = \frac{0{,}85.\ 22{,}5.\ 0{,}85}{240}\left(\frac{600}{600+240}\right) = 0{,}0484$$

$$\rho_{min} = \frac{1{,}4}{fy} = \frac{1{,}4}{240} = 0{,}00583$$

$$\rho_{max} = 0{,}75\ .\ \rho b = 0{,}75\ .\ 0{,}0484 = 0{,}0363$$

$$m = \frac{fy}{0{,}85.f'c} = \frac{240}{0{,}85.22{,}5} = 12{,}5490$$

Koefisien ketahanan (Rn) :

$$Rn = \frac{Mu/\phi}{b.d^2} = \frac{5{,}4x10^6}{1000.\ 85^2} = 0{,}7520\ \text{Mpa}$$

$$\rho = \frac{1}{m}\left(1-\sqrt{1-\frac{2m.Rn}{fy}}\right) = \frac{1}{12{,}5490}\left(1-\sqrt{1-\frac{2.12{,}5490.\ 0{,}7520}{240}}\right)$$

$$= 0{,}0032 \quad < \rho_{max} = 0{,}04032$$

$$< \rho_{min} = 0{,}00583$$

$1{,}33\ \rho = 1{,}333\ .\ 0{,}0032 = 0{,}0043 < \rho_{min} = 0{,}00583$, maka :

$$\rho_{pakai} = 1{,}33\ \rho = 0{,}0043$$

$$As_p = \rho_{pakai}\ .\ b\ .\ d \geq 0{,}002\ .\ b\ .\ h$$

$$= 0{,}0043\ .\ 1000\ .\ 85$$

$$= 361{,}4701\ mm^2 \geq 240\ mm^2$$

digunakan tulangan pokok Ø 10 mm, sehingga :

$$A_1 Ø = \tfrac{1}{4}\ .\ \pi\ .\ D^2 = \tfrac{1}{4}\ .\ \pi\ .\ 10^2 = 78{,}50\ mm^2$$

Jarak tulangan (s) $= \dfrac{A_1 \phi . b}{As_p}$

$= \dfrac{78{,}50 . 1000}{361{,}4701} = 217{,}1688$ mm

Berdasarkan SK SNI T-15-1991-03, pasal 3.6.4, ayat 2 bahwa jarak antar tulangan pada penampang kritis tidak boleh melebihi dua kali tebal pelat, dipakai s bagi = 200 mm < 2 × 120 = 240 mm

maka Tulangan Bagi : P10 – 200

$As_{ada} = \dfrac{A_1 \phi . b}{s} = \dfrac{78{,}50 . 1000}{200} = 392{,}5 \text{ mm}^2$

Kontrol Kapasitas Lentur Pelat (arah y) :

$a = \dfrac{As_{ada} . fy}{0{,}85 . f'c . b} = \dfrac{392{,}50 . 240}{0{,}85 . 22{,}5 . 1000} = 4{,}9255$ mm

Mn $= As_{ada} . fy \left(d - \frac{a}{2} \right) \geq 1{,}33 . \frac{Mu}{\phi}$ (karena $\rho_{pakai} = 1{,}33\rho$)

$= 392{,}50 . 240 \left(85 - \frac{4{,}9255}{2} \right) / 10^6$

$= 7{,}7750$ KNm $\geq 1{,}33 . 5{,}4331 = 7{,}2260$ kN m .....OK!

3) Perencanaan Tulangan Bagi

$As_{susut} = 0{,}002 . b . h$

$= 0{,}002 . 1000 . 120 = 240 \text{ mm}^2$

digunakan tulangan bagi Ø 10 mm, sehingga :

$A_1 Ø = \frac{1}{4} . \pi . D^2 = \frac{1}{4} . \pi . 10^2 = 78{,}5 \text{ mm}^2$

Jarak tulangan bagi (s) = $\frac{A_1 \phi . b}{As_{susut}}$

$= \frac{78,5.1000}{240} = 327,08$ mm

Berdasarkan SK SNI T-15-1991-03, pasal 3.6.4, ayat 2 bahwa jarak antar tulangan pada penampang kritis tidak boleh melebihi dua kali tebal pelat, dipakai s bagi = 200 mm < 2 × 120 = 240 mm

maka Tulangan Bagi : P10 - 200

4.2.2 Perencanaan Pelat Bak air

a. Pembebanan Pelat bak air

1. Beban mati pelat bak air (berdasarkan PPIUG 1983, Pasal 2.2, Tabel 2.1)

a. Berat sendiri pelat (tebal 14 cm)	: 0,14 x 24	= 3,36 KN/m^2
b. Pasir (tebal 5 cm)	: 0,05 x 16	= 0,80 KN/m^2
c. Spesi (tebal 2 cm)	: 0,02 x 21	= 0,42 KN/m^2
d. Ubin semen portland (tebal 2 cm)	: 0,02 x 24	= 0,48 KN/m^2
Beban mati total (qD)		= 5,06 KN/m^2

2. Beban hidup pelat bak air:

Untuk pelat bak air di asumsikan beban hidup berupa beban air sebesar 1000 kg/m^3. dengan ketinggian bak 1,5 m, maka berat air adalah :

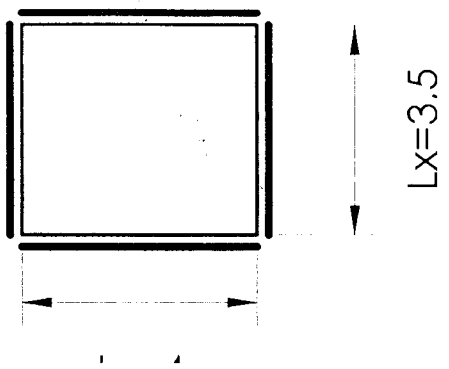
Beban hidup (qL) = 1000 kg/m^3 x 1,5 = 1500 kg/m^2 = 15 kN/m^2

Dengan Kombinasi pembebanan menurut SK SNI T-15-1991-03, Pasal 3.2.2 adalah:

$$qU = 1,2.qD + 1,6.qL = 1,2(5,06) + 1,6(15) = 30,072 \text{ kN/m}^2$$

b. Perencanaan Pelat Bak Air Tipe PL3 (3,5x4,0)

Pelat dianggap terjepit elastis pada keempat sisinya



$\frac{ly}{lx} = \frac{4,0}{3,5} = 1,14$ dihitung sebagai pelat dua arah.

Koefisien momen (C) pada kondisi menerus atau terjepit elastis (lihat tabel 13.3.2 halaman 203 PBBI 1971 NI-2)

Koef. Momen Pelat (C)	1,1	1,14	1,2
Mlx = -Mtx	42	43,6	46
Mly = -Mty	37	37,4	38

Untuk nilai koefisien momen pelat (C) diantara yang tercantum pada tabel, maka nilainya diperoleh dengan cara interpolasi linier, yaitu sebagai berikut :

$$C = 42\left(\frac{1,14-1,1}{1,2-1,1} \times (46-42)\right) = 43,6$$

Diperkirakan balok tepi pelat mempunyai lebar, b = 250 mm, maka :

lnx = 3500 – ½ x 250 = 3375 mm

lny = 4000 – ½ x 250 = 3875 mm

Dengan asumsi bahwa pembebanan pada pelat bak mandi sebagai beban khusus (QL=15 kN/m^2), maka :

berdasarkan persyaratan PBBI 1971 bahwa tebal pelat tidak boleh kurang dari 7 cm untuk pelat atap, dan 12 cm untuk pelat lantai, serta memperhitungkan tebal selimut beton pada kondisi bersentuhan dengan air dan jarak antar tulangan atas dan bawah tidak boleh kurang dari 2,5 cm, serta luas bidang pelat (Lx = 3,5 m dan Ly = 4 m) maka asumsi awal tebal pelat lantai bak adalah 14 cm = 140 mm, dengan :

- Menggunakan tulangan pokok Ø 10 mm
- Penutup beton (Pb) digunakan 35 mm

Maka, tinggi manfaat tulangan pelat lantai :

- Arah x : dx $= h - Pb - \frac{1}{2}\emptyset_{tul.x}$

$= 140 - 35 - \frac{1}{2} \times 10$

$= 100$ mm

- Arah y : dy $= h - Pb - \emptyset_{tul.x} - \frac{1}{2}\emptyset_{tul.y}$

$= 140 - 35 - 10 - \frac{1}{2}.10$

$= 90$mm

➢ Momen-momen yang bekerja pada pelat :

Mulx = -Mutx $= 0{,}001 \,.\, qU \,.\, lx^2 \,.\, C$

$= 0{,}001 \,.\, 30{,}072 \,.\, 3{,}5^2 \,.\, 43{,}6 = 16{,}061$ kN m

Muly = (-)Muty $= 0{,}001 \,.\, 30{,}072 \,.\, 3{,}5^2 \,.\, 37{,}4 = 13{,}111$ kN m

1) Perencanaan Tulangan lx dan tx

Mulx = (-)Mutx $= 16{,}061$ kN m

$Mu/\phi = 16{,}061/0{,}8 = 20{,}1$ kNm

Rasio Tulangan (ρ)

$$\rho b = \frac{0{,}85.f'c.\beta_1}{fy}\left(\frac{600}{600+fy}\right) = \frac{0{,}85.\,22{,}5.\,0{,}85}{240}\left(\frac{600}{600+240}\right) = 0{,}0484$$

$$\rho_{min} = \frac{1{,}4}{fy} = \frac{1{,}4}{240} = 0{,}00583$$

$$\rho_{max} = 0{,}75 \,.\, \rho b = 0{,}75 \,.\, 0{,}0484 = 0{,}0363$$

$$m = \frac{fy}{0{,}85.f'c} = \frac{240}{0{,}85.22{,}5} = 12{,}50$$

Koefisien ketahanan (Rn) :

$$Rn = \frac{Mu/\phi}{b.d^2} = \frac{20{,}1 \; x \; 1.10^6}{1000.100^2} = 2{,}0 \text{ Mpa}$$

$$\rho_{ada} = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2m.Rn}{fy}}\right) = \frac{1}{12{,}5}\left(1 - \sqrt{1 - \frac{2 \times 12{,}5 \times 2{,}0}{240}}\right)$$

$$= 0{,}0088 \quad < \rho_{max} = 0{,}0363$$

$$> \rho_{min} = 0{,}0058$$

$$\rho_{pakai} = \rho_{ada} = 0{,}0088$$

$$As_{\rho} = \rho_{pakai} \; . \; b \; . \; d \geq 0{,}002 \; . \; b \; . \; h$$

$$= 0{,}0088 \; . \; 1000 \; . \; 100 \geq 0{,}002 \; . \; 1000 \; . \; 140$$

$$= 885{,}7624 \text{ mm}^2 \geq 280 \text{ mm}^2$$

digunakan tulangan pokok Ø 10 mm, sehingga :

$$A_1 Ø = \tfrac{1}{4} \; . \; \pi \; . \; D^2 = \tfrac{1}{4} \; . \; \pi \; . \; 10^2 = 78{,}50 \text{ mm}^2$$

Jarak tulangan (s) $= \dfrac{A_1 \phi . b}{As_{\rho}}$

$$= \frac{78{,}5. \; 1000}{885{,}7624}$$

$$= 88{,}6242 \text{ mm}$$

dipakai s = 85 mm, maka Tulangan Pokok : P10 – 85

$$As_{ada} = \frac{A_1 \phi . b}{s} = \frac{78{,}50. \; 1000}{85} = 923{,}5294 \text{ mm}^2$$

Kontrol Kapasitas Lentur Pelat (arah x) :

$$a = \frac{As_{ada}.fy}{0{,}85.f'c.b} = \frac{923{,}5294 \,.\, 240}{0{,}85.22{,}5.1000} = 11{,}6 \text{ mm}$$

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

$$= 923{,}5294 \,.\, 240 \left(100 - \frac{11{,}6}{2} \right) / 10^6$$

$$= 20{,}8803 \text{ kNm} \geq 20{,}077 \text{ kN m} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{OK !}$$

2) Perencanaan Tulangan ly dan ty

Muly = -Muty = 13,111 kN m

$$\frac{Mu}{\phi} = \frac{13{,}111}{0{,}8} = 17{,}2 \text{ kN m}$$

Rasio Tulangan (ρ)

$$\rho b = \frac{0{,}85.f'c.\beta_1}{fy}\left(\frac{600}{600+fy}\right) = \frac{0{,}85.\,22{,}5.\,0{,}85}{240}\left(\frac{600}{600+240}\right) = 0{,}0484$$

$$\rho_{min} = \frac{1{,}4}{fy} = \frac{1{,}4}{240} = 0{,}00583$$

$$\rho_{max} = 0{,}75 \,.\, \rho b = 0{,}75 \,.\, 0{,}0484 = 0{,}0363$$

$$m = \frac{fy}{0{,}85.f'c} = \frac{240}{0{,}85.22{,}5} = 12{,}5$$

Koefisien ketahanan (Rn) :

$$Rn = \frac{\frac{Mu}{\phi}}{b.d^2} = \frac{17{,}2219x10^6}{1000.\,90^2} = 2{,}1 \text{ Mpa}$$

$$\rho_{ada} = \frac{1}{m}\left(1-\sqrt{1-\frac{2m.Rn}{fy}}\right) = \frac{1}{12,5}\left(1-\sqrt{1-\frac{2\times 12,5\times 2,1}{240}}\right)$$

$= 0,0094 \quad < \rho_{max} = 0,04032$

$> \rho_{min} = 0,00583$, maka :

$\rho_{pakai} = \rho_{ada} = 0,0094$

$As_p = \rho_{pakai} \cdot b \cdot d \geq 0,002 \cdot b \cdot h$

$= 0,0094 \cdot 1000 \cdot 90$

$= 847,3671 \text{ mm}^2 \geq 280 \text{ mm}^2$

digunakan tulangan pokok Ø 10 mm, sehingga :

$A_1 Ø = \frac{1}{4} \cdot \pi \cdot D^2 = \frac{1}{4} \cdot \pi \cdot 10^2 = 78,50 \text{ mm}^2$

Jarak tulangan (s) $= \frac{A_1 \phi . b}{As_p}$

$= \frac{78,50 . 1000}{847,3671}$

$= 92,6399 \text{ mm}$

Dipakai s = 90 mm, maka Tulangan Pokok : P10 – 90

$As_{ada} = \frac{A_1 \phi . b}{s} = \frac{78,50 \cdot 1000}{90} = 862,6374 \text{ mm}^2$

Kontrol Kapasitas Lentur Pelat (arah y) :

$a = \frac{As_{ada} . fy}{0,85 . f'c . b} = \frac{862,6374 . 240}{0,85 . 22,5 . 1000} = 10,8253 \text{ mm}$

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

$= 862{,}6374 \cdot 240 \left(90 - \frac{10{,}8253}{2} \right) / 10^6$

$= 17{,}5 \text{ kN m} \geq \frac{Mu}{\phi} = 17{,}2 \text{ kN m}$ .....OK!

3) Perencanaan Tulangan Bagi

$As_{susut} = 0{,}002 \cdot b \cdot h = 0{,}002 \cdot 1000 \cdot 140 = 280 \text{ mm}^2$

digunakan tulangan bagi Ø 10 mm, sehingga :

$A_1 Ø = \frac{1}{4} \cdot \pi \cdot D^2 = \frac{1}{4} \cdot \pi \cdot 10^2 = 78{,}5 \text{ mm}^2$

Jarak tulangan bagi (s) $= \frac{A_1 \phi . b}{As_{susut}}$

$= \frac{78{,}5 . 1000}{280} = 280{,}35 \text{ mm}$

maka dipakai Tulangan Bagi : P10 - 280

4) Perencanaan Tulangan Susut Pelat Bak Air

$As_{susut} = 0{,}002 \cdot b \cdot h$

$= 0{,}002 \cdot 1000 \cdot 140 = 280 \text{ mm}^2$

digunakan tulangan susut Ø 8 mm, sehingga :

$A_1 Ø = \frac{1}{4} \cdot \pi \cdot D^2 = \frac{1}{4} \cdot \pi \cdot 8^2 = 50{,}24 \text{ mm}^2$

Jarak tulangan susut (s) $= \frac{A_1 \phi . b}{As_{susut}}$

$= \frac{50{,}24 . 1000}{280} = 179{,}4285 \text{ mm}$

dipakai s susut = 170 mm, maka Tulangan Bagi : P8 - 170

4.3 Perencanaan Balok Anak

4.3.1 Pembebanan dan perhitungan Balok anak

a. Pembebanan Balok Anak

Beban mati (QD) = 4,88 KN/m^2 (diambil dari hitungan pembebanan pelat lantai)

Beban hidup (QL) = 2,5 KN/m^2 (diambil dari hitungan pembebanan pelat lantai)

Perkiraan ukuran balok :

L = 3,5 m = 350 cm

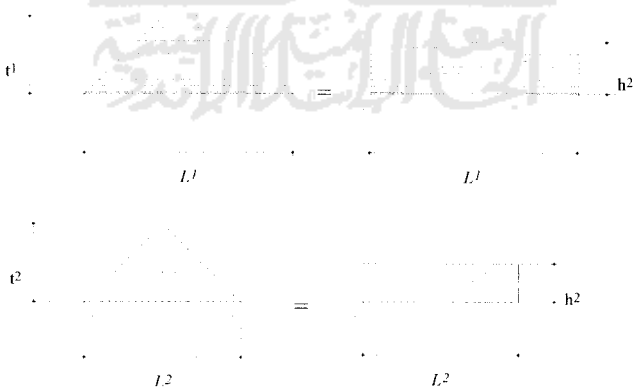
$$h = \frac{1}{10}.L$$

$$h = \frac{1}{10}.350 = 35 \text{ cm} \approx 40 \text{ cm} = 0{,}4 \text{ m}$$

$$b = \frac{1}{2}.h = \frac{1}{2}.40 = 20 \text{ cm} = 0{,}2 \text{ m}$$

sehingga asumsi ukuran balok = 0,2 m x 0,4 m

Berat sendiri = (0,2 x 0,4) x 24 = 1,92 kN/m'



Gambar 4.10 pembebanan balok anak

$$h_1 = t_1 - \frac{4}{3}.\frac{t_1^{\,3}}{L_1^{\,2}}$$

$$h_2 = \frac{2}{3}t_2$$

Untuk bentang 3,5 m, maka $h_1 = 1{,}15 - \frac{4}{3}.\frac{1{,}15^3}{3{,}5^2} = 0{,}984$ m

$$h_2 = \frac{2}{3}.1{,}75 = 1{,}167 \text{ m}$$

qD = ((4,58 x 0,984) + (4,88 x 1,167)) + 1,92 = 11,75 KN/m'

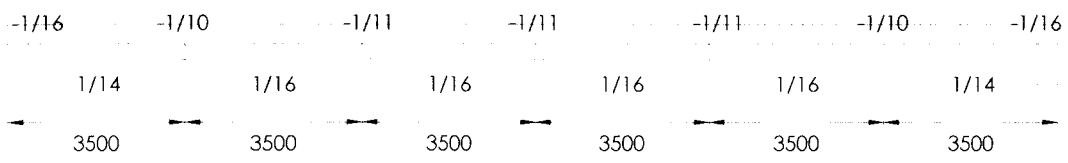
qL = (2,5 x 0,984) + (2,5 x 1,167) = 5,378 KN/m'

qU = (1,2 x 11,75) + (1,6 x 5,378) = 22,581 KN/m'

b. Perhitungan Momen Balok Anak

Berdasarkan SK SNI T – 15 – 1991 – 03 Bab 3 disebutkan bahwa cara pendekatan untuk momen yang terjadi pada balok yang terletak atas 4 atau lebih tumpuan, terjepit elastis atau menerus pada tumpuan-tumpuan tengah dan terjepit elastis pada tumpuan-tumpuan ujung adalah sebagai berikut :

- Momen tumpuan ujung $-\frac{1}{16}ql_t^2$
- Momen lapangan ujung $+\frac{1}{14}ql_t^2$
- Momen tumpuan kedua $-\frac{1}{10}ql_t^2$
- Momen lapangan berikutnya $+\frac{1}{16}ql_t^2$
- Momen tumpuan berikutnya $-\frac{1}{11}ql_t^2$



Gambar 4.11 Koefisien Momen

Dengan panjang (l) tiap Bentang 3,5 m, maka :

$$Mu_1 = \frac{1}{16}.q_u.l^2 = \frac{1}{16}.22{,}58.3{,}5^2 = 17{,}29 \text{ KNm}$$

$$Mu_2 = \frac{1}{14}.q_u.l^2 = \frac{1}{14}.22{,}58.3{,}5^2 = 19{,}757 \text{ KNm}$$

$$Mu_3 = \frac{1}{11}.q_u.l^2 = \frac{1}{11}.22{,}58.3{,}5^2 = 25{,}15 \text{ KNm}$$

$$Mu_4 = \frac{1}{10}.q_u.l^2 = \frac{1}{10}.22.58.3{,}5^2 = 27{,}66 \text{ KNm}$$

4.3.2 Perencanaan Penulangan Balok Anak

4.3.2.1 Perencanaan Tulangan Lentur Balok Anak

Data :

- f'c = 22,5 Mpa
- fy ulir = 400 Mpa
- fy polos = 240 Mpa
- Dia. tul. pokok = 16 mm
- Dia tul. sengkang = 10 mm

→ untuk f'c ≤ 30 Mpa → $\beta_1 = 0{,}85$

f'c > 30 Mpa → $\beta_1 = 0{,}85 - 0{,}008\ (f'c - 30) \geq 0{,}65$

a. Tulangan Tumpuan

Tumpuan 2 = 6 :

Mu = 27,66 KNm → $Mu/\phi = \frac{27{,}66}{0{,}8} = 32{,}668$ KNm

Dimensi rencana balok anak $^{20}/_{40}$, maka :

tinggi efektif balok (d) = 400 – 70 (dianggap tulangan sebelah)

= 330 mm

$$\rho b = \frac{0{,}85.f'c}{fy}.\beta_1\left(\frac{600}{600+fy}\right) = \frac{0{,}85.22{,}5}{400}.0{,}85\left(\frac{600}{600+400}\right) = 0{,}0244$$

$\rho_{maks} = 0{,}75 \;.\; \rho b = 0{,}75 \;.\; 0{,}0244 = 0{,}0183$

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

$\rho_{pakai} = 0{,}5 \;.\; \rho_{maks} = 0{,}5 \;.\; 0{,}0183 = 0{,}00915$

$$m = \frac{fy}{0{,}85.f'c} = \frac{400}{0{,}85.22{,}5} = 20{,}915$$

$Rn = \rho \;.\; fy\left(1 - {}^{1}/_{2}\rho \;.\; m\right) = 0{,}00915.400\left(1 - {}^{1}/_{2}\right).0{,}00915 \;.\; 20{,}915\ ) = 3{,}31$ Mpa

$$b.d^2 = \frac{Mu/\phi}{Rn}$$

$$d_{perlu} = \sqrt{\frac{Mu/\phi}{Rn.b}} = \sqrt{\frac{32{,}668.10^6}{3{,}31.200}} = 222{,}143 \text{ mm} > d = 330 \text{ mm} \rightarrow \text{dipakai tul. sebelah}$$

$$Rn_{ada} = \frac{Mu/\phi}{b.d^2{}_{ada}} = \frac{32{,}668.10^6}{200.330^2} = 1{,}4999 \text{ Mpa}$$

$$\rho_{ada} = \frac{Rn_{ada}}{Rn}\rho = \frac{1{,}4999}{3{,}31}0{,}00915 = 0{,}0041 > \rho_{min} = 0{,}0035 \text{ (OK!)}$$

$As = \rho_{ada}.b.d_{ada} = 0{,}0041 \;.\; 200 \;.\; 330 = 270{,}6 \text{ mm}^2$

Dipakai diameter tulangan D16, maka : $A_1\emptyset = 201{,}062 \text{ mm}^2$

$$n = \frac{As}{A_1\phi} = \frac{270{,}6}{201{,}062} = 1{,}346 \text{ batang}$$

Dipakai tulangan memanjang 2D16, maka :

As_{ada} = 2 . 201,062 = 402,124 mm^2 > As = 270,6 mm^2

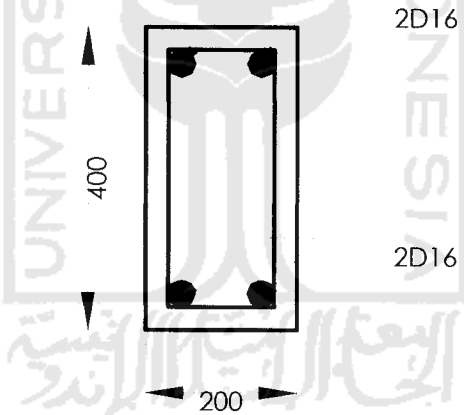
Kontrol Kapasitas Lentur yang terjadi :

$$a = \frac{As_{ada}.fy}{0{,}85.f'c.b} = \frac{402{,}124.400}{0{,}85.22{,}5.200} = 42{,}052 \text{ mm}$$

$$Mn = As_{ada} \text{ . fy . (d - } \frac{a}{2} \text{)} \geq Mu/\phi$$

$$= 402{,}124 \text{ . } 400 \text{ . (} 330 - \frac{42{,}052}{2} \text{)}$$

$$= 49{,}698 \text{ kN m} > Mu/\phi = 32{,}668 \text{ kN m} \qquad \text{(OK!)}$$



Gambar 4.12 Detail Penulangan Tumpuan 2 - 6

b. Tulangan Lapangan

Lapangan ujung :

Mu = 19,757 kN m

$$Mu/\phi = \frac{19,757}{0,8} = 24,696 \text{ KNm}$$

$$\rho b = \frac{0,85.f'c}{fy}.\beta_1\left(\frac{600}{600+fy}\right) = \frac{0,85.22,5}{400}.0,85\left(\frac{600}{600+400}\right) = 0,0244$$

$\rho_{maks} = 0,75 \cdot \rho b = 0,75 \cdot 0,0244 = 0,0183$

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

$\rho_{pakai} = 0,5 \cdot \rho_{maks} = 0,5 \cdot 0,0183 = 0,00915$

$$m = \frac{fy}{0,85.f'c} = \frac{400}{0,85.22,5} = 20,915$$

$Rn = \rho \cdot fy \left(1 - \frac{1}{2}\rho \cdot m \right) = 0,00915.400 \left(1 - \frac{1}{2} .0,00915 \cdot 20,915 \right) = 3,31$ Mpa

$$b.d^2 = \frac{Mu/\phi}{Rn}$$

$$d_{perlu} = \sqrt{\frac{Mu/\phi}{Rn.b}} = \sqrt{\frac{29,698.10^6}{3,31.200}} = 211,804 \text{ mm} < d = 330 \text{ mm}, \rightarrow \text{dipakai tul sebelah}$$

$$Rn_{ada} = \frac{Mu/\phi}{b.d^2_{ada}} = \frac{29,698.10^6}{200.330^2} = 1,364 \text{ Mpa}$$

$$\rho_{ada} = \frac{Rn_{ada}}{Rn}\rho = \frac{1,364}{3,31}0,00915 = 0,0038 > \rho_{min} = 0,0035 \text{ (OK!)}$$

$As = \rho_{ada}.b.d_{ada} = 0,0038 \cdot 200 \cdot 330 = 250,8 \text{ mm}^2$

Dipakai diameter tulangan D16, maka : $A_1Ø = 201,062 \text{ mm}^2$

$$n = \frac{As}{A_1\phi} = \frac{250,8}{201,062} = 1,247 \text{ batang}$$

Dipakai tulangan memanjang 2D16, maka :

$As_{ada} = 2 \,.\, 201,062 = 402,124 \text{ mm}^2 > As = 270,6 \text{ mm}^2$

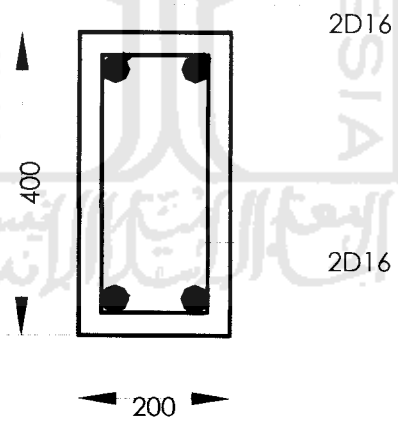
Kontrol Kapasitas Lentur yang terjadi :

$$a = \frac{As_{ada}.fy}{0,85.f'c.b} = \frac{402,124.400}{0,85.22,5.200} = 42,052 \text{ mm}$$

$$Mn = As_{ada} \,.\, fy \,.\, \left(d - \frac{a}{2} \right) \geq Mu/\phi$$

$$= 402,124 \,.\, 400 \,.\, \left(330 - \frac{42,052}{2} \right)$$

$$= 49,698 \text{ KNm} > Mu/\phi = 24,696 \text{ KNm} \qquad (\text{OK!})$$



Gambar 4.13 Detail Penulangan Lapangan 2-6

4.3.2.2 Perencanaan Tulangan Geser Balok Anak

a. Gaya Geser Dukungan

Berdasarkan SK SNI T – 15 – 1991 – 03 Bab 3 disebutkan bahwa cara pendekatan untuk geser yang terjadi pada struktur bentanga menerus balok (minimum 2 bentang) sebagai berikut :

Geser tumpuan ujung $1{,}15\left(\frac{1}{2}.qU.L\right)$

Geser tumpuan lainnya $\frac{1}{2}.qU.L$

Vu dukungan ujung $= 1{,}15\left(\frac{1}{2}.qU.L\right)$

$= 1{,}15\left(\frac{1}{2}.22{,}58.3{,}5\right) = 45{,}42$ kN

maka $Vu/\phi = \frac{45{,}42}{0{,}6} = 75{,}7$ kN

b. Gaya Geser Tengah Bentang

Vu tengah bentang $= \frac{1}{8}.qU.L$

$= \frac{1}{8}.22{,}58.3{,}5 = 9{,}87$ kN

maka $Vu/\phi = \frac{9{,}87}{0{,}6} = 16{,}46$ kN

Tegangan Geser Beton (Vc) :

$Vc = \left(\frac{1}{6}\sqrt{f'c}\right).b.d = \left(\frac{1}{6}\sqrt{22{,}5}\right).200.330.10^{-3} = 52{,}2\ kN$

$Vu/\phi = 75{,}7 > Vc = 52{,}2$ ➔ maka perlu tulangan geser

½ Vc = ½ × 52,2 = 26,1 kN

Vs_{min} = $\frac{1}{3}$.b.d = $\frac{1}{3}$. 200 . 330 = 22 kN

Penampang kritis sejarak d = 0,33 m dari muka tumpuan

$$Vu/\phi\ kritis = \frac{((1{,}75 - 0{,}33)(75{,}7 - 16{,}46))}{1{,}75} + 16{,}46 = 64{,}53 \text{ kN}$$

Vs = $Vu/\phi\ kritis - Vc$

= 64,53 – 52,2 = 12,33 < Vs_{min} = 22 ➔ maka dipakai Vs_{min}

Gambar 4.14 Diagram Tegangan Geser Balok Anak

Daerah I :

$Vu/\phi\ kritis$ = 64,53 < (Vc + Vs_{min}) = 74,2

Digunakan sengkang P8 mm, maka : Av = 2 . $\frac{1}{4}$. π . 8^2 = 100,5 mm^2

Jarak sengkang :

$$s \le \frac{Av.fy.d}{Vs} = \frac{100{,}5 \ . \ 240.330}{22}.10^{-3} = 361{,}7 \text{ mm}$$

$\le d/2 = 330/2 = 165$ mm

≤ 600 mm

Jadi dipakai tulangan sengkang P8 – 165 mm

Daerah II :

$0{,}5\ Vc < Vu/\phi \leq Vc = 52{,}178$ kN

Digunakan sengkang P8 mm, maka : $Av = 2 \cdot \frac{1}{4} \cdot \pi \cdot 8^2 = 100{,}5\ mm^2$

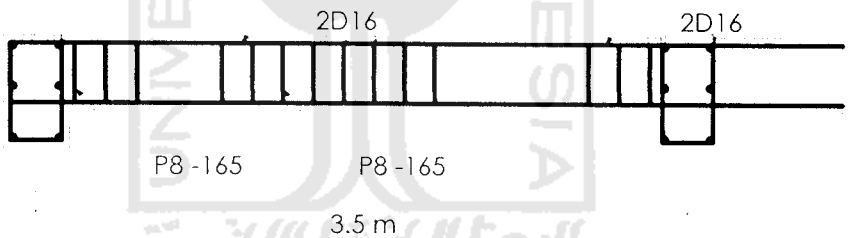
Jarak sengkang :

$$s \leq \frac{Av.fy.d}{Vs_{MIN}} = \frac{100{,}5.240.330}{22}.10^{-3} = 361{,}7 \text{ mm}$$

$$\leq d/2 = 330/2 = 165 \text{ mm}$$

$$\leq 600 \text{ mm}$$

Jadi dipakai tulangan sengkang P8 – 165 mm



Gambar 4.15 Tulangan Geser Balok Anak

4.4 Perencanaan struktur portal dengan daktilitas penuh

Pada perencananaan ulang Pembangunan Gedung Ruang IRI dan IRNA Rumah Sakit Bethesda Jogjakarta dengan SAP 2000 dengan analisis struktur tiga (3) Dimensi, dan beban yang bekerja pada struktur adalah

4.4.1 Perhitungan Gaya Gravitasi Total Akibat beban mati dan beban hidup

1. Beban Mati (QD)

- Pembebanan plat lantai : 4,88 kN/m^2
- Pembebanan Plat Atap dan Canopi : 3,06 kN/m^2
- Pembebanan Plat Bak Air dan mesin : 5,06 kN/m^2
- Pembebanan Dinding ½ Bata (PPIUG '83; tabel 2.1) : 2,50 kN/m^2

2. Beban hidup (QL)

- Beban hidup plat lantai untuk rumah sakit (PPIUG '83) : 2,50 kN/m^2
- Beban hidup plat atap (PPIUG '83; pasal 3.1) : 1,00 kN/m^2
- Beban hidup plat bak air dan mesin (PPIUG '83) : 15,0 kN/m^2
- Beban hidup pekerja pada atap (PPIUG '83; P 3.2.2b) : 1,00 kN

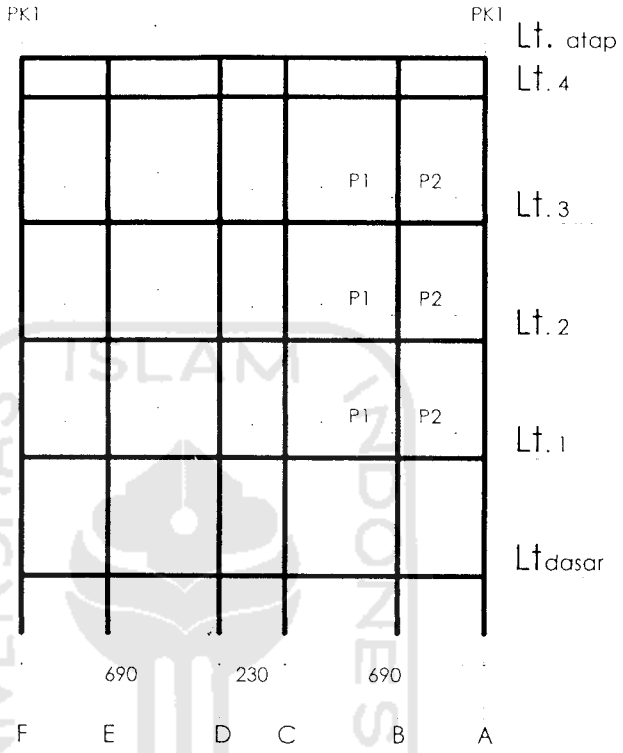
Pemodelan jenis beban pada SAP 2000, terbagi atas :

1. Pemodelan Trapesium, untuk beban mati dan beban hidup plat
2. Pemodelan Segitiga, untuk beban mati dan beban hidup plat
3. Pemodelan Merata, untuk beban penyaluran dari dinding pas bata ½ batu
4. Pemodelan titik, untuk beban penyaluran dari atap, dan balok anak

   P = Q (beban merata) × L (panjang penyaluran beban)

4.4.4.1 Perhitungan Beban Akibat Gravitasi

A. Portal As a – a



2) lantai 1,2,3

➢ beban merata

Bentang F-E

Plat lantai (QD)	= 1,25 × 4,88	= 6,10	kN/m (trapesium)
Plat lantai (QL)	= 1,25 × 2,50	= 3,12	kN/m (trapesium)
Plat canopi	= 0,50 × 3,06	= 1,53	kN/m (trapesium)
Dinding ½ bt	= 3,5 × 2,5	= 8,75	kN/m (merata)

Bentang E-D

Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (trapesium)
Plat lantai (QL)	= 1,75 × 2,50	= 4,38	kN/m (trapesium
Plat canopi	= 0,50 × 3,06	= 1,53	kN/m (trapesium)
Dinding ½ bt	= 3,5 × 2,5	= 8,75	kN/m (merata)

Bentang D-C

Plat lantai (QD)	= 1,15 × 4,88	= 5,61	kN/m (segitiga)
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (segitiga)
Plat canopi	= 0,50 × 3,06	= 1,53	kN/m (trapesium)
Dinding ½ bt	= 3,5 × 2,5	= 8,75	kN/m (merata)

Bentang C-B1

Plat lantai (QD)	= 1,25 × 4,88	= 6,10	kN/m (segitiga)
Plat lantai (QL)	= 1,25 × 2,50	= 3,12	kN/m (segitiga)

Bentang C-B

Plat canopi	= 0,50 × 3,06	= 1,53	kN/m (trapesium)
Dinding ½ bt	= 3,5 × 2,5	= 8,75	kN/m (merata)

Bentang B1-A1

Plat lantai (QD)	= 0,875 × 4,88	= 4,27	kN/m (trapesium)
Plat lantai (QL)	= 0,875 × 2,50	= 2,20	kN/m (trapesium)

Bentang B-A

Plat canopi	= 0,50 × 3,06	= 1,53	kN/m (trapesium)
Dinding ½ bt	= 3,5 × 2,5	= 8,75	kN/m (merata)

Bentang A1-A

Plat lantai (QD) = 0,875 × 4,88 = 4,27 kN/m (trapesium)

Plat lantai (QL) = 0,875 × 2,50 = 2,20 kN/m (trapesium)

- beban terpusat

beban terpusat merupakan beban penyaluran dari beban balok anak, maka beban terpusat diambil dari reaksi yang terjadi pada balok anak. Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

PD1 = ½ qD × L = ½ × 13,1 × 3,5 = 22,9 kN

PL1 = ½ qD × L = ½ × 5,83 × 3,5 = 10,2 kN

PD2 = ½ qD × L = ½ × 13,08 × 3,5 = 22,9 kN

PL2 = ½ qD × L = ½ × 5,83 × 3,5 = 10,2 kN

3) lantai 4

Bentang F-E; E-D; D-C; C-B; B-A

Plat canopi = 0,50 × 3,06 = 1,53 kN/m (trapesium)

Dinding ½ bt = 1,00 × 2,50 = 2,50 kN/m (merata)

- beban terpusat

beban terpusat merupakan beban penyaluran dari atap, maka beban terpusat diambil dari reaksi yang terjadi pada kostruksi atap. Terbagi atas :

Genteng, usuk, reng : 0,5 kN/m^2 × 3,5 × (9,55× 1/cos 35) = 20,49 kN

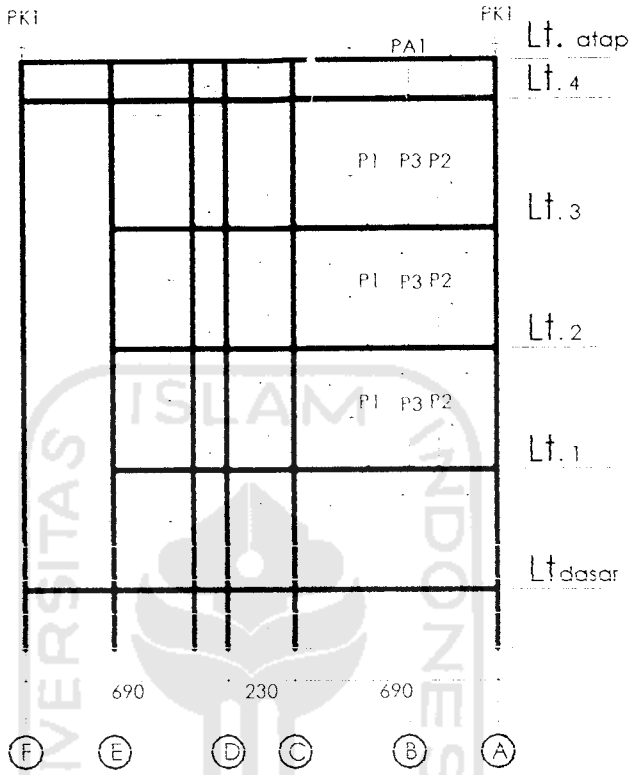
Gording (150x50x20x2,3) : 0,0496 × 3,5 m × 7 baris = 1,215 kN

Kuda-kuda (KK1) : 0,5 kN/m × 8,05 = 4,025 kN

Beban mati PK 1 = 25,73 kN

Beban Hidup PK 1 : 1 kN × 7 titik = 7,0 kN

B. Portal As b – b



1) lantai 1,2,3

- beban merata

Bentang E-D

Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (trapesium)
Plat lantai (QL)	= 1,75 × 2,50	= 4,38	kN/m (trapesium)

Bentang D2-D

Plat lantai (QD)	= 0,50 × 4,88	= 2,44	kN/m (segitiga)
Plat lantai (QL)	= 0,50 × 2,50	= 1,25	kN/m (segitiga)

Bentang D-C

Plat lantai (QD)	= 1,15 × 4,88	= 5,621	kN/m (segitiga) × 2
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (segitiga) × 2

Bentang C-B1

Plat lantai (QD)	= 1,25 · 4,88	= 6,10	kN/m (segitiga)
Plat lantai (QL)	= 1,25 · 2,50	= 3,13	kN/m (segitiga)

Bentang C-B

Plat lantai (QD)	= 1,75 · 4,88	= 8,54	kN/m (trapesium)
Plat lantai (QL)	= 1,75 · 2,50	= 4,38	kN/m (trapesium)
Dinding ½ bt	= 3,50 · 2,50	= 8,75	kN/m (merata)

Bentang B1-A1

Plat lantai (QD)	= 0,875 × 4,88	= 4,29	kN/m (trapesium)
Plat lantai (QL)	= 0,875 × 2,50	= 2,19	kN/m (trapesium).

Bentang B-A

Plat lantai (QD)	= 1,50 × 4,88	= 7,32	kN/m (segitiga)
Plat lantai (QL)	= 1,50 × 2,50	= 3,75	kN/m (segitiga)
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang A1-A

Plat lantai (QD)	= 0,875 × 4,88	= 4,27	kN/m (trapesium)
Plat lantai (QL)	= 0,875 × 2,50	= 2,19	kN/m (trapesium)

- beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

PD1	= ½ qD × L	= ½ × 13,1 × 3,5	= 22,9 kN
PL1	= ½ qD × L	= ½ × 5,83 × 3,5	= 10,2 kN
PD2	= ½ qD × L	= ½ × 13,08 × 3,5	= 22,9 kN
PL2	= ½ qD × L	= ½ × 5,83 × 3,5	= 10,2 kN

PD3 = ½ qD × L = ½ × 12,94 × 3,5 = 22,65 kN

PL3 = ½ qD × L = ½ × 5,76 × 3,5 = 10,10 kN

2) lantai 4

Bentang E-D

Plat lantai (QD) = 0,50 × 5,06 = 2,53 kN/m (trapesium)

Plat lantai (QL) = 0,50 × 15,0 = 7,50 kN/m (trapesium)

Bentang D2-D

Plat lantai (QD) = 0,50 × 5,06 = 2,53 kN/m (segitiga)

Plat lantai (QL) = 0,50 × 15,0 = 7,50 kN/m (segitiga)

Bentang D-C

Plat bak air (QD) = 1,15 × 5,06 = 5,82 kN/m (segitiga)

Plat bak air (QL) = 1,15 × 15 = 17,25 kN/m (segitiga)

Bentang C-B

Plat bak air (QD) = 1,75 × 5,06 = 8,86 kN/m (trapesium)

Plat bak air (QL) = 1,75 × 15 = 26,25 kN/m (trapesium)

Bentang B-A

Plat bak air (QD) = 1,50 × 5,06 = 7,59 kN/m (segitiga)

Plat bak air (QL) = 1,50 × 15 = 22,5 kN/m (segitiga)

- beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

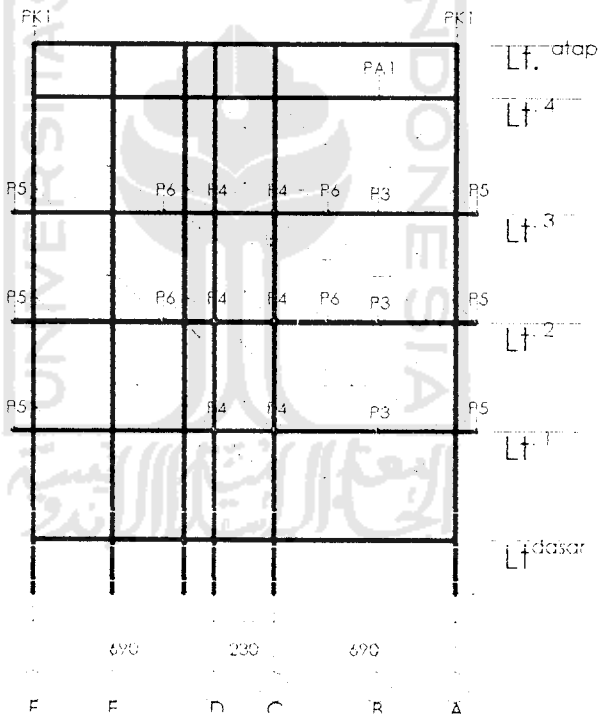
Pa D1 = ½ qD × L = ½ × 13,48 × 3,5 = 23,6 kN

Pa L1 = ½ qD × L = ½ × 34,35 × 3,5 = 60,4 kN

kostruksi atap. Terbagi atas :

Genteng, usuk, reng	: 0,5 kN/m^2 × 3,5 × (9,55×1/cos 35)	= 20,49	kN
Gording (150x50x20x2,3)	: 0,0496 × 3,5 m × 7 baris	= 1,215	kN
Kuda-kuda (KK1)	: 0,5 kN/m × 8,05	= 4,025	kN
	Beban mati PK 1	= 25,73	kN
Beban Hidup PK 1	: 1 kN × 7 titik	= 7,0	kN

C. Portal As c – c



1) Lantai 1

- Beban merata

Bentang F1-E1

Plat lantai (QD)	= 0,875 × 4,88	= 4,27	kN/m (segitiga)
Plat lantai (QL)	= 0,875 × 2,50	= 2,19	kN/m (segitiga)
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang E1-D

Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (trapesium)
Plat lantai (QL)	= 1,75 × 2,50	= 4,38	kN/m (trapesium)
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang D2-D

Plat lantai (QD)	= 0,58 × 4,88	= 2,83	kN/m (segitiga)
Plat lantai (QL)	= 0,58 × 2,50	= 1,45	kN/m (segitiga)

Bentang D-C

Plat lantai (QD)	= 1,15 × 4,88	= 5,61	kN/m (segitiga) × 2
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (segitiga) × 2

Bentang C-B

Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (trapesium)
Plat lantai (QL)	= 1,75 × 2,50	= 4,38	kN/m (trapesium)
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang C-A1

Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (trapesium)
Plat lantai (QL)	= 1,75 × 2,50	= 4,38	kN/m (trapesium)

Bentang B-A

Plat lantai (QD)	= 1,50 × 4,88	= 7,32	kN/m (segitiga)
Plat lantai (QL)	= 1,50 × 2,50	= 3,75	kN/m (segitiga)
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang A-A`1

Plat lantai (QD) = 0,875 · 4,88 = 4,27 kN/m (segitiga)

Plat lantai (QL) = 0,875 · 2,50 = 2,19 kN/m (segitiga)

- Beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

PD3 = ½ qD · L = ½ · 12,94 · 3,5 = 22,65 kN

PL3 = ½ qD · L = ½ · 5,76 · 3,5 = 10,1 kN

PD4 = ½ qD · L = ½ · 12,52 · 3,5 = 21,44 kN

PL4 = ½ qD · L = ½ · 5,38 · 3,5 = 9,41 kN

PD5 = ½ qD · L = ½ · 7,74 · 3,5 = 13,55 kN

PL5 = ½ qD · L = ½ · 2,92 · 3,5 = 5,11 kN

2) lantai 2,3

- Beban merata

Bentang F1-E1

Plat lantai (QD) = 0,875 × 4,88 = 4,27 kN/m (segitiga)

Plat lantai (QL) = 0,875 × 2,50 = 2,19 kN/m (segitiga)

Dinding ½ bt = 3,50 × 2,50 = 8,75 kN/m (merata)

Bentang E1-D1

Plat lantai (QD) = 1,75 × 4,88 = 8,54 kN/m (trapesium)

Plat lantai (QL) = 1,75 × 2,50 = 4,38 kN/m (trapesium)

Dinding ½ bt = 3,50 × 2,50 = 8,75 kN/m (merata)

Bentang D-D1

Plat lantai (QD) = 0,875 × 4,88 = 4,27 kN/m (trapesium)

Plat lantai (QL)	= 0,875 × 2,50	= 2,19	kN/m (trapesium)
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)
<u>Bentang D2-D</u>			
Plat lantai (QD)	= 0,58 × 4,88	= 2,83	kN/m (segitiga)
Plat lantai (QL)	= 0,58 × 2,50	= 1,45	kN/m (segitiga)
<u>Bentang D-C</u>			
Plat lantai (QD)	= 1,15 × 4,88	= 5,61	kN/m (segitiga) × 2
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (segitiga) × 2
<u>Bentang C-B</u>			
Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (trapesium)
Plat lantai (QL)	= 1,75 × 2,50	= 4,38	kN/m (trapesium)
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)
<u>Bentang C-B1</u>			
Plat lantai (QD)	= 0,875 × 4,88	= 4,27	kN/m (trapesium)
Plat lantai (QL)	= 0,875 × 2,50	= 2,19	kN/m (trapesium)
<u>Bentang B1-A1</u>			
Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (trapesium)
Plat lantai (QL)	= 1,75 × 2,50	= 4,38	kN/m (trapesium)
<u>Bentang B-A</u>			
Plat lantai (QD)	= 1,50 × 4,88	= 7,32	kN/m (segitiga)
Plat lantai (QL)	= 1,50 × 2,50	= 3,75	kN/m (segitiga)
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang A-A'1

Plat lantai (QD) = 0,875 × 4,88 = 4,27 kN/m (segitiga)

Plat lantai (QL) = 0,875 × 2,50 = 2,19 kN/m (segitiga)

- Beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

PD3 = ½ qD × L = ½ × 12,94 × 3,5 = 22,65 kN

PL3 = ½ qD × L = ½ × 5,76 × 3,5 = 10,1 kN

PD4 = ½ qD × L = ½ × 12,52 × 3,5 = 21,44 kN

PL4 = ½ qD × L = ½ × 5,38 × 3,5 = 9,41 kN

PD5 = ½ qD × L = ½ × 7,74 × 3,5 = 13,55 kN

PL5 = ½ qD × L = ½ × 2,92 × 3,5 = 5,11 kN

PD6 = ½ qD × L = ½ × 15,77 × 3,5 = 27,6 kN

PL6 = ½ qD × L = ½ × 5,84 × 3,5 = 10,22 kN

3) lantai 4

- beban merata

Bentang D-C

Plat lantai (QD) = 1,15 × 5,06 = 5,82 kN/m (segitiga)

Plat lantai (QL) = 1,15 × 15 = 17,25 kN/m (segitiga)

Bentang C-B

Plat lantai (QD) = 1,75 × 5,06 = 8,86 kN/m (trapesium)

Plat lantai (QL) = 1,75 × 15 = 26,25 kN/m (trapesium)

Bentang B-A

Plat lantai (QD) = 1,50 × 5,06 = 7,59 kN/m (segitiga)

Plat lantai (QL) = 1,50 × 15 = 22,5 kN/m (segitiga)

- beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

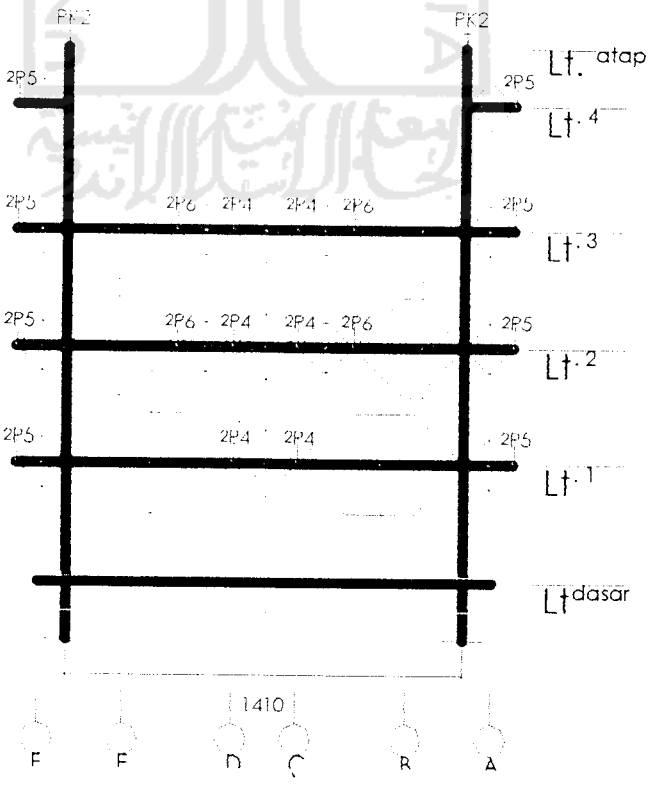
Pa D1 = ½ qD × L = ½ × 13,48 × 3,5 = 23,6 kN

Pa L1 = ½ qD × L = ½ × 34,35 × 3,5 = 60,4 kN

kostruksi atap. Terbagi atas :

Genteng, usuk, reng	: 0,5 kN/m^2 × 3,5 × (9,55×1/cos 35)	= 20,49	kN
Gording (150x50x20x2,3)	: 0,0496 × 3,5 m × 7 baris	= 1,215	kN
Kuda-kuda (KK1)	: 0,5 kN/m × 8,05	= 4,025	kN
	Beban mati PK 1	= 25,73	kN
Beban Hidup PK 1	: 1 kN × 7 titik	= 7,0	kN

D. Portal As d – d s/d Portal As h – h



1) Lantai 1

- Beban merata

Bentang F1-F

Plat lantai (QD)	= 0,875 · 4,88	= 4,27	kN/m (segitiga) × 2
Plat lantai (QL)	= 0,875 · 2,50	= 2,19	kN/m (segitiga) × 2
Dinding ½ bt	= 3,50 · 2,50	= 8,75	kN/m (merata)

Bentang E1-D

Plat lantai (QD)	= 1,75 · 4,88	= 8,54	kN/m (trapesium) × 2
Plat lantai (QL)	= 1,75 · 2,50	= 4,38	kN/m (trapesium) × 2
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang D-C

Plat lantai (QD)	= 1,15 · 4,88	= 4,27	kN/m (segitiga) × 2
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (segitiga) × 2

Bentang C-A1

Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (trapesium) × 2
Plat lantai (QL)	= 1,75 × 2,50	= 4,38	kN/m (trapesium) × 2

Bentang A1-A`1

Plat lantai (QD)	= 0,875 × 4,88	= 4,27	kN/m (segitiga) × 2
Plat lantai (QL)	= 0,875 × 2,50	= 2,19	kN/m (segitiga) × 2
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)

- Beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

2PD4 = ½ qD × L = ½ × 12,52 × 3,5 = 21,44 kN

2PL4 = ½ qD × L = ½ × 5,38 × 3,5 = 9,41 kN

2PD5 = ½ qD × L = ½ × 7,74 × 3,5 = 13,55 kN

2PL5 = ½ qD × L = ½ × 2,92 × 3,5 = 5,11 kN

2) lantai 2,3

➢ Beban merata

Bentang F1-F

Plat lantai (QD)	= 0,875 × 4,88	= 4,27	kN/m (segitiga) × 2
Plat lantai (QL)	= 0,875 × 2,50	= 2,19	kN/m (segitiga) × 2
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang E1-D1

Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (trapesium) × 2
Plat lantai (QL)	= 1,75 × 2,50	= 4,38	kN/m (trapesium) × 2
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang D1-D

Plat lantai (QD)	= 0,875 × 4,88	= 4,27	kN/m (trapesium) × 2
Plat lantai (QL)	= 0,875 × 2,50	= 2,19	kN/m (trapesium) × 2
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang D-C

Plat lantai (QD)	= 1,15 × 4,88	= 4,27	kN/m (segitiga) × 2
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (segitiga) × 2

Bentang C-B1

Plat lantai (QD)	= 0,875 × 4,88	= 4,27	kN/m (trapesium) × 2
Plat lantai (QL)	= 0,875 × 2,50	= 2,19	kN/m (trapesium) × 2

Bentang B1-A1

Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (trapesium) × 2
Plat lantai (QL)	= 1,75 × 2,50	= 4,38	kN/m (trapesium) × 2
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang A1-A`1

Plat lantai (QD)	= 0,875 × 4,88	= 4,27	kN/m (segitiga) × 2
Plat lantai (QL)	= 0,875 × 2,50	= 2,19	kN/m (segitiga) × 2
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)

- Beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

2PD4 = ½ qD × L = ½ × 12,52 × 3,5 = 21,44 kN

2PL4 = ½ qD × L = ½ × 5,38 × 3,5 = 9,41 kN

2PD5 = ½ qD × L = ½ × 7,74 × 3,5 = 13,55 kN

2PL5 = ½ qD × L = ½ × 2,92 × 3,5 = 5,11 kN

2PD6 = ½ qD × L = ½ × 15,77 × 3,5 = 27,6 kN

2PL6 = ½ qD × L = ½ × 5,84 × 3,5 = 10,22 kN

3) lantai 4

- beban merata

Bentang F1-E1

Plat atap (QD)	= 0,875 × 3,06	= 2,68	kN/m (segitiga) × 2
Plat atap (QL)	= 0,875 × 1,0	= 0,875	kN/m (segitiga) × 2

Bentang A1-A`1

Plat atap (QD)	= 0,875 × 3,06	= 2,68	kN/m (segitiga) × 2

Plat atap (QL) = 0,875 × 1,0 = 0,875 kN/m (segitiga) × 2

- Beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

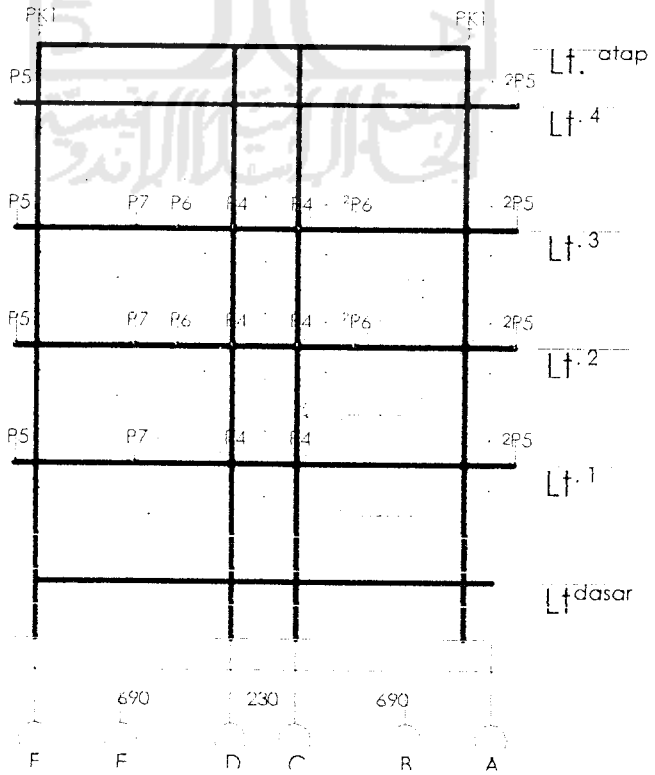
2PD5 = ½ qD × L = ½ × 7,74 × 3,5 = 13,55 kN

2PL5 = ½ qD × L = ½ × 2,92 × 3,5 = 5,11 kN

kostruksi atap. Terbagi atas :

Genteng, usuk, reng	: 0,5 kN/m^2 × 3,5 × (9,55 × 1/cos 35)	= 20,49	kN
Gording (150x50x20x2,3)	: 0,0496 × 3,5 m × 7 baris	= 1,215	kN
Kuda-kuda (KK I)	: 0,5 kN/m × 7,05	= 3,52	kN
	Beban mati PK 2	= 25,20	kN
Beban Hidup PK 2	: 1 kN × 7 titik	= 7,0	kN

E. Portal As I – I



1) Lantai 1

- Beban merata

Bentang F1-E1

Plat lantai (QD)	= 0,875 · 4,88	= 4,27	kN/m (segitiga)
Plat lantai (QL)	= 0,875 · 2,50	= 2,19	kN/m (segitiga)
Dinding ½ bt	= 3,50 · 2,50	= 8,75	kN/m (merata)

Bentang F-E

Plat lantai (QD)	= 1,70 · 4,88	= 8,30	kN/m (segitiga)
Plat lantai (QL)	= 1,70 · 2,50	= 4,25	kN/m (segitiga)
Dinding ½ bt	= 3,50 · 2,50	= 8,75	kN/m (merata)

Bentang E-D

Plat lantai (QD)	= 1,75 · 4,88	= 8,54	kN/m (segitiga)
Plat lantai (QL)	= 1,75 · 2,50	= 4,38	kN/m (segitiga)
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang E1-D

Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (trapesium)
Plat lantai (QL)	= 1,75 × 2,50	= 4,38	kN/m (trapesium)

Bentang D-C

Plat lantai (QD)	= 1,15 × 4,88	= 5,61	kN/m (segitiga) × 2
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (segitiga) × 2

Bentang C-A1

Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (trapesium) × 2
Plat lantai (QL)	= 1,75 × 2,50	= 4,38	kN/m (trapesium) × 2

Dinding ½ bt	= 3,50 · 2,50	= 8,75	kN/m (merata)

Bentang A1-A'1

Plat lantai (QD)	= 0,875 · 4,88	= 4,27	kN/m (segitiga) × 2
Plat lantai (QL)	= 0,875 · 2,50	= 2,19	kN/m (segitiga) × 2
Dinding ½ bt	= 3,50 · 2,50	= 8,75	kN/m (merata)

- Beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

PD4	= ½ qD × L = ½ × 12,52 × 3,5	= 21,44 kN
PL4	= ½ qD × L = ½ × 5,38 × 3,5	= 9,41 kN
2PD5	= ½ qD × L = ½ × 7,74 × 3,5	= 13,55 kN
2PL5	= ½ qD × L = ½ × 2,92 × 3,5	= 5,11 kN
PD7	= ½ qD × L = ½ × 31,11 × 3,5	= 54,44 kN
PL7	= ½ qD × L = ½ × 8,52 × 3,5	= 14,91 kN

2) lantai 2,3

- Beban merata

Bentang F1-E1

Plat lantai (QD)	= 0,875 × 4,88	= 4,27	kN/m (segitiga)
Plat lantai (QL)	= 0,875 × 2,50	= 2,19	kN/m (segitiga)
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang F-E

Plat lantai (QD)	= 1,70 × 4,88	= 8,30	kN/m (segitiga)
Plat lantai (QL)	= 1,70 × 2,50	= 4,25	kN/m (segitiga)
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang E-D

Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (segitiga)
Plat lantai (QL)	= 1,75 × 2,50	= 4,38	kN/m (segitiga)
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang E1-D1

Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (trapesium)
Plat lantai (QL)	= 1,75 × 2,50	= 4,38	kN/m (trapesium)

Bentang D1-D

Plat lantai (QD)	= 0,875 × 4,88	= 4,27	kN/m (trapesium)
Plat lantai (QL)	= 0,875 × 2,50	= 2,19	kN/m (trapesium)

Bentang D-C

Plat lantai (QD)	= 1,15 × 4,88	= 5,61	kN/m (segitiga) × 2
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (segitiga) × 2

Bentang C-B1

Plat lantai (QD)	= 0,875 × 4,88	= 4,27	kN/m (trapesium)
Plat lantai (QL)	= 0,875 × 2,50	= 2,19	kN/m (trapesium)

Bentang B1-A1

Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (trapesium) × 2
Plat lantai (QL)	= 1,75 × 2,50	= 4,38	kN/m (trapesium) × 2
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang A1-A'1

Plat lantai (QD)	= 0,875 × 4,88	= 4,27	kN/m (segitiga) × 2
Plat lantai (QL)	= 0,875 × 2,50	= 2,19	kN/m (segitiga) × 2

Dinding ½ bt = 3,50 × 2,50 = 8,75 kN/m (merata)

- Beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

PD4 = ½ qD × L = ½ × 12,52 × 3,5 = 21,44 kN

PL4 = ½ qD × L = ½ × 5,38 × 3,5 = 9,41 kN

2PD5 = ½ qD × L = ½ × 7,74 × 3,5 = 13,55 kN

2PL5 = ½ qD × L = ½ × 2,92 × 3,5 = 5,11 kN

2PD6 = ½ qD × L = ½ × 15,77 × 3,5 = 27,6 kN

2PL6 = ½ qD × L = ½ × 5,84 × 3,5 = 10,22 kN

PD6 = ½ qD × L = ½ × 15,77 × 3,5 = 27,6 kN

PL6 = ½ qD × L = ½ × 5,84 × 3,5 = 10,22 kN

PD7 = ½ qD × L = ½ × 31,11 × 3,5 = 54,44 kN

PL7 = ½ qD × L = ½ × 8,52 × 3,5 = 14,91 kN

3) lantai 4

- beban merata

Bentang F1-E1

Plat atap (QD) = 0,875 × 3,06 = 2,68 kN/m (segitiga) × 2

Plat atap (QL) = 0,875 × 1,0 = 0,875 kN/m (segitiga) × 2

Bentang A1-A'1

Plat atap (QD) = 0,875 × 3,06 = 2,68 kN/m (segitiga) × 2

Plat atap (QL) = 0,875 × 1,0 = 0,875 kN/m (segitiga) × 2

- Beban terpusat

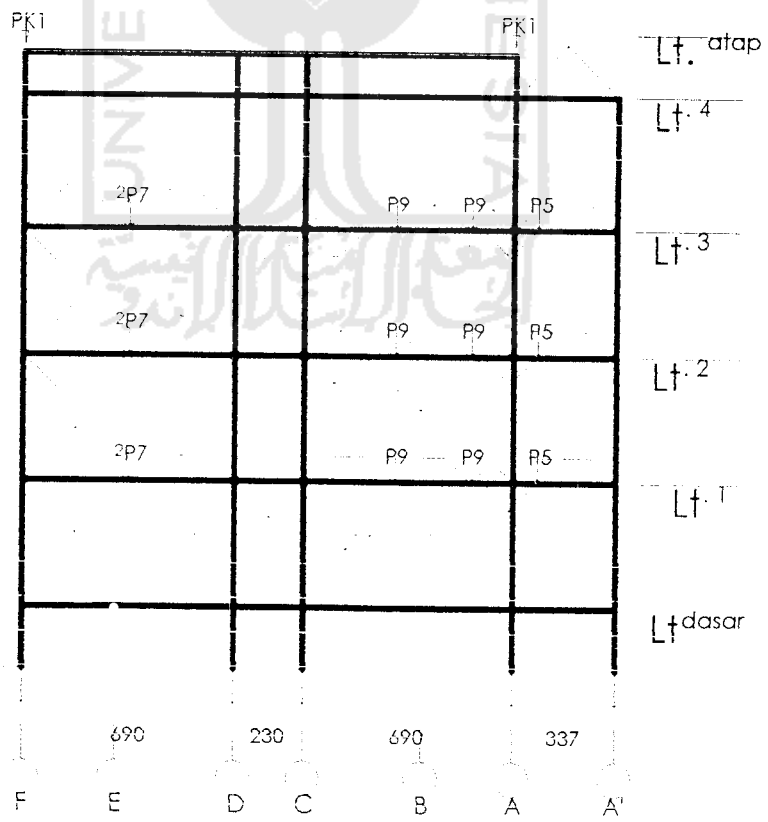
Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

PD5 = ½ qD · L = ½ · 7,74 × 3,5 = 13,55 kN

PL5 = ½ qD × L = ½ × 2,92 × 3,5 = 5,11 kN

Genteng, usuk, reng	: 0,5 kN/m^2 × 3,5 × (9,55×1/cos 35)	= 20,49	kN
Gording (150x50x20x2,3)	: 0,0496 × 3,5 m × 7 baris	= 1,215	kN
Kuda-kuda (KK1)	: 0,5 kN/m × 7,05	= 3,52	kN
	Beban mati PK 1	= 25,20	kN
Beban Hidup PK 1	: 1 kN × 7 titik	= 7,0	kN

F. Portal As j – j



1) Lantai 1

- Beban merata

Bentang F-E

Plat lantai (QD)	= 1,70 · 4,88	= 8,30	kN/m (segitiga) × 2
Plat lantai (QL)	= 1,70 · 2,50	= 4,25	kN/m (segitiga) × 2
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang E-D

Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (segitiga)
Plat lantai (QL)	= 1,75 × 2,50	= 4,38	kN/m (segitiga)
Plat lantai (QD)	= 0,82 × 4,88	= 4,00	kN/m (trapesium)
Plat lantai (QL)	= 0,82 × 2,50	= 2,05	kN/m (trapesium)
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang D-C

Plat lantai (QD)	= 1,15 × 4,88	= 5,61	kN/m (segitiga) × 2
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (segitiga) × 2

Bentang C-A1

Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (trapesium)
Plat lantai (QL)	= 1,75 × 2,50	= 4,38	kN/m (trapesium)

Bentang A1-A`1

Plat lantai (QD)	= 0,875 × 4,88	= 4,27	kN/m (segitiga)
Plat lantai (QL)	= 0,875 × 2,50	= 2,19	kN/m (segitiga)

Bentang C-B2

Plat lantai (QD)	= 0,82 × 4,88	= 4,00	kN/m (trapesium)
Plat lantai (QL)	= 0,82 × 2,50	= 2,05	kN/m (trapesium)
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang B2-A2

Plat lantai (QD)	= 0,82 × 4,88	= 4,00	kN/m (trapesium)
Plat lantai (QL)	= 0,82 × 2,50	= 2,05	kN/m (trapesium)
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang A2-A

Plat lantai (QD)	= 0,70 × 4,88	= 3,42	kN/m (segitiga)
Plat lantai (QL)	= 0,70 × 2,50	= 1,75	kN/m (segitiga)
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang A-A'1

Plat lantai (QD)	= 0,82 × 4,88	= 4,00	kN/m (trapesium)
Plat lantai (QL)	= 0,82 × 2,50	= 2,05	kN/m (trapesium)
Dinding ½ bt	= 3,50 × 2,50	= 8,75	kN/m (merata)

- Beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

PD5	= ½ qD × L = ½ × 7,74 × 3,5	= 13,55 kN
PL5	= ½ qD × L = ½ × 2,92 × 3,5	= 5,11 kN
2PD7	= ½ qD × L = ½ × 31,11 × 3,5	= 54,44 kN
2PL7	= ½ qD × L = ½ × 8,52 × 3,5	= 14,91 kN
2PD9	= ½ qD × L = ½ × 7,44 × 1,64	= 6,11 kN
2PL9	= ½ qD × L = ½ × 0,75 × 1,64	= 2,30 kN

2) lantai 2,3

- Beban merata

Bentang F-E

Plat lantai (QD)	= 1,70 × 4,88	= 8,30	kN/m (segitiga) × 2
Plat lantai (QL)	= 1,70 × 2,50	= 4,25	kN/m (segitiga) × 2
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang E-D

Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (segitiga)
Plat lantai (QL)	= 1,75 × 2,50	= 4,38	kN/m (segitiga)
Plat lantai (QD)	= 1,25 × 4,88	= 6,10	kN/m (trapesium)
Plat lantai (QL)	= 1,25 × 2,50	= 3,13	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang D-C

Plat lantai (QD)	= 1,15 × 4,88	= 8,30	kN/m (segitiga) × 2
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (segitiga) × 2

Bentang C-B1

Plat lantai (QD)	= 0,875 × 4,88	= 4,27	kN/m (trapesium)
Plat lantai (QL)	= 0,875 × 2,50	= 2,19	kN/m (trapesium)

Bentang B1-A1

Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (trapesium)
[illegible]	[illegible]	[illegible]	[illegible]

Bentang A1-A'1

Plat lantai (QD)	= 0,875 × 4,88	= 4,27	kN/m (segitiga)
Plat lantai (QL)	= 0,875 × 2,50	= 2,19	kN/m (segitiga)

Bentang C-B2

Plat lantai (QD)	= 0,82 × 4,88	= 4,00	kN/m (trapesium)
Plat lantai (QL)	0,82 × 2,50	= 2,05	kN/m (trapesium)

Bentang B2-A2

Plat lantai (QD)	= 0,82 × 4,88	= 4,00	kN/m (trapesium)
Plat lantai (QL)	= 0,82 × 2,50	= 2,05	kN/m (trapesium)

Bentang A2-A

Plat lantai (QD)	= 0,70 × 4,88	= 3,42	kN/m (segitiga)
Plat lantai (QL)	= 0,70 × 2,50	= 1,75	kN/m (segitiga)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang A-A'1

Plat lantai (QD)	= 0,82 × 4,88	= 4,00	kN/m (trapesium)
Plat lantai (QL)	= 0,82 × 2,50	= 2,05	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

- Beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

PD5	= ½ qD × L	= ½ × 7,74 × 3,5	= 13,55 kN
PL5	= ½ qD × L	= ½ × 2,92 × 3,5	= 5,11 kN
2PD7	= ½ qD × L	= ½ × 31,11 × 3,5	= 54,44 kN
2PL7	= ½ qD × L	= ½ × 8,52 × 3,5	= 14,91 kN
PD9	= ½ qD × L	= ½ × 7,44 × 1,64	= 6,11 kN
PL9	= ½ qD × L	= ½ × 0,75 × 1,64	= 2,30 kN

3) lantai 4

- beban merata

  Bentang A1-A'1

  Plat lantai (QD) = 1,69 × 3,06 = 5,17 kN/m (segitiga)

  Plat lantai (QL) = 1,69 × 1,00 = 1,69 KN/m (segitiga)

- beban terpusat

  beban terpusat merupakan beban penyaluran dari atap, maka beban terpusat diambil dari reaksi yang terjadi pada kostruksi atap. Terbagi atas :

  Genteng, usuk, reng : 0,5 kN/m^2 × 3,5 × (9,55×1/cos 35) = 20,49 kN

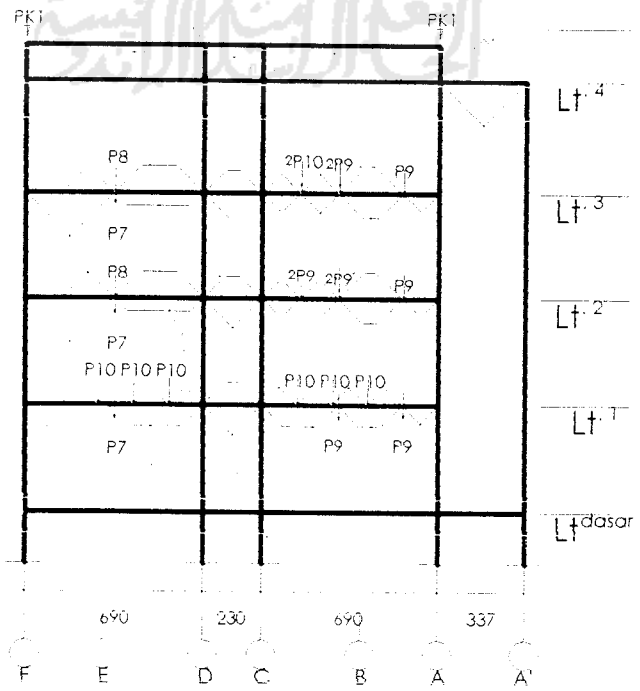
  Gording (150x50x20x2,3) : 0,0496 × 3,5 m × 7 baris = 1,215 kN

  Kuda-kuda (KK1) : 0,5 kN/m × 8,05 = 4,025 kN

  Beban mati PK 1 = 25,73 kN

  Beban Hidup PK 1 : 1 kN × 7 titik = 7,0 kN

G. Portal As k – k



1) Lantai 1

- Beban merata

Bentang F-E

Plat lantai (QD)	= 1,70 × 4,88	= 8,30	kN/m (segitiga)
Plat lantai (QL)	= 1,70 × 2,50	= 4,25	kN/m (segitiga)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang E-D

Plat lantai (QD)	= 0,82 × 4,88	= 4,00	kN/m (trapesium)
Plat lantai (QL)	= 0,82 × 2,50	= 2,05	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang E1-E2; E2-D2; D2-D3; D3-D

Plat lantai (QD)	= 0,70 × 4,88	= 3,42	kN/m (segitiga)
Plat lantai (QL)	= 0,70 × 2,50	= 1,75	kN/m (segitiga)

Bentang D-C

Plat lantai (QD)	= 1,15 × 4,88	= 5,61	kN/m (segitiga)
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (segitiga)
Plat canopi (QD)	= 1,0 × 3,06	= 3,06	kN/m (trapesium)
Plat canopi (QL)	= 1,0 × 2,50	= 2,50	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang A1-A

Plat lantai (QD)	= 0,70 × 4,88	= 3,66	kN/m (segitiga)
Plat lantai (QL)	= 0,70 × 2,50	= 1,75	kN/m (segitiga)

Bentang C-B3; B3-B2; B2-A2; A2-A1

Plat lantai (QD)	= 0,7 × 4,88	= 3,42	kN/m (segitiga)
Plat lantai (QL)	= 0,7 × 2,50	= 1,75	kN/m (segitiga)

- Beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

PD7	= ½ qD × L = ½ × 31,11 × 3,5	= 54,44 kN
PL7	= ½ qD × L = ½ × 8,52 × 3,5	= 14,91 kN
PD9	= ½ qD × L = ½ × 7,44 × 1,64	= 6,11 kN
PL9	= ½ qD × L = ½ × 0,75 × 1,64	= 2,30 kN
PD10	= ½ qD × L = ½ × 7,9 × 2,1	= 8,30 kN
PL9	= ½ qD × L = ½ × 3,00 × 2,1	= 3,15 kN

2) lantai 2,3

- Beban merata

Bentang F-E

Plat lantai (QD)	= 1,70 × 4,88	= 8,30	kN/m (segitiga)
Plat lantai (QL)	= 1,70 × 2,50	= 4,25	kN/m (segitiga)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang E-D

Plat lantai (QD)	= 0,50 × 4,88	= 2,44	kN/m (trapesium)
Plat lantai (QL)	= 0,50 × 2,50	= 1,25	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang E1-E

Plat lantai (QD)	= 1,00 × 4,88	= 4,88	kN/m (segitiga)
Plat lantai (QL)	= 1,00 × 2,50	= 2,5	kN/m (segitiga)

Bentang E-D

Plat lantai (QD)	= 1,05 × 4,88	= 5,12	kN/m (trapesium)
Plat lantai (QL)	= 1,05 × 2,50	= 2,63	kN/m (trapesium)

Bentang D-C

Plat lantai (QD)	= 1,15 × 4,88	= 5,61	kN/m (segitiga)
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (segitiga)
Plat canopi (QD)	= 1,0 × 4,88	= 3,06	kN/m (trapesium)
Plat canopi (QL)	= 1,0 × 2,50	= 2,50	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang C-B3'1; B3'1-B1

Plat lantai (QD)	= 0,70 × 4,88	= 3,66	kN/m (segitiga) × 2
Plat lantai (QL)	= 0,70 × 2,50	= 1,75	kN/m (segitiga) × 2
Plat lantai (QD)	= 0,875 × 4,88	= 4,27	kN/m (trapesium)

Bentang B1-A1

Plat lantai (QD)	= 0,93 × 4,88	= 4,5	kN/m (trapesium)
Plat lantai (QL)	= 0,93 × 2,50	= 2,33	kN/m (trapesium)
Plat lantai (QD)	= 1,05 × 4,88	= 5,12	kN/m (trapesium)
Plat lantai (QL)	= 1,05 × 2,50	= 2,63	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang A1-A

Plat lantai (QD)	= 0,70 × 4,88	= 3,66	kN/m (segitiga)
Plat lantai (QL)	= 0,70 × 2,50	= 1,75	kN/m (segitiga)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

- Beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

PD7	= ½ qD × L = ½ × 31,11 × 3,5	= 54,44 kN
PL7	= ½ qD × L = ½ × 8,52 × 3,5	= 14,91 kN
PD8	= ½ qD × L = ½ × 8,8 × 2,1	= 9,24 kN
PL8	= ½ qD × L = ½ × 3,50 × 2,1	= 3,68 kN
2PD9	= ½ qD × L = ½ × 7,44 × 1,64	= 6,11 kN
2PL9	= ½ qD × L = ½ × 0,75 × 1,64	= 2,30 kN
2PD10	= ½ qD × L = ½ × 7,9 × 2,1	= 8,30 kN
2PL10	= ½ qD × L = ½ × 3,00 × 2,1	= 3,15 kN

3) lantai 4

- beban merata

Bentang E1-D1

Plat lantai (QD)	= 1,05 × 3,06	= 3,21	kN/m (trapesium)
Plat lantai (QL)	= 1,05 × 1,00	= 1,05	kN/m (trapesium)

Bentang D-C

Plat canopi (QD)	= 1,0 × 3,06	= 3,06	kN/m (trapesium)
Plat canopi (QL)	= 1,0 × 1,00	= 2,50	kN/m (trapesium)

Bentang C-A1

Plat lantai (QD)	= 1,05 × 3,06	= 3,21	kN/m (trapesium)
Plat lantai (QL)	= 1,05 × 1,00	= 1,05	kN/m (trapesium)

Bentang A-A'

Plat lantai (QD)	= 1,75 × 3,06	= 5,35	kN/m (segitiga)
Plat lantai (QL)	= 1,75 × 1,0	= 1,75	kN/m (segitiga)
Plat lantai (QD)	= 1,65 × 3,06	= 5,17	kN/m (trapesium)
Plat lantai (QL)	= 1,65 × 1,0	= 1,65	kN/m (trapesium)

Bentang F-A

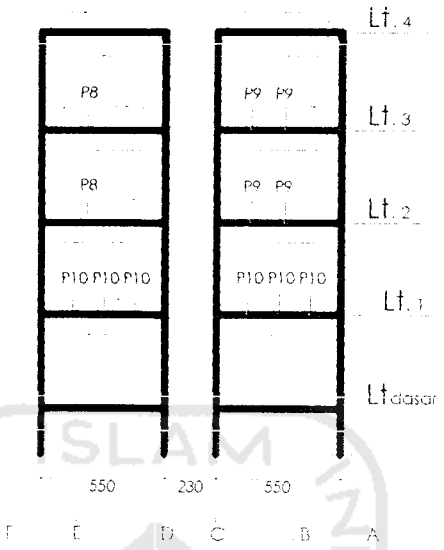
Dinding	= 1,0 × 2,50	= 2,50	kN/m (merata)

- beban terpusat

beban terpusat merupakan beban penyaluran dari atap, maka beban terpusat diambil dari reaksi yang terjadi pada kostruksi atap. Terbagi atas :

Genteng, usuk, reng	: 0,5 kN/m^2 × 3,5 × (9,55×1/cos 35)	= 20,49	kN
Gording (150x50x20x2,3)	: 0,0496 × 3,5 m × 7 baris	= 1,215	kN
Kuda-kuda (KK1)	: 0,5 kN/m × 8,05	= 4,025	kN
	Beban mati PK 1	= 25,73	kN
Beban Hidup PK 1	: 1 kN × 7 titik	= 7,0	kN

H. Portal As L – L



1) Lantai 1

- Beban merata

Bentang E1-E2; E2-D2; D2-D3; D3-D; C-B3; B3-B2; B2-A2; A2-A1

Plat lantai (QD)	= 0,70 × 4,88	= 3,66	kN/m (segitiga)
Plat lantai (QL)	= 0,70 × 2,50	= 1,75	kN/m (segitiga)
Plat canopi	= 0,50 × 3,06	= 1,53	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang E1-D; E1-E

Plat canopi (QD)	= 1,0 × 3,06	= 3,06	kN/m (trapesium)
Plat canopi (QL)	= 1,0 × 1,00	= 1,0	kN/m (trapesium)

- Beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

$PD10 = \frac{1}{2} qD \times L = \frac{1}{2} \times 7,9 \times 2,1 = 8,30$ kN

$PL10 = \frac{1}{2} qD \times L = \frac{1}{2} \times 3,00 \times 2,1 = 3,15$ kN

2) lantai 2,3

➢ Beban merata

Bentang E1-E

Plat lantai (QD)	= 1,00 · 4,88	= 1,88	kN/m (segitiga)
Plat lantai (QL)	= 1,00 · 2,50	= 2,50	kN/m (segitiga)
Dinding	= 3,50 · 2,50	= 8,75	kN/m (merata)

Bentang E-D

Plat lantai (QD)	= 1,05 · 4,88	= 5,12	kN/m (trapesium)
Plat lantai (QL)	= 1,05 · 2,50	= 2,63	kN/m (trapesium)
Dinding	= 3,50 · 2,50	= 8,75	kN/m (merata)

Bentang C-B'3; B'3-B'2

Plat lantai (QD)	= 0,75 · 4,88	= 3,66	kN/m (segitiga)
Plat lantai (QL)	= 1,00 · 2,50	= 2,50	kN/m (segitiga)

Bentang B'2-A1

Plat lantai (QD)	= 1,05 × 4,88	= 5,12	kN/m (trapesium)
Plat lantai (QL)	= 1,05 × 2,50	= 2,63	kN/m (trapesium)

Bentang E1-D; C-A1

Plat canopi (QD)	= 1,0 × 3,06	= 3,06	kN/m (trapesium)
Plat canopi (QL)	= 1,0 × 1,00	= 1,0	kN/m (trapesium)

➢ Beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

PD9 = ½ qD × L = ½ × 7,44 × 1,64 = 6,11 kN

PL9 = ½ qD × L = ½ × 0,75 × 1,64 = 2,30 kN

PD8 = ½ qD · L = ½ · 8,8 · 2,1 = 9,24 kN

PL8 = ½ qD · L = ½ · 3,50 · 2,1 = 3,68 kN

3) lantai 4

- beban merata

Bentang E1-D

Plat atap (QD)	= 1,05 · 3,06	= 3,21	kN/m (trapesium)
Plat atap (QL)	= 1,05 · 1,00	= 1,05	kN/m (trapesium)

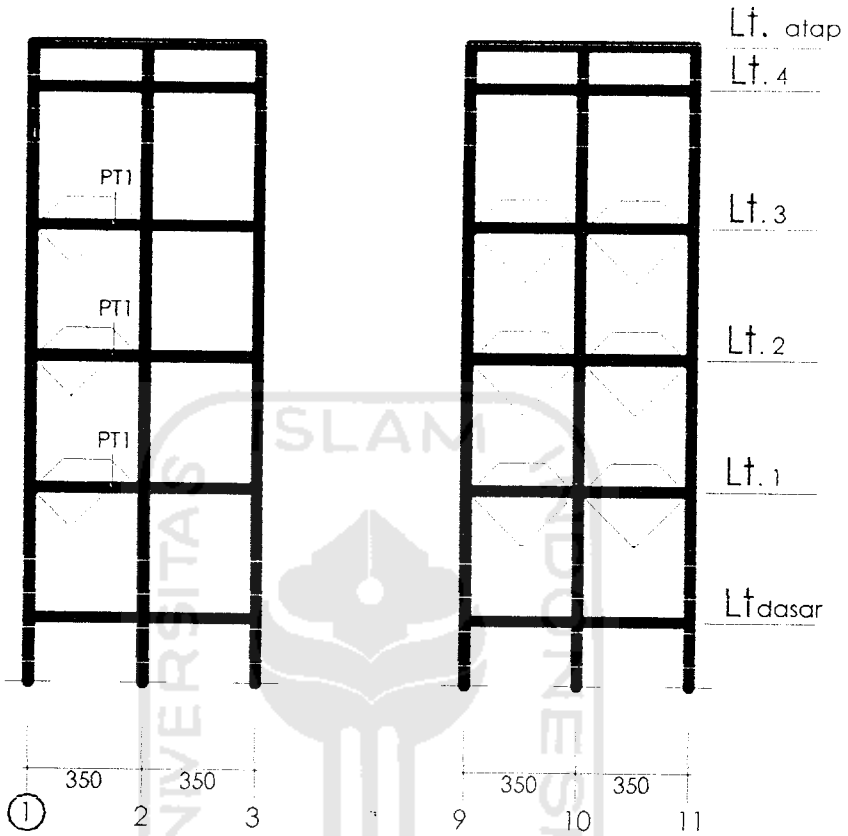
Bentang C-A1

Plat atap (QD)	= 1,05 · 3,06	= 3,21	kN/m (trapesium)
Plat atap (QL)	= 1,05 · 1,00	= 1,05	kN/m (trapesium)

Bentang A-A^0

Plat atap (QD)	= 1,65 · 3,06	= 5,17	kN/m (trapesium)
Plat atap (QL)	= 1,65 · 1,00	= 1,65	kN/m (trapesium)

I. Portal As 1 – 1



1) Lantai 1,2,3

➢ Beban merata

Bentang 1-2A

Plat lantai (QD)	= 1,25 × 4,88	= 6,10	kN/m (segitiga)
Plat lantai (QL)	= 1,25 × 2,50	= 3,13	kN/m (segitiga)

Bentang 1-2

Plat canopi (QD)	= 0,5 × 3,06	= 1,53	kN/m (trapesium)
Plat canopi (QL)	= 0,5 × 1,00	= 0,50	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang 9-10; 10-11

Plat lantai (QD)	= 1,70 × 4,88	= 8,30	kN/m (trapesium)
Plat lantai (QL)	= 1,70 × 2,50	= 3,13	kN/m (trapesium)
Plat canopi (QD)	= 0,5 × 3,06	= 1,53	kN/m (trapesium)
Plat canopi (QL)	= 0,5 × 1,00	= 0,50	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

➢ Beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

Pt D1 = ½ qD × L = ½ x 6,8 x 3 = 10,2 kN

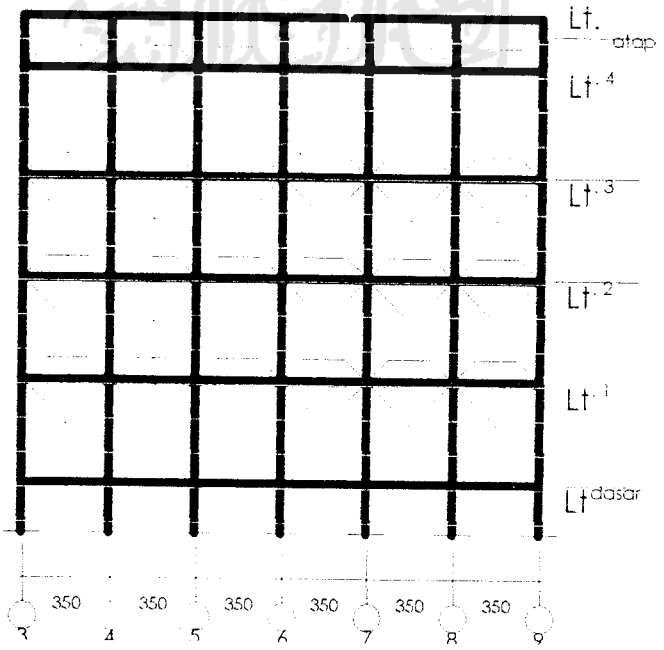
Pt L1 = ½ qL × L = ½ × 2,4 x 3 = 3,6 kN

2) Lantai 4

Bentang 1-2-3; 9-10-11

Dinding	= 1,5 × 2,5	= 3,75	kN/m (merata)

J. Portal As 2 – 2



1) Lantai 1,2,3

➢ Beban merata

Bentang 3-4 s/d 8-9

Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (segitiga)
Plat lantai (QL)	= 1,75 × 2,50	= 4,36	kN/m (segitiga)
Plat lantai (QD)	= 0,875 × 4,88	= 4,27	kN/m (trapesium)
Plat lantai (QL)	= 0,875 × 2,50	= 2,19	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

2) lantai 4

➢ beban merata

Bentang 3-4 s/d 8-9

Plat lantai (QD)	= 0,875 × 3,06	= 2,68	kN/m (trapesium)
Plat lantai (QL)	= 0,875 × 1,00	= 0,88	kN/m (trapesium)
Dinding	= 1,50 × 2,50	= 3,75	kN/m (merata)

K. Portal As 3 – 3

1) Lantai 1

➢ Beban merata

Bentang 11-12

Plat lantai (QD)	= 0,88 × 4,88	= 4,27	kN/m (trapesium)
Plat lantai (QL)	= 0,88 × 2,50	= 2,19	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

2) lantai 2,3

➢ Beban merata

Bentang 11-12a

Plat lantai (QD)	= 1,00 · 4,88	= 4,88	kN/m (trapesium)
Plat lantai (QL)	= 1,00 · 2,50	= 2,50	kN/m (trapesium)
Dinding	= 3,50 · 2,50	= 8,75	kN/m (merata)

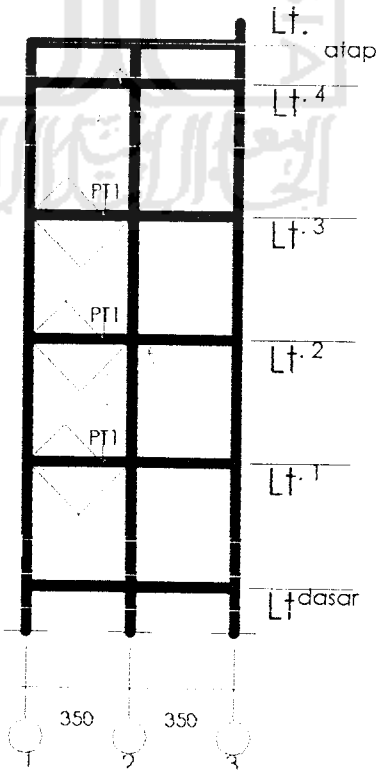
2) lantai 4

➢ beban merata

Bentang 11-12

Plat atap (QD)	= 1,05 × 3,06	= 3,21	kN/m (segitiga)
Plat atap (QL)	= 1,05 × 1,00	= 1,05	kN/m (segitiga)

L. Portal As 4 – 4



2)

1) **Lantai 1,2,3**

➢

➢ Beban merata

Ter

Bentang 1-2a

Plat lantai (QD)	= 1,25 × 4,88	= 6,10	kN/m (segitiga)
Plat lantai (QL)	= 1,25 × 2,50	= 3,13	kN/m (segitiga)

N. Po

Bentang 1-2

Plat canopi (QD)	= 1,75 × 4,88	= 8,54	kN/m (trapesium)
Plat canopi (QL)	= 1,75 × 2,50	= 4,36	kN/m (trapesium)

➢ Beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

Pt D1 = ½ qD × L = ½ x 6,8 x 3 = 10,2 kN

Pt L1 = ½ qL × L = ½ × 2,4 x 3 = 3,6 kN

2) Lantai 4

Bentang 2-2a

Plat bak air (QD)	= 1,0 × 5,06	= 5,06	kN/m (segitiga)
Plat bak air (QL)	= 1,01× 15,0	= 15,0	kN/m (segitiga)

1)

M. Portal As 5 - 5

➢

1) Lantai 1,2,3,4

➢ Beban merata

Bentang 2-3

Plat lantai (QD)	= 0,50 × 4,88	= 2,44	kN/m (trapesuim)
Plat lantai (QL)	= 0,50 × 2,50	= 1,25	kN/m (trapesuim)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

2) Lantai 4

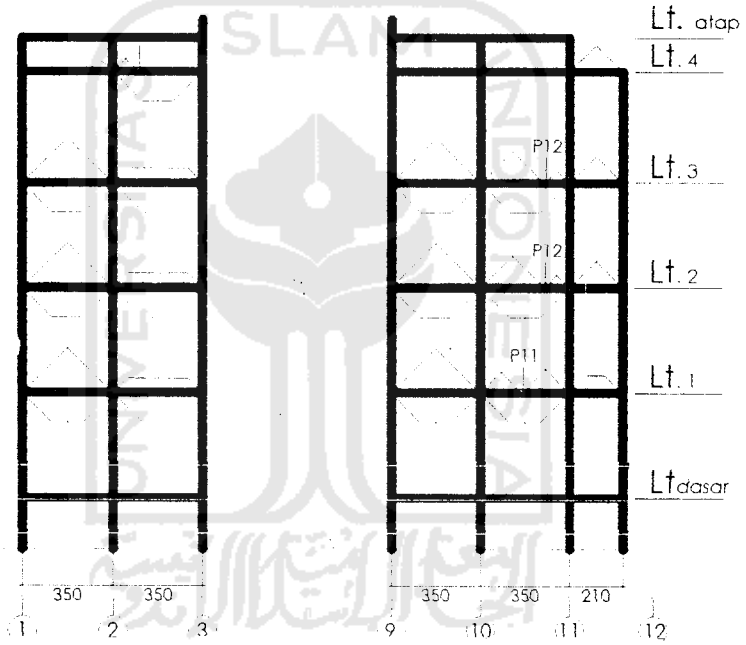
➢ Beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

PaD2 = ½ qD × L = ½ x 4,31 x 1,42 = 3,06 kN

PaL2 = ½ qL × L = ½ × 1,043 x 1,42 = 0,741 kN

N. Portal As 6 – 6



1) Lantai 1

➢ Beban merata

Bentang 1-2

Plat lantai (QD) = 1,15 × 4,88 = 5,61 kN/m (trapesium)

Plat lantai (QL) = 1,15 × 2,50 = 2,88 kN/m (trapesium)

Plat lantai (QD) = 1,75 × 4,88 = 8,54 kN/m (segitiga)

Plat lantai (QL) = 1,75 × 2,50 = 4,36 kN/m (segitiga)

Bentang 2-3

Plat lantai (QD)	= 1,15 × 4,88	= 5,61	kN/m (trapesium)
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (trapesium)
Plat lantai (QD)	= 0,58 × 4,88	= 2,83	kN/m (trapesium)
Plat lantai (QL)	= 0,58 × 2,50	= 1,45	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang 9-10

Plat lantai (QD)	= 1,15 × 4,88	= 5,61	kN/m (trapesium)
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (trapesium)
Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (segitiga)
Plat lantai (QL)	= 1,75 × 2,50	= 4,38	kN/m (segitiga)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang 10-11

Plat lantai (QD)	= 1,15 × 4,88	= 5,61	kN/m (trapesium)
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang 10-11a

Plat lantai (QD)	= 0,82 × 4,88	= 4,00	kN/m (segitiga)
Plat lantai (QL)	= 0,82 × 2,50	= 2,05	kN/m (segitiga)

Bentang 11a-11

Plat lantai (QD)	= 0,93 × 4,88	= 4,54	kN/m (segitiga)
Plat lantai (QL)	= 0,93 × 2,50	= 2,33	kN/m (segitiga)

Bentang 11-12

Plat lantai (QD)	= 0,70 × 4,88	= 3,42	kN/m (trapesium)
Plat lantai (QL)	= 0,70 × 2,50	= 1,75	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

- Beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

PD11 = ½.qD × L = ½ x 9,17 x 3,45 = 15,818 kN

PL11 = ½.qL × L = ½ x 3,995 x 3,45 = 6,892 kN

2) lantai 2,3

- Beban merata

Bentang 1-2

Plat lantai (QD)	= 1,15 × 4,88	= 5,61	kN/m (trapesium)
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (trapesium)
Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (segitiga)
Plat lantai (QL)	= 1,75 × 2,50	= 4,36	kN/m (segitiga)

Bentang 2-3

Plat lantai (QD)	= 1,15 × 4,88	= 5,61	kN/m (trapesium)
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (trapesium)
Plat lantai (QD)	= 0,58 × 4,88	= 2,83	kN/m (trapesium)
Plat lantai (QL)	= 0,58 × 2,50	= 1,45	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang 9-10

Plat lantai (QD)	= 1,15 × 4,88	= 5,61	kN/m (trapesium)
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (trapesium)
Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (segitiga)
Plat lantai (QL)	= 1,75 × 2,50	= 4,38	kN/m (segitiga)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang 10-11

Plat lantai (QD)	= 1,15 × 4,88	= 5,61	kN/m (trapesium)
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang 10-11b

Plat lantai (QD)	= 1,25 × 4,88	= 6,10	kN/m (segitiga)
Plat lantai (QL)	= 1,25 × 2,50	= 3,13	kN/m (segitiga)

Bentang 11b-11

Plat lantai (QD)	= 0,50 × 4,88	= 2,44	kN/m (segitiga)
Plat lantai (QL)	= 0,50 × 2,50	= 1,25	kN/m (segitiga)

Bentang 11-12

Plat lantai (QD)	= 1,05 × 4,88	= 5,12	kN/m (segitiga)
Plat lantai (QL)	= 1,05 × 2,50	= 2,63	kN/m (segitiga)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

- Beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

PD11 = ½.qD × L = ½ x 9,17 x 3,45 = 15,818 kN

PL11 = ½.qL × L = ½ x 3,995 x 3,45 = 6,892 kN

3) lantai 4

- beban merata

Bentang 11-12

Plat lantai (QD) = 1,05 × 3,06 = 3,21 kN/m (segitiga)

Plat lantai (QL) = 1,05 × 1,00 = 1,05 kN/m (segitiga)

Bentang 2-3

Plat bak air (QD) = 1,15 × 5,06 = 5,82 kN/m (trapesium)

Plat bak air (QL) = 1,15 × 15,0 = 17,25 kN/m (trapesium)

- Beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

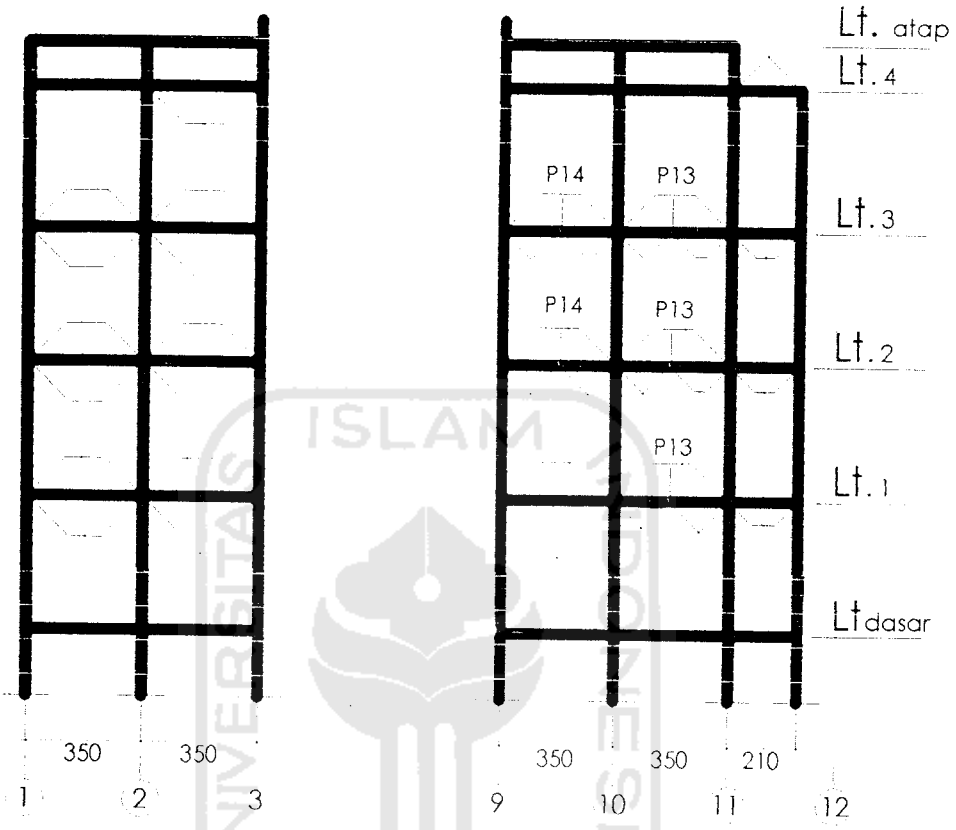
PaD3 = ½ qD × L = ½ x 4,64 x 3,9 = 9,048 kN

PaL3 = ½ qL × L = ½ × 1,223 x 3,9 = 2,385 kN

PaD2 = ½ qD × L = ½ x 4,31 x 1,42 = 3,06 kN

PaL2 = ½ qL × L = ½ × 1,043 x 1,42 = 0,741 kN

O. Portal As 7 – 7



1) Lantai 1

- Beban merata

Bentang 1-2

Plat lantai (QD)	= 1,15 × 4,88	= 5,61	kN/m (trapesium)
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (trapesium)
Plat lantai (QD)	= 1,25 × 4,88	= 6,10	kN/m (trapesium)
Plat lantai (QL)	= 1,25 × 2,50	= 3,13	kN/m (trapesium)

Bentang 2-3

Plat lantai (QD)	= 1,15 × 4,88	= 5,61	kN/m (trapesium)
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (trapesium)

Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (segitiga)
Plat lantai (QL)	= 1,75 × 2,50	= 4,38	kN/m (segitiga)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)
<u>Bentang 9-10</u>			
Plat lantai (QD)	= 1,15 × 4,88	= 5,61	kN/m (trapesium)
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (trapesium)
Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (segitiga)
Plat lantai (QL)	= 1,75 × 2,50	= 4,38	kN/m (segitiga)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)
<u>Bentang 10-11a</u>			
Plat lantai (QD)	= 0,82 × 4,88	= 4,00	kN/m (segitiga)
Plat lantai (QL)	= 0,82 × 2,50	= 2,05	kN/m (segitiga)
<u>Bentang 11a-11</u>			
Plat lantai (QD)	= 0,93 × 4,88	= 4,54	kN/m (segitiga)
Plat lantai (QL)	= 0,93 × 2,50	= 2,33	kN/m (segitiga)
<u>Bentang 10-11</u>			
Plat lantai (QD)	= 1,15 × 4,88	= 5,61	kN/m (trapesium)
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)
<u>Bentang 11-12</u>			
Plat lantai (QD)	= 0,70 × 4,88	= 3,42	kN/m (trapesium)
Plat lantai (QL)	= 0,70 × 2,50	= 1,75	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

- Beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

PD13 = ½.qD · L = ½ x 9,33 x 2,76 = 12,876 kN

PL13 = ½.qL · L = ½ x 3,783 x 2,76 = 5,221 kN

2) lantai 2,3

- Beban merata

Bentang 1-2

Plat lantai (QD)	= 1,15 × 4,88	= 5,61	kN/m (trapesium)
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (trapesium)

Bentang 2-3

Plat lantai (QD)	= 1,15 × 4,88	= 5,61	kN/m (trapesium)
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (trapesium)
Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (segitiga)
Plat lantai (QL)	= 1,75 × 2,50	= 4,38	kN/m (segitiga)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang 9-10a; 10a-10

Plat lantai (QD)	= 0,875 × 4,88	= 4,27	kN/m (segitiga)
Plat lantai (QL)	= 0,875 × 2,50	= 2,19	kN/m (segitiga)

Bentang 9-10

Plat lantai (QD)	= 1,15 × 4,88	= 5,61	kN/m (trapesium)
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang 10-11

Plat lantai (QD)	= 1,15 × 4,88	= 5,61	kN/m (trapesium)
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang 10-11a

Plat lantai (QD)	= 0,82 × 4,88	= 4,00	kN/m (segitiga)
Plat lantai (QL)	= 0,82 × 2,50	= 2,05	kN/m (segitiga)

Bentang 11a-11

Plat lantai (QD)	= 0,75 × 4,88	= 3,66	kN/m (trapesium)
Plat lantai (QL)	= 0,75 × 2,50	= 1,88	kN/m (trapesium)

Bentang 10-11

Plat lantai (QD)	= 1,15 × 4,88	= 5,61	kN/m (trapesium)
Plat lantai (QL)	= 1,15 × 2,50	= 2,88	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang 11-12

Plat lantai (QD)	= 0,75 × 4,88	= 3,66	kN/m (trapesium)
Plat lantai (QL)	= 0,75 × 2,50	= 1,88	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

- Beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

PD13	= ½ x 9,33 x 2,76	= 12,876 kN
PL13	= ½ x 3,783 x 2,76	= 5,221 kN
PD14	= ½ x 8,38 x 2	= 8,38 kN
PL14	= ½ x 3,265 x 2	= 3,265 kN

3) lantai 4

- beban merata

Bentang 11-12a

Plat atap (QD)	= 1,05 × 3,06	= 3,21	kN/m (segitiga)
Plat atap (QL)	= 1,05 × 1,00	= 1,05	kN/m (segitiga)

Bentang 2-3

Plat bak air (QD)	= 1,15 × 5,06	= 5,82	kN/m (trapesium)
Plat bak air (QL)	= 1,15 × 15,0	= 17,25	kN/m (trapesium)

P. Portal As 8 - 8

1) Lantai 1

- Beban merata

Bentang 10-11a

Plat lantai (QD)	= 0,82 × 4,88	= 4,00	kN/m (segitiga)
Plat lantai (QL)	= 0,82 × 2,50	= 2,05	kN/m (segitiga)
Plat lantai (QD)	= 0,70 × 4,88	= 3,42	kN/m (trapesium)
Plat lantai (QL)	= 0,70 × 2,50	= 1,75	kN/m (trapesium)

Bentang 11a-11

Plat lantai (QD)	= 0,93 × 4,88	= 4,54	kN/m (segitiga)
Plat lantai (QL)	= 0,93 × 2,50	= 2,33	kN/m (segitiga)
Plat lantai (QD)	= 0,70 × 4,88	= 3,42	kN/m (trapesium)
Plat lantai (QL)	= 0,70 × 2,50	= 1,75	kN/m (trapesium)

Bentang 11-12a

Plat lantai (QD)	= 0,88 × 4,88	= 4,27	kN/m (trapesium)
Plat lantai (QL)	= 0,88 × 2,50	= 2,19	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

2) lantai 2,3

➢ Beban merata

Bentang 10-11a

Plat lantai (QD)	= 0,82 × 4,88	= 4,00	kN/m (segitiga)
Plat lantai (QL)	= 0,82 × 2,50	= 2,05	kN/m (segitiga)
Plat lantai (QD)	= 0,70 × 4,88	= 3,42	kN/m (trapesium)
Plat lantai (QL)	= 0,70 × 2,50	= 1,75	kN/m (trapesium)

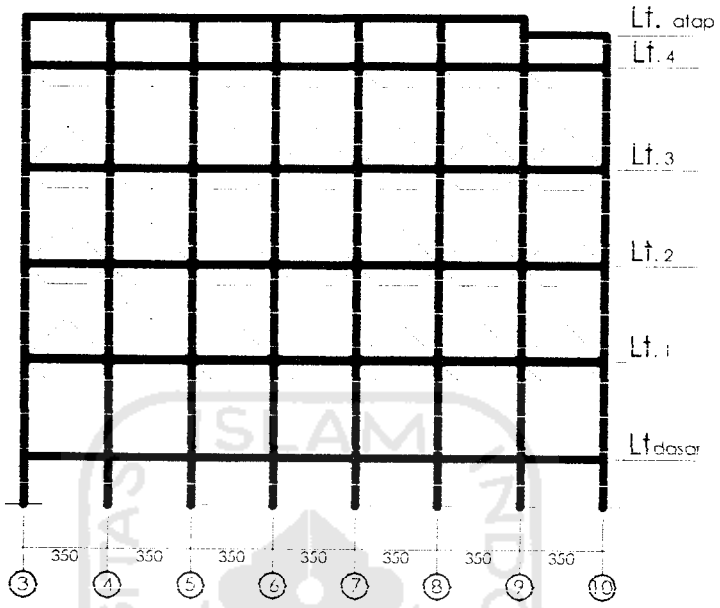
Bentang 11a-11

Plat lantai (QD)	= 0,93 × 4,88	= 4,54	kN/m (segitiga)
Plat lantai (QL)	= 0,93 × 2,50	= 2,33	kN/m (segitiga)
Plat lantai (QD)	= 0,70 × 4,88	= 3,42	kN/m (trapesium)
Plat lantai (QL)	= 0,70 × 2,50	= 1,75	kN/m (trapesium)

Bentang 11-12a

Plat lantai (QD)	= 1,00 × 4,88	= 4,88	kN/m (segitiga)
Plat lantai (QL)	= 1,00 × 2,50	= 2,50	kN/m (segitiga)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Q. Portal As 9 – 9



1) Lantai 1,2,3

- Beban merata

Bentang 3-4 s/d 9-10

Plat lantai (QD)	= 1,75 × 4,88	= 8,54	kN/m (segitiga)
Plat lantai (QL)	= 1,75 × 2,50	= 4,36	kN/m (segitiga)
Plat lantai (QD)	= 0,875 × 4,88	= 4,27	kN/m (trapesium)
Plat lantai (QL)	= 0,875 × 2,50	= 2,19	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

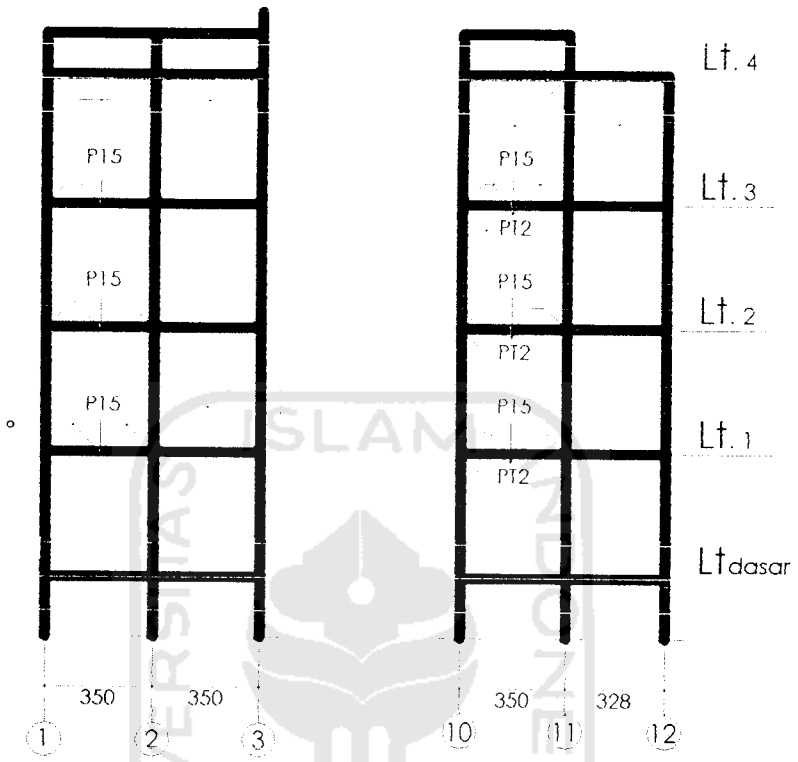
2) lantai 4

- beban merata

Bentang 3-4 s/d 9-10

Plat atap (QD)	= 0,875 × 3,06	= 2,68	kN/m (trapesium)
Plat atap (QL)	= 0,875 × 1,00	= 0,88	kN/m (trapesium)
Dinding	= 1,50 × 2,50	= 3,75	kN/m (merata)

R. Portal As 10-10



1) Lantai 1,2,3

➢ Beban merata

Bentang 1-2a; 2a-2

Plat lantai (QD)	= 0,88 × 4,88	= 4,27	kN/m (segitiga)
Plat lantai (QL)	= 0,88 × 2,50	= 2,19	kN/m (segitiga)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang 2-3

Plat lantai (QD)	= 1,50 × 4,88	= 7,32	kN/m (trapesium)
Plat lantai (QL)	= 1,50 × 2,50	= 3,75	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang 10-11a

Plat lantai (QD)	= 0,82 × 4,88	= 4,00	kN/m (segitiga)
Plat lantai (QL)	= 0,82 × 2,50	= 2,05	kN/m (segitiga)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)
Plat lantai (QD)	= 0,70 × 4,88	= 3,42	kN/m (trapesium)
Plat lantai (QL)	= 0,70 × 2,50	= 1,75	kN/m (trapesium)

Bentang 11a-11

Plat lantai (QD)	= 0,70 × 4,88	= 3,42	kN/m (trapesium)
Plat lantai (QL)	= 0,70 × 2,50	= 1,75	kN/m (trapesium)
Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

Bentang 11-12

Dinding	= 3,50 × 2,50	= 8,75	kN/m (merata)

- Beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

PD15 = ½.qD × L = ½ x 8,38 x 2 = 8,38 kN

PL15 = ½.qL × L = ½ x 3,265 x 2 = 3,265 kN

Pt2D = ½ x qD x L = ½ x 5,876 x 3,37 = 9,901 kN

Pt2L = ½ x qL x L = ½ x 1,898 x 3,37 = 3,198 kN

2) lantai 4

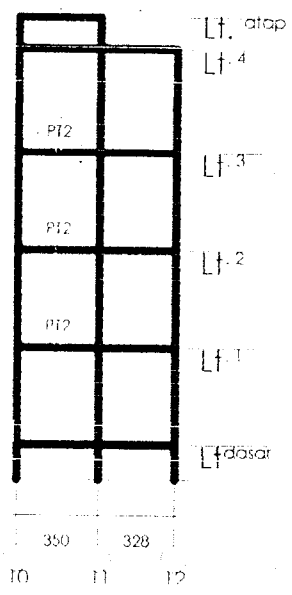
- beban merata

Bentang 1-2

Plat canopi (QD)	= 0,50 × 3,06	= 1,53	kN/m (trapesium)
Plat canopi (QL)	= 0,50 × 1,00	= 0,5	kN/m (trapesium)

Dinding	= 1,50 × 2,50	= 3,75	kN/m (merata)
Bentang 2-3			
Plat bak air (QD)	= 1,50 × 5,06	= 7,59	kN/m (trapesium)
Plat bak air (QL)	= 1,50 × 15,00	= 22,5	kN/m (trapesium)
Dinding	= 1,50 × 2,50	= 3,75	kN/m (merata)
Plat canopi (QD)	= 0,50 × 3,06	= 1,53	kN/m (trapesium)
Plat canopi (QL)	= 0,50 × 1,00	= 0,5	kN/m (trapesium)
Bentang 10-11			
Plat atap (QD)	= 1,68 × 3,06	= 5,14	kN/m (trapesium)
Plat atap (QL)	= 1,68 × 1,00	= 1,68	kN/m (trapesium)
Dinding	= 1,50 × 2,50	= 3,75	kN/m (merata)
Bentang 11-12			
Plat atap (QD)	= 1,64× 3,06	= 5,02	kN/m (segitiga)
Plat atap (QL)	= 1,64× 1,00	= 1,64	kN/m (segitiga)

S. Portal As 11-11



3) Lantai 1,2,3

- Beban merata

Bentang 10-11

Plat atap (QD) = 0,82 × 3,06 = 2,51 kN/m (segitiga)

Plat lantai (QL) = 0,82 × 1,00 = 0,82 kN/m (segitiga)

- Beban terpusat

Terbagi atas : akibat beban mati (PD) dan beban hidup (PL), jadi :

Pt2D = ½ x qD x L = ½ x 5,876 x 3,37 = 9,901 kN

Pt2L = ½ x qL x L = ½ x 1,898 x 3,37 = 3,198 kN

4) lantai 4

- beban merata

Bentang 10-11

Plat atap (QD) = 1,68 × 3,06 = 5,14 kN/m (trapesium)

Plat bak air (QL) = 1,68 × 1,00 = 1,68 kN/m (trapesium)

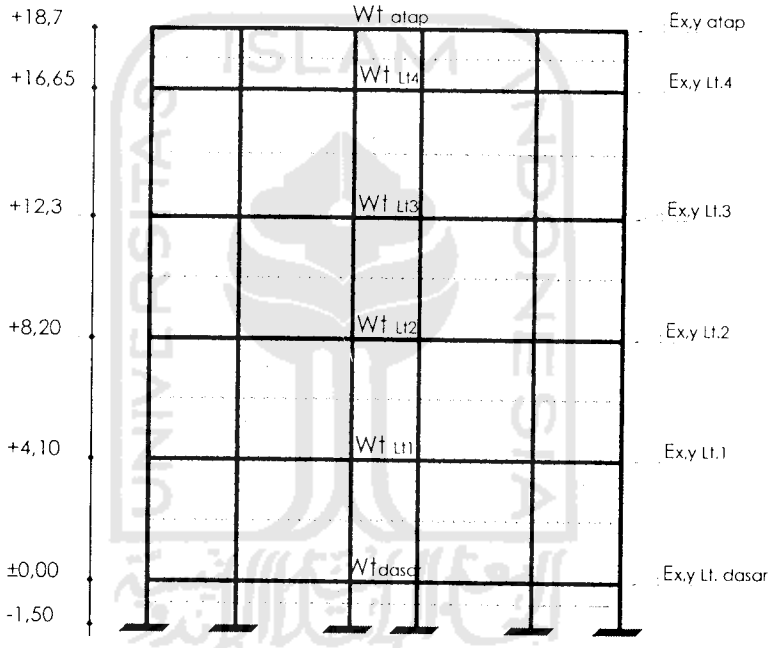
Bentang 11-12

Plat atap (QD) = 1,64× 3,06 = 5,02 kN/m (segitiga)

Plat bak air (QL) = 1,64× 1,00 = 1,64 kN/m (segitiga)

4.4.2 Perhitungan Gaya Geser Dasar Horizontal Total Akibat Gempa

Gaya geser dasar horizontal akibat gempa dipengaruhi oleh berat total dari keseluruhan struktur yang direncanakan ditambah dengan beban hidup yang bekerja. Sesuai fungsi penggunaan gedung yaitu sebagai gedung rumah sakit, maka menurut Peraturan Pembebanan Indonesia 1983 (Tabel 3.3) untuk perencanaan beban gempa, beban hidup direduksi sebesar 0,3.



Gambar 4.16 Penyebaran berat bangunan

a. Berat total bangunan

1) Lantai dasar

- Beban mati :

Sloof B1	= (0,25 x 0.5) x 42,30 x 24	= 126,9	kN
Sloof B2	= (0,25 x 0.5) x 216,44 x 24	= 649,3	kN
Sloof B3	= (0,15 x 0,3) x 89,6 x 24	= 96,8	kN
Kolom K1	= (0,4 x 0,8 x 2,05) x 10 x 24	= 157,4	kN

Kolom K2	= (0,4 x 0,6 x 2,05) x 36 x 24		= 425,1	kN
Kolom K3	= (0,3 x 0,3 x 2,05) x 2 x 24		= 8,9	kN
Dinding	= (2,05 × 129,5) × 2,5		= 663,7	kN
		WD	= 1464,3	kN

Wt_{dasar} = 1464,3 kN

2) Lantai 1

- Beban mati :

Pelat lantai 1	= (35 x 16,10) x 4,88		= 2749,8	kN
Balok B1	= (0,35 x (0,8 – 0,12) x 89,75) x 24		= 512,65	kN
Balok B2	= (0,25 x (0,5 – 0,12) x 216,44) x 24		= 493,4	kN
Balok B3	= (0,2 x (0,4 – 0,12) x 150,22) x 24		= 201,9	kN
Kolom K1	= (0,4 x 0,8 x 4,1) x 10 x 24		= 314,9	kN
Kolom K2	= (0,4 x 0,6 x 4,1) x 36 x 24		= 850,2	kN
Kolom K3	= (0,3 x 0,3 x 4,1) x 2 x 24		= 17,71	kN
Dinding	= 3,5 x 129,5 x 2,5		=1133,1	kN +
		WD	= 6273,4	kN

- Beban hidup :

Beban Hidup pelat lantai (WL) = 0,3 x 2,5 x (35 x 16,10) = 422,625 kN

Wt_1 = 6273,4 + 422,62 = 6696,1 kN

3) Lantai 2

- Beban mati :

Pelat lantai 2	= 35 x 16,10 x 4,88	= 2749,88	kN
Balok B1	= (0,35 x (0,8 – 0,12) x 89,75) x 24	= 512,4	kN

Balok B2	= (0,25 x (0,5 – 0,12) x 216,44) x 24	= 493,4	kN
Balok B3	= (0,2 x (0,8 – 0,12) x 216,2) x 24	= 290,6	kN
Kolom K1	= (0,4 x 0,8 x 4,1) x 10 x 24	= 314,9	kN
Kolom K2	= (0,4 x 0,6 x 4,1) x 36 x 24	= 850,2	kN
Kolom K3	= (0,3 x 0,3 x 4,1) x 2 x 24	= 17,7	kN
Dinding	= 3,5 x 129,5 x 2,5	= 1133,1	kN +
	WD	= 6362,1	kN

- Beban hidup :

Beban Hidup pelat lantai (WL) = 0,3 x 2,5 x 35 x 16,10 = 422,625 kN

Wt_2 = 6362,1 + 422,625 = 6784,7 kN

4) Lantai 3

- Beban mati :

Pelat lantai 3	= 35 x 16,10 x 4,88	= 2749,88	kN
Balok B1	= (0,35 x (0,8 – 0,12) x 89,75) x 24	= 512,4	kN
Balok B2	= (0,25 x (0,5 – 0,12) x 216,44) x 24	= 493,4	kN
Balok B3	= (0,2 x (0,8 – 0,12) x 216,2) x 24	= 290,6	kN
Kolom K1	= (0,4 x 0,8 x 4,225) x 10 x 24	= 324,5	kN
Kolom K2	= (0,4 x 0,6 x 4,225) x 36 x 24	= 876,1	kN
Kolom K3	= (0,3 x 0,3 x 4,225) x 2 x 24	= 18,3	kN
Dinding	= 3,725 x 129,5 x 2,5	= 1206,0	kN +
	WD	= 6471,0	kN

- Beban hidup :

Beban Hidup pelat lantai (WL) = 0,3 x 2,5 x 35 x 16,10 = 422,6 kN

Wt_3 = 6471,0 + 422,6 = 6893,6 kN

5) Lantai 4

- Beban mati :

Pelat atap	= 114,25 x 3,06	= 349,65	kN	
Pelat bak air	= 194,45 x 5,06	= 984,2	kN	
Plafond	= 35 x 16,1 x 0,18	= 101,4	kN	
Balok B2	= (0,25 x 0,5 x 216,44) x 24	= 649,3	kN	
Kolom K1	= (0,4 x 0,8 x 3,2) x 10 x 24	= 245,8	kN	
Kolom K2	= (0,4 x 0,6 x 3,2) x 36 x 24	= 663,6	kN	
Kolom K3	= (0,3 x 0,3 x 3,2) x 2 x 24	= 13,8	kN	
Dinding	= 2,8 x 129,5 x 2,5	= 906,5	kN	+
	WD	= 3914,1	kN	

- Beban hidup :

Pelat atap	= 1,0 x 114,25	= 114,3	kN	
Pelat bak air	= 15 x 194,45	= 2917,5	kN	+
	WL	= 3031,8	kN	

Wt_4 = 3914,1 + 3031,8 = 6945,9 kN

6) Struktur atap

- Beban mati :

Balok B2	= (0,25 x 0,5 x 216,44) x 24	= 649,3	kN
Kolom K2	= (0,4 x 0,6 x 1,025) x 10 x 24	= 59,0	kN
Kolom K2'	= (0,4 x 0,6 x 0,325) x 36 x 24	= 67,4	kN
Kolom K3	= (0,3 x 0,3 x 0,325) x 2 x 24	= 1,4	kN
Dinding	= 0,325 x 87,5 x 2,5	= 71,1	kN
Dinding	= 1,025 x 42 x 2,5	= 107,6	kN +
	WD	= 955,8	kN

Berat atap =

Luasan A $= \frac{(18,9+38)}{2} \times \left(\frac{1}{\cos 35} 9,55 \right) \times 2 = 663,28 \text{ m}^2$

Luasan B $\frac{1}{2} \times \left(\frac{1.19,10}{\cos 35} 9,55 \right) \times 2 = 222,64 \text{ m}^2$

Luasan total = 663,28 + 222,64 = 885,92 m^2

$WD_{penutup\ atap}$ = 885,92 x 0,5 = 442,96 kN

Berat gording = panjang gording x berat profil per meter

Berat profil = 0,0496 kN/m (150x50x20x2,3)

Pj gording A = (38 + (38-(2x1,5)) + (38-(2x2,5)) + (38-(2x5)) + (38-(2x6,5)) + (38-(2x8,5)) + (38-(2x10,5))) x 2 = 410 m

Pj gording B = (19,1 + (19,1-(2x1,5)) + (19,1-(2x2,5)) + (19,1-(2x5)) + (19,1 -(2x6,5)) + (19,1 -(2x8,5))) x 2 = 145,4 m

$WD_{Gording}$ = (410 + 145,4) x 0,0496 = 27,55 kN

Berat kuda – kuda :

KK1	= 60,52 m x 0,099 kN/m x 5	= 29,95 kN
KK2	= 78,4 m x 0,099 kN/m x 2	= 15,52 kN
KK3	= 58,1 m x 0,099 kN/m x 2	= 11,5 kN
KK4	= 33,8 m x 0,099 kN/m x 4	= 13,38 kN
KK5	= 14,2 m x 0,099 kN/m x 4	= 5,62 kN +
	$WD_{kuda\text{-}kuda}$	= 75,99 kN

Plafon + Rangka = luas total plafon x berat per m^2

$WD_{plafond}$ = 197,3 m^2 x 0,18 kN/m^2 = 35,51 kN

Maka, total WD_{atap} = 1537,8 kN

- Beban hidup Atap:

  Berdasarkan PPIUG pasal 3.2 , berupa beban terpusat dari seorang pekerja sebesar minimum 100 kg = 1 kN, jadi beban hidup atap = 140 x 1 = 140 kN

Wt_4 = 1537,8 + 140 = 1677,8 kN

Maka, berat total bangunan (Wt) = $Wt_{dasar} + Wt_1 + Wt_2 + Wt_3 + Wt_4 + Wt_{atap}$

= 1464,3 + 6693,1 + 6784,7 + 6893,6 + 6945,9 +1677,8 = 30462,2 kN

b. Waktu Getar Bangunan (T)

Waktu getar struktur untuk struktur portal terbuka beton bertulang dapat dihitung dengan :

$$T = 0,06 \cdot H^{3/4} = 0,06 \cdot 18,7^{3/4} = 0,5396 \text{ dt}$$

c. Koefisien Gempa Dasar (C)

Pada Redisain ini bangunan berada dalam wilayah gempa 3 pada kondisi tanah keras. Waktu getar struktur (T) = 0,5396 dt, maka berdasarkan grafik respon spectrum untuk wilayah 3 didapatkan koefisien gempa dasar (C) = 0,048

d. Faktor Keutamaan (I) dan faktor jenis struktur (K)

Berdasarkan fungsi bangunan yaitu rumah sakit, maka faktor keutamaan bangunan (I) diambil = 1,5 (PPKGURG 1987, tabel 2.1)

Sedangkan untuk faktor jenis struktur (K) diambil = 1,0 yaitu untuk portal daktail.

e. Gaya Geser Horizontal Akibat Gempa (V)

Gaya geser horizontal akibat gempa yang bekerja dapat dihitung dengan :

$$V = C \,.\, I \,.\, K \,.\, Wt = 0{,}048 \,.\, 1{,}5 \,.\, 1{,}0 \,.\, 30462{,}2 = 2193{,}3 \text{ kN}$$

f. Distribusi gaya horizontal total akibat gempa ke sepanjang tinggi gedung

1) Arah x

$$H/B = \frac{18{,}7}{35} = 0{,}534 < 3, \text{ maka :}$$

$$F_i x = \frac{Wi.hi}{\Sigma W.hi} V$$

2) Arah y

$$H/B = \frac{18{,}7}{16{,}1} = 1{,}161 < 3, \text{ maka :}$$

$$F_i y = \frac{Wi.hi}{\Sigma Wi.hi} V$$

Tabel 4.19 Distribusi Gaya Geser Horizontal total akibat gempa arah x dan arah y

Tingkat	hi (m)	Wi (kN)	V (kN)	Wi.hi (kNm)	Fi x,y (kN)
Atap	18.7	1677.8	2193.28	31374.52	218,52
Lantai 4	16.65	6945.8	2193.28	115647.42	805.48
Lantai 3	12.3	6893.6	2193.28	84791.69	590.57
Lantai 2	8.2	6784.7	2193.28	55634.78	387.49
Lantai 1	4.1	6696.1	2193.28	27453.81	191.21
Lantai dasar	0	1464.3	2193.28	0.00	0.00
Σ =				314902.21	2193.28

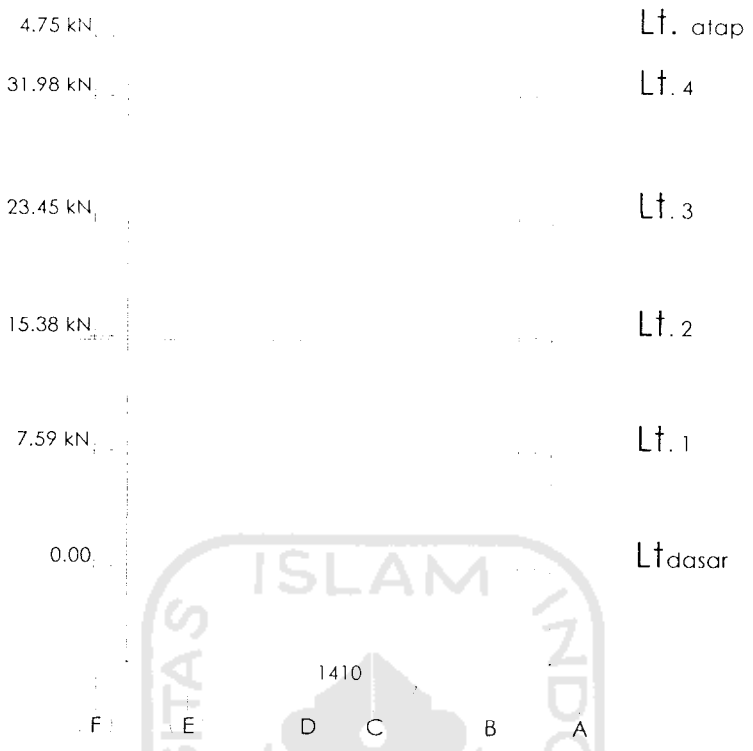
$Ix = 1/12 . h.b^3$ $\qquad$ $Iy = 1/12 . h.b^3$

$$Exy = \frac{Ii}{\Sigma Ii} xFi$$

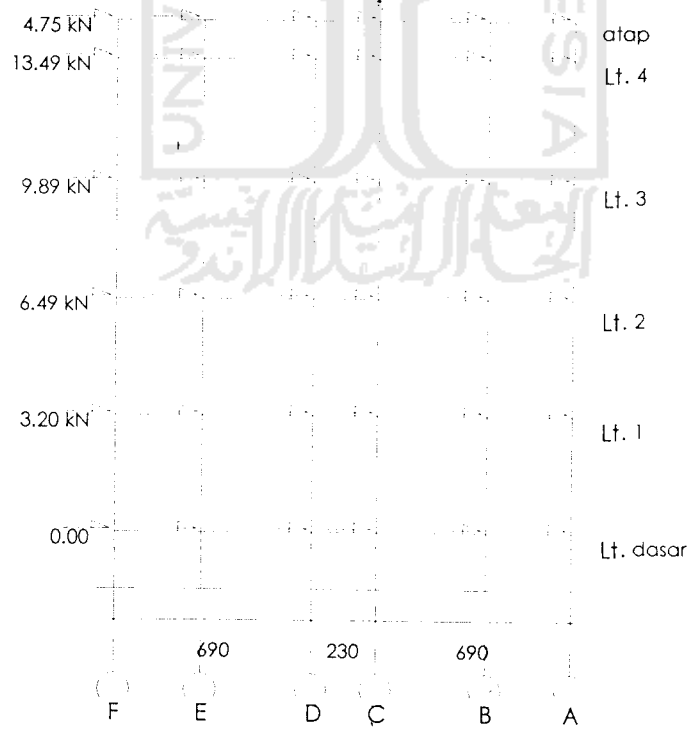
Tabel 4.20 Distribusi gaya geser horizontal untuk tiap portal arah X dan arah Y

Kolom	b m	h m	Iy m^4	Ix m^4	N bh	Total (m^4) Iy	Total (m^4) Ix	Fi kN	Fy kN	Fx kN
atap										
K40X60	0.4	0.6	0.0072	0.003	46	0.3312	0.1472	218.52	4.75	4.75
Total						0.3312	0.1472			
Lantai 4										
K40x80	0.4	0.8	0.0171	0.004	10	0.1707	0.0427	805.48	31.98	21.77
K40x60	0.4	0.6	0.0072	0.003	36	0.2592	0.1152	805.48	13.49	16.33
Total						0.4299	0.1579			
Lantai 3										
K40x80	0.4	0.8	0.0171	0.004	10	0.1707	0.0427	590.57	23.45	15.96
K40x60	0.4	0.6	0.0072	0.003	36	0.2592	0.1152	590.57	9.89	11.97
Total						0.4299	0.1579			

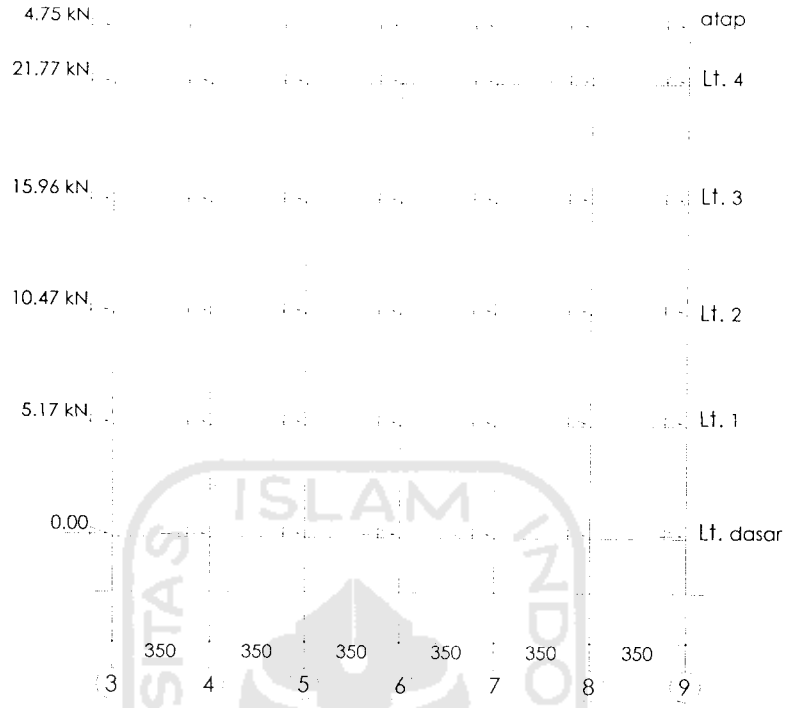
Kolom	b m	h m	Iy m^4	Ix m^4	N bh	Total (m^4) Iy	Total (m^4) Ix	Fi kN	Fy kN	Fx kN
Lantai 2										
K40x80	0.4	0.8	0.0171	0.004	10	0.1707	0.0427	387.49	15.38	10.47
K40x60	0.4	0.6	0.0072	0.003	36	0.2592	0.1152	387.49	6.49	7.85
Total						0.4299	0.1579			
Lantai 1										
K40x80	0.4	0.8	0.0171	0.004	10	0.1707	0.0427	191.21	7.59	5.17
K40x60	0.4	0.6	0.0072	0.003	36	0.2592	0.1152	191.21	3.20	3.88
Total						0.4299	0.1579			
dasar										
K40x80	0.4	0.8	0.0171	0.004	10	0.1707	0.0427	0.00	0.00	0.00
K40x60	0.4	0.6	0.0072	0.003	36	0.2592	0.1152	0.00	0.00	0.00
Total						0.4299	0.1579			



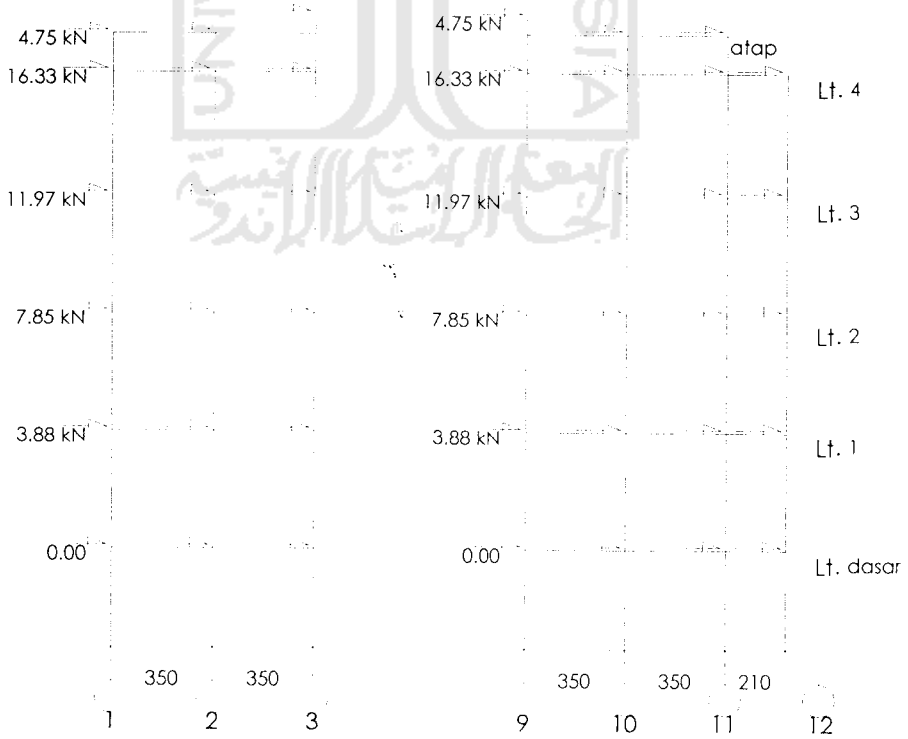
Gambar 4.17 Pembebanan gempa arah Fx (kolom 400/800)



Gambar 4.18 Pembebanan gempa arah Fx (kolom 400/600)



Gambar 4.19 Pembebanan gempa arah Fy (kolom 400/800)



Gambar 4.20 Pembebanan gempa arah Fy (kolom 400/600)

4.4.3 Disain Balok

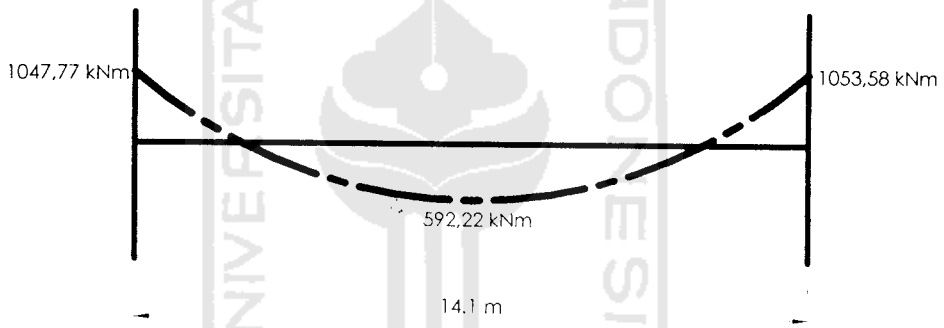
4.4.3.1 Disain Tulangan Lentur Balok

A. Momen Rencana Balok

Momen rencana balok diambil yang terbesar dari hasil kombinasi beban sebagai berikut :

1. $1{,}2\ M_D + 1{,}6\ M_L$
2. $1{,}05\ (M_D + 0{,}9\ M_L \pm M_E)$

Berikut diberikan contoh perhitungan balok F119 (bentang E1 – A1)



Gambar 4.21 Momen balok F119

B. Tulangan Tumpuan E1

Dipakai dimensi rencana 350/800

f'c = 22,5 Mpa fy = 400 Mpa

Mu = 1047,77 kNm

$$\frac{Mu}{\phi} = \frac{1047{,}77}{0{,}8} = 1309{,}713 \text{ kNm}$$

$$\rho_b = \frac{0{,}85.f'c}{fy}\beta_1\left(\frac{600}{600+fy}\right) = \frac{0{,}85.22{,}5.0{,}85}{400}\left(\frac{600}{600+400}\right) = 0{,}0244$$

ρ_{maks} = 0,75 ρb = 0,75 . 0,0244 = 0,0183

rasio tulangan rencana (ρ) = 0,5 . ρ_{maks} = 0,5 . 0,0183 = 0,0091

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

$m = \dfrac{fy}{0,85.f'c} = \dfrac{400}{0,85.22,5} = 20,915$

$Rn = \rho.fy\left(1 - \dfrac{1}{2}.\rho.m\right) = 0,00915.400\left(1 - \dfrac{1}{2}.0,00915.20,915\right) = 3,31$ Mpa

$d_{perlu} = \sqrt{\dfrac{Mu/\phi}{Rn.b}} = \sqrt{\dfrac{1309,713.10^6}{3,31.350}} = 1063,261$ mm

d_{ada} = h – d' (d' = 75 mm, diasumsikan menggunakan tulangan 2 lapis)

= 800 – 75 = 725 mm < d_{perlu}, maka dipakai tulangan rangkap.

$As_1 = \rho_{pakai}$. b . d = 0,00915 . 350 . 725 = 2321,813 mm^2

$a = \dfrac{As_1.fy}{0,85.f'c.b} = \dfrac{2321,813.400}{0,85.22,5.350} = 138,745$ mm

$Mn_1 = As_1.fy.(d - ({a}/{2})).10^{-6} = 2321,813.400.(725 - ({138,745}/{2})).10^{-6}$

= 608,898 kNm

Tulangan desak

$Mn_2 = ({Mu}/{\phi}) - Mn_1 = 1309,713 - 608,898 = 700,815$ kNm

$fs' = 600\left[1 - \dfrac{(0,85.f'c.\beta.d')}{\rho_{pakai}.fy.d}\right] = 600\left[1 - \dfrac{(0,85.22,5.0,85.75)}{0,00915.400.725}\right] = 324,6$ Mpa

➔ karena fs' < fy, maka baja desak belum leleh,

sehingga dipakai fs' = fs = 324,6 Mpa

$As' = \dfrac{Mn_2.10^6}{fs'(d - d')} = \dfrac{700,815.10^6}{324,6(725 - 75)} = 3321,556$ mm^2

➔ Dipakai tulangan D25 dengan A1Ø = 490,874 mm^2

Jumlah tulangan (n) = $\frac{As'_{perlu}}{A1\phi} = \frac{3321,556}{490,874} = 6,77 \approx 7$ batang

Dipakai tulangan 7D25 – $As'_{ada} = 3436,118\ mm^2 > As'_{perlu} = 3321,556\ mm^2$

Tulangan tarik

$As = As_1 + As' = 2321,813 + 3321,556 = 5643,369\ mm^2$

➔ Dipakai tulangan D25 dengan A1Ø = 490,874 mm^2

Jumlah tulangan (n) = $\frac{As_{perlu}}{A1\phi} = \frac{5643,369}{490,874} = 11,5 \approx 12$ batang

Dipakai 12D25 = $As_{ada} = 5890,488\ mm^2 > As_{perlu} = 5643,369\ mm^2$

b = 2Pb + 2Øsengkang + nØtul + (n-1)25

= 2.25 + 2.10 + nØtul + (n-1).25

= n (Øtul + 25) + 45

$n_{\ 1\ lapis} = \frac{b-45}{\phi tul + 25} = \frac{350-45}{25+25} = 6,1 \approx 6$ tulangan

Kontrol kapasitas momen nominal tumpuan negatif :

Tulangan atas = 12 D25 dengan As_{ada} = 5890,488 mm^2

Tulangan bawah = 7 D25 dengan As'_{ada} = 3436,118 mm^2

$\rho = \frac{As_{ada}}{b.d} = \frac{5890,488}{350.725} = 0,023$

$\rho' = \frac{As'_{ada}}{b.d} = \frac{3436,118}{350.725} = 0,014$

$\rho - \rho' = 0,023 - 0,014 = 0,009$

$fs' = 600\left[1 - \frac{(0,85.f'c.\beta.d')}{(\rho-\rho').fy.d}\right] = 600\left[1 - \frac{(0,85.22,5.0,85.75)}{0,009.400.725}\right] = 319,8$ Mpa

$$a = \frac{(As_{ada}.fy)-(As'_{ada}.fs')}{0{,}85.f'c.b}$$

$$= \frac{(5890{,}488.400)-(3436{,}118.319{,}8)}{0{,}85.22{,}5.350}$$

$$= 187{,}836 \text{ mm}$$

$Mnak,b = Mn_1 + Mn_2$

$= ((As_{ada}.fy - As'_{ada}.fs').(d-a/2) + (As'_{ada}.fs ')(d-d')).10^{-6}$

$= ((5890{,}488 . 400 - 3436{,}118 . 319{,}8) . (725 - 187{,}836/2) +$

$(3436{,}118.319{,}8) . (725 - 75).10^{-6}$

$= 1507{,}741 \text{ kNm} > \frac{Mu}{\phi} = 1309{,}713 \text{ kNm}$ (OK)

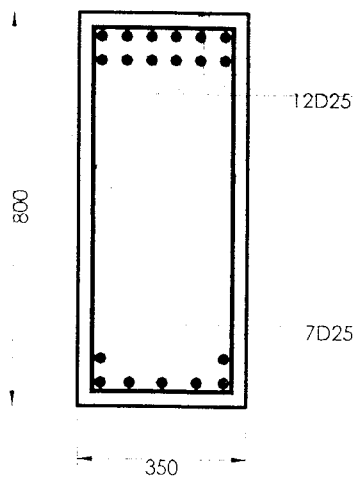
kapasitas momen nominal tumpuan positif :

$\rho_{aktual} = \frac{As'_{ada}}{b.d_{pakai}} = \frac{3436{,}118}{350.725} = 0{,}014$

$Rn = \rho . fy . (1 - ½ . \rho . m) = 0{,}014 . 400 . (1 - ½ . 0{,}014 . 20{,}915)$

$= 4{,}78$ Mpa

$Mnak,b' = Rn . b . d^2 = 4{,}78 . 350 . 725^2 . 10^{-6} = 879{,}371$ kNm



Gambar 4.22 Penulangan balok portal F119 daerah Tumpuan E1

C. Tulangan Lapangan

Mu = 592,22 kNm

$$\frac{Mu}{\phi} = \frac{592,22}{0,8} = 740,275 \text{ kNm}$$

$$\rho_b = \frac{0,85.f'c}{fy}\beta_1\left(\frac{600}{600+fy}\right) = \frac{0,85.22,5.0,85}{400}\left(\frac{600}{600+400}\right) = 0,0244$$

ρ_{maks} = 0,75 ρb = 0,75 . 0,0244 = 0,0183

rasio tulangan rencana (ρ) = 0,5 . ρ_{maks} = 0,5 . 0,0183 = 0,00915

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

$$m = \frac{fy}{0,85.f'c} = \frac{400}{0,85.22,5} = 20,915$$

$$Rn = \rho.fy\left(1-\frac{1}{2}.\rho.m\right) = 0,00915.400\left(1-\frac{1}{2}.0,00915.20,915\right) = 3,31 \text{ Mpa}$$

$$d_{perlu} = \sqrt{\frac{\frac{Mu}{\phi}}{Rn.b}} = \sqrt{\frac{740,275.10^6}{3,31.350}} = 799,371 \text{ mm}$$

d_{ada} = h – d' (d' = 75 mm, diasumsikan menggunakan tulangan 2 lapis)

800 75 725 mm d_{perlu}, maka dipakai tulangan rangkap.

As_1 = ρ_{pakai} . b . d = 0,00915 . 350 . 725 = 2321,813 mm^2

$$a = \frac{As_1.fy}{0,85.f'c.b} = \frac{2321,813.400}{0,85.22,5.350} = 138,745 \text{ mm}$$

Mn_1 = As_1.fy.(d – ($\frac{a}{2}$)).10^{-6} = 2321,813.400.(725 – ($\frac{138,745}{2}$)).10^{-6}

= 608,898 kNm

Tulangan desak

$Mn_2 = \left(Mu/\phi \right) - Mn_1 = 799{,}371 - 608{,}898 = 190{,}473$ kNm

$$fs' = 600\left[1 - \frac{(0{,}85.f'c.\beta.d')}{\rho_{pakai}.fy.d}\right] = 600\left[1 - \frac{(0{,}85.22{,}5.0{,}85.75)}{0{,}00915.400.725}\right] = 324{,}6 \text{ Mpa}$$

➔ fs' < fy, maka baja desak belum leleh,

sehingga dipakai fs' = fs = 324,6 Mpa

$$As' = \frac{Mn_2.10^6}{fs'(d-d')} = \frac{190{,}473.10^6}{324{,}6(725-75)} = 902{,}758 \text{ mm}^2$$

➔ Dipakai tulangan D25 dengan A1Ø = 490,874 mm^2

$$\text{Jumlah tulangan (n)} = \frac{As'_{perlu}}{A1\phi} = \frac{902{,}758}{490{,}874} = 1{,}84 \approx 2 \text{ batang}$$

Dipakai tulangan 2D25 = As'_{ada} = 981,748 mm^2 > As'_{perlu} = 902,758 mm^2

Tulangan tarik

$As = As_1 + As' = 2321{,}813 + 902{,}758 = 3224{,}571 \text{ mm}^2$

➔ Dipakai tulangan D25 dengan A1Ø = 490,874 mm^2

$$\text{Jumlah tulangan (n)} = \frac{As_{perlu}}{A1\phi} = \frac{3224{,}571}{490{,}874} = 6{,}57 \approx 7 \text{ batang}$$

Dipakai 7D25 = As_{ada} = 3436,118 mm^2 > As_{perlu} = 3224,571 mm^2

b = 2Pb + 2Øsengkang + nØtul + (n-1)25

= 2.25 + 2.10 + nØtul + (n-1).25

= n (Øtul + 25) + 45

$$n\ 1_{lapis} = \frac{b-45}{\phi tul + 25} = \frac{350-45}{25+25} = 6{,}1 \approx 6 \text{ tulangan}$$

Kontrol kapasitas momen nominal tumpuan negatif :

Tulangan atas = 2 D25 dengan As'_{ada} = 981,748 mm^2

Tulangan bawah = 7 D25 dengan As_{ada} = 3436,118 mm^2

$$\rho = \frac{As_{ada}}{b.d} = \frac{3436,118}{350.725} = 0,014$$

$$\rho' = \frac{As'_{ada}}{b.d} = \frac{981,748}{350.725} = 0,004$$

$$\rho - \rho' = 0,014 - 0,004 = 0,01$$

$$fs' = 600\left[1 - \frac{(0,85.f'c.\beta.d')}{(\rho - \rho').fy.d}\right] = 600\left[1 - \frac{(0,85.22,5.0,85.75)}{0,01.400.725}\right] = 348 \text{ Mpa}$$

$$a = \frac{(As_{ada}.fy) - (As'_{ada}.fs')}{0,85.f'c.b}$$

$$= \frac{(3436,118.400) - (981,748.348)}{0,85.22,5.350}$$

$$= 154,293 \text{ mm}$$

$$Mnak,b = Mn_1 + Mn_2$$

$$= ((\ As_{ada}.fy - As'_{ada}.fs'\ ).(\ d-a/2\ ) + (\ As'_{ada}.fs'\ )(\ d-d'\ ))^{.10-6}$$

$$= ((\ 3436,118\ .\ 400 - 981,748\ .\ 348\ )\ .\ (\ 725 - 154,293/2\ ) +$$

$$(\ 981,748\ .\ 348\ )\ .\ (\ 725 - 75\ )^{.10-6}$$

$$= 891,174 \text{ kNm} > \frac{Mu}{\phi} = 740,275 \text{ kNm} \quad \text{.....(OK)}$$

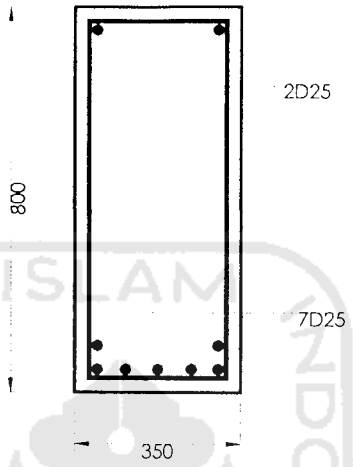
kapasitas momen nominal tumpuan positif :

$$\rho_{aktual} = \frac{As'_{ada}}{b.d_{pakai}} = \frac{981,748}{350.725} = 0,004$$

Rn = ρ . fy . (1 – ½ . ρ . m) = 0,004 . 400 . (1 – ½ . 0,004 . 20,915)

= 1,53 Mpa

Mnak,b' = Rn . b . d^2 = 1,53 . 350 . 725^2 . 10^{-6} = 281,472 kNm



Gambar 4.23 Penulangan balok portal F119 daerah lapangan

D. Tulangan Tumpuan A1

Mu = 1053,58 kNm

$$\frac{Mu}{\phi} = \frac{1053,58}{0,8} = 1316,975 \text{ kNm}$$

$$\rho_b = \frac{0,85.f'c}{fy}\beta_1\left(\frac{600}{600+fy}\right) = \frac{0,85.22,5.0,85}{400}\left(\frac{600}{600+400}\right) = 0,0244$$

ρ_{maks} = 0,75 ρb = 0,75 . 0,0244 = 0,0183

rasio tulangan rencana (ρ) = 0,5 . ρ_{maks} = 0,5 . 0,0183 = 0,00915

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

$$m = \frac{fy}{0,85.f'c} = \frac{400}{0,85.22,5} = 20,915$$

$$Rn = \rho.fy.\left(1 - \frac{1}{2}.\rho.m\right) = 0{,}00915.400.\left(1 - \frac{1}{2}.0{,}00915.20{,}915\right) = 3{,}31 \text{ Mpa}$$

$$d_{perlu} = \sqrt{\frac{Mu/\phi}{Rn.b}} = \sqrt{\frac{1316{,}975.10^6}{3{,}31.350}} = 1066{,}205 \text{ mm}$$

d_{ada} = h – d' (d' = 75 mm, diasumsikan menggunakan tulangan 2 lapis)

= 800 – 75 = 725 mm < d_{perlu}, maka dipakai tulangan rangkap.

$As_1 = \rho_{pakai}$. b . d = 0,00915 . 350 . 725 = 2321,813 mm^2

$$a = \frac{As_1.fy}{0{,}85.f'c.b} = \frac{2321{,}813.400}{0{,}85.22{,}5.350} = 138{,}745 \text{ mm}$$

$Mn_1 = As_1.fy.(d - (a/2)).10^{-6} = 2321{,}813.400.(725 - (138{,}745/2)).10^{-6}$

= 608,898 kNm

Tulangan desak

$Mn_2 = (Mu/\phi) - Mn_1 = 1316{,}975 - 608{,}898 = 708{,}077$ kNm

$$fs' = 600\left[1 - \frac{(0{,}85.f'c.\beta.d')}{\rho_{pakai}.fy.d}\right] = 600\left[1 - \frac{(0{,}85.22{,}5.0{,}85.75)}{0{,}00915.400.725}\right] = 324{,}6 \text{ Mpa}$$

➔ fs' < fy, maka baja desak belum leleh,

sehingga dipakai fs' fs 324,6 Mpa

$$As' = \frac{Mn_2.10^6}{fs'(d - d')} = \frac{708{,}077.10^6}{324{,}6(725 - 75)} = 3355{,}974 \text{ mm}^2$$

➔ Dipakai tulangan D25 dengan A1Ø = 490,874 mm^2

$$\text{Jumlah tulangan (n)} = \frac{As'_{perlu}}{A1\phi} = \frac{3355{,}974}{490{,}874} = 6{,}84 \approx 7 \text{ batang}$$

Dipakai tulangan 7D25 = As'_{ada} = 3436,118 mm^2 > As'_{perlu} = 3355,974 mm^2

Tulangan tarik

As = As_1 + As' = 2321,813 + 3355,974 = 5677,787 mm^2

➔ Dipakai tulangan D25 dengan A1Ø = 490,874 mm^2

Jumlah tulangan (n) $= \frac{As_{perlu}}{A1\phi} = \frac{5677,787}{490,874} = 11,57 \approx 12$ batang

Dipakai 12D25 = As_{ada} = 5890,488 mm^2 > As_{perlu} = 5677,787 mm^2

b = 2Pb + 2Øsengkang + nØtul + (n-1)25

= 2.25 + 2.10 + nØtul + (n-1).25

= n (Øtul + 25) + 45

$n\ 1_{lapis} = \frac{b-45}{\phi tul + 25} = \frac{350-45}{25+25} = 6,1 \approx 6$ tulangan

Kontrol kapasitas momen nominal tumpuan negative :

Tulangan atas = 12 D25 dengan As_{ada} = 5890,488 mm^2

Tulangan bawah = 7 D25 dengan As'_{ada} = 3436,118 mm^2

$\rho = \frac{As_{ada}}{b.d} = \frac{5890,488}{350.725} = 0,023$

$\rho' = \frac{As'_{ada}}{b.d} = \frac{3436,118}{350.725} = 0,014$

$\rho - \rho' = 0,023 - 0,014 = 0,009$

$fs' = 600\left[1 - \frac{(0,85.f'c.\beta.d')}{(\rho-\rho').fy.d}\right] = 600\left[1 - \frac{(0,85.22,5.0,85.75)}{0,009.400.725}\right] = 319,8$ Mpa

$a = \frac{(As_{ada}.fy) - (As'_{ada}.fs')}{0,85.f'c.b}$

$= \frac{(5890,488.400) - (3436,118.319,8)}{0,85.22,5.350} = 187,836$ mm

Mnak,b $= Mn_1 + Mn_2$

$= ((As_{ada}.fy - As'_{ada}.fs').(d-a/2) + (As'_{ada}.fs ')(d-d')).^{10-6}$

$= ((5890,488 . 400 - 3436,118 . 319,8) . (725 - 187,836/2) +$

$(3436,118.319,8) . (725 - 75).^{10-6}$

$= 1507,741 \text{ kNm} > \frac{Mu}{\phi} = 1316,975 \text{ kNm} \ldots\ldots\ldots$ **(OK)**

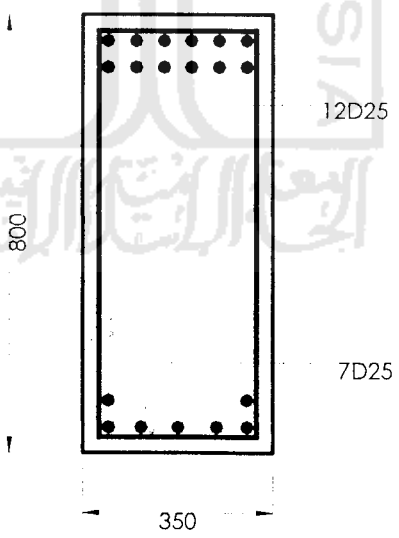
kapasitas momen nominal tumpuan positif :

$\rho_{aktual} = \frac{As'_{ada}}{b.d_{pakai}} = \frac{3436,118}{350.725} = 0,014$

Rn $= \rho . fy . (1 - ½ . \rho . m) = 0,014 . 400 . (1 - ½ . 0,014 . 20,915)$

$= 4,78$ Mpa

Mnak,b' $= Rn . b . d^2 = 4,78 . 350 . 725^2 . 10^{-6} = 879,371$ kNm



Gambar 4.24 Penulangan balok portal F119 daerah Tumpuan A1

E. Perencanaan Tulangan Geser Balok

Adapun syarat penentuan gaya geser rencana balok adalah sebagai berikut :

$$Vu,b = 0,7\phi_0\left[\frac{M_{nak,b} + M_{nak,b'}}{Ln}\right] + 1,05.Vg$$

Tetapi tidak lebih besar dari :

$$Vu,b = 1,07\ (\ V_{D,b} + V_{L,b} + 4/k\ .\ V_{E,b}\ )$$

$V_D = 258,53$ kN ; $V_L = 66,48$ kN ; $V_E = 25,88$ kN

$$Vu,b = 0,7\phi_0\left[\frac{M_{nak,b} + M_{nak,b'}}{Ln}\right] + 1,05.Vg$$

$$Vu,b = 0,7.1,25\left[\frac{1507,741 + 879,371}{14,1}\right] + 1,05.(258,53 + 66,48) = 489,397 \text{ kN}$$

Dengan syarat tidak lebih besar dari :

$$Vu,b = 1,07\ (\ 258,53 + 66,48 + 4/1\ .\ 25,88\ ) = 458,527 \text{ kN}$$

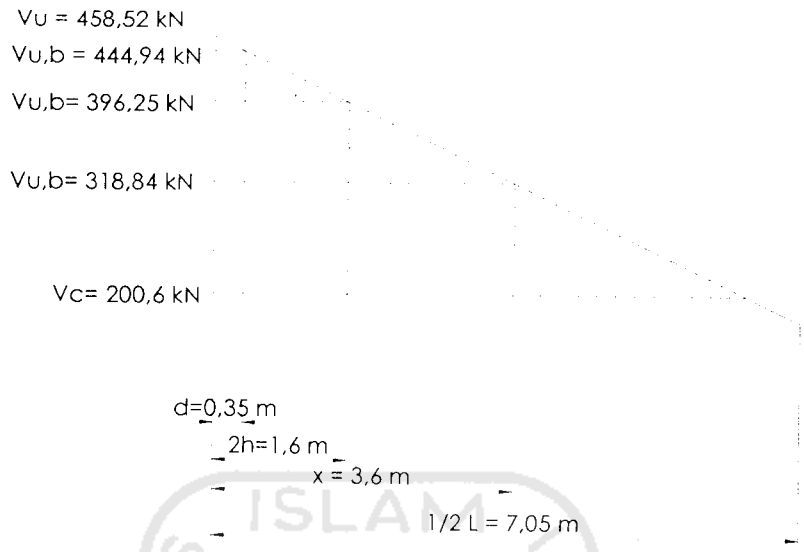
$$Vu,b_{pakai} = \left[1,05Vg - 0,7\phi_0\left(\frac{Mnak,b + Mnak,b'}{Ln}\right)\right] +$$

$$\frac{Ln - d}{Ln}\left[Vu,b - \left[1,05Vg - 0,7\phi_0\left[\frac{Mnak,b + Mnak,b'}{Ln}\right]\right]\right]$$

$$= \left[1,05.325,01 - 0,7.1,25\left(\frac{1507,741 + 879,371}{14,1}\right)\right] +$$

$$\frac{14,1 - 0,725}{14,1}\left[458,527 - \left[1,05.325,01 - 0,7.1,25\left[\frac{1507,741 + 879,371}{14,1}\right]\right]\right]$$

$= 444,991$ kN



Gambar 4.25 Diagram tegangan geser balok portal (F119)

1) Dalam daerah sendi plastis

Vu,b untuk perencanaan di dalam daerah sendi plastis diambil sejauh d dari tumpuan, yaitu :

Vu,b = 444,991 kN

Vc = 0

$$\frac{Vu,b}{\phi} = \frac{444,991}{0,6} = 741,652 \text{ kN}$$

digunakan sengkang P12 mm, maka : Av = 2 . ¼ . π . 12^2 = 226,19 mm^2

Jarak sengkang :

$$s \leq \frac{Av.fy.d}{Vu,b/\phi - Vc} = \frac{226,19.240.725}{741,652 - 0}.10^{-3} = 53,07 \text{ mm} \approx 50 \text{ mm}$$

$$\leq d/4 = 725/4 = 181,25 \text{ mm}$$

$$\leq 300 \text{ mm}$$

jadi dipakai tulangan geser **2P12 – 100 mm**

2) Diluar sendi plastis

a. Diambil jarak sejauh 2h = 2 . 800 = 1600 mm dengan Vu,b = 396,257 kN

$$Vc = 1/6.\sqrt{f'c}.b.d = 1/6.\sqrt{22,5}.350.725 = 200,61 \text{ kN}$$

$$Vs = \frac{Vu,b}{\phi} - Vc = \frac{396,257}{0,6} - 200,61 = 459,818 \text{ kN}$$

Digunakan sengkang P12 mm, maka : $Av = 2 . \frac{1}{4} . \pi . 12^2 = 226,19 \text{ mm}^2$

Jarak sengkang :

$$s \leq \frac{Av.fy.d}{Vs} = \frac{226,19.240.725}{459,818}.10^{-3} = 85,59 \text{ mm} \approx 80 \text{ mm}$$

$$\leq d/2 = 725/2 = 362,5 \text{ mm}$$

$$\leq 600 \text{ mm}$$

Jadi dipakai tulangan geser **1,5P12 – 120 mm**

b. Diambil jarak sejauh x = 3,6 m maka,

$$Vu,b = 458,52 - \frac{(458,52 - 444,94).3,6}{0,35} = 318,84 \text{ kN}$$

$$Vs = \frac{Vu,b}{\phi} - Vc = \frac{318,94}{0,6} - 200,61 = 330,79 \text{ kN}$$

Digunakan sengkang P12 mm, maka : $Av = 2 . \frac{1}{4} . \pi . 12^2 = 226,19 \text{ mm}^2$

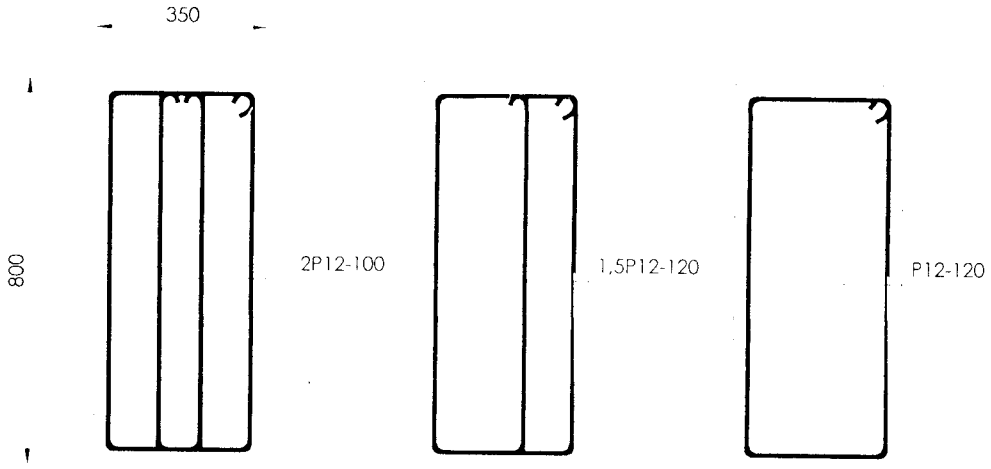
Jarak sengkang :

$$s \leq \frac{Av.fy.d}{Vs} = \frac{226,19.240.725}{330,79}.10^{3} = 121,98 \text{ mm}$$

$$\leq d/2 = 725/2 = 362,5 \text{ mm}$$

$$\leq 600 \text{ mm}$$

Jadi dipakai tulangan geser **P12 – 120 mm**



kondisi (1) kondisi (2a) kondisi (2b)

Gambar 4.34 Penulangan sengkang balok portal F119

F. Perencanaan Tulangan Torsi

Tu = 0,728 kNm

$\Sigma x^2.y = 350^2 . 725 = 88{,}81.10^6$ mm^3

Pada redisain ini komponen struktur portal merupakan komponen statis tak tentu. Untuk komponen statis tak tentu setelah terjadi retak akibat torsi, dalam rangka untuk mencapai keseimbangan terjadi redistribusi tegangan torsional yang mempengaruhi komponen lain yang bertemu pada satu titik buhul. Maka untuk menganalisa torsi dipakai torsi keserasian.

Kemampuan penampang beton menahan torsi untuk torsi keserasian :

$$Tu,b = \phi\left(\frac{1}{9}\sqrt{f'c}.\Sigma x^2.y\right) = 0{,}6\left(\frac{1}{9}\sqrt{22{,}5}.88{,}81.10^6\right)$$

= 28,084 kNm > Tu = 0,728 kNm, tulangan torsi diabaikan.

4.4.4 Perencanaan Kolom

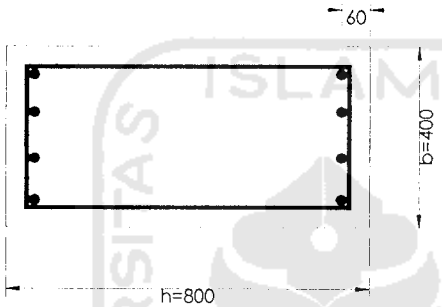
4.4.4.1 Grafik Interaksi Mn-Pn

Ukuran kolom : 400 mm x 800 mm

Ast : 1% s/d 4%

fc' : 22,5 Mpa

fy : 400 Mpa



Grafik Mn-Pn untuk Ast = 1%

Ag : 400×800 $= 320000\ mm^2$

Ast : $1\% \times 400 \times 800$ $= 3200\ mm^2$

As = As' = ½ Ast $= 1600\ mm^2$

P_o $= 0{,}85\ fc'\ (Ag-Ast) + Ast.fy$

$= (0{,}85 \times 22{,}5\ (320000-3200) + 3200 \times 400) \times 10^{-3}$

$= 7338{,}8\ kN$

Pno $= 0{,}8\ P^o$ $= 0{,}8 \times 7338{,}8 = 5871{,}04\ kN$

Desak Aksial + Momen (seimbang)

d' = 60 mm

fc' = 22,5 Mpa

fy = 400 Mpa

Ast = 3200 mm^2

$$Xb = \frac{600.d}{600 + fy} = \frac{600.(800 - 60)}{600 + 400} = 444 \text{ mm}$$

$$a = \beta_1 \times Xb = 0{,}85 \times 444 = 377{,}4 \text{ mm}$$

$$fs' = 600 \times \frac{(Xb - d')}{Xb} = 600 \times \frac{(444 - 60)}{444}$$

= 518,92 Mpa > fy = 400 Mpa,

dengan demikian digunakan f's = fy = 400 Mpa

Ccb = 0,85×f'c×b×ab = (0,85×22,5×400×377,4)×10^{-3} = 2887,1 kN

Csb = As'(f's-0,85f'c) = (1600 (400-0,85×22,5)) ×10^{-3} = 609,4 kN

Tsb = As×fy = (1600 × 400) ×10^{-3} = 640 kN

Pnb = Ccb + Csb –Tsb = 2887,1 + 609,4 – 640

= 2856,51 kN

$$Mnb = Ccb\left[\frac{h}{2} - \frac{ab}{2}\right] + Csb\left(\frac{h}{2} - d'\right) + Tsb\left(d - \frac{h}{2}\right)$$

$$= 2848{,}1\left(\frac{800}{2} - \frac{377{,}4}{2}\right) + 609{,}4\left(\frac{800}{2} - 60\right) + \left(740 - \frac{800}{2}\right)640$$

= 1034,84 kN m

$$eb = \frac{Mnb}{Pnb} = \frac{1034{,}84}{2856{,}51} = 0{,}36 \text{ m}$$

Patah Desak (syarat X > Xb)

Misal X diambil = 1,2 Xb mm

fc' = 22,5 Mpa

fy = 400 Mpa

d = (800-60) = 740 mm

a $= \beta_1 \times Xb = 0{,}85 \times (1{,}2 \times 444) = 301{,}92$ mm

Cc $= 0{,}85 \times f'c \times b \times ab = (0{,}85 \times 22{,}5 \times 400 \times 301{,}92) \times 10^{-3} = 3464{,}53$ kN

$$fs' = 600 \times \frac{(X - d')}{X} = 600 \times \frac{(532{,}8 - 60)}{500}$$

$= 534{,}43$ Mpa > fy = 400 Mpa

dengan demikian digunakan fs' = 400 Mpa

$$fs = 600 \times \frac{(d - X)}{X} = 600 \times \frac{(740 - 532{,}8)}{532{,}8}$$

$= 233$ Mpa < fy = 400 Mpa

dengan demikian digunakan fs = 233 Mpa

Cs $= As'(fs'-0{,}85f'c) = (1600\ (400-0{,}85 \times 22{,}5)) \times 10^{-3} = 609{,}4$ kN

Ts $= As \times fs = (1600 \times 233) \times 10^{-3} = 373{,}3$ kN

Pn $= Cc + Cs - Ts = 3464{,}53 + 609{,}4 - 373{,}3$

$= 3700{,}6$ kN > Pnb = 2856,51 kN .....OK

$$Mn = Ccb\left[\frac{h}{2} - \frac{ab}{2}\right] + Csb\left(\frac{h}{2} - d'\right) + Tsb\left(d - \frac{h}{2}\right)$$

$$= 3464{,}53\left(\frac{800}{2} - \frac{452{,}8}{2}\right) + 609{,}4\left(\frac{800}{2} - 60\right) + 373{,}3\left(740 - \frac{800}{2}\right)$$

$= 935{,}43$ kN m

$$e = \frac{Mn}{Pn} = \frac{935{,}43}{3700{,}6} = 0{,}25 \text{ m} < eb = 0{,}36 \text{ .....OK}$$

Patah Tarik (syarat X < Xb)

Misal X diambil = 0,8.Xb mm

fc' = 22,5 Mpa

fy = 400 Mpa

d = (800-60) = 740 mm

$$fs = 600 \times \frac{(d - X)}{X} = 600 \times \frac{(740 - 355{,}2)}{355{,}2}$$

= 498,64 Mpa > fy = 400 Mpa

dengan demikian digunakan fs = 400 Mpa

$$fs' = 600 \times \frac{(X - d')}{X} = 600 \times \frac{(355{,}2 - 60)}{355{,}2}$$

= 498,65 Mpa > fy = 400 Mpa

dengan demikian digunakan fs` = 400 Mpa

a = $\beta_1 \times X$ = 0,85 × 355,2 = 301,92 mm

Cc = 0,85×f`c×b×ab = (0,85×22,5×400×340)×10^{-3} = 2309,6 kN

Cs = As`(fs`-0.85f`c) = (1600 (400-(0,85×22,5)))×10^{-3} = 609,4 kN

Ts = As×fs = (1600 × 400) ×10^{-3} = 640 kN

Pn = Cc + Cs –Ts = 2309,64 + 609,4 – 640

= 2279,1 kN < Pnb = 2856,51 kN .....OK

$$Mn = Ccb\left[\frac{h}{2} - \frac{ab}{2}\right] + Csb\left(\frac{h}{2} - d'\right) + Tsb\left(d - \frac{h}{2}\right)$$

$$= 2309{,}6\left(\frac{800}{2} - \frac{425}{2}\right) + 609{,}4\left(\frac{800}{2} - 60\right) + 640\left(740 - \frac{800}{2}\right)$$

= 1000 kN m

$$e = \frac{Mn}{Pn} = \frac{1000}{2570{,}4}$$ = 0,44 m > eb = 0,36 .....OK

Lentur Murni

$$a = \frac{As.fy}{0{,}85.f'c.b} = \frac{1600.400}{0{,}85.22{,}5.400}$$ = 83,66 mm

$$Mn = As \times fy\left(d - \frac{a}{2}\right) = 1500.400\left(740 - \frac{83{,}66}{2}\right) \times 10^{-6}$$ = 446,83 kNm

Tabel 4.25 Perhitungan Grafik Mn-Pn Ast = 1 % s/d 4 % (b = 400 ; h = 800)

1%	Lentur	Patah tarik			Seimbang	Patah Desak			Aksial
		0.4 X	0.6X	0.8 X	X = 444	1.2 X	1.4 X	1.6 X	
a		150.96	226.44	301.92	377.40	452.88	528.36	603.84	
fs		400.00	400.00	400.00	400.00	233.33	114.29	25.00	
fs'		400.00	400.00	400.00	400.00	400.00	400.00	400.00	
As=As'		1600	1600	1600	1600	1600	1600	1600	
Cc		1154.84	1732.27	2309.69	2887.11	3464.53	4041.95	4619.38	
Cs		609.40	609.40	609.40	609.40	609.40	609.40	609.40	
Ts		640.00	640.00	640.00	640.00	373.33	182.86	40.00	
Pn	0	1119.92	1701.67	2279.09	2856.51	3700.60	4468.50	5188.78	7338.8
Mn	446.83	798.10	921.58	1000.00	1034.84	935.43	818.35	673.86	0

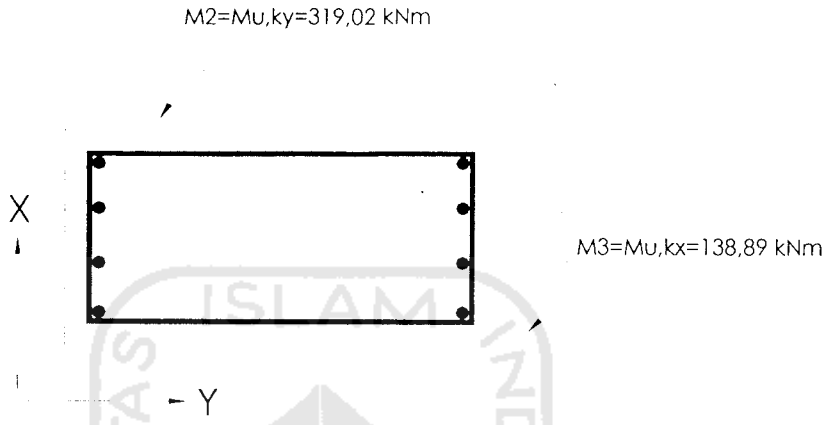
2%	Lentur	Patah tarik			Seimbang	Patah Desak			Aksial
		0.4 X	0.6X	0.8 X	X = 444	1.2 X	1.4 X	1.6 X	
a		150.96	226.44	301.92	377.40	452.88	528.36	603.84	
fs		400.00	400.00	400.00	400.00	233.33	114.29	25.00	
fs'		400.00	400.00	400.00	400.00	400.00	400.00	400.00	
As=As'		3200	3200	3200	3200	3200	3200	3200	
Cc		1154.84	1732.27	2309.69	2887.11	3464.53	4041.95	4619.38	
Cs		609.40	1218.80	1218.80	1218.80	1218.80	1218.80	1218.80	
Ts		1280.00	1280.00	1280.00	1280.00	746.67	365.71	80.00	
Pn	0	1085.00	1671.07	2248.49	2825.91	3936.67	4895.04	5758.18	8557.6
Mn	840.12	1221.42	1346.37	1424.80	1459.64	1269.56	1087.71	894.66	0

3%	Lentur	Patah tarik			Seimbang	Patah Desak			Aksial
		0.4 X	0.6X	0.8 X	X = 444	1.2 X	1.4 X	1.6 X	
a		150.96	226.44	301.92	377.40	452.88	528.36	603.84	
fs		400.00	400.00	400.00	400.00	233.33	114.29	25.00	
fs'		400.00	400.00	400.00	400.00	400.00	400.00	400.00	
As=As'		4800	4800	4800	4800	4800	4800	4800	
Cc		1154.84	1732.27	2309.69	2887.11	3464.53	4041.95	4619.38	
Cs		1828.20	1828.20	1828.20	1828.20	1828.20	1828.20	1828.20	
Ts		1920.00	1920.00	1920.00	1920.00	1120.00	548.57	120.00	
Pn	0	1050.12	1640.47	2217.89	2795.31	4172.73	5321.58	6327.58	9776.4
Mn	1179.86	1644.75	1771.17	1849.59	1884.43	1603.69	1357.08	1115.46	0

4%	Lentur	Patah tarik			Seimbang	Patah Desak			Aksial
		0.4 X	0.6X	0.8 X	X = 444	1.2 X	1.4 X	1.6 X	
a		150.96	226.44	301.92	377.40	452.88	528.36	603.84	
fs		400.00	400.00	400.00	400.00	233.33	114.29	25.00	
fs'		400.00	400.00	400.00	400.00	400.00	400.00	400.00	
As=As'		6400	6400	6400	6400	6400	6400	6400	
Cc		1154.84	1732.27	2309.69	2887.11	3464.53	4041.95	4619.38	
Cs		2437.60	2437.60	2437.60	2437.60	2437.60	2437.60	2437.60	
Ts		2560.00	2560.00	2560.00	2560.00	1493.33	731.43	160.00	
Pn	0	1015.15	1609.87	2187.29	2764.71	4408.80	5748.13	6896.98	10995.2
Mn	1466.06	2068.07	2195.96	2274.39	2309.23	1937.82	1626.45	1336.25	0

4.4.4.2 Perencanaan Tulangan Lentur Kolom

Untuk perencanaan penulangan kolom dipakai nilai terbesar dari hasil analisis SAP2000, dari beban kombinasi 1, 2, atau 3. ditinjau frame K107, dengan :



$P_{u,k}$ = 2024,72 kN

M_{u,k_x} = 138,89 kN m

M_{u,k_y} = 319,02 kN m

$\frac{P_{u,k}}{\phi} = \frac{2024,72}{0,65} = 3114,95$ kN

$\frac{M_{u,k_x}}{\phi} = \frac{138,89}{0,65} = 213,69$ kNm

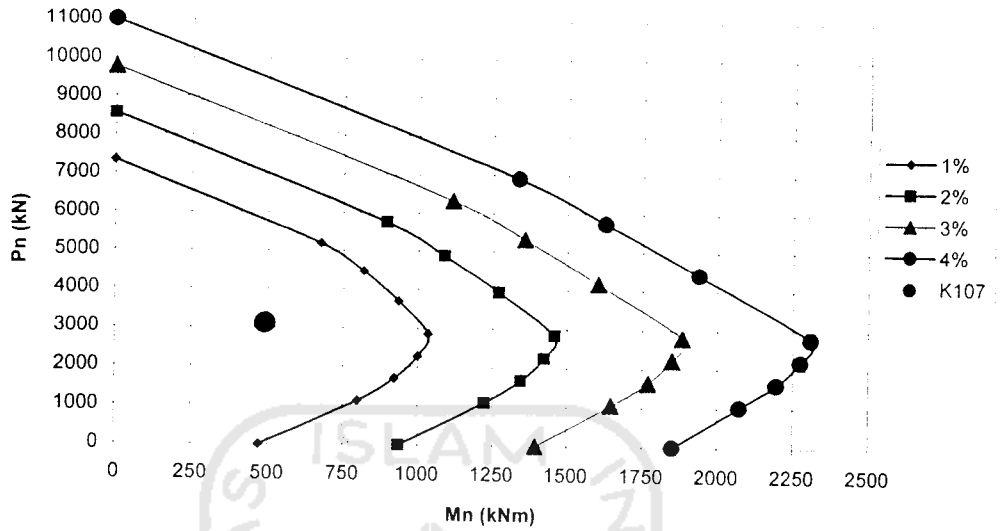
$\frac{M_{u,k_y}}{\phi} = \frac{319,02}{0,65} = 490,80$ kNm

a. Arah x

$\frac{M_{u,k_y}}{\phi} = 490,80$ kN m

$\frac{P_{u,k}}{\phi} = 3114,95$ kN

f`c = 22,5 Mpa
fy = 400 Mpa



Gambar 4.27 Grafik interaksi Mn-Pn kolom 400x800

Dari Grafik Mn-Pn didapat $\rho_g = 1\%$

Ast $= 0{,}01 \times 400 \times 800 = 3200\ mm^2$

As = As` $= 0{,}5 \times Ast = 1600\ mm^2$

Dipakai 5D22 dengan $As_{ada} = As`_{ada} = 1899{,}7\ mm^2$

Cek eksentrisitas balance (e_b)

$$Xb = \frac{600.d}{600 + fy} = \frac{600.740}{600 + 400} = 444\ mm$$

$$Ab = \beta_1 \times Xb = 0{,}85 \times 444 = 377{,}4\ mm$$

$$f's = 600 \times \frac{(Xb - d')}{Xb} = 600 \times \frac{(444 - 60)}{444}$$

$= 519$ Mpa > fy = 400 Mpa, maka digunakan f`s = fy = 400 Mpa

Ccb $= 0{,}85 \times f`c \times b \times ab = (0{,}85 \times 22{,}5 \times 400 \times 377{,}4) \times 10^{-3} = 2887{,}1$ kN

Csb $= As`(f`s - 0{,}85 f`c) = (1899{,}7\ (400 - 0{,}85 \times 22{,}5)) \times 10^{-3} = 723{,}55$ kN

Tsb $= As \times fy = (1899{,}7 \times 400) \times 10^{-3} = 759{,}88$ kN

Pnb $= Ccb + Csb - Tsb = 2887,1 + 723,55 - 759,88$

$= 2850,78$ kN

Mnb $= Ccb\left[\frac{h}{2} - \frac{ab}{2}\right] + Csb\left(\frac{h}{2} - d'\right) + Tsb\left(d - \frac{h}{2}\right)$

$= 2887,1\left(\frac{800}{2} - \frac{377,4}{2}\right) + 723,55\left(\frac{800}{2} - 60\right) + 759,88\left(740 - \frac{800}{2}\right)$

$= 1114,41$ kN m

eb $= \frac{Mnb}{Pnb} = \frac{1114,68}{2850,75} = 0,39$ m

e $= \frac{Mu_K \,.\, y/\phi}{Pu_K/\phi} = \frac{490,80}{3114,95} = 0,16$ m

karena e<eb ➔ maka kolom mengalami patah desak

kontrol tegangan pada daerah desak :

Pn $= \frac{As'.fy}{\frac{e}{(d-d')} + 0,5} + \frac{b.h.fc'}{\frac{3h.e}{d^2} + 1,18}$

$= \frac{1899,7.\ 400}{\frac{(0,16.10^3)}{(740-60)} + 0,5} + \frac{400.\ 800.\ 22,5'}{\frac{3.\ 800.(0,16.10^3)}{740^2} + 1,18}$

$= 4887616,4$ N $= 4887,62$ kN

Pn $= 48887,62$ kN $> \frac{Pu_K}{\phi} = 3114,95$ kN .....OK!

Mn $= Pn \times e$

$= 4857,19 \times 0,16$

$= 770,11$ kN m $> \frac{Mu_K.K_y}{\phi} = 490,80$ kN m .....OK!

b. Arah y

$$\frac{Pu,k}{\phi} = \frac{2024,72}{0,65} = 3114,95 \text{ kN}$$

$$\frac{Mu,k_x}{\phi} = \frac{138,89}{0,65} = 213,69 \text{ kNm}$$

Dari Grafik Mn-Pn didapat $\rho_g = 1\%$

Ast $= 0,01 \times 400 \times 800 = 3200 \text{ mm}^2$

As = As' $= 0,5 \times Ast = 1600 \text{ mm}^2$

Dipakai 4D22 dengan $As_{ada} = As'_{ada} = 1519,76 \text{ mm}^2$

Cek eksentrisitas balance (e_b)

cb $= \frac{600.d}{600 + fy} = \frac{600.340}{600 + 400} = 204 \text{ mm}$

Ab $= \beta_1 \times cb = 0,85 \times 204 = 173,4 \text{ mm}$

f's $= 600 \times \frac{(cb - d')}{cb} = 600 \times \frac{(204 - 60)}{204}$

$= 423,53 \text{ Mpa} > fy = 400 \text{ Mpa}$

Dengan demikian digunakan f`s = fy = 400 Mpa

Ccb $= 0,85 \times f`c \times b \times ab = (0,85 \times 22,5 \times 800 \times 173,4) \times 10^{-3} = 2653,01 \text{ kN}$

Csb $= As'(f`s - 0,85f`c) = (1519,76\ (400 - 0,85 \times 22,5)) \times 10^{-3} = 578,84 \text{ kN}$

Tsb $= As \times fy = (1519,76 \times 400) \times 10^{-3} = 607,9 \text{ kN}$

Pnb $= Ccb + Csb - Tsb = 2653,01 + 578,84 - 607,9$

$= 2623,95 \text{ kN}$

Mnb $= Ccb\left[\frac{h}{2} - \frac{ab}{2}\right] + Csb\left(\frac{h}{2} - d'\right) + Tsb\left(d - \frac{h}{2}\right)$

$$= 2653{,}01\left(\frac{400}{2}-\frac{173{,}4}{2}\right)+578{,}84\left(\frac{400}{2}-60\right)$$

$$+607{,}9\left(740-\frac{400}{2}\right)$$

$$= 466{,}73 \text{ kN m}$$

$$eb = \frac{Mnb}{Pnb} = \frac{466{,}73}{2623{,}95} = 0{,}18 \text{ m}$$

$$e = \frac{Mu_K \cdot y/\phi}{Pu_K/\phi} = \frac{213{,}69}{3114{,}95} = 0{,}07 \text{ m}$$

karena e<eb ➔ maka kolom mengalami patah desak

kontrol tegangan pada daerah desak :

$$Pn = \frac{As'.fy}{\frac{e}{(d-d')}+0{,}5}+\frac{b.h.fc'}{\frac{3h.e}{d^2}+1{,}18}$$

$$= \frac{1519{,}76.400}{\frac{(0{,}07.10^3)}{(740-60)}+0{,}5}+\frac{400.400.22{,}5}{\frac{3.400.(0{,}07.10^3)}{740^2}+1{,}18}$$

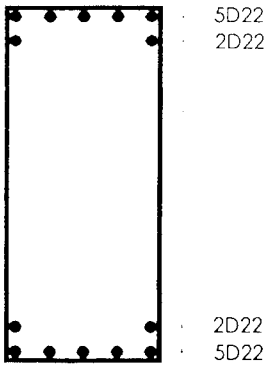
$$= 4621323{,}57 \text{ N}$$

$$Pn = 4621{,}32 \text{ kN} > \frac{Pu_K}{\phi} = 3114{,}95 \text{ kN} \ldots\ldots\ldots\ldots\ldots\text{OK!}$$

$$Mn = Pn \times e$$

$$= 4621{,}32 \times 0{,}07$$

$$= 317{,}01 \text{ kN m} > \frac{Mu_K.K_y}{\phi} = 213{,}69 \text{ kNm} \ldots\ldots\ldots\ldots\ldots\text{OK!}$$



Gambar 4.28 Penampang Kolom 400/800 dengan Tulangan

4.4.4.3 Perencanaan Tulangan Geser Kolom

Dari hasil analisis dengan menggunakan program SAP2000, maka untuk frame K107 didapat nilai terbesar, sebagai berikut :

$Mu_{,K}$ atas = -319,02 kN m

$Mu_{,K}$ bawah = 88,68 kN m

$V_{D,}K$ = -62,717 kN

$V_{L,}K$ = -15,113 kN

$V_{E,}K$ = 66,399 kN

h_n = 3,3 m

$$V_{u,K} = \frac{Mu,ky_{atas} + Mu,ky_{bawah}}{h_n} = \frac{-319,02 + 88,68}{3,3} = -68,8 \text{ kN}$$

Tetapi tidak perlu lebih besar dari :

$$V_{u,K} = 1,05\ (V_{D,K} + V_{L,K} + \frac{4}{k}(V_{E,K}))$$

$$= 1{,}05\ (-62{,}717+(-15{,}113) + \frac{4}{1}.\ 66{,}399)$$

$$= 197{,}15\ \text{kN}$$

$$\frac{V_{U,K}}{\phi} = \frac{-68{,}8}{0{,}6} = -116{,}33\ \text{kN}$$

di daerah sejauh *lo*

kekuatan beton dalam menahan gaya geser dianggap 0 (Vc = 0)

Dipakai tulangan geser P10 mm, maka :

Av $= 2 \times \frac{1}{4} \times \pi \times 10^2 = 157\ \text{mm}^2$

Jarak (s) $< \frac{Av.fy.d}{Vs} = \frac{157.240.740}{116{,}33.10^3} = 240\ \text{mm}$

$< b/4 = 400/4 = 100\ \text{mm}$

$< 8D = 8 \times 22 = 176\ \text{mm}$

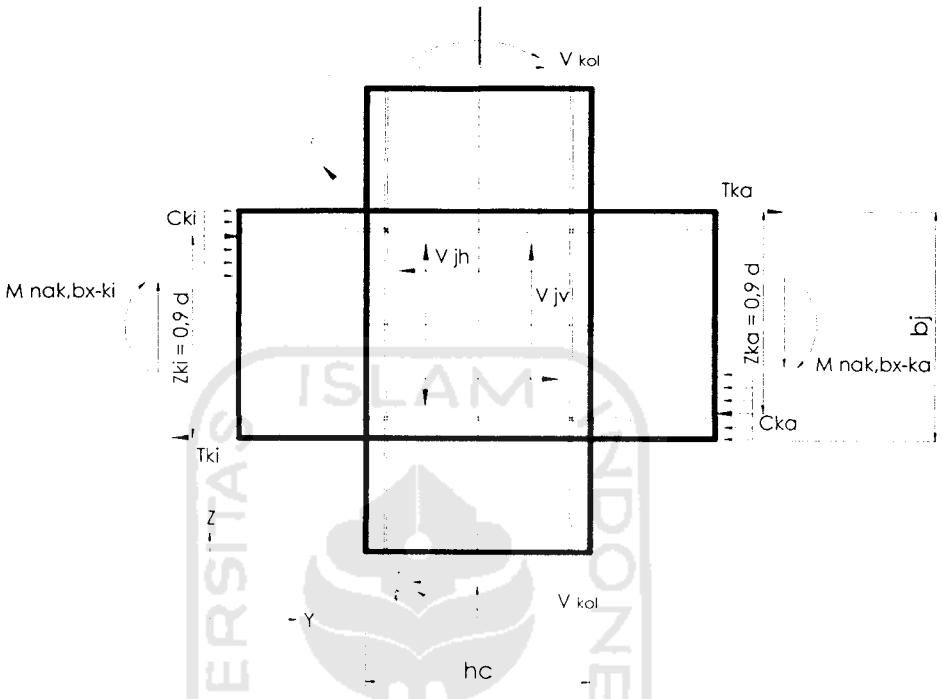
digunakan sengkang P10 - 100 mm

di luar daerah *lo*

$$Vc = \left(1+\frac{P_{U,K}}{14.Ag}\right)\frac{1}{6}\sqrt{fc'}.b.d = \left(\left(1+\frac{3114{,}95.10^3}{14.(400.800)}\right)\frac{1}{6}\sqrt{22{,}5}.400.740\right).10^{-3}$$

$= 396{,}72 > \frac{V_{U,K}}{\phi} = 116{,}33$ kN, maka tidak perlu tulangan geser

4.4.5 Pertemuan Balok Kolom



Gambar 4.29 Joint Balok Kolom dalam

a. Perhitungan gaya-gaya dalam

$M_{nak,by\ ki}$ (F123) = 102,21 kNm

l_{ki} = 1,75 m

$l_{n,ki}$ = 1,35 m

$M_{nak,by\ ka}$(F124) = 891,517 kNm

l_{ka} = 14,1 m

$l_{n,ka}$ = 13,3 m

$M_{nak,bx\ ki}$ (F121) = 169,22 kNm

l_{ki} = 3,5 m

$l_{n,ki}$ = 3,3 m

$M_{nak,bx\ ka}$(F126) = 34,276 kNm

l_{ka} = 3,5 m

$l_{n,ka}$ = 3,3 m

1) Sumbu y

b_j = bc = 400 mm

bb + 0,5hc = 350 + 0,5 × 800 = 750 mm

b_j pakai = 400 mm

h_c = 800 mm

$$V_{kol,y} = \frac{0,7.\phi_o\left(\sum \frac{l_y}{l_{ny}}.M_{nak.ky} + 0,3\sum \frac{l_x}{l_{nx}}.M_{nak.kx}\right)}{\frac{1}{2}.(h_a - h_b)}$$

$$= 0,7.\ 1,25\left[\left(\frac{1,75}{1,35}.\ 102,21 + \frac{14,1}{13,3}.\ 897,233\right) + 0,3\left(\frac{3,5}{3,3}.\ 169,22 + \frac{3,5}{3,3}.34,27\right)\right]\Big/\frac{1}{2}\ (4+4)$$

$$= \frac{0,7 \times 1,25\,(1083,69 + 64,89)}{4} = 226,12\ \text{kN}$$

$Z_{Ki,y}$ = 0,9d = 0,9×340 = 306 mm = 0,306 m

$Z_{Ka,y}$ = 0,9d = 0,9×725 = 652 mm = 0,652 m

$$C_{Ki,y} = T_{Ki,y} = \frac{0,7.\phi_o.(M_{nak,by-ki})}{Z_{Ki,y}} = \frac{0,7.\ 1,25.\ (102,21)}{0,306} = 292,26\ \text{kN}$$

$$C_{Ka,y} = T_{Ka,y} = \frac{0,7.\phi_o.(M_{nak,by-ka})}{Z_{ka,y}} = \frac{0,7.\ 1,25.\ (897,23)}{0,652} = 1204,10\ \text{kN}$$

$V_{jh,y} = C_{ki,y} + T_{ka,y} - V_{kol,y}$ = 292,26 +1204,10 - 226,12

= 1270,24 kN

Kontrol tegangan geser horizontal :

$$V_{jh.y} = \frac{V_{jh.y}}{b_j.h_c} \le 1{,}5\sqrt{f'c} = \frac{1270{,}24}{0{,}4.\,0{,}8} = 3969{,}5 \text{ kN/m}^2 = 3{,}96 \text{ Nmm}^2$$

$$= 3{,}96 < 1{,}5\sqrt{22{,}5} = 7{,}115 \text{ Nmm}^2 \text{ .....OK}$$

$$V_{ch.y} = 2/3 \sqrt{\left\{\left(Pu.k/Ag\right) - 0{,}1.fc'\right\}}.b_j.h_c$$

$$= 2/3 \sqrt{\left\{\left(2024{,}72.10^3/(400.800)\right) - 0{,}1.22{,}5\right\}}\ 400.\ 800$$

$$= 430766{,}96 \text{ N} = 430{,}767 \text{ kN}$$

$$V_{sh.y} = V_{jh.y} - V_{ch.y}$$

$$= 1270{,}24 - 430{,}76 = 839{,}48 \text{ kN}$$

2) Sumbu x

$b_j = bc = 800$ mm

$bb + 0{,}5hc = 250 + (0{,}5 \times 400) = 450$ mm

b_j pakai $= 450$ mm

$h_c = 400$ mm

$$V_{kol,x} = \frac{0{,}7.\phi_o\left(0{,}3\sum \frac{I_y}{I_{ny}}.M_{nak.by} + \sum \frac{I_x}{I_{nx}}.M_{nak.bx}\right)}{\frac{1}{2}.(h_a - h_b)}$$

$$= 0{,}7.\ 1{,}25\left[0{,}3\left(\frac{1{,}75}{1{,}35}.\ 102{,}21 + \frac{14{,}1}{13{,}3}.\ 897{,}233\right)\right.$$

$$\left. + \left(\frac{3{,}5}{3{,}3}.\ 169{,}22 + \frac{3{,}5}{3{,}3}.34{,}27\right)\right] \Big/ \frac{1}{2}\ (4+4)$$

$$= \frac{0{,}7 \times 1{,}25\,(325{,}12 + 216{,}3)}{4} = 118{,}43 \text{ kN}$$

$Z_{Ki,x}$ = 0,9d = 0,9×430 = 387 mm = 0,387 m

$Z_{Ka,x}$ = 0,9d = 0,9×430 = 387 mm = 0,387 m

$$C_{Ki,x} = T_{Ki,x} = \frac{0,7.\phi_o.(M_{nak,bx-ki})}{Z_{Ki,y}} = \frac{0,7.\ 1,25.\ (169,22)}{0,387} = 382,60 \text{ kN}$$

$$C_{Ka,x} = T_{Ka,x} = \frac{0,7.\phi_o.(M_{nak,bx-ka})}{Z_{ka,y}} = \frac{0,7.\ 1,25.\ (34,276)}{0,387} = 77,49 \text{ kN}$$

$V_{jh,x} = C_{ki,x} + T_{ka,x} - V_{kol,x} = 382,6 + 77,49 - 118,43$

$= 341,66$ kN

Kontrol tegangan geser horizontal :

$$V_{jh,x} = \frac{V_{jh,x}}{b_j.h_c} \leq 1,5\sqrt{f'c}$$

$$= \frac{341,66}{0,45.\ 0,4} = 1898,11 \text{ kN/m}^2 = 1,898 \text{ Nmm}^2$$

$= 1,898 \text{ Nmm}^2 < 1,5\sqrt{22,5} = 7,115 \text{ Nmm}^2$ .....OK

$$V_{ch,x} = {}^2/_3 \sqrt{\left\{\left(Pu,k/Ag\right) - 0,1.fc'\right\}}.b_j.h_c$$

$$= 2/3 \sqrt{\left\{\left(2024,72.\ 10^3/(400.800)\right) - 0,1.22,5\right\}}\ 450.\ 400$$

$= 242306,42$ N $= 242,31$ kN

$V_{sh,x} = V_{jh,x} - V_{ch,x}$

$= 341,66 - 242,31 = 99,35$ kN

b. Penulangan Geser Horizontal

Dari nilai :

$V_{sh,y}$ = 839,48 kN

$V_{sh,x}$ = 99,35 kN

Maka,

$V_{sh,\ maks}$ = $V_{sh,y}$ = 839,48 kN

$A_{jh} = \frac{V_{Sh,\ maks}}{fy} = \frac{839,48.10^3}{400} = 2098,7\ mm^2$

Digunakan sengkang P12 dengan Av= 2. ¼ .π. 12^2 = 226,19 mm^2

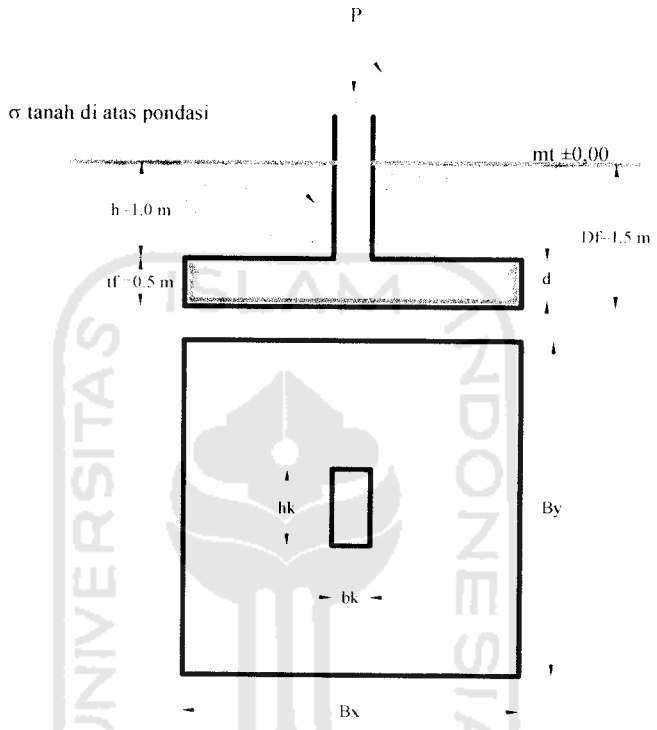
Jumlah lapis sengkang $= \frac{2098,7}{226,19} = 9,27$ lapis ➔ disesuaikan =10

Digunakan sengkang 10P12

4.5 Perencanaan Pondasi

4.5.1 Perencanaan pondasi telapak setempat (PSI)

A. Perencanaan Dimensi Pondasi



Gambar 4.30 Pondasi telapak setempat

σ tanah	= 170 kN/m^2	γb tanah	= 14 kN/m^3
f'c	= 25 Mpa	γ beton	= 24 kN/m^3
fy	= 400 Mpa	Asumsi tebal pelat (tf)	= 500 mm
P	= 1687 kN	ukuran kolom :	
Mx tetap	= 0,12 kN m	hk = 400 mm	
My tetap	= 73,63 kN m	bk = 800 mm	
Mx sementara	= 112,8 kN m		
My sementara	= 223,29 kN m		

σ netto tanah $= \sigma$ tanah $- \Sigma$ (h $\times \gamma$ beton) - Σ (h $\times \gamma$ tanah)

$= 170 - (0,5 \times 24) - (1,0 \times 14)$

$= 151,8$ kN/m^2

1. Tinjauan terhadap beban tetap

Digunakan pondasi penampang bujur sangkar, dicoba dengan nilai Bx=By=3,5 m, luas penampang pelat lantai :

$A = Bx \times By = 3,5 \times 3,5 = 12,25$ m^2

Kontrol luas pelat pondasi dan tegangan yang terjadi :

$$\sigma \text{ terjadi} = \frac{P}{A} + \frac{6\ My}{By^2.\ Bx} + \frac{6\ Mx}{Bx^2.\ By}$$

$$\sigma \text{ terjadi max} = \frac{1687}{12,25} + \frac{(6).73,63}{3,5^2.3,5} + \frac{(6).0,12}{3,5^2.3,5}$$

$= 148,03$ kN/m$^2 < \sigma$ netto tanah $= 151,8$ kN/m^2.....OK !

2. Tinjauan terhadap beban sementara

Eksentrisitas yang terjadi :

$$Ey = \frac{My}{P} = \frac{223,29}{1687} = 0,132 \text{ m}$$

$$Ex = \frac{Mx}{P} = \frac{112,8}{1687} = 0,067 \text{ m}$$

$\frac{B}{6} = \frac{3,5}{6} = 0,583 >$ ex dan ey (beban eksentrisitas di dalam teras), maka :

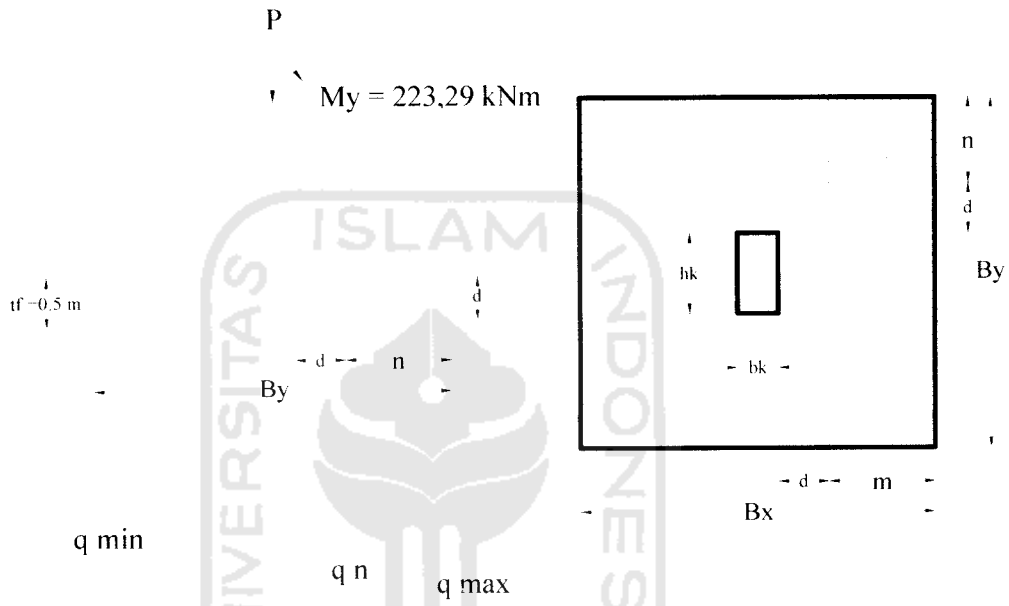
kontrol tegangan yang terjadi :

$$\sigma \text{ terjadi} = \frac{P}{A} \times \left(1 + \frac{6\ ex}{Bx} + \frac{6\ ey}{By}\right)$$

$$= \frac{1687}{12,25} \times \left(1 + \frac{(6).0,132}{3,5} + \frac{(6).0,067}{3,5}\right)$$

$= 184,747$ kN/m2 $< 1,5 \times \sigma_{netto} = 1,5 \times 151,8 = 227,7$ kN/m2.....OK !

B. Perencanaan geser satu arah



Gambar 4.31 Pondasi dengan geser satu arah

➔ dintinjau pada arah momen terbesar

P = 1687 kN

Mx = 112,8 kN m

My = 223,29 kN m

Jarak pusat tulangan tarik ke serat tekan beton :

d_b = tf - Pb - ½ . $\emptyset_{tul.\ Pokok}$ = 500 – 75 – ½.(25) = 412,5 mm = 0,4125 m

$$n = \frac{By - hk - 2.d}{2} = \frac{3,5 - 0,8 - 2.(0,4125)}{2} = 0,937 \text{ m}$$

$$m = \frac{Bx - bk - 2.d}{2} = \frac{3,5 - 0,4 - 2.(0,4125)}{2} = 1,137 \text{ m}$$

berdasarkan momen yang terbesar yaitu My = 223,29 kN m, maka geser yang ditinjau adalah arah y

- Tegangan kontak yang terjadi :

$$q_{U\ terjadi} = \frac{P}{A} \pm \frac{6\,My}{By^2.Bx}$$

$$= \frac{16878}{12,25} \pm \frac{(6).223,29}{3,5^2.3,5}$$

$q_{U\ terjadi\ maks} = 168,96\ kN/m^2$

$q_{U\ terjadi\ min} = 106,46\ kN/m^2$

$$q_{U1\ terjadi\ sejauh\ n} = \frac{(q_{terjadi\ maks} - q_{terjadi\ min}) \times (By - n)}{By} + q_{terjadi\ min}$$

$$= \frac{(168,96 - 106,46) \times (3,5 - 0,937)}{3,5} + 106,46$$

$$= 148,651\ kN/m^2$$

$$q_{U2\ terjadi\ sejauh\ n} = \tfrac{1}{2}(q_{terjadi\ x_{maks}} + q_{terjadi\ x_{min}}) = \tfrac{1}{2}(168,96 + 106,46)$$

$$= 137,714\ kN/m^2$$

jadi $q_{U\ terjadi\ sejauh\ n} = 148,65\ kN/m^2$

- Gaya geser akibat beban luar yang bekerja pada penampang kritis

$Vu = q_{terjadi}\ n \times n \times Bx = 148,65 \times 0,937 \times 3,5 = 487,761\ kN$

$\frac{Vu}{\phi} = \frac{487,761}{0,6} = 812,935\ kN$

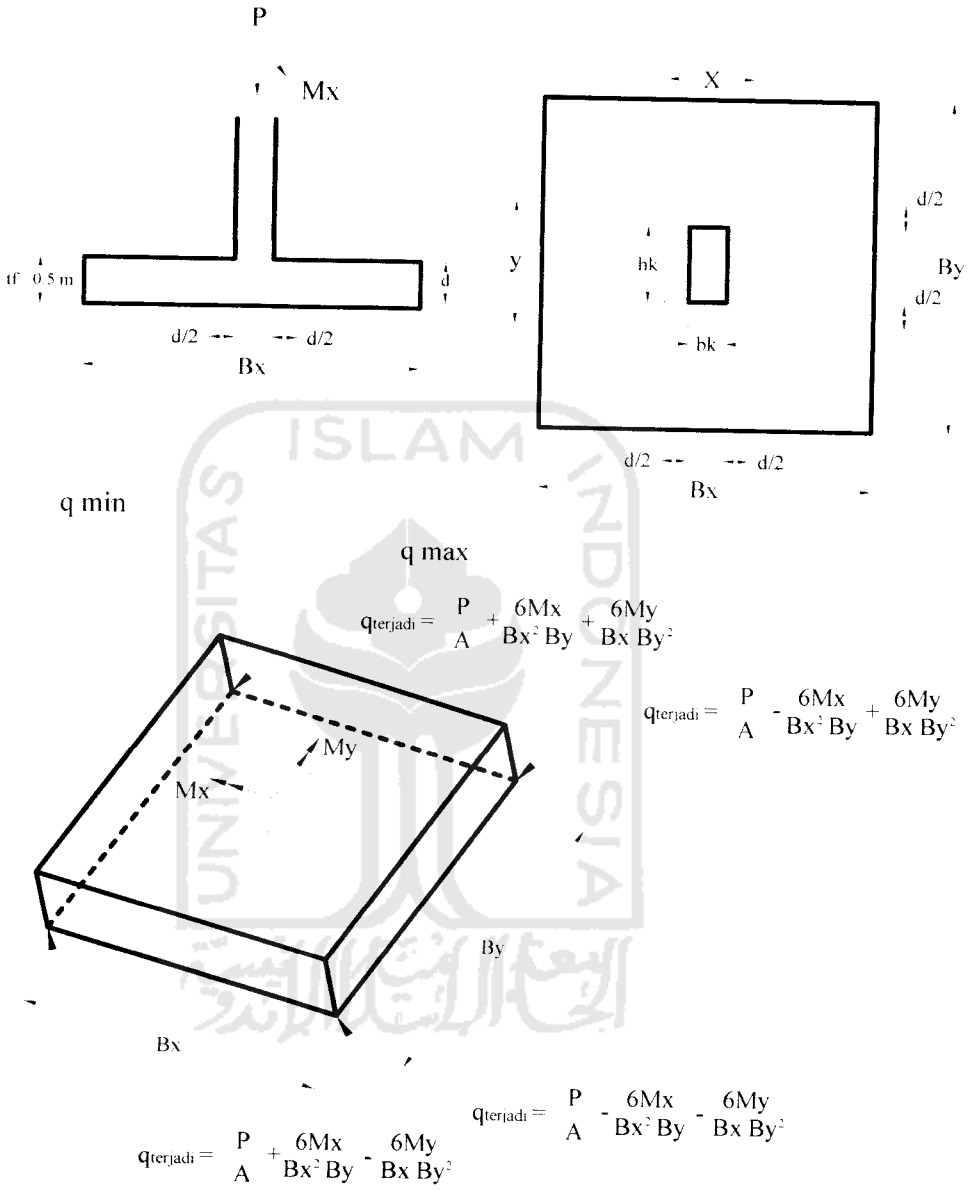
- Kekuatan beton menahan geser :

$Vc = \frac{1}{6}\sqrt{f'c}\,By.d = (\frac{1}{6}\sqrt{25}.3,5.0,4125).10^3 = 1203,12\ kN$

- Kontrol gaya geser :

$Vc = 1203,12\ kN \geq \frac{Vu}{\phi} = 812,935\ kN$ .....OK!

C. Perencanaan geser dua arah



Gambar 4.32 Pondasi dengan geser dua arah

x = bk + d

= 400 + 412,5

= 812,5 mm = 0,8125 m

y = hk + d

= 800 + 412,5

= 1212,5 mm = 1,2125 m

- Tegangan kontak yang terjadi :

$$q_{U\ terjadi} = \frac{P}{A} \pm \frac{6\ My}{By^2 . Bx} \pm \frac{6\ Mx}{Bx^2 . By}$$

$$= \frac{1687}{12,25} \pm \frac{(6).223,29}{3,5^2.3,5} \pm \frac{(6).112,8}{3,5^2.3,5}$$

$q_{U\ terjadi\ max} = 184,74\ kN/m^2$

$q_{U\ terjadi\ min} = 90,68\ kN/m^2$

$q_{U\ terjadi\ pakai} = \frac{1}{2}(q_{terjadi\ maks} + q_{terjadi\ min}) = \frac{1}{2}.(184,74+90,68) = 137,71\ kN/m^2$

- Gaya geser akibat beban luar yang bekerja pada penampang kritis :

$Vu = q\ terjadi\ pakai \times ((Bx.By) - (x.y))$

$= 137,71 \times ((3,5 \times 3,5) - (0,8125 \times 1,2125)) = 1551,33\ kN/m^2$

$\frac{Vu}{\phi} = \frac{1551,33}{0,6} = 2585,55\ kN$

- Kekuatan Beton menahan geser :

$\beta c = \frac{sisi\ panjang}{sisi\ pendek} = \frac{y}{x} = \frac{1,2125}{0,8125} = 1,492$

$bo = 2 \times (y + x) = 2 \times (1212,5 + 812,5) = 4052\ mm$

$Vc_1 = \left(1 + \frac{2}{\beta c}\right).\left(2.\sqrt{f'c}\right) bo . d$

$= \left(1 + \frac{2}{1,492}\right).\left(2.\sqrt{25}\right) 4052 . 412,5.10^{-3} = 39096,1\ kN$

$Vc_2 = 4.\sqrt{f'c}.\ bo . d$

$= 4.\sqrt{25}.\ 4052 . 412,5.10^{-3} = 33412,5\ kN$

$Vc = 33412,5\ kN \geq \frac{Vu}{\phi} = 2585,55\ kN$.....OK!

D. Kuat Tumpuan Pondasi

- Kuat tumpuan pondasi

$$\phi Pn = \phi \left(0{,}85 \,.\, f'c.\, A_1 \cdot \sqrt{A_2 / A_1} \right)$$

Luas Pelat Pondasi (A_2) $= Bx \times By = 3{,}5 \times 3{,}5 = 12{,}25\ m^2$

Luas Penampang kolom (A1) $= hk \times bk = 0{,}8 \times 0{,}4 = 0{,}32\ m^2$

$$\sqrt{\frac{A_2}{A_1}} = \sqrt{\frac{12{,}25}{0{,}32}} = 6{,}187 > 2$$ (jika lebih besar dari 2, dipakai nilai 2)

$$\phi Pn = \phi \left(0{,}85 \,.\, f'c.\, A_1 \,.\, 2\right)$$

$$= 0{,}7 \left(0{,}85 \,.\, 25.\, 0{,}32 \,.\, 2\right) \times 10^3 = 9520\ kN$$

- Kuat tumpuan kolom

$$\phi Pn = \phi \left(0{,}85 \,.\, f'c.\, A_1\right)$$

$$= 0{,}7 \left(0{,}85 \,.\, 25 \,.\, 0{,}32 \right) \times 10^3 = 4760\ kN$$

- Kontrol Kuat tumpuan

$\phi Pn_{pondasi} = 9520\ kN > \phi Pn_{kolom} = 4760$ .....OK!

E. Perencanaan tulangan lentur pondasi

Karena penampang pondasi berbentuk bujur sangkar, sehingga arah x dan arah y sama panjang, maka perencanaan lenturnya dianggap sama.

$$L = \frac{Bx - bk}{2} = \frac{3{,}5 - 0{,}4}{2} = 1{,}55\ m$$

$q_{U\ terjadi} = 184{,}747\ kN\ m_2$

$Mu = 1{,}0\ (½ \times q_{U\ terjadi} \times L^2) = 0{,}5 \times 184{,}747 \times 1{,}55^2\ (1{,}0) = 221{,}927\ kNm$

$$Mu/\phi = 221{,}927/0{,}8 = 277{,}409\ kN\ m$$

digunakan tulangan pokok Ø19 mm, maka A1Ø = 283,529 mm^2

tebal pelat pondasi : tf = 500 mm, selimut beton (pb) = 75 mm

d = tf – pb – ½ Øtul. Pokok = 500 – 75 – ½ .19 = 415,5 mm

$$m = \frac{fy}{0{,}85\ f'c} = \frac{400}{0{,}85\ .\ 25} = 18{,}824$$

koefisien ketahanan (Rn), diambil nilai nilai b tiap 1000 mm ;

$$Rn_{ada} = \frac{Mu/\phi}{b.d_{ada}^2} = \frac{277{,}409.10^6}{1000.\ 415{,}5^2} = 1{,}61 \text{ Mpa}$$

Rasio tulangan :

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

$$\rho b = \frac{0{,}85.f'c.\beta_1}{fy} \cdot \left(\frac{600}{600 + fy}\right) = \frac{0{,}85.25\ .\ 0{,}85}{400} \cdot \left(\frac{600}{600 + 400}\right) = 0{,}027$$

$$\rho_{maks} = 0{,}75\ .\ \rho b = 0{,}75 \times 0{,}027 = 0{,}0203$$

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

$$= \frac{1}{18{,}824}\left(1 - \sqrt{1 - \frac{2.(1{,}61).(18{,}824)}{400}}\right) = 0{,}0041 < \rho_{maks} = 0{,}020$$

$$> \rho_{min} = 0{,}0035$$

➔ maka $\rho_{perlu} = \rho_{ada} = 0{,}0041$

$As_{perlu} = \rho_{perlu}\ b.d = 0{,}0041\ .\ 1000\ .\ 415{,}5 = 1703{,}55 \geq 0{,}002\ b.h$

$0{,}002b.h = 0{,}002 \times 1000 \times 500 = 1000\ mm2 < As_{perlu}$, maka $As_{perlu} = 1703{,}55$ mm

$$S \leq \frac{A_{1\phi}.1000}{As_{perlu}} = \frac{283{,}259.1000}{1703{,}55} = 166{,}275 \text{ mm}$$

$S \leq 2h = 2 \cdot 500 = 1000$ mm

$S \leq 250$ mm

➔ **dipakai tulangan Pokok : D19 – 160 mm**

$$As_{ada} = \frac{A1Ø\ 1000}{S} = \frac{283{,}529 \cdot 1000}{160} = 1772{,}056 \text{ mm}^2$$

- Kontrol kapasitas lentur yang terjadi :

$$a = \frac{As_{ada} \cdot fy}{0{,}85.f'c.b} = \frac{1772{,}056 \cdot 400}{0{,}85 \cdot 25 \cdot 1000} = 33{,}356 \text{ mm}$$

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

$$= 1772{,}056 \times 400 \left(415{,}5 - \frac{33{,}356}{2}\right). 10^{-6}$$

$$= 282{,}693 \text{ kN m} \geq \frac{Mu}{\phi} = 277{,}409 \text{ kN m} \ldots\ldots\ldots\text{OK!}$$

- Perencanaan tulangan susut Pondasi

$AS_{tul\ susut} = 0{,}002.b.h = 0{,}002 \times 1000 \times 500 = 1000 \text{ mm}^2$

Digunakan tulangan bagi Ø12 mm, maka A1Ø = 113,097 mm^2

$$S \leq \frac{A_{1\phi}.b}{As_{susut}} = \frac{113{,}097.1000}{1000} = 113{,}097 \text{ mm}$$

➔ dipakai tulangan susut P12 – 110 mm