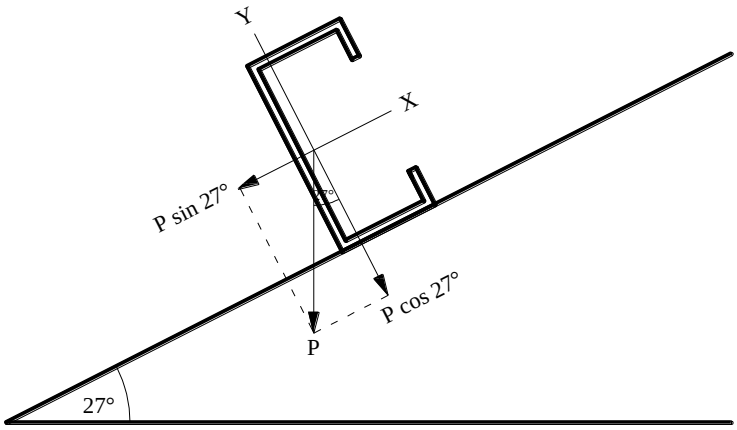
BAB III
PERHITUNGAN KONSTRUKSI

3.1 Perhitungan Gording



Gambar 3.1 Perhitungan Gording

Diketahui tipe kuda-kuda kerangka *single beam* dengan data-data sebagai berikut:

- Bentang Kuda-kuda = 20,00 m
- Jarak antar Gording = 1,50 m
- Jarak antar Portal = 5,00 m
- Kemiringan Kuda-kuda = 27^o
- Gording yang Digunakan = Baja Profil *Light Lip Channels* 150.65.20.3,2
- Berat Sendiri Gording = 7,51 kg/m
- Berat Penutup Atap = 2,65 kg/m^2 (Atap *Zincalume* t = 0,35 mm)
- Mutu Baja = BJ 37
- Jumlah *Treckstang* = 2 Batang

Data-data dari baja *Light Lip Channels* 150.65.20.3,2 adalah:

w = 7,51 kg/m

A = 9,567 cm^2

I_x = 332 cm^4

I_y = 53,8 cm^4

W_x = 44,3 cm^4

W_y = 12,2 cm^4

3.1.1 Perhitungan Pembebanan

1. Akibat Beban Mati

Berat sendiri gording = 7,51 kg/m

Berat sendiri atap = 1,50 m . 2,65 kg/m^2 = 3,975 kg/m

Berat beban mati = Berat sendiri gording + Berat sendiri atap

= 7,51 kg/m + 3,975 kg/m

= 11, 485 kg/m

Alat pengikat = 10 % . 11, 485 kg/m = 1,15 kg/m

Berat total beban mati (q_{dl}) = 11, 485 kg/m + 1,15 kg/m

= 12,635 kg/m

q_{dlx} = 12,635 kg/m . cos 27^o = 11,258 kg/m

q_{dly} = 12,635 kg/m . sin 27^o = 5,736 kg/m

2. Akibat Beban Pekerja

Beban terpusat pekerja ditetapkan (P) = 100 kg.

P_x = 100 kg . cos 20^o = 93,97 kg

P_y = 100 kg . sin 20^o = 34,20 kg

3. Akibat Beban Air Hujan

Diambil koefisien (40 – 0,8 . α) kg/m^2, dengan ketentuan besar minimal 20 kg/m^2.

Beban air hujan (q) = 40 – 0,8 . α

= 40 – (0,8 . 27^o)

= 18,4 kg/m^2 < 20 kg/m^2 (Diambil 20 kg/m^2)

q_{ll} = Jarak horizontal gording . q

= (1,50 m . cos 27^o) . 20 kg/m^2

= 26,73 kg/m

q_{llx} = 26,73 kg/m . (1,50 m . cos 27^o) = 35,72 kg/m

q_{lly} = 26,73 kg/m . (1,50 m . sin 27^o) = 18,20 kg/m

3.1.2 Cek Kekompokan Penampang

1. Pelat badan

$\lambda = \frac{h-2t_f}{t_w} = \frac{150-2(3,2)}{20} = 7,18$

$\lambda_p = \frac{1680}{\sqrt{f_y}} = \frac{1680}{\sqrt{240}} = 108,44$

$\lambda_r = \frac{2550}{\sqrt{f_y}} = \frac{2550}{\sqrt{240}} = 164,60$

$\lambda < \lambda_p < \lambda_r \longrightarrow$ Penampang kompak

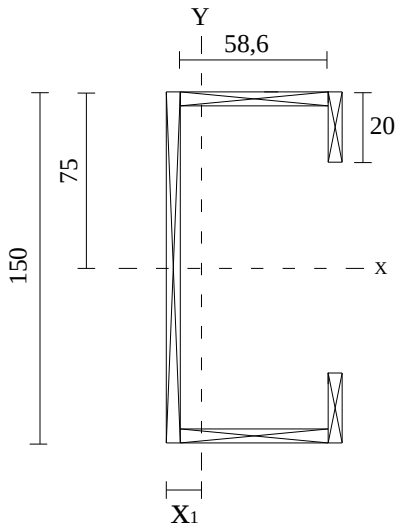
2. Pelat sayap

$\lambda = \frac{h_f}{2t_f} = \frac{65}{2\,.\,3,2} = 10,156$

$\lambda_p = \frac{170}{\sqrt{f_y}} = \frac{170}{\sqrt{240}} = 10,97$

$\lambda_r = \frac{370}{\sqrt{f_{y-f_r}}} = \frac{370}{\sqrt{240-70}} = 28,37$

$\lambda < \lambda_p < \lambda_r \longrightarrow$ Penampang kompak



Gambar 3.2 Perhitungan Z_x dan Z_y Penampang Gording

A = (150 . 3,2) + 2(58,6 . 3,2) + 2(20 . 3,2)

= 983,04 mm^2

Dianggap berbentuk balok, maka A dibagi dua $\frac{A}{2} = \frac{983,04\ mm^2}{2} = 491,52\ mm^2$

Diasumsikan $X_1 > 3,2$ mm

$(150 . 3,2) + 2 . (X_1 - 3,2) . 3,2 = 491,52\ mm^2$

$480 + 2 . (X_1 - 3,2) . 3,2 = 491,52\ mm^2$

$2 . (X_1 - 3,2) . 3,2 = 11,52$ mm

$2X_1 - 6,4 = 3,6$ mm

$X_1 = 10/2 = 5$ mm > 3,2 mm (Oke)

Z_x = 2 . (75 . 3,2) . 37,5 + 2 . (58,6 . 3,2) . 73,4 + 2 . (20 . 3,2) . 65

= 53847,936 mm^3

= 53,848 cm^3

Z_y = (75 . 3,2 . 3,4 . 2) + (1,8 . 3,2 . 0,9 . 2) + ((58,6 – 1,8) . 3,2 . ½ . (58,6 – 1,8) . 2) + (20 . 3,2 . ((58,6 – 1,8) + 1,6) . 2)

= 19441,536 mm^3

= 19,442 cm^3

Momen Nominal Terhadap Sumbu X:

$M_{nx} = Z_x . f_y$

= 53,848 . 10^3 mm^3 . 240 N/mm^2

= 12923520 N.mm

= 12,924 kN.m

Momen Nominal Terhadap Sumbu Y:

$M_{ny} = Z_y \times f_y$

= 19,442 . 10^3 mm^3 . 240 N/mm^2

= 4666080 N.mm

= 4,666 kN.m

3.1.3 Kontrol Kekuatan

1. Kontrol kekuatan Akibat Beban Mati dan Beban Air Hujan

   Beban ultimate = Beban mati + Beban air hujan

   q_{ux} = 1,2 q_{dlx} + 1,6 q_{llx}

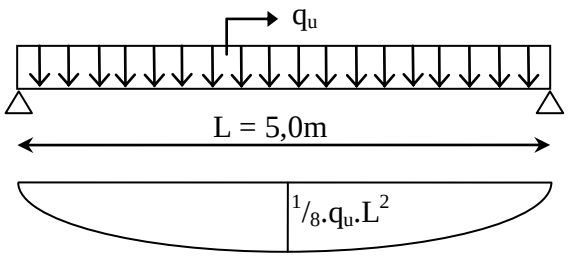
   = (1,2 . 11,258 kg/m) + (1,6 . 35,73 kg/m)

   = 70,68 kg/m

   q_{uy} = 1,2 q_{dly} + 1,6 q_{lly}

   = (1,2 . 5,736 kg/m) + (1,6 . 18,20 kg/m)

   = 36,00 kg/m



Gambar 3.3 Pembebanan Akibat Beban Merata

$M_{ux} = \frac{1}{8} . q_{ux} . L_x^2$

$= \frac{1}{8} . 70,68 \text{ kg/m} . (5,0 \text{ m})^2$

$= 220,85 \text{ kg.m}$

$M_{uy} = \frac{1}{8} . q_{uy} . L_y^2$

$= \frac{1}{8} . 36,00 \text{ kg/m} . (5,0 \text{ m})^2$

$= 112,5 \text{ kg.m}$

$$\frac{M_{ux}}{\emptyset b . M_{nx}} + \frac{M_{uy}}{\emptyset b . M_{ny}} \leq 1,0$$

$$\frac{220,85 . 10^4}{0,9 . 12923520} + \frac{112,5 . 10^4}{0,9 . 4666080} \leq 1,0$$

$0,458 \leq 1,0$ (Oke)

Untuk mengantisipasi masalah puntiran maka M_{ny} dapat dibagi dua sehingga:

$$\frac{M_{ux}}{\emptyset b . M_{nx}} + \frac{M_{uy}}{\emptyset b . \frac{M_{ny}}{2}} \leq 1,0$$

$$\frac{257,63 . 10^4}{0,9 . 12923520} + \frac{131,22 . 10^4}{0,9 . \frac{4666080}{2}} \leq 1,0$$

$0,725 \leq 1,0$ (Oke)

2. Kontrol kekuatan Akibat Beban Mati dan Beban Pekerja

   Beban ultimate = Beban mati + Beban pekerja

   $P_{ux} = 1,2 \, q_{dlx} + 1,6 \, P_x$

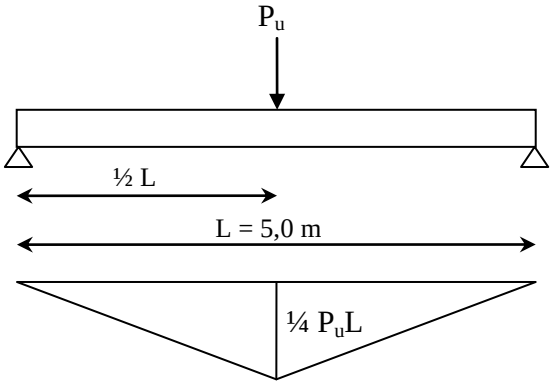
   $= (1,2 . 11,258 \text{ kg/m} . 5,0 \text{ m}) + (1,6 . 89,10 \text{ kg})$

   $= 210,108 \text{ kg}$

P_{uy} = 1,2 q_{dly} + 1,6 P_y

= (1,2 . 5,736 kg/m . 5,0 m) + (1,6 . 45,40 kg)

= 107,056 kg



Gambar 3.4 Pembebanan Akibat Beban Terpusat

$M_{ux} = \frac{1}{4} . P_{ux} . L_x$

$= \frac{1}{4} . 210,108 \text{ kg} . 5,0 \text{ m}$

= 262,635 kg.m

$M_{uy} = \frac{1}{4} . P_{uy} . L_y$

$= \frac{1}{4} . 107,056 \text{ kg} . 5,0 \text{ m}$

= 133,82 kg.m

$$\frac{M_{ux}}{\emptyset b . M_{nx}} + \frac{M_{uy}}{\emptyset b . M_{ny}} \leq 1,0$$

$$\frac{262,635 . 10^4}{0,9 . 12923520} + \frac{133,82 . 10^4}{0,9 . 4666080} \leq 1,0$$

0,544 ≤ 1,0 (Oke)

Untuk mengantisipasi masalah puntiran maka M_{ny} dapat dibagi dua sehingga:

$$\frac{M_{ux}}{\emptyset b . M_{nx}} + \frac{M_{uy}}{\emptyset b . \frac{M_{ny}}{2}} \leq 1,0$$

$$\frac{262,635 . 10^4}{0,9 . 12923520} + \frac{133,82 . 10^4}{0,9 . \frac{4666080}{2}} \leq 1,0$$

0,863 ≤ 1,0 (Oke)

3.1.4 Kontrol Lendutan

1. Kontrol Lendutan Akibat Beban Mati dan Beban Air Hujan

$q_x = q_{dlx} + q_{llx}$

$= 11{,}258 \text{ kg/m} + 35{,}73 \text{ kg/m}$

$= 46{,}988 \text{ kg/m}$

$= 0{,}4699 \text{ kg/cm}$

$$\delta_x = \frac{5 \,.\, q_x \,.\, L_x^{\,4}}{384 \,.\, EI_x}$$

$$= \frac{5 \,.\, 0{,}4699 \text{ kg/cm} \,.\, (500 \text{ cm})^4}{384 \,.\, 2 \,.\, 10^6 \text{ kg/cm}^2 . 332 \text{ cm}^4}$$

$= 0{,}576$ cm

Pada arah sumbu lemah bentang dipasang treckstang dengan jumlah 2 batang sehingga $L_y = \frac{L}{3} = \frac{5{,}0 \text{ m}}{3} = 1{,}67$ m.

$q_y = q_{dly} + q_{lly}$

$= 5{,}736 \text{ kg/m} + 18{,}20 \text{ kg/m}$

$= 23{,}936 \text{ kg/m}$

$= 0{,}2394 \text{ kg/cm}$

$$\delta_y = \frac{5 . q_y \,.\, L_y^{\,4}}{384 \,.\, EI_y}$$

$$= \frac{5 \,.\, 0{,}2394 \text{ kg/cm} \,.\, (167 \text{ cm})^4}{384 \,.\, 2 . 10^6 \text{ kg/cm}^2 . 53{,}8 \text{ cm}^4}$$

$= 0{,}022$ cm

$$\delta_{maks} = \sqrt{\delta_x^{\,2} + \delta_y^{\,2}} \qquad < \frac{L}{240}$$

$$= \sqrt{(0{,}576)^2 + (0{,}022)^2} \qquad < \frac{540 \text{ cm}}{240}$$

$= 0{,}576$ cm $\qquad < 2{,}25$ cm (Oke)

2. Kontrol Lendutan Akibat Beban Mati dan Beban Pekerja

$P_x = q_{dlx} + P_x$

$= (11{,}258 \text{ kg/m} \,.\, 5{,}0 \text{ m}) + (89{,}10 \text{ kg})$

$= 145{,}39$ kg

$$\delta_x = \frac{P_x \cdot L_x^4}{48 \cdot EI_x}$$

$$= \frac{145{,}39 \text{ kg} \cdot (500 \text{ cm})^3}{48 \cdot 2 \cdot 10^6 \text{ kg/cm}^2 \cdot 332 \text{ cm}^4}$$

$$= 0{,}570 \text{ cm}$$

Pada arah sumbu lemah bentang dipasang treckstang dengan jumlah 2 batang sehingga $L_y = \frac{L}{3} = \frac{5{,}0 \text{ m}}{3} = 1{,}67$ m.

$P_y = q_{dly} + P_y$

$= (5{,}736 \text{ kg/m} \cdot 5{,}0 \text{ m}) + (45{,}40 \text{ kg})$

$= 74{,}08$ kg

$$\delta_y = \frac{P_y \cdot L_y^4}{48 \cdot EI_y}$$

$$= \frac{74{,}08 \text{ kg} \cdot (167 \text{ cm})^3}{48 \cdot 2 \cdot 10^6 \text{ kg/cm}^2 \cdot 53{,}8 \text{ cm}^4}$$

$$= 0{,}067 \text{ cm}$$

$$\delta_{maks} = \sqrt{\delta_x^2 + \delta_y^2} \qquad < \frac{L}{240}$$

$$= \sqrt{(0{,}057)^2 + (0{,}067)^2} \qquad < \frac{540 \text{ cm}}{240}$$

$$= 0{,}88 \text{ cm} \qquad < 2{,}25 \text{ cm (Oke)}$$

3.2 Perhitungan *Treckstang*

3.2.1 Perhitungan Pembebanan

1. Akibat Beban Mati + Beban Hidup

   $q_u = 1{,}2\ q_{dly} + 1{,}6\ q_{lly}$

   $= (1{,}2 \cdot 5{,}736 \text{ kg/m}) + (1{,}6 \cdot 18{,}20 \text{ kg/m})$

   $= 36{,}003 \text{ kg/m}$

   $V_A = V_B = ½ \cdot q_u \cdot L$

   $= ½ \cdot 36{,}003 \text{ kg/m} \cdot 1{,}67 \text{ m}$

   $= 30{,}062 \text{ kg} = 300{,}62 \text{ N}$

2. Akibat Beban Mati + Beban Pekerja

   $P_u = 1{,}2\ q_{dly} + 1{,}6\ P_y$

$= (1{,}2 \,.\, 5{,}736 \text{ kg/m} \,.\, 1{,}67 \text{ m}) + (1{,}6 \,.\, 45{,}40 \text{ kg})$

$= 84{,}13 \text{ kg}$

$V_A = V_B = ½ \,.\, P_u$

$= ½ \,.\, 84{,}13 \text{ kg}$

$= 42{,}065 \text{ kg} = 420{,}65 \text{ N} \longrightarrow$ (Diambil)

3.2.2 Perencanaan Diameter *Treckstang*

V yang diambil = 420,65 N x 2 = 841,3 N

$$A_{treckstang} = \frac{V}{\emptyset . f_y}$$

$$= \frac{841{,}3 \text{ N}}{0{,}9 \,.\, 240 \text{ N/mm}^2}$$

$$= 3{,}895 \text{ mm}^2$$

$$d_{treckstang} = \sqrt{\frac{4 \,.\, A_{treckstang}}{\pi}}$$

$$= \sqrt{\frac{4 \,.\, 3{,}895 \text{ mm}^2}{3{,}14}}$$

$$= 2{,}227 \text{ mm} \sim 12 \text{ mm}$$

Jadi, dipakai treckstang diameter 12 mm.

3.3 Perhitungan Portal

3.3.1 Portal Akibat Beban Mati

Diketahui:

- Jarak antar portal = 5,00 m
- Berat penutup atap = 2,65 kg/m^2
- Jumlah gording = 22 buah
- Berat sendiri profil = 172 kg/m (IWF 400.400.13.21)
- Berat gording = 7,51 kg/m (*Light Lip Channels* 150.65.20.3,2)
- Mutu baja = BJ 37 $\longrightarrow$ fy = 240 Mpa
  fu = 370 Mpa

Pembebanan:

Beban penutup atap = Berat atap . Jarak kuda-kuda

= 2,65 kg/m^2 . 5,0 m

= 13,25 kg/m

Beban miring atap = Beban atap . cos 27°

= 12,35 kg/m . cos 27°

= 11,80 kg/m

$$\text{Beban gording} = \frac{\text{Berat gording} \,.\, \sum \text{Gording} \,.\, \text{Jarak portal}}{\text{Panjang bentang}}$$

$$= \frac{7{,}51 \text{ kg/m} \,.\, 22 \text{ bh} \,.\, 5{,}0 \text{ m}}{20 \text{ m}}$$

= 41,30 kg/m

Beban miring gording = Beban gording . cos 27°

= 41,30 kg/m . cos 27°

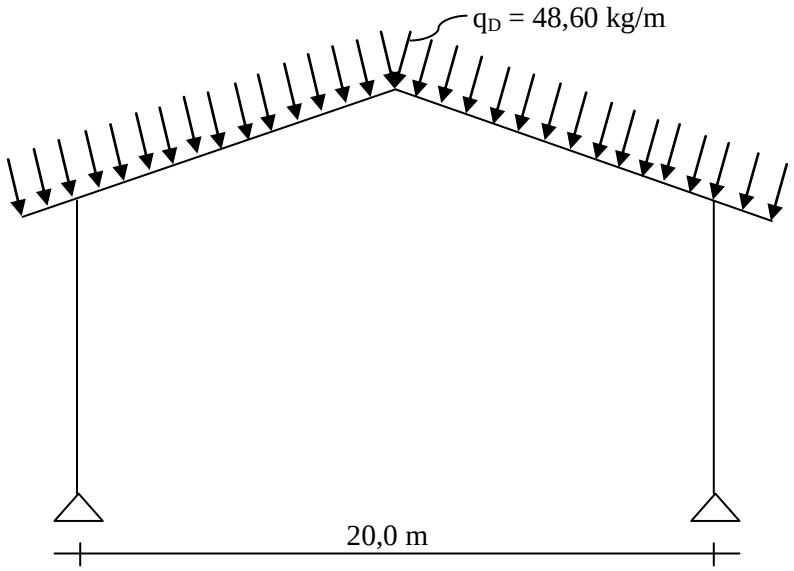
= 36,80 kg/m

Berat sendiri profil tidak dihitung lagi secara manual, karena sudah dianalisa langsung oleh program SAP2000, sehingga kita hanya memasukkan beban miring atap dan beban miring gording.

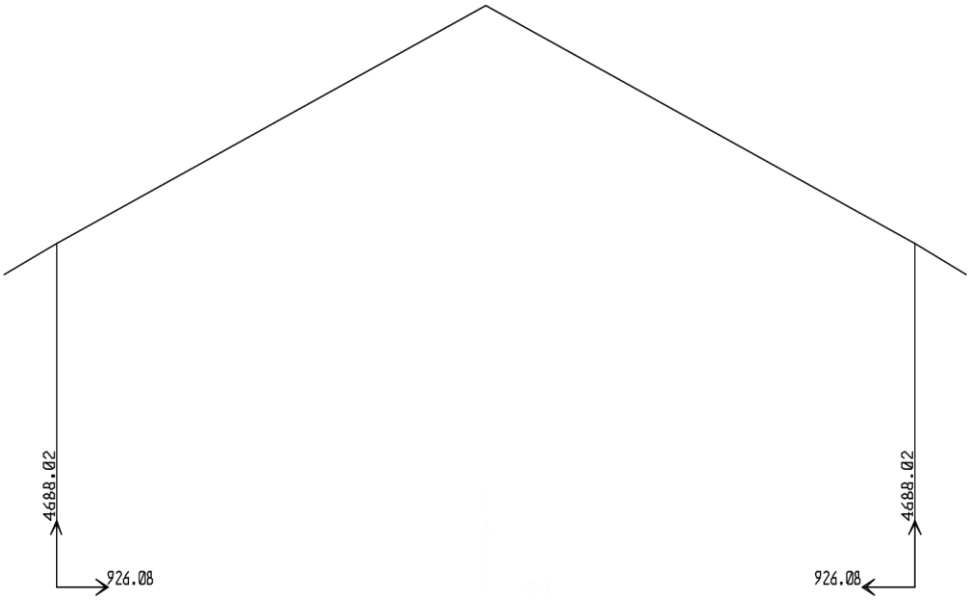
Beban mati (q_D) = Beban miring atap + Beban miring gording

= 11,80 kg/m + 36,80 kg/m

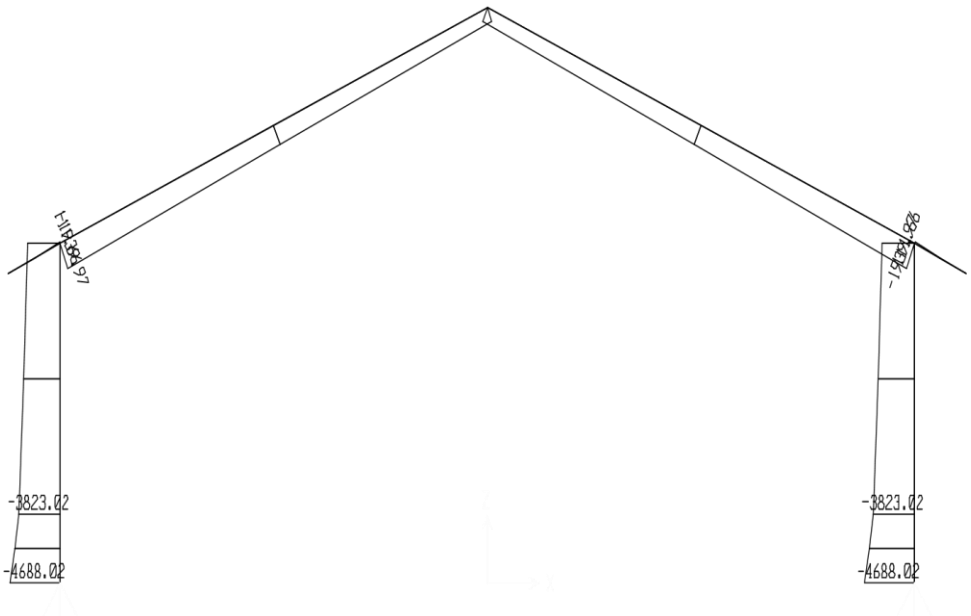
= 48,60 kg/m



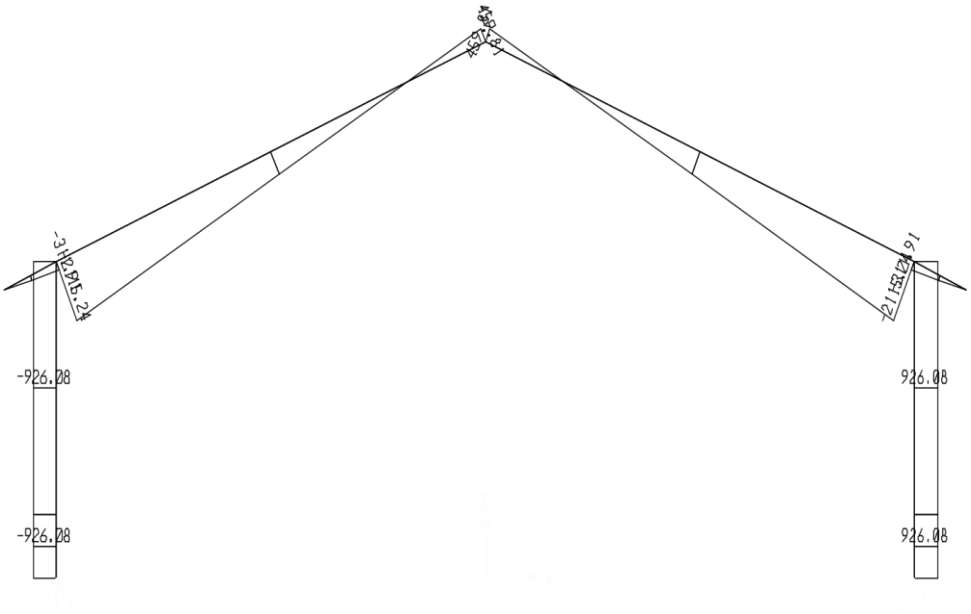
Gambar 3.5 Pembebanan Portal Akibat Beban Mati



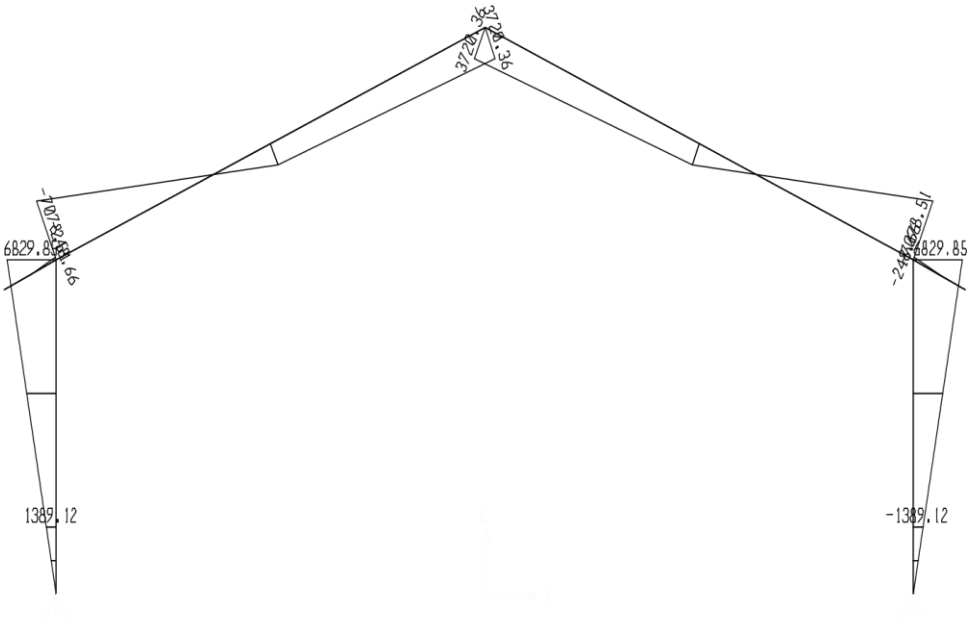
Gambar 3.6 Perletakan Gaya Akibat Beban Mati



Gambar 3.7 Gaya Normal Akibat Beban Mati



Gambar 3.8 Gaya Lintang Akibat Beban Mati



Gambar 3.9 Gaya Momen Akibat Beban Mati

3.3.2 Portal Akibat Beban Hidup

Pembebanan:

Beban hidup (air hujan)

$q = (40 - 0{,}8 \cdot \alpha)$

$= (40 - 0{,}8 \cdot 27°)$

$= 18{,}4 \text{ kg/m}^2 < 20 \text{ kg/m}^2$

Karena beban air hujan minimum 20 kg/m^2 sehingga diambil beban air hujan sebesar 20 kg/m^2.

Beban air hujan = Beban hujan . Jarak antar portal

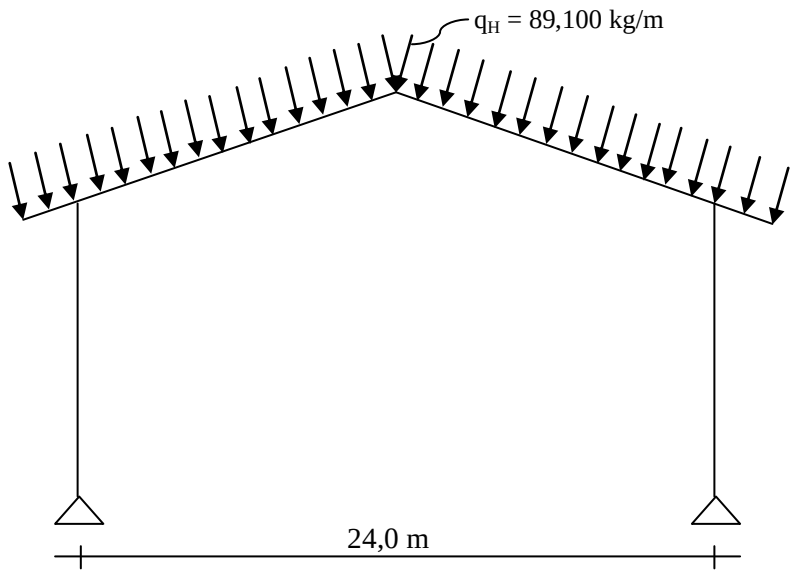
$= 20 \text{ kg/m}^2 \cdot 5{,}0 \text{ m}$

$= 100 \text{ kg/m}$

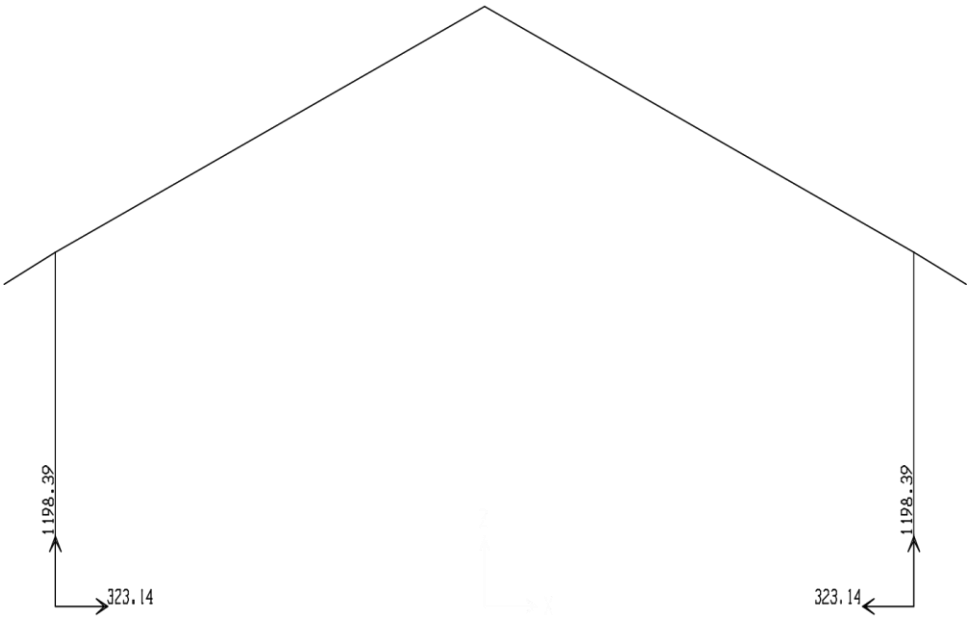
Beban miring air hujan (q_H) = Beban air hujan . cos 27°

= 100 kg/m . cos 27°

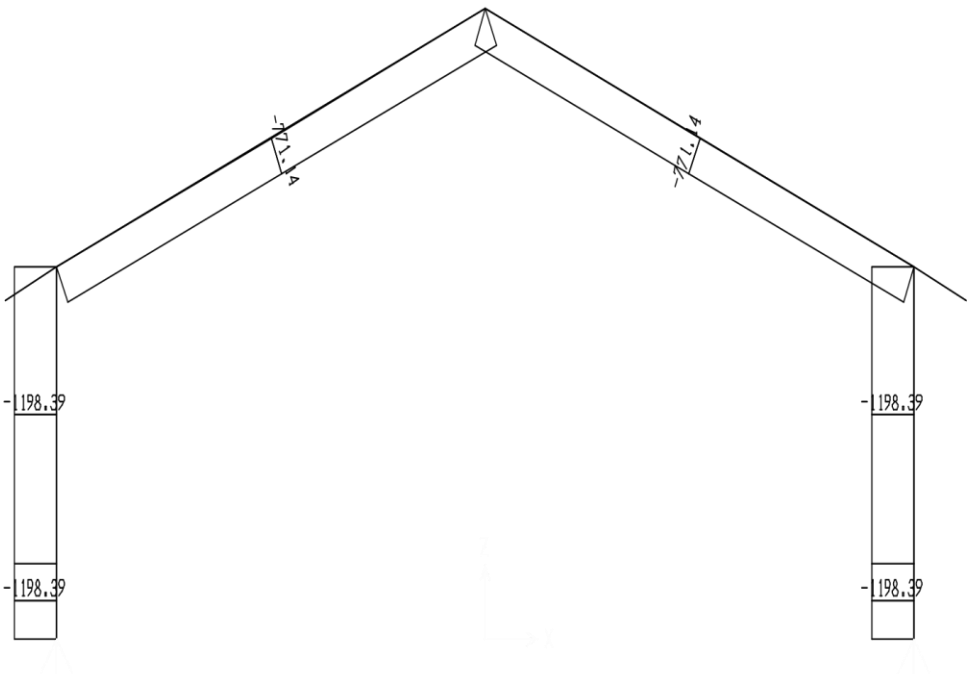
= 89,100 kg/m



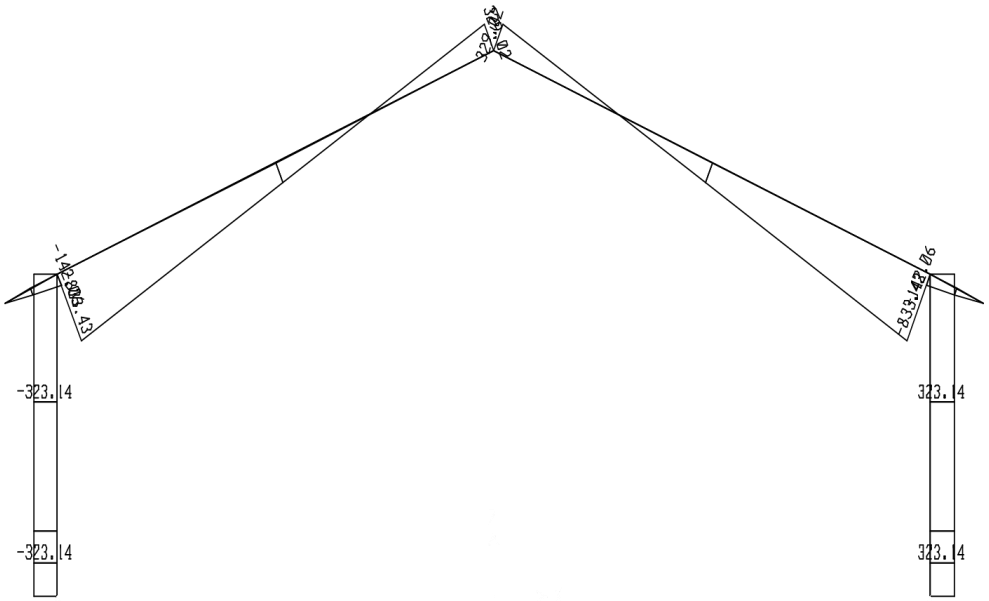
Gambar 3.10 Pembebanan Portal Akibat Beban Hidup



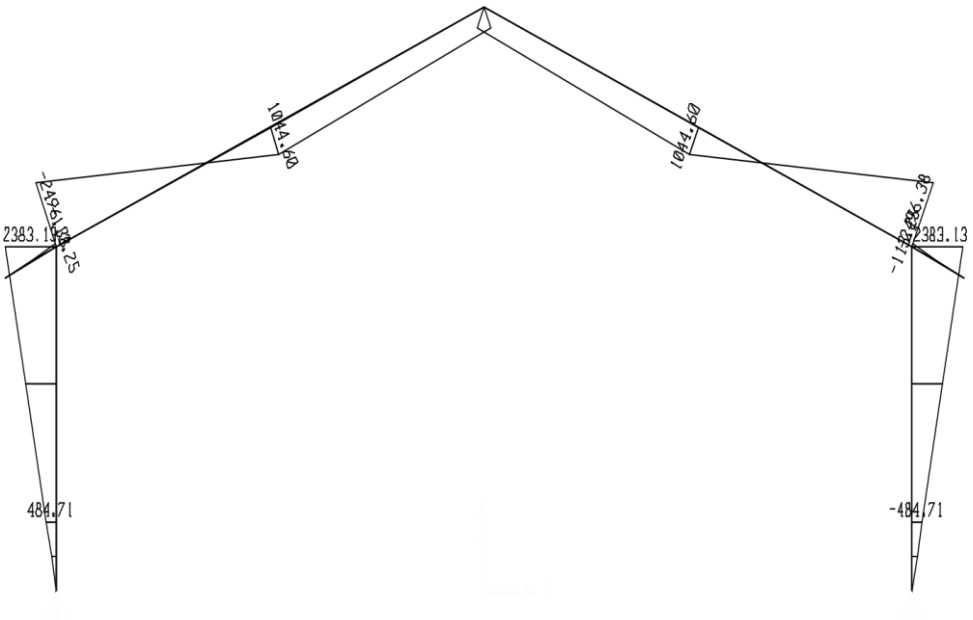
Gambar 3.11 Perletakan Portal Akibat Beban Hidup



Gambar 3.12 Gaya Normal Akibat Beban Hidup



Gambar 3.13 Gaya Lintang Akibat Beban Hidup



Gambar 3.14 Gaya Momen Akibat Beban Hidup

Tabel 3.1 Bidang Gaya Dalam Akibat Beban Mati

Frame (Text)	Station (m)	OutputCase (Text)	CaseType (Text)	P (Kgf)	V2 (Kgf)	M3 (Kgf-m)
K1	0,000	B. MATI	LinStatic	-4688,02	-926,08	0,000
K1	0,750	B. MATI	LinStatic	-4255,52	-926,08	694,56
K1	1,500	B. MATI	LinStatic	-3823,02	-926,08	1389,12
K2	0,000	B. MATI	LinStatic	-3823,02	-926,08	1389,12
K2	1,469	B. MATI	LinStatic	-3626,50	-926,08	2749,30
K2	2,938	B. MATI	LinStatic	-3430,00	-926,08	4109,49
K2	4,406	B. MATI	LinStatic	-3233,48	-926,08	5469,67
K2	5,875	B. MATI	LinStatic	-3036,97	-926,08	6829,85
K3	0,000	B. MATI	LinStatic	0,000	0,000	0,000
K3	0,797	B. MATI	LinStatic	55,83	155,96	-62,16
K3	1,594	B. MATI	LinStatic	111,66	311,91	-248,66
K4	0,000	B. MATI	LinStatic	-1939,97	-2115,24	-7078,51
K4	3,262	B. MATI	LinStatic	-1724,40	-1471,47	-1533,75
K4	6,523	B. MATI	LinStatic	-1508,83	-827,71	2520,4
K4	9,784	B. MATI	LinStatic	-1293,26	-183,94	3152,15
K4	13,047	B. MATI	LinStatic	-1077,69	459,81	3720,36
K5	0,000	B. MATI	LinStatic	-1077,69	-459,81	3720,36
K5	3,262	B. MATI	LinStatic	-1293,26	183,94	3152,15
K5	6,523	B. MATI	LinStatic	-1508,83	827,71	2520,4
K5	9,784	B. MATI	LinStatic	-1724,40	1471,47	-1533,75
K5	13,047	B. MATI	LinStatic	-1939,97	2115,24	-7078,51
K6	0,000	B. MATI	LinStatic	111,66	-311,91	-248,66
K6	0,797	B. MATI	LinStatic	55,830	-155,96	-62,16
K6	1,594	B. MATI	LinStatic	0,000	0,000	0,000
K7	0,000	B. MATI	LinStatic	-3036,97	-926,08	-6829,85
K7	1,469	B. MATI	LinStatic	-3233,48	-926,08	-5469,67
K7	2,938	B. MATI	LinStatic	-3430,00	-926,08	-4109,49
K7	4,406	B. MATI	LinStatic	-3626,50	-926,08	-2749,30
K7	5,875	B. MATI	LinStatic	-3823,02	-926,08	-1389,12
K8	0,000	B. MATI	LinStatic	-3823,02	-926,08	-1389,12
K8	0,750	B. MATI	LinStatic	-4255,52	-926,08	-694,56
K8	1,500	B. MATI	LinStatic	-4688,02	-926,08	0,000

Sumber : Hasil SAP 2000v.14

3.3.3 Portal Akibat Beban Angin Kiri = Beban Angin Kanan

Pembebanan:

Beban angin diambil (q_W) diambil tekanan tiup minimum sebesar 25 kg/m^2.

$q_{W1} = (0{,}9 \,.\, q_W \,.$ Jarak antar portal)

$= 0{,}9 \,.\, 25 \text{ kg/m}^2 \,.\, 5{,}0 \text{ m}$

$= 112{,}5 \text{ kg/m}$

$q_{W2} = (0{,}02 \,.\, \propto - 0{,}4) \,.\, q_W \,.$ Jarak antar portal

$= (0{,}02 \,.\, 27° - 0{,}4) \,.\, 25 \text{ kg/m}^2 \,.\, 5{,}0 \text{ m}$

$= 17{,}5 \text{ kg/m}$

$q_{W3} = (-0{,}4) \,.\, q_W \,.$ Jarak antar portal

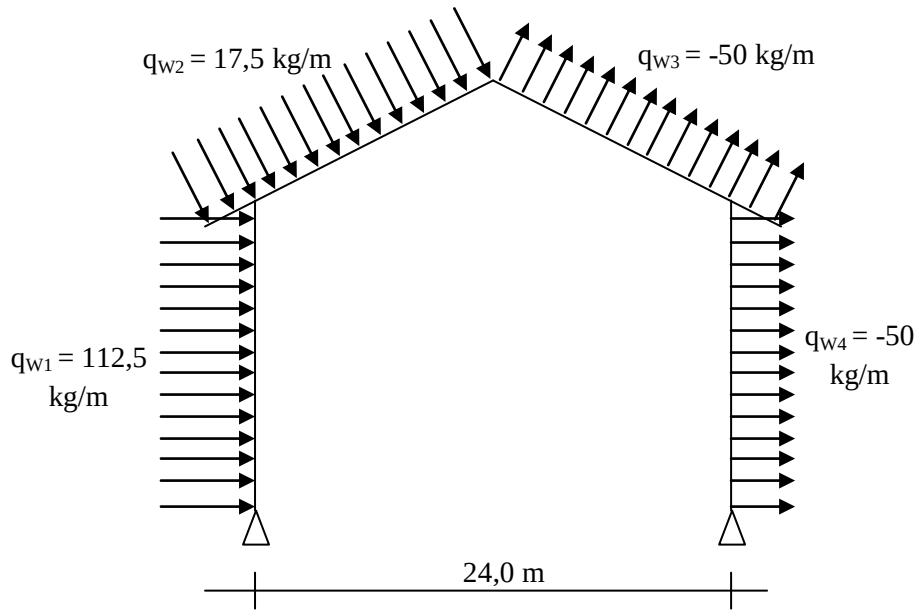
$= (-0{,}4) \,.25 \text{ kg/m}^2 \,.\, 5{,}0 \text{ m}$

$= -50 \text{ kg/m}$

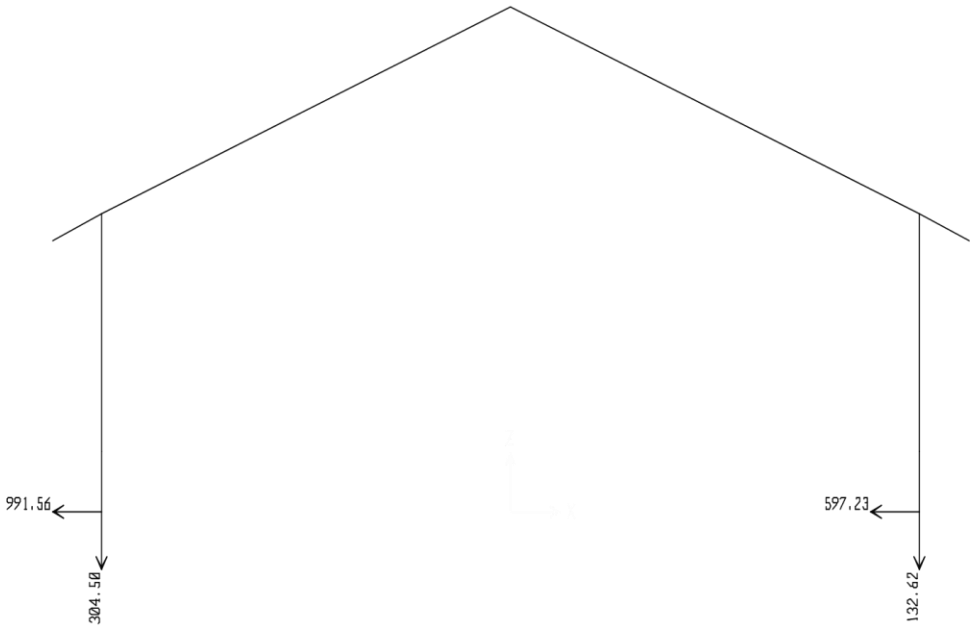
$q_{W4} = (-0{,}4) \,.\, q_W \,.$ Jarak antar portal

$= (-0{,}4) \,.\, 25 \text{ kg/m}^2 \,.\, 5{,}0 \text{ m}$

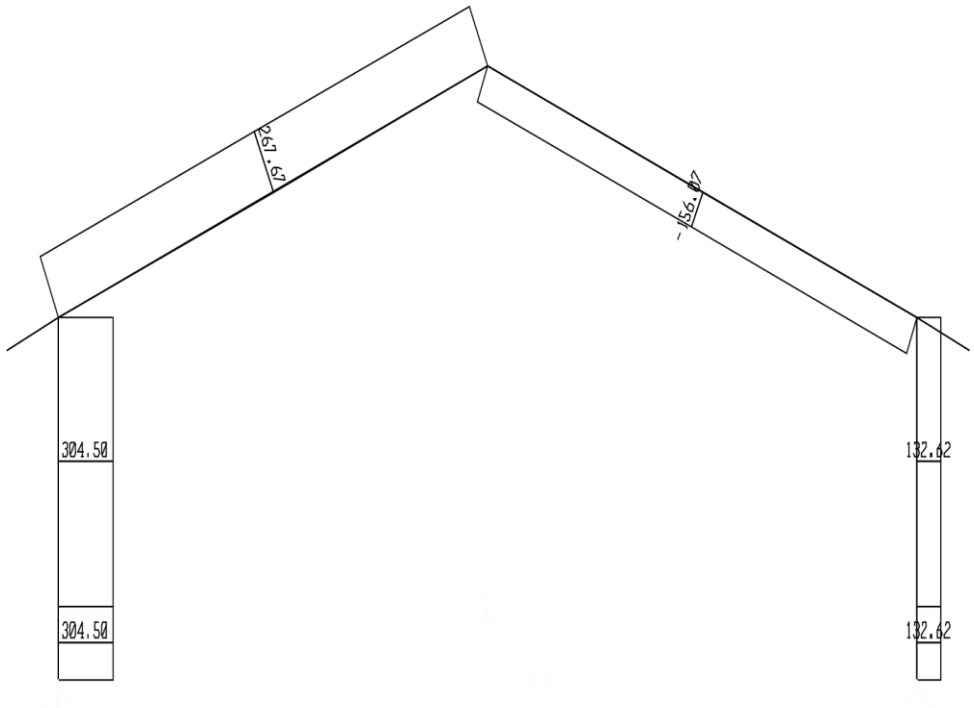
$= -50 \text{ kg/m}$



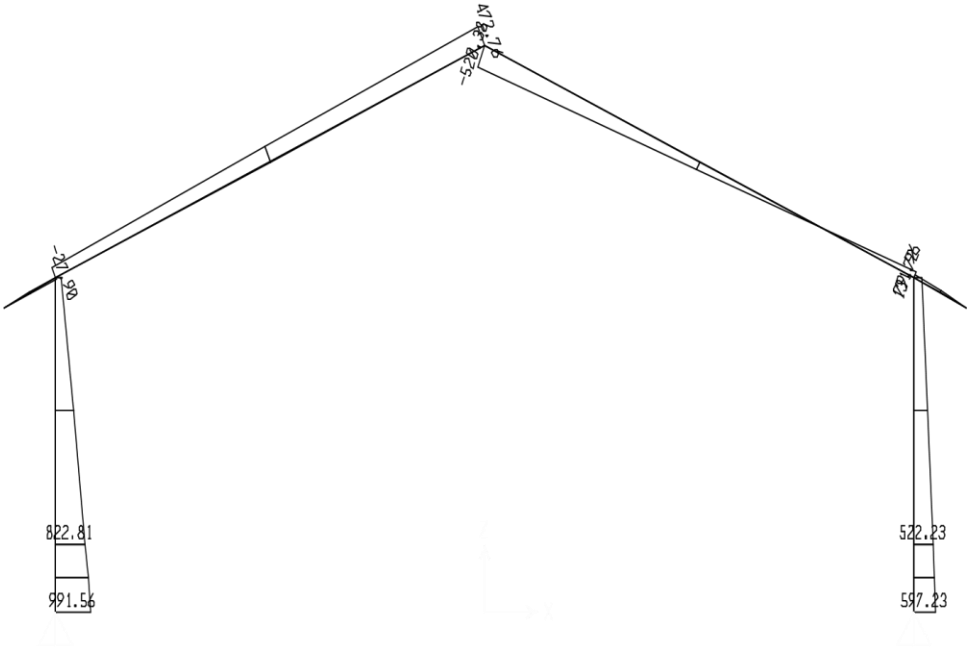
Gambar 3.15 Pembebanan Portal Akibat Beban Angin Kiri



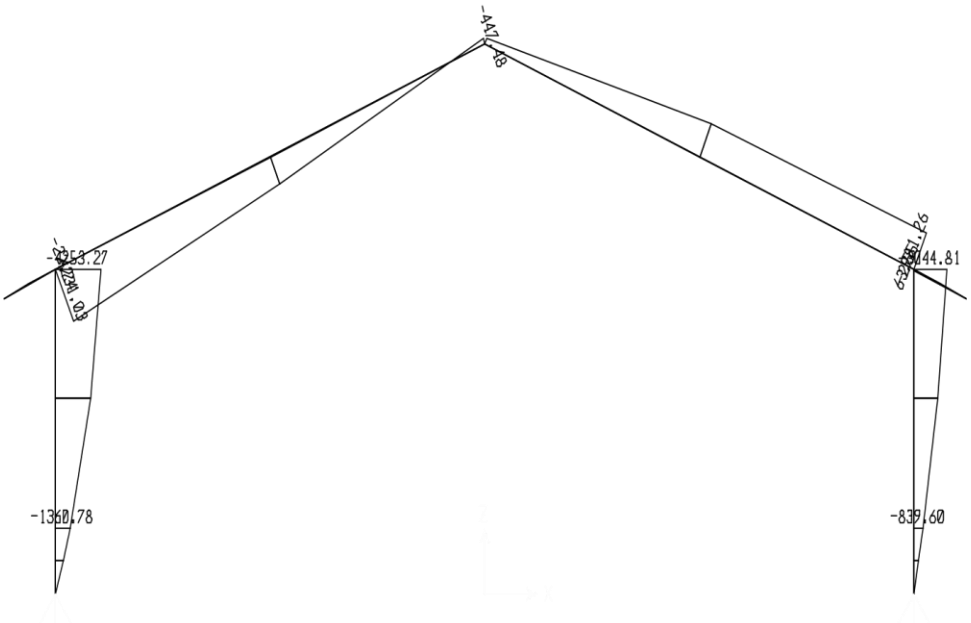
Gambar 3.16 Perletakan Gaya Akibat Beban Angin Kiri



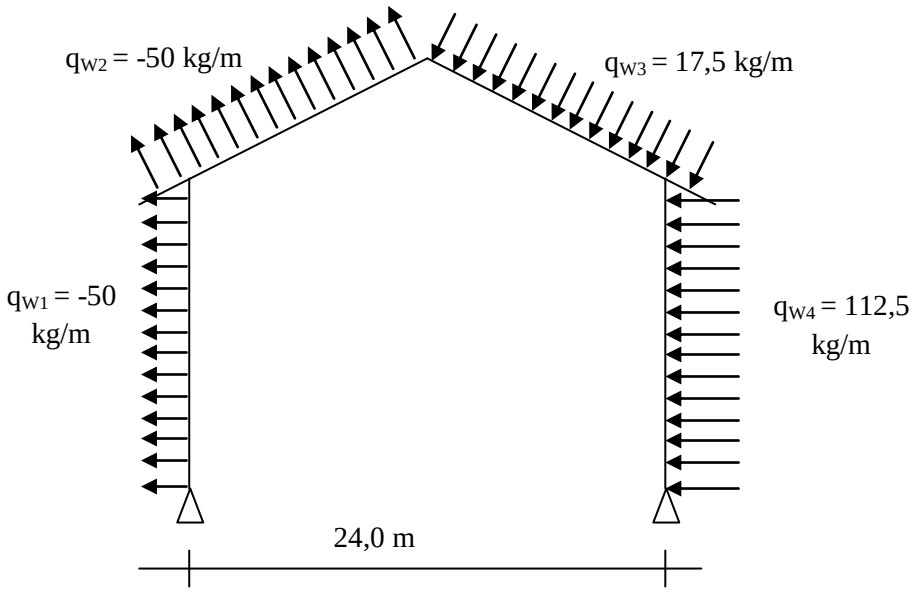
Gambar 3.17 Gaya Normal Akibat Beban Angin Kiri



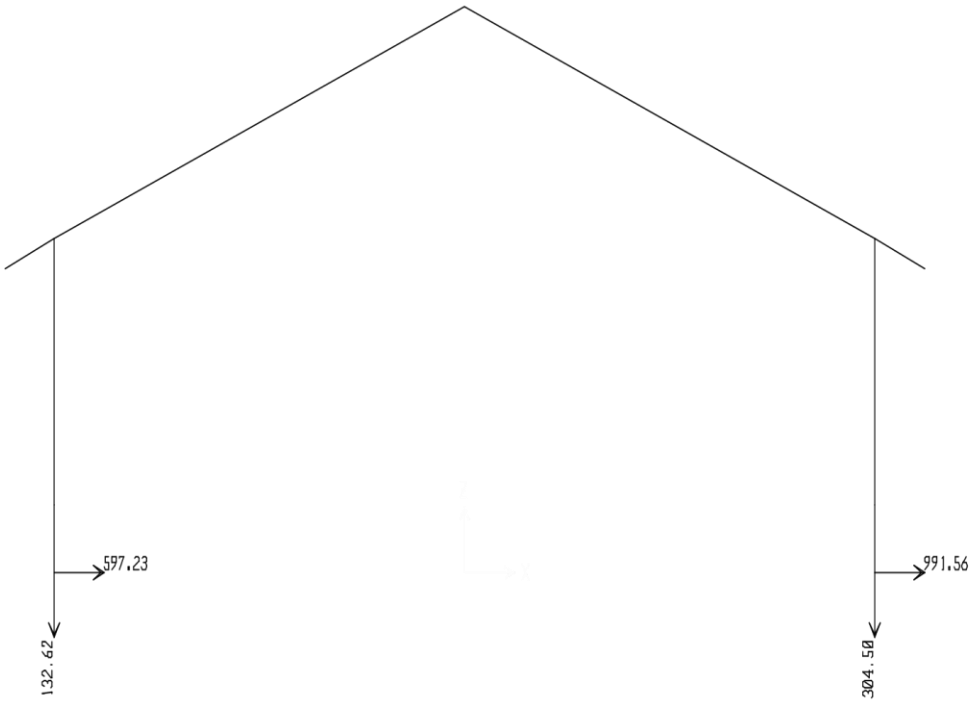
Gambar 3.18 Gaya lintang Akibat Beban Angin Kiri



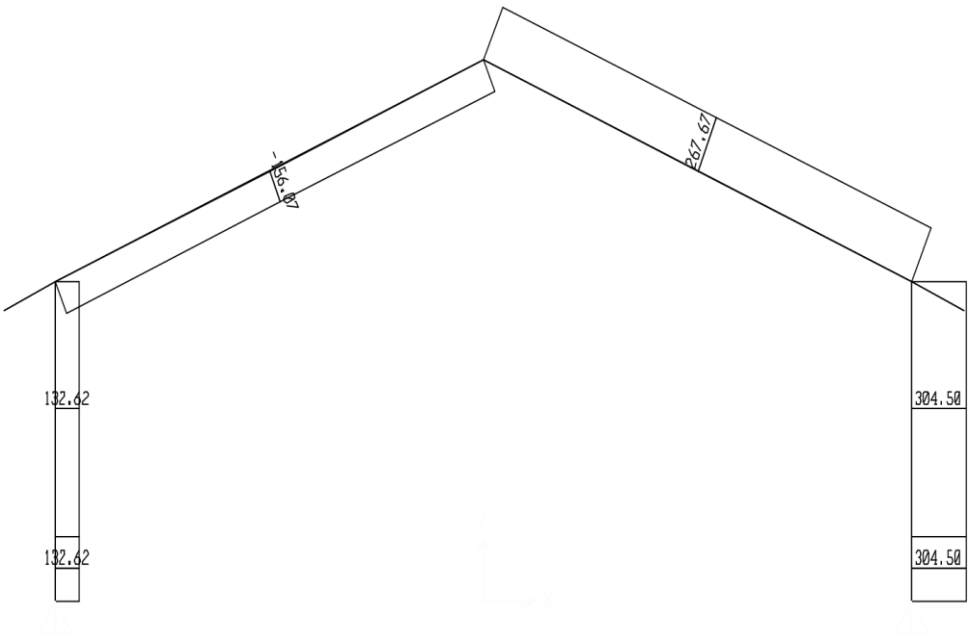
Gambar 3.19 Gaya Momen Akibat Beban Angin Kiri



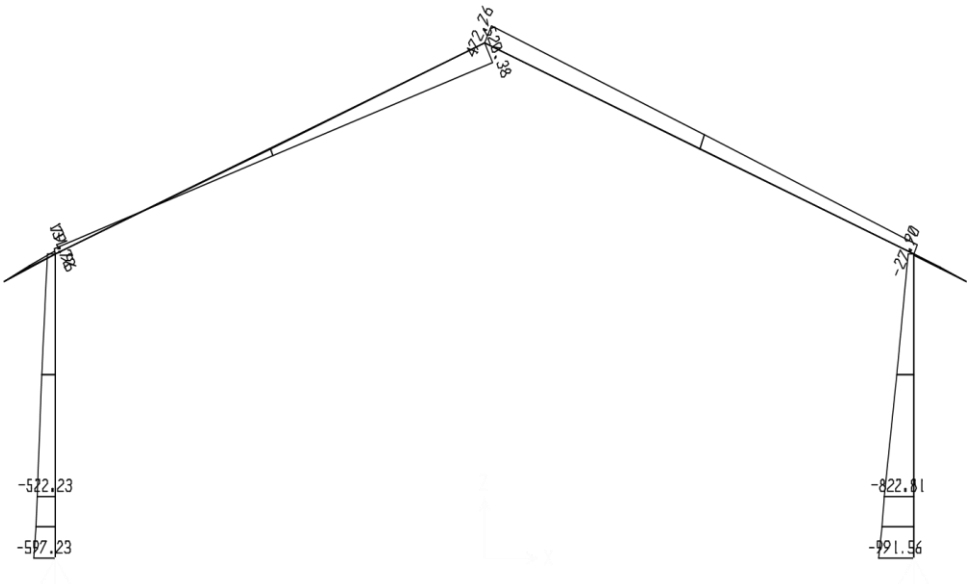
Gambar 3.20 Pembebanan Portal Akibat Beban Angin Kanan



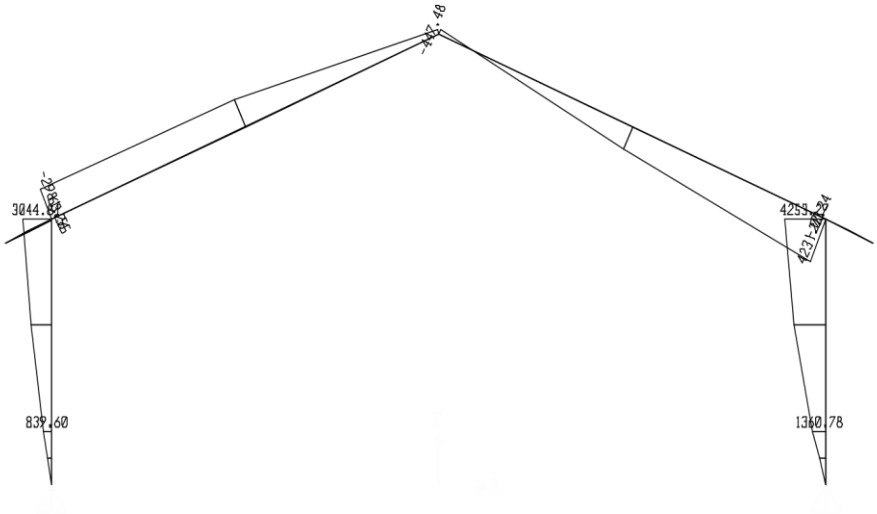
Gambar 3.21 Perletakan Gaya Akibat Beban Angin Kanan



Gambar 3.22 Gaya Normal Akibat Beban Angin Kanan



Gambar 3.23 Gaya Lintang Akibat Beban Angin Kanan



Gambar 3.24 Gaya Momen Akibat Beban Angin Kanan

Tabel 3.2 Bidang Gaya Dalam Akibat Beban Hidup

Frame (Text)	Station (m)	OutputCase (Text)	CaseType (Text)	P (Kgf)	V2 (Kgf)	M3 (Kgf-m)
K1	0,000	B. HIDUP	LinStatic	-1198,39	-323,14	0
K1	0,750	B. HIDUP	LinStatic	-1198,39	-323,14	242,35
K1	1,500	B. HIDUP	LinStatic	-1198,39	-323,14	484,71
K2	0,000	B. HIDUP	LinStatic	-1198,39	-323,14	484,71
K2	1,469	B. HIDUP	LinStatic	-1198,39	-323,14	959,31
K2	2,938	B. HIDUP	LinStatic	-1198,39	-323,14	1433,92
K2	4,406	B. HIDUP	LinStatic	-1198,39	-323,14	1908,52
K2	5,875	B. HIDUP	LinStatic	-1198,39	-323,14	2383,13
K3	0,000	B. HIDUP	LinStatic	0,000	0,000	0,000
K3	0,797	B. HIDUP	LinStatic	0,000	71,03	-28,31
K3	1,594	B. HIDUP	LinStatic	0,000	142,06	-113,25
K4	0,000	B. HIDUP	LinStatic	-771,14	-833,43	-2496,38
K4	3,262	B. HIDUP	LinStatic	-771,14	-542,82	-245,36
K4	6,523	B. HIDUP	LinStatic	-771,14	-252,21	1044,6
K4	9,784	B. HIDUP	LinStatic	-771,14	38,400	952,53
K4	13,047	B. HIDUP	LinStatic	-771,14	329,02	-794,05
K5	0,000	B. HIDUP	LinStatic	-771,14	-329,02	-794,05
K5	3,262	B. HIDUP	LinStatic	-771,14	-38,400	952,53
K5	6,523	B. HIDUP	LinStatic	-771,14	252,21	1044,6
K5	9,784	B. HIDUP	LinStatic	-771,14	542,82	-245,36
K5	13,047	B. HIDUP	LinStatic	-771,14	833,43	-2496,38
K6	0,000	B. HIDUP	LinStatic	0,000	-142,06	-113,25
K6	0,797	B. HIDUP	LinStatic	0,000	-71,03	-28,31
K6	1,594	B. HIDUP	LinStatic	0,000	0,000	0,000
K7	0,000	B. HIDUP	LinStatic	-1198,39	-323,14	-2383,13
K7	1,469	B. HIDUP	LinStatic	-1198,39	-323,14	-1908,52
K7	2,938	B. HIDUP	LinStatic	-1198,39	-323,14	-1433,92
K7	4,406	B. HIDUP	LinStatic	-1198,39	-323,14	-959,31
K7	5,875	B. HIDUP	LinStatic	-1198,39	-323,14	-484,71
K8	0,000	B. HIDUP	LinStatic	-1198,39	-323,14	-484,71
K8	0,750	B. HIDUP	LinStatic	-1198,39	-323,14	-242,35
K8	1,500	B. HIDUP	LinStatic	-1198,39	-323,14	0

Sumber : Hasil SAP 2000v.14

Tabel 3.3 Bidang Gaya Dalam Akibat Beban Angin

Frame (Text)	Station (m)	OutputCase (Text)	CaseType (Text)	P (Kgf)	V2 (Kgf)	M3 (Kgf-m)
K1	0,000	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	304,500	991,560	0,000
K1	0,750	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	304,500	907,180	-712,030
K1	1,500	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	304,500	822,810	-1360,780
K2	0,000	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	304,500	822,810	-1360,780
K2	1,469	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	304,500	657,575	-2811,965
K2	2,938	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	304,500	492,340	-3292,400
K2	4,406	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	304,500	327,105	-3772,835
K2	5,875	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	304,500	161,870	-4253,270
K3	0,000	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	0,000	0,000	0,000
K3	0,797	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	0,000	13,950	-5,560
K3	1,594	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	0,000	27,900	-22,240
K4	0,000	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	267,670	244,440	4231,030
K4	3,262	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	267,670	187,360	3457,960
K4	6,523	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	267,670	358,600	2264,120
K4	9,784	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	267,670	415,680	1270,892
K4	13,047	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	267,670	472,760	-447,480
K5	0,000	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	-156,070	520,380	-447,480
K5	3,262	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	-156,070	357,295	-1076,670
K5	6,523	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	-156,070	194,210	-2778,210
K5	9,784	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	-156,070	31,125	-2885,520
K5	13,047	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	-156,070	-131,960	-2981,260
K6	0,000	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	0,000	79,720	63,550
K6	0,797	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	0,000	39,860	15,890
K6	1,594	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	0,000	0,000	0,000
K7	0,000	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	132,620	-228,480	-3044,810
K7	1,469	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	132,620	-301,925	-2601,370
K7	2,938	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	132,620	-375,360	-2157,930
K7	4,406	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	132,620	-448,795	-1714,490
K7	5,875	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	132,620	-522,230	-839,600
K8	0,000	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	132,620	-522,230	-839,600
K8	0,750	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	132,620	-559,730	-433,860
K8	1,500	B. ANGIN KIRI = B. ANGIN KANAN	LinStatic	132,620	-597,230	0,000

Sumber : Hasil SAP 2000v.14

Tabel 3.4 Kombinasi Beban Aksial

Batang	Beban Mati (D)	Beban Hidup (H)	Beban Angin (W)	U = 1,4 D	U = 1,2 D + 0,5 H	U = 1,2 D + 1,6 H + 0,8 W	U = 1,2 D + 1,3 W + 0,5 H	U = 0,9 D + 1,3 W	U = 0,9 D - 1,3 W	Nu Max
A1	-4688,020	-1198,390	304,500	-6563,228	-6224,819	-7299,448	-5828,969	-3823,368	-4615,068	-7299,448
1A	-3823,020	-1198,390	304,500	-5352,228	-5186,819	-6261,448	-4790,969	-3044,868	-3836,568	-6261,448
12	-3823,020	-1198,390	304,500	-5352,228	-5186,819	-6261,448	-4790,969	-3044,868	-3836,568	-6261,448
21	-3036,970	-1198,390	304,500	-4251,758	-4243,559	-5318,188	-3847,709	-2337,423	-3129,123	-5318,188
2X	111,660	0,000	0,000	156,324	133,992	133,992	133,992	100,494	100,494	133,992
X2	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
23	-1939,970	-771,140	267,670	-2715,958	-2713,534	-3347,652	-2365,563	-1398,002	-2093,944	-3347,652
32	-1077,690	-771,140	267,670	-1508,766	-1678,798	-2312,916	-1330,827	-621,950	-1317,892	-2312,916
34	-1077,690	-771,140	-156,070	-1508,766	-1678,798	-2651,908	-1881,689	-1172,812	-767,030	-2651,908
43	-1939,970	-771,140	-156,070	-2715,958	-2713,534	-3686,644	-2916,425	-1948,864	-1543,082	-3686,644
Y4	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
4Y	111,660	0,000	0,000	156,324	133,992	133,992	133,992	100,494	100,494	133,992
45	-3036,970	-1198,390	132,620	-4251,758	-4243,559	-5455,692	-4071,153	-2560,867	-2905,679	-5455,692
54	-3823,020	-1198,390	132,620	-5352,228	-5186,819	-6398,952	-5014,413	-3268,312	-3613,124	-6398,952
5B	-3823,020	-1198,390	132,620	-5352,228	-5186,819	-6398,952	-5014,413	-3268,312	-3613,124	-6398,952
B5	-4688,020	-1198,390	132,620	-6563,228	-6224,819	-7436,952	-6052,413	-4046,812	-4391,624	-7436,952

Sumber : Hasil SAP 2000v.14

Tabel 3.5 Kombinasi Beban Lintang

Batang	Beban Mati (D)	Beban Hidup (H)	Beban Angin (W)	U = 1,4 D	U = 1,2 D + 0,5 H	U = 1,2 D + 1,6 H + 0,8 W	U = 1,2 D + 1,3 W + 0,5 H	U = 0,9 D + 1,3 W	U = 0,9 D - 1,3 W	Lu Max
A1	-926,080	-323,140	991,560	-1296,512	-1272,866	-835,072	16,162	455,556	-2122,500	-2122,500
1A	-926,080	-323,140	822,810	-1296,512	-1272,866	-970,072	-203,213	236,181	-1903,125	-1903,125
12	-926,080	-323,140	822,810	-1296,512	-1272,866	-970,072	-203,213	236,181	-1903,125	-1903,125
21	-926,080	-323,140	161,870	-1296,512	-1272,866	-1498,824	-1062,435	-623,041	-1043,903	-1043,903
2X	311,910	142,060	27,900	436,674	445,322	623,908	481,592	316,989	244,449	244,449
X2	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
23	-2115,240	-833,430	244,440	-2961,336	-2955,003	-3676,224	-2637,231	-1585,944	-2221,488	-2221,488
32	459,810	329,020	472,760	643,734	716,282	1456,412	1330,870	1028,417	-200,759	-200,759
34	-459,810	-329,020	520,380	-643,734	-716,282	-661,900	-39,788	262,665	-1090,323	-1090,323
43	2115,240	833,430	-131,960	2961,336	2955,003	3766,208	2783,455	1732,168	2075,264	2075,264
Y4	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
4Y	-311,910	-142,060	79,720	-436,674	-445,322	-537,812	-341,686	-177,083	-384,355	-384,355
45	-926,080	-323,140	-228,480	-1296,512	-1272,866	-1811,104	-1569,890	-1130,496	-536,448	-536,448
54	-926,080	-323,140	-522,230	-1296,512	-1272,866	-2046,104	-1951,765	-1512,371	-154,573	-154,573
5B	-926,080	-323,140	-522,230	-1296,512	-1272,866	-2046,104	-1951,765	-1512,371	-154,573	-154,573
B5	-926,080	-323,140	-597,230	-1296,512	-1272,866	-2106,104	-2049,265	-1609,871	-57,073	-57,073

Sumber : Hasil SAP 2000v.14

Tabel 3.6 Kombinasi Beban Momen

Batang	Beban Mati (D)	Beban Hidup (H)	Beban Angin (W)	U = 1,4 D	U = 1,2 D + 0,5 H	U = 1,2 D + 1,6 H + 0,8 W	U = 1,2 D + 1,3 W + 0,5 H	U = 0,9 D + 1,3 W	U = 0,9 D - 1,3 W	Mu Max
A1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1A	1389.120	484.710	-1360.780	1944.768	1909.299	1353.856	140.285	-518.806	3019.222	3019.222
12	1389.120	484.710	-1360.780	1944.768	1909.299	1353.856	140.285	-518.806	3019.222	3019.222
21	6829.850	2383.130	-4253.270	9561.790	9387.385	8606.212	3858.134	617.614	11676.116	8606.212
2X	-248.660	-113.250	-22.240	-348.124	-355.017	-497.384	-383.929	-252.706	-194.882	-497.384
X2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23	-7078.510	-2496.380	4231.030	-9909.914	-9742.402	-9103.596	-4242.063	-870.320	-11870.998	-9103.596
32	3720.360	-794.050	-447.480	5208.504	4067.407	2835.968	3485.683	2766.600	3930.048	5208.504
34	3720.360	-794.050	-447.480	5208.504	4067.407	2835.968	3485.683	2766.600	3930.048	5208.504
43	-7078.510	-2496.380	-2981.260	-9909.914	-9742.402	-14873.428	-13618.040	-10246.297	-2495.021	-14873.428
Y4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4Y	-248.660	-113.250	63.550	-348.124	-355.017	-428.752	-272.402	-141.179	-306.409	-428.752
45	-6829.850	-2383.130	-3044.810	-9561.790	-9387.385	-14444.676	-13345.638	-10105.118	-2188.612	-14444.676
54	-1389.120	-484.710	-839.600	-1944.768	-1909.299	-3114.160	-3000.779	-2341.688	-158.728	-3114.160
5B	-1389.120	-484.710	-839.600	-1944.768	-1909.299	-3114.160	-3000.779	-2341.688	-158.728	-3114.160
B5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Sumber : Hasil SAP 2000v.14

Tabel 3.7 Kombinasi Beban Momen pada Tengah Batang

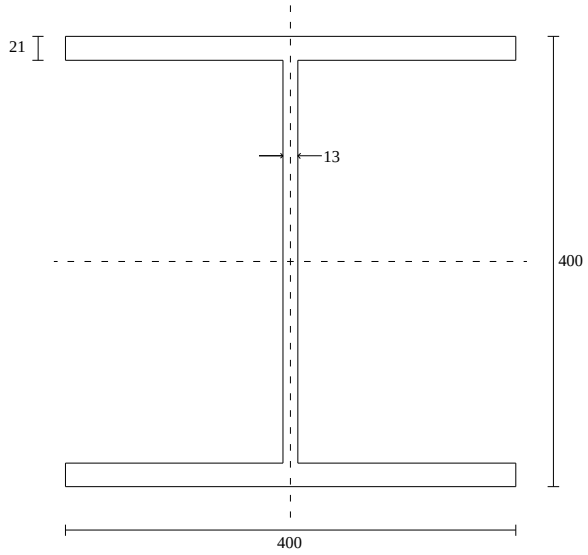
Batang	Beban Mati (D)	Beban Hidup (H)	Beban Angin (W)	U = 1,4 D	U = 1,2 D + 0,5 H	U = 1,2 D + 1,6 H + 0,8 W	U = 1,2 D + 1,3 W + 0,5 H	U = 0,9 D + 1,3 W	U = 0,9 D - 1,3 W	Mu Max
12	2749.300	959.310	-2811.965	3849.020	3778.815	2584.484	123.261	-1181.185	6129.925	6129.925
12	4109.490	1433.920	-3292.400	5753.286	5648.348	4591.740	1368.228	-581.579	7978.661	7978.661
12	5469.670	1908.520	-3772.835	7657.538	7517.864	6598.968	2613.179	18.017	9827.389	9827.389
23	-1533.750	-245.360	3457.960	-2147.250	-1963.180	533.292	2532.168	3114.973	-5875.723	-5875.723
23	2520.400	1044.600	2264.120	3528.560	3546.780	6507.136	6490.136	5211.716	-674.996	6507.136
23	3152.150	952.530	1270.892	4413.010	4258.845	6323.342	5911.005	4489.095	1184.775	6323.342
34	3152.150	952.530	-1076.670	4413.010	4258.845	4445.292	2859.174	1437.264	4236.606	4236.606
34	2520.400	1044.600	-2778.210	3528.560	3546.780	2473.272	-64.893	-1343.313	5880.033	5880.033
34	-1533.750	-245.360	-2885.520	-2147.250	-1963.180	-4541.492	-5714.356	-5131.551	2370.801	-5714.356
45	-5469.670	-1908.520	-2601.370	-7657.538	-7517.864	-11698.332	-10899.645	-8304.484	-1540.922	-11698.332
45	-4109.490	-1433.920	-2157.930	-5753.286	-5648.348	-8952.004	-8453.657	-6503.850	-893.232	-8952.004
45	-2749.300	-959.310	-1714.490	-3849.020	-3778.815	-6205.648	-6007.652	-4703.207	-245.533	-6205.648

Sumber : Hasil SAP 2000v.14

3.4 Perhitungan Kontrol Penampang Single Beam

3.4.1 Kontrol Penampang Balok Miring

Perencanaan portal penampang balok miring (konstruksi kuda-kuda) menggunakan profil IWF 400.400.13.21.

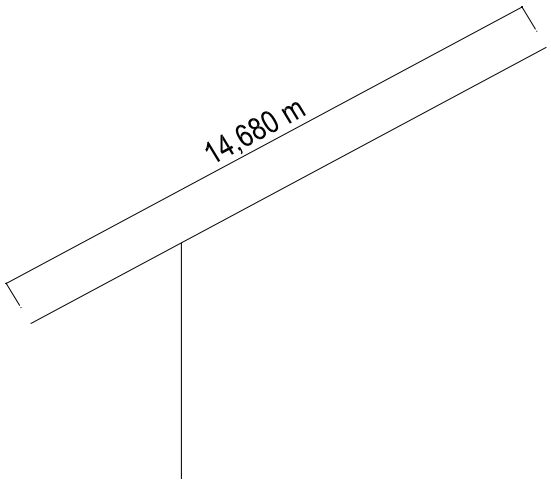


Gambar 3.25 Profil Kuda-kuda IWF 400.400.13.21

Diketahui data-data profil IWF 400.400.13.21 sebagai berikut:

- h = 400 mm
- b = 400 mm
- t_b = 13 mm
- t_f = 21 mm
- r = 22 mm
- A_g = 218,7 cm^2
- I_x = 66600 cm^4
- I_y = 22400 cm^4
- i_x = 17,5 cm
- i_y = 10,1 cm

Kontrol tegangan penampang balok miring dengan panjang bentang L = 14,680 meter.



Gambar 3.26 Panjang Balok Miring yang Diperhitungkan

Diketahui data-data sebagai berikut:

- Nu = 33,477 kN
- Vu = 36,762 kN
- Mltu = 91,036 kN.m
- Mntu = 52,085 kN.m
- Mutu baja BJ 37 ⟶ fy = 240 MPa
  fu = 370 Mpa
- Modulus Elastisitas = 200.000 Mpa

Panjang tekuk untuk jepit-jepit kc = 0,65 (SNI Baja 03-1729-2002)

1. Aksi Kolom

- Lk = Kc . L
  = 0,65 . 14,68 m
  = 9,542 m
  = 954,2 cm
- $\lambda y = \frac{Lk}{iy} < 200$
  $= \frac{954{,}2\ cm}{10{,}1\ cm} < 200$
  $= 94{,}475 < 200$ (Oke)

- $\lambda c = \frac{1}{\pi} \cdot \frac{Lk}{iy} \cdot \sqrt{\frac{fy}{Es}}$

  $= \frac{1}{\pi} \cdot \frac{954{,}2 \text{ mm}}{101 \text{ mm}} \cdot \sqrt{\frac{240 \text{ N/mm}^2}{200000 \text{ N/mm}^2}}$

  $= 0{,}104 \longrightarrow$ Dipakai ($\lambda c > 1{,}2$)

- $\omega = 1{,}25\ (\lambda c)^2$

  $= 1{,}25\ (1{,}2)^2$

  $= 1{,}8$

- $Nn = \frac{Ag\ .\ fy}{\omega}$

  $= \frac{21870 \text{ mm}^2\ .\ 240 \text{ N/mm}^2}{1{,}8}$

  $= 2916$ kN

- $\varnothing Nn > Nu$

  $0{,}85\ .\ 2916 \text{ kN} > Nu$

  $2478{,}6 \text{ kN} > 33{,}477 \text{ kN}$ (Oke)

- $\frac{Nu}{\varnothing Nn} = \frac{33{,}477 \text{ kN}}{0{,}85\ .\ 2478{,}6 \text{ kN}}$

  $= 0{,}016 < 0{,}2$

2. Aksi Balok

- $\frac{b_f}{2t_f} = \frac{400 \text{ mm}}{2\ .\ 21 \text{ mm}}$

  $= 9{,}524$ mm

- $\frac{Nu}{\emptyset Ny} = \frac{Nu}{\emptyset fy\ .\ Ag}$

  $= \frac{33476{,}52 \text{ N}}{0{,}9\ .\ 240 \text{ N/mm}^2\ .\ 21870 \text{ mm}^2}$

  $= 0{,}007 < 0{,}125$

  Karena $\frac{Nu}{\emptyset Ny} < 0{,}125$, maka $\lambda_p = \frac{1680}{\sqrt{fy}} \left(1 - \frac{2{,}75\ Nu}{\emptyset b\ .\ Ny}\right)$

- $\lambda_p = \frac{1680}{\sqrt{fy}} \left(1 - \frac{2{,}75\ Nu}{\emptyset b\ .\ Ny}\right)$

  $= \frac{1680}{\sqrt{240}} \left(1 - (2{,}75\ .\ 0{,}0145)\right)$

$= 104{,}119$

- $\lambda = \frac{h}{tw}$

$= \frac{(400\ mm - 2\ .\ 21\ mm)}{13\ mm}$

$= 27{,}538$

Karena, $\lambda < \lambda_p \longrightarrow$ Penampang Kompak

- $Lp = 1{,}76\ .\ r_y\ .\ \sqrt{\frac{Es}{Fy}}$

$= 1{,}76\ .\ 101\ mm\ .\ \sqrt{\frac{200000\ N/mm^2}{240\ N/mm^2}}$

$= 5131{,}489\ mm$

$= 5{,}131\ m$

- $J = \frac{2.\ b\ .\ t_f^3 + (d - t_f)\ .\ t_w^3}{3} b$

$= \left(\frac{1}{3}\ .(2\ x\ (400\ .\ 21^3) + (400 - 21).\ 13^3)\right)$

$= 2747154{,}333\ mm^4$

- $G = 80000\ Mpa$

- $Sx = \frac{I_x}{h/2}$

$= \frac{66600\ .\ 10^4\ mm^4}{400\ mm/2}$

$= 3330000\ mm^3$

- $X_1 = \frac{\pi}{Sx}\ .\ \sqrt{\frac{EGJA}{2}}$

$= \frac{\pi}{3330000\ mm^3}\ .\ \sqrt{\frac{200000\ N/mm^2\ .\ 80000\ N/mm^2\ .\ 2747154{,}333\ mm^4\ .\ 21870\ mm^2}{2}}$

$= 20683{,}144\ N/mm^2$

- $I_w = \frac{I_y\ .\ h^2}{4}$

$= \frac{22400\ .\ 10^4\ mm^4\ x\ 400^2\ mm^2}{4}$

$= 8{,}96\ x\ 10^{12}\ mm^6$

- $X_2 = 4 \cdot \frac{l_w}{l_y} \left(\frac{Sx}{GJ}\right)^2$

  $= 4 \cdot \frac{8{,}96 \cdot 10^{12}\ mm^6}{22400 \cdot 10^4\ mm^4} \cdot \left(\frac{3330000\ mm^3}{80000\ N/mm^2 \cdot\ 2747154{,}333\ mm^4}\right)^2$

  $= 3{,}673 \times 10^{-5}$

- $Lr = \frac{ry \cdot X_1}{(fy-fr)} \cdot \sqrt{1 + \sqrt{1 + X_2(fy - fr)^2}}$

  $= \frac{101\ mm \cdot\ 20683{,}144\ N/mm^2}{(240\ N/mm^2 - 70\ N/mm^2)} \cdot \sqrt{1 + \sqrt{1 + 3{,}673.10^{-5}.(240 - 70)^2}}$

  $= 12178$ mm

  $= 12{,}178$ m

  Lr < L

  12,178 m < 14,68 m (Oke)

- $Zx = 2\left(400 \cdot 21 \cdot 189{,}5 + 179 \cdot 13 \cdot \frac{179}{2}\right)$

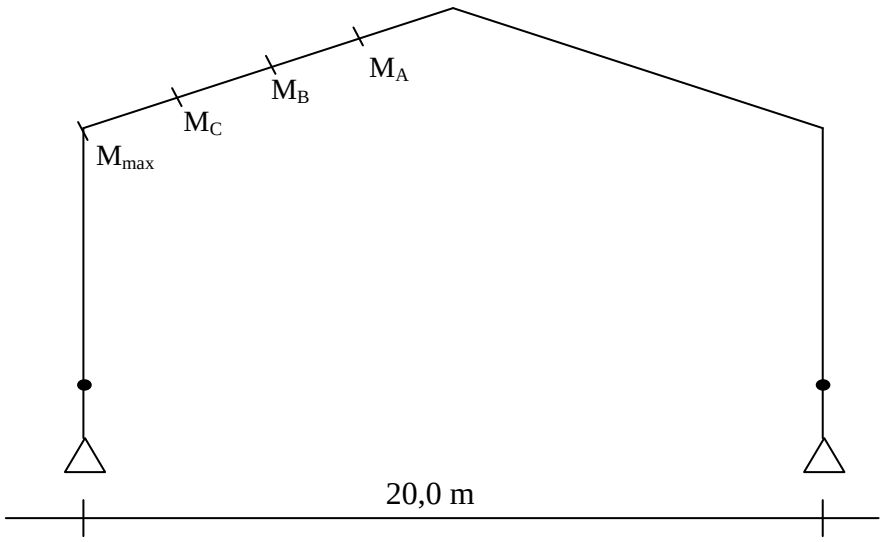
  $= 3600133\ mm^3$

- Mp = Zx . fy

  $= 3600133\ mm^3 \cdot 240\ N/mm^2$

  $= 864031920$ N.mm

  $= 864{,}032$ kN.m



Gambar 3.27 Momen pada Bentang Balok Miring yang Ditinjau

- Nilai momen sebagai berikut:

  M_{maks} = 91,036 kN.m

  M_A = 73,876 kN.m

  M_B = 68,443 kN.m

  M_C = 50,215 kN.m

- $C_b = \frac{12{,}5\ M_{maks}}{2{,}5\ M_{maks}+3M_A+4M_B+3M_C} < 2{,}3$

  $= \frac{(12{,}5\ .\ 91{,}036\ \text{kN.m})}{((2{,}5\ .\ 91{,}036\ \text{kN.m})+(3\ .73{,}876\ \text{kN.m})+(4\ .68{,}443\ \text{kN.m})+(3\ .\ 50{,}215\ \text{kN.m}))} < 2{,}3$

  = 1,682 < 2,3 (Oke)

- $M_n = Cb\ .\ \frac{\pi}{L}\ .\sqrt{E\ .\ I_y\ .\ G\ .\ J + \left(\frac{\pi.E}{L}\right)^2\ .\ I_y\ .\ I_W} \leq Mp$

  $= 1{,}682\ .\frac{\pi}{22784}.\sqrt{(2.10^5).(22400.10^4).(8.10^4).(2747154{,}333) + \left(\frac{\pi.2.10^5}{22784}\right)^2.(22400.10^4).(8{,}96.10^{12})}$

  = 782109060,1 N.mm ≤ Mp

  = 782,109 kN.m < 864,032 kN.m (Oke)

- $\varnothing M_n$ = 0,9 . 782,109 kN.m

  = 703,898 kN.m

3. Pembesaran Momen δ_b

- $C_m = 0{,}6 - 0{,}4\left(\frac{M_1}{M_2}\right)$

  $= 0{,}6 - 0{,}4\left(\frac{52{,}085\text{kN.m}}{91{,}036\ \text{kN.m}}\right)$

  = 0,371

- $\frac{K_C.L}{i_x} = \frac{0{,}65\ .\ 1468{,}0\ \text{cm}}{17{,}5\ \text{cm}}$

  = 54,525

- $N_{el} = \frac{\pi^2.\ E\ .\ A_g}{\left(\frac{K_C\ .\ L}{i_x}\right)^2}$

  $= \frac{\pi^2.2.10^5\ \text{N/mm}^2.21870\ \text{mm}^2}{(54{,}525)^2}$

  = 14520687,38 N

  = 14520,687 kN

- $\delta_b = \frac{C_m}{1-\frac{N_u}{N_{el}}} \geq 1{,}0$

$$= \frac{0{,}371}{1-\frac{33{,}477\ \text{kN}}{14520{,}687\ \text{kN}}} \geq 1{,}0$$

$$= 0{,}372 < 1{,}0$$

Karena $\delta_b < 1{,}0$ maka diambil $\delta_b = 1{,}0$

4. Pembesaran Momen δ_s

- $\frac{K_C.L}{i_x} = \frac{0{,}65\ .\ 1468{,}0\ \text{cm}}{17{,}5\ \text{cm}}$

$$= 54{,}525$$

- $N_{el} = \frac{\pi^2.\ E\ .A_g}{\left(\frac{K_C\ .\ L}{i_x}\right)^2}$

$$= \frac{\pi^2.2.10^5\ \text{N/mm}^2\ .21870\ \text{mm}^2}{(54{,}525)^2}$$

$$= 14520687{,}38\ \text{N}$$

$$= 14520{,}687\ \text{kN}$$

- $\delta_s = \frac{1}{1-\frac{N_u}{N_{el}}} \geq 1{,}0$

$$= \frac{1}{1-\frac{33{,}477\ \text{kN}}{14520{,}687\ \text{kN}\ \text{kN}}} \geq 1{,}0$$

$$= 1{,}002 > 1{,}0\ \text{(Oke)}$$

5. Cek kekuatan terhadap Tarik dan Lentur

- $M_{ux} = \delta_b.M_{ntu} + \delta_s.M_{ltu}$

$$= (1{,}0\ .\ 52{,}085\ \text{kN.m}) + (1{,}002\ .\ 91{,}036\ \text{kN.m})$$

$$= 143{,}303\ \text{kN.m}$$

- $\frac{N_u}{\emptyset N_n} = \frac{33{,}477\ \text{kN}}{0{,}85\ .1608{,}088\ \text{kN}} \leq 0{,}2$

$$= 0{,}024 < 0{,}2\ \text{(Oke)}$$

Karena $\frac{N_u}{\emptyset N_y} < 0{,}2$, maka $\frac{N_u}{2\emptyset N_n} + \left(\frac{M_{ux}}{\emptyset_b M_{nx}}\right) \leq 1{,}0$

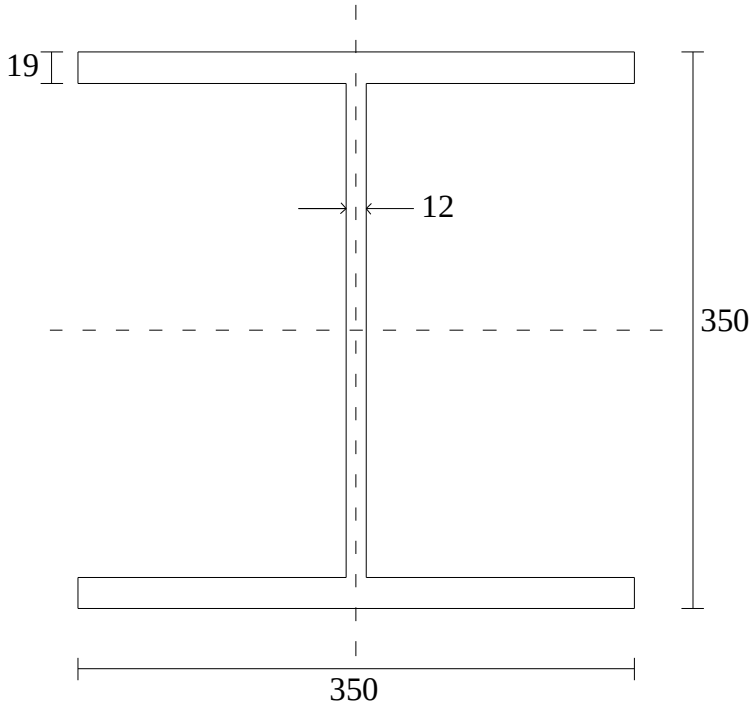
- $\frac{N_u}{2\emptyset N_n} + \left(\frac{M_{ux}}{\emptyset_b M_{nx}}\right) \leq 1{,}0$

$$\frac{33{,}477\ \text{kN}}{2\ .\ 0{,}85\ .\ 1608{,}088\ \text{kN}} + \frac{143{,}303\ \text{kN.m}}{0{,}9\ .\ 782{,}109\ \text{kN.m}} \leq 1{,}0$$

$$0{,}216 \leq 1{,}0\ \text{(Oke)}$$

3.4.2 Kontrol Penampang Kolom

Perencanaan portal penampang kolom menggunakan profil HB 350.350.12.19.

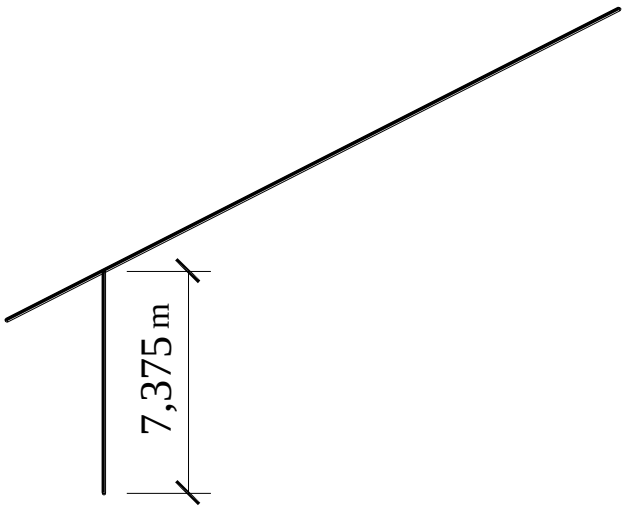


Gambar 3.28 Profil Kolom HB 350.350.12.19

Diketahui data-data profil HB 350.350.12.19 sebagai berikut:

- h = 350 mm
- b = 350 mm
- t_b = 12 mm
- t_f = 19 mm
- r = 20 mm
- A_g = 173,9 cm^2
- I_x = 40300 cm^4
- I_y = 13600 cm^4
- i_x = 15,2 cm
- i_y = 8,84 cm

Kontrol tegangan penampang kolom dengan panjang bentang L = 7,375 m



Gambar 3.29 Panjang Kolom yang Diperhitungkan

Diketahui data-data sebagai berikut:

- Nu = 53,182 kN
- Vu = 14,988 kN
- Mltu = 86,062 kN.m
- Mntu = 30,192 kN.m
- Mutu baja BJ 37 ⟶ fy = 240 MPa
  fu = 370 Mpa
- Modulus Elastisitas = 200.000 Mpa

Panjang tekuk untuk sendi-jepit kc = 0,8 (SNI Baja 03-1729-2002)

1. Aksi Kolom

- Lk = Kc.L
  = 0,8 . 7,375 m
  = 5,90 m
  = 590 cm
- $\lambda_y = \frac{Lk}{iy} < 200$
  $= \frac{590\ cm}{8{,}84\ cm} < 200$
  $= 66{,}742 < 200$ (Oke)

- $\lambda_x = \frac{Lk}{ix}$

  $= \frac{590\ cm}{15{,}2\ cm}$

  $= 38{,}816$

  $\lambda_y > \lambda_x \longrightarrow$ Tekuk terhadap sumbu y

- $\lambda_C = \frac{1}{\pi} \cdot \frac{Lk}{iy} \cdot \sqrt{\frac{fy}{Es}}$

  $= \frac{1}{\pi} \cdot \frac{5900\ mm}{88{,}4\ mm} \cdot \sqrt{\frac{240\ N/mm^2}{200000\ N/mm^2}}$

  $= 0{,}736 \longrightarrow 0{,}25 < \lambda_C < 1{,}2$

- $\omega = \frac{1{,}43}{1{,}6 - 0{,}67\ .\ \lambda_C}$

  $= \frac{1{,}43}{1{,}6 - 0{,}67\ .\ 0{,}736}$

  $= 1{,}292$

- $Nn = \frac{Ag\ .\ fy}{\omega}$

  $= \frac{17390\ mm^2 . 240\ N/mm^2}{1{,}292}$

  $= 3230340{,}557\ N$

  $= 3230{,}341\ kN$

- $\varnothing Nn > Nu$

  $0{,}85\ .\ 3230{,}341\ kN > Nu$

  $2745{,}789\ kN > 53{,}182\ kN$ (Oke)

- $\frac{N_u}{\varnothing N_n} = \frac{53{,}182\ kN}{0{,}85\ .\ 3230{,}341\ kN}$

  $= 0{,}019 < 0{,}2$

2. Aksi Balok

- $\frac{b_f}{2t_f} = \frac{350\ mm}{2\ .\ 19\ mm}$

  $= 9{,}211\ mm$

- $\frac{Nu}{\varnothing Ny} = \frac{Nu}{\varnothing fy\ .\ Ag}$

$$= \frac{85616{,}72\ \text{N}}{0{,}9\ .\ 240\ \text{N/mm}^2.\ 17390\ \text{mm}^2}$$

$$= 0{,}023 < 0{,}125$$

Karena $\frac{\text{Nu}}{\text{ØNy}} < 0{,}125$, maka $\lambda_P = \frac{1680}{\sqrt{\text{fy}}}\left(1 - \frac{2{,}75\ \text{Nu}}{\text{Øb}\ .\ \text{Ny}}\right)$

- $\lambda_P = \frac{1680}{\sqrt{\text{fy}}}\left(1 - \frac{2{,}75\ \text{Nu}}{\text{Øb}\ .\ \text{Ny}}\right)$

$$= \frac{1680}{\sqrt{240}}\left(1 - (2{,}75\ .\ 0{,}023)\right)$$

$$= 101{,}584$$

- $\lambda = \frac{\text{h}}{\text{tw}}$

$$= \frac{350\ \text{mm} - (2\ .\ 19\ \text{mm})}{12\ \text{mm}}$$

$$= 26{,}00$$

Karena, $\lambda < \lambda_p \longrightarrow$ Penampang Kompak

- $\text{Lp} = 1{,}76\ .\ r_y\ .\ \sqrt{\frac{\text{E}}{\text{Fy}}}$

$$= 1{,}76\ .\ 88{,}4\ \text{mm}\ .\ \sqrt{\frac{200000\ \text{N/mm}^2}{240\ \text{N/mm}^2}}$$

$$= 4491{,}323\ \text{mm}$$

$$= 4{,}491\ \text{m}$$

- $\text{J} = \frac{2.\ \text{b}\ .\ t_f^3 + (\text{d} - t_f)\ .\ t_w^3}{3}$

$$= \left(\frac{1}{3}\ .\ (2\ .\ (350\ .\ 19^3) + (350 - 19).\ 12^3)\right)$$

$$= 1791089{,}333\ \text{mm}^4$$

- G = 80000 Mpa

- $\text{Sx} = \frac{I_x}{\text{h}/2}$

$$= \frac{40300\ .\ 10^4\ \text{mm}^4}{350\ \text{mm}/2}$$

$$= 2302857{,}143\ \text{mm}^3$$

- $X_1 = \frac{\pi}{\text{Sx}}\ .\ \sqrt{\frac{\text{EGJA}}{2}}$

$$= \frac{\pi}{2302857{,}143\ \text{mm}^3} \cdot \sqrt{\frac{2.10^5\ \text{N/mm}^2\ \ 8.10^4\ \text{N/mm}^2\ .\ 1791089{,}333\ \text{mm}^4\ .\ 17390\ \text{mm}^2}{2}}$$

$$= 21534{,}574\ \text{N/mm}^2$$

- $I_w = \frac{I_y\ .\ h^2}{4}$

$$= \frac{13600.10^4\ .\ (350)^2}{4}$$

$$= 4{,}165\ .\ 10^{12}\ \text{mm}^6$$

- $X_2 = 4\ .\ \frac{l_w}{l_y}\left(\frac{Sx}{GJ}\right)^2$

$$= 4\ .\ \frac{4{,}165\ .10^{12}\ \text{mm}^6}{13600.10^4\ \text{mm}^4} \cdot \left(\frac{2302857{,}143\ \text{mm}^3}{80000\ \text{N/mm}^2\ .\ 1791089{,}333\ \text{mm}^4}\right)^2$$

$$= 3{,}164\ .\ 10^{-5}$$

- $fr = 70$ Mpa

- $Lr = \frac{ry\ .\ X_1}{(fy-fr)}\ x\ \sqrt{1+\sqrt{1+X_2(fy-fr)^2}}$

$$= \frac{88{,}4\ \text{mm x}\ 21534{,}574\ \text{N/mm}^2}{(240\ \text{N/mm}^2\ -70\ \text{N/mm}^2)} \cdot \sqrt{1+\sqrt{1+3{,}164.10^{-5}\text{N/mm}^2\ .(240-70)^2\text{N/mm}^2}}$$

$$= 15846{,}963\ \text{mm}$$

$$= 15{,}847\ \text{m}$$

$Lp < L < Lr$

$4{,}491\ \text{m} < 7{,}375\ \text{m} < 15{,}847\ \text{m}$

- $Zx = 2\left(350\ \text{mm}\ .\ 19\ \text{mm}\ .165{,}5\ \text{mm}\ +\ 156\ .\ 12\ \text{mm}\ .\frac{156}{2}\ \text{mm}\right)$

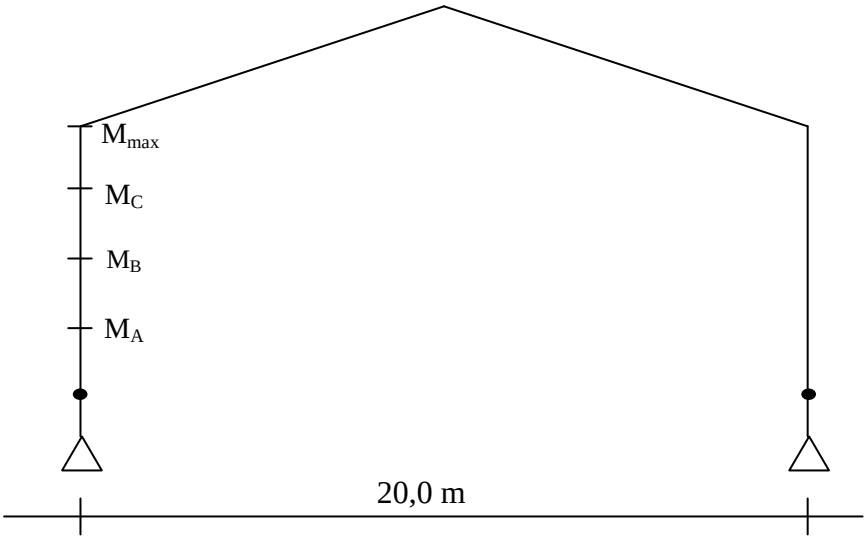
$$= 2493182\ \text{mm}^3$$

- $Mp = Zx\ .\ f_y$

$$= 2493182\ \text{mm}^3\ \text{x}\ 240\ \text{N/mm}^2$$

$$= 598363680\ \text{N.mm}$$

$$= 598{,}364\ \text{kN.m}$$



Gambar 3.30 Momem pada Bentang Kolom yang Ditinjau

- Nilai momen sebagai berikut:

  M_{maks} = 86,062 kN.m

  M_A = 37,888 kN.m

  M_B = 53,946 kN.m

  M_C = 70,004 kN.m

- $C_b = \frac{12{,}5\ M_{maks}}{2{,}5\ M_{maks}+3M_A+4M_B+3M_C} < 2{,}3$

  $= \frac{(12{,}5\ .\ 86{,}062\ \text{kN.m})}{((2{,}5\ .\ 86{,}062\ \text{kN.m})+(3\ .\ 37{,}888\ \text{kN.m})+(4\ .\ 53{,}946\ \text{kN.m})+(3\ .\ 70{,}004\ \text{kN.m}))} < 2{,}3$

  = 1,425 < 2,3 (Oke)

- $M_n = Cb\ .\ \frac{\pi}{L}\ .\ \sqrt{E\ .\ L_y\ .\ G\ .\ J + \left(\frac{\pi.E}{L}\right)^2\ .\ I_y\ .\ I_W} \leq Mp$

  $= 1{,}425\ .\ \frac{\pi}{7375}\ .\ \sqrt{(2.10^5).(13600.10^4).(8.10^4).(1791089{,}333\ ) + \left(\frac{\pi.(2.10^5)}{7375}\right)^2\ .\ (13600.10^4).(4{,}165\ .\ 10^{12})}$

  = 1700978539 N.mm ≤ Mp

  = 1700,978 kN.m > 598,364 kN.m (Tidak Oke)

  Karena nilai Mn lebih bear daripada nilai Mp, maka diambil Mn sebesar nilai Mp (Mn=Mp) sehingga Mn = 598,364 KN.m

- ∅ Mn = 0,9 . 598,364 kN.m

  = 538,528 kN.m

  = 53852,76 kg.m

3. Pembesaran Momen δ_b

- $C_m = 0{,}6 - 0{,}4\left(\frac{M_1}{M_2}\right)$

  $= 0{,}6 - 0{,}4\left(\frac{30{,}192\ \text{kN.m}}{86{,}062\ \text{kN.m}}\right)$

  $= 0{,}459$

- $\frac{K_C.L}{i_x} = \frac{0{,}8\ .\ 737{,}5\ \text{cm}}{15{,}2\ \text{cm}}$

  $= 38{,}816$

- $N_{el} = \frac{\pi^2.\ E\ .A_g}{\left(\frac{K_C\ .\ L}{i_x}\right)^2}$

  $= \frac{\pi^2.\ 2.10^5\ \text{N/mm}^2\ .17390\ \text{mm}^2}{(38{,}816)^2}$

  $= 22782834{,}99\ \text{N}$

  $= 22782{,}835\ \text{kN}$

- $\delta_b = \frac{C_m}{1-\frac{N_u}{N_{el}}} \geq 1{,}0$

  $= \frac{0{,}507}{1 - \frac{53{,}182\ \text{kN}}{22782{,}835\ \text{kN}}} \geq 1{,}0$

  $= 0{,}508 < 1{,}0$

  Karena $\delta_b < 1{,}0$ maka diambil $\delta_b = 1{,}0$

4. Pembesaran Momen δ_s

- $\frac{K_C.L}{i_x} = \frac{0{,}8\ .\ 737{,}5\ \text{cm}}{15{,}2\ \text{cm}}$

  $= 38{,}816$

- $N_{el} = \frac{\pi^2.\ E\ .A_g}{\left(\frac{K_C\ .\ L}{i_x}\right)^2}$

  $= \frac{\pi^2.\ 2.10^5\ \text{N/mm}^2\ .17390\ \text{mm}^2}{(38{,}816)^2}$

  $= 22782834{,}99\ \text{N}$

  $= 22782{,}835\ \text{kN}$

- $\delta_s = \frac{1}{1-\frac{N_u}{N_{el}}} \geq 1{,}0$

$$= \frac{1}{1-\frac{53{,}182\ \text{kN}}{22782{,}835\ \text{kN}}} \geq 1{,}0$$

$= 1{,}002 > 1{,}0$ (Oke)

5. Cek Kekuatan terhadap Tarik dan Lentur

- $M_{ux} = \delta_b . M_{ntu} + \delta_s . M_{ltu}$

  $= (1{,}0 \ . \ 30{,}192\ \text{kN.m}) + (1{,}002 \ . 86{,}062\ \text{kN.m})$

  $= 116{,}426\ \text{kN.m}$

- $\frac{N_u}{\emptyset N_n} = \frac{53{,}182\ \text{kN}}{0{,}85 \ . \ 3230{,}341\ \text{kN}} \leq 0{,}2$

  $= 0{,}019 < 0{,}2$ (Oke)

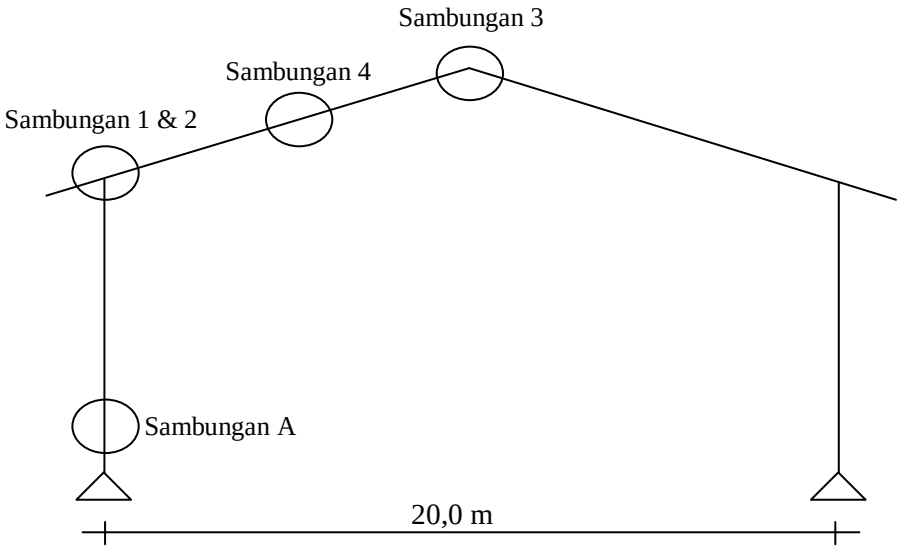
  Bila $\frac{N_u}{\emptyset N_y} < 0{,}2$ Maka $\frac{N_u}{2\emptyset N_n} + \left(\frac{M_{ux}}{\emptyset_b M_{nx}}\right) \leq 1{,}0$

- $\frac{N_u}{2\emptyset N_n} + \left(\frac{M_{ux}}{\emptyset_b M_{nx}}\right) \leq 1{,}0$

  $\frac{53{,}182\ \text{kN}}{2 \ . 0{,}85 \ . 3230{,}341\ \text{kN}} + \frac{116{,}426\ \text{kN}}{0{,}9 \ . 598{,}364\ \text{kN.m}} \leq 1{,}0$

  $0{,}226 < \ 1{,}0$ (Oke)

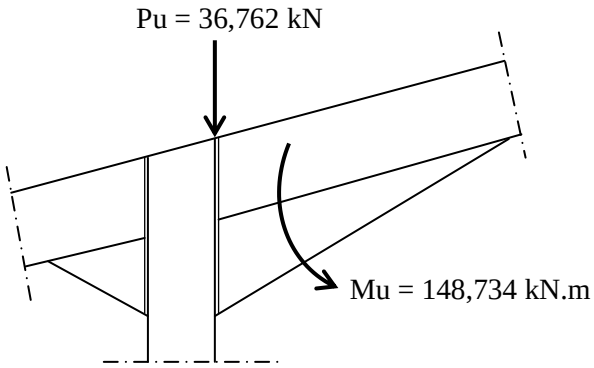
3.5 Perencanaan Sambungan



Gambar 3.31 Sambungan pada *Single Beam*

3.5.1 Sambungan 1

1. Sambungan Las pada *End Plate*

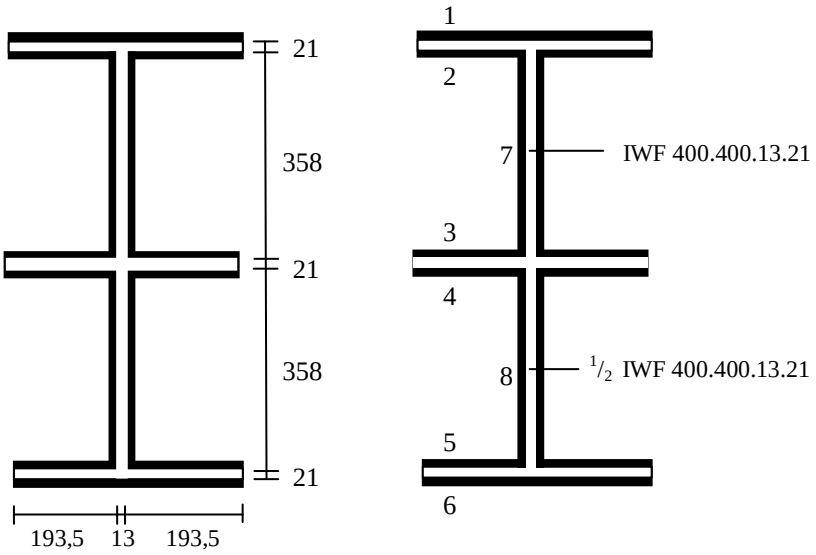


Gambar 3.32 Potongan pada Sambungan 1

Diketahui :

Pu = 36,762 kN

Mu = 148,734 kN.m



Gambar 3.33 Sambungan Las Profil pada Penampang Sambungan 1

- Akibat Geser Langsung

$(R_n)_v = \frac{P_u}{A}$

Dicoba a = 3 mm

A_1 = 400 mm x 3 mm = 1200 mm^2

A_2 = 193,5 mm x 3 mm x 2 = 1161 mm^2

A_3 = 193,5 mm x 3 mm x 2 = 1161 mm^2

A_4 = 193,5 mm x 3 mm x 2 = 1161 mm^2

A_5 = 193,5 mm x 3 mm x 2 = 1161 mm^2

A_6 = 400 mm x 3 mm = 1200 mm^2

A_7 = 358 mm x 3 mm x 2 = 2148 mm^2

A_8 = 358 mm x 3 mm x 2 = 2148 mm^2 +

A_{tot} = 11340 mm^2

$$(R_n)_v = \frac{P_u}{A}$$

$$= \frac{36762{,}24\ \text{N}}{11340\ \text{mm}^2}$$

$$= 3{,}242\ \text{N/mm}^2$$

- Akibat Momen

$$(R_n)_t = \frac{M_u . C}{I}$$

$Ix_1 = \frac{1}{12}$ x 400 x 3^3 + 400 x 3 x 400^2 = 192 . 10^6 mm^4

$Ix_2 = \frac{1}{12}$ x 193,5 x 3^3 + 193,5 x 3 x 379^2 = 83,384 . 10^6 mm^4

$Ix_3 = \frac{1}{12}$ x 193,5 x 3^3 + 193,5 x 3 x 379^2 = 83,384 . 10^6 mm^4

$Ix_4 = \frac{1}{12}$ x 193,5 x 3^3 + 193,5 x 3 x 379^2 = 83,384 . 10^6 mm^4

$Ix_5 = \frac{1}{12}$ x 193,5 x 3^3 + 193,5 x 3 x 379^2 = 83,384 . 10^6 mm^4

$Ix_6 = \frac{1}{12}$ x 400 x 3^3 + 400 x 3 x 400^2 = 192 . 10^6 mm^4

$Ix_7 = \frac{1}{12}$ x 3 x 400^3 + 3 x 400 x 200^2 = 64 . 10^6 mm^4

$Ix_8 = \frac{1}{12}$ x 3 x 400^3 + 3 x 400 x 200^2 = 64 . 10^6 mm^4 +

Ix_{tot} = 845,536 . 10^6 mm^4

$$(R_n)_t = \frac{M_u . C}{I}$$

$$= \frac{148{,}734 . 10^6\ \text{N.mm} . 400\ \text{mm}}{845{,}536 . 10^6\ \text{mm}^4}$$

$$= 70{,}362\ \text{N/mm}^2$$

- Resultan Gaya

$$\phi R_{n\ perlu} = \sqrt{(R_n)_v^{\,2} + (R_n)_t^{\,2}}$$

$= \sqrt{3{,}242^2 + 70{,}362^2}$

$= 70{,}436\ \text{N/mm}^2$

- Tahanan Las

$\phi R_{nw} = \phi \,.\, 0{,}6 \,.\, f_{uw}$

$= 0{,}75 \,.\, 0{,}6 \,.\, 490\ \text{N/mm}^2$

$= 220{,}5\ \text{N/mm}^2$

$\phi R_{n\ perlu} < \phi R_{nw}$

$70{,}436\ \text{N/mm}^2 < 220{,}5\ \text{N/mm}^2$ (Oke)

2. Sambungan Baut ke Kolom

- Diketahui :

h = 400 mm

tf = 21 mm

Ø baut (d_b) = 40 mm

Ø lubang (d_l) = 42 mm

Tebal plat (t_p) = 16 mm

Mu = 148,734 kN.m

Pu = 36,762 kN

Direncanakan menggunakan 12 baut (6 buah baut per baris)

Jarak maksimum :	Jarak minimum :
S1 < 200 mm	S1 > 1,5 . d_b = 60 mm
S1 < (4 . t_p + 100 mm) = 164 mm	S > 3 . d_b = 120 mm

S < 200 mm

S < 15 . t_p = 240 mm

Jadi jarak antar baut yang diambil, S1 = 59 mm

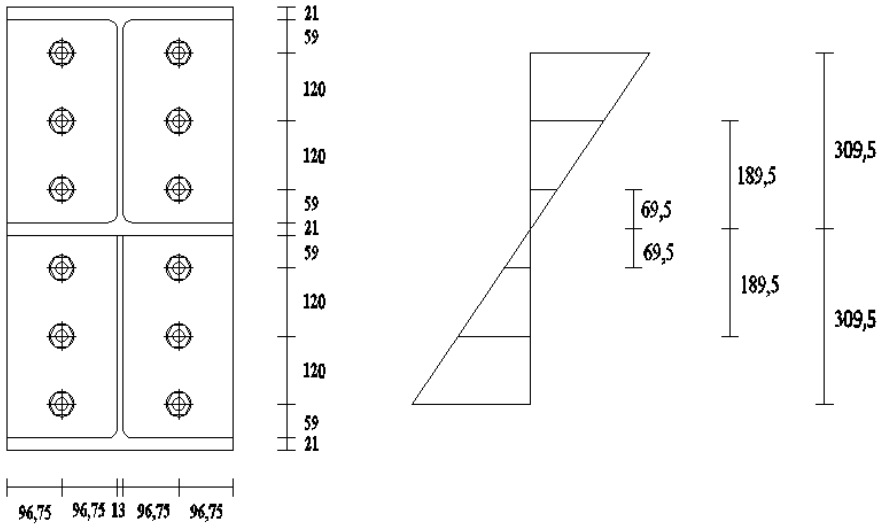
S = 120 mm

- $\phi R_{nv} = 0{,}75 \,.\, (0{,}5 \,.\, f_u^{\,b}) \,.\, m \,.\, A_b$

$= 0{,}75 \,.\, (0{,}5 \,.\, 60\ \text{N/mm}^2) \,.1\, .\, \frac{1}{4} \,.\, \pi \,.\, 40^2\ \text{mm}^2$

$= 28274{,}334\ \text{N}$

$= 28{,}274\ \text{kN}$



Gambar 3.34 Sambungan Baut Profil pada Penampang Sambungan 1

- $Tu = \frac{Mu.y}{\sum y^2}$

  y1 = 309,5 mm y4 = 69,5 mm

  y2 = 189,5 mm y5 = 189,5 mm

  y3 = 69,5 mm y6 = 309,5 mm

  $\sum y^2 = 2 . (309{,}5^2 + 189{,}5^2 + 69{,}5^2 + 69{,}5^2 + 189{,}5^2 + 309{,}5^2)$

  $= 546123 \text{ mm}^2$

  $Tu = \frac{Mu.y}{\sum y^2}$

  $= \frac{148{,}734 . 10^6 \text{ N.mm} . 309{,}5 \text{ mm}}{546123 \text{ mm}^2}$

  = 84290,85 N

  = 84,291 kN

- $Vu = \frac{Pu}{n}$

  $= \frac{36{,}762 \text{ kN}}{12 \text{ baut}}$

  $= 3{,}063 \text{ kN/baut } (R_{uv})$

  $R_{uv} < \phi R_{nv}$

  3,063 kN < 28,274 kN (Oke)

- Periksa Interaksi Geser dan Tarik

  $f_t = (807 – 1{,}5 . f_{uv}) < 621 \text{ Mpa}$

$= (807 - 1{,}5 \cdot \frac{R_{uv}}{A_b}) < 621$ Mpa

$= (807 - 1{,}5 \cdot \frac{4{,}575 \cdot 10^3 \text{ N}}{1/4 \cdot \pi \cdot 40^2 \text{ mm}^2}) < 621$ Mpa

$= 801{,}539$ Mpa > 621 Mpa

Karena $f_t > 621$ Mpa, maka digunakan f_t sebesar 621 Mpa.

- $\phi R_{nt} = \phi f_t \cdot A_b$

  $= 0{,}75 \cdot 621 \text{ N/mm}^2 \cdot 1/4 \cdot \pi \cdot 40^2 \text{mm}^2$

  $= 585278{,}711$ N

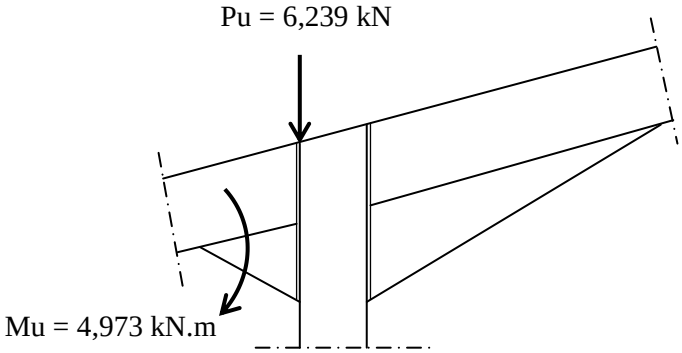
  $= 585{,}279$ kN

  $Tu < \phi R_{nt}$

  84,291 kN < 585,279 kN (Oke)

3.5.2 Sambungan 2

1. Sambungan Las pada *End Plate*

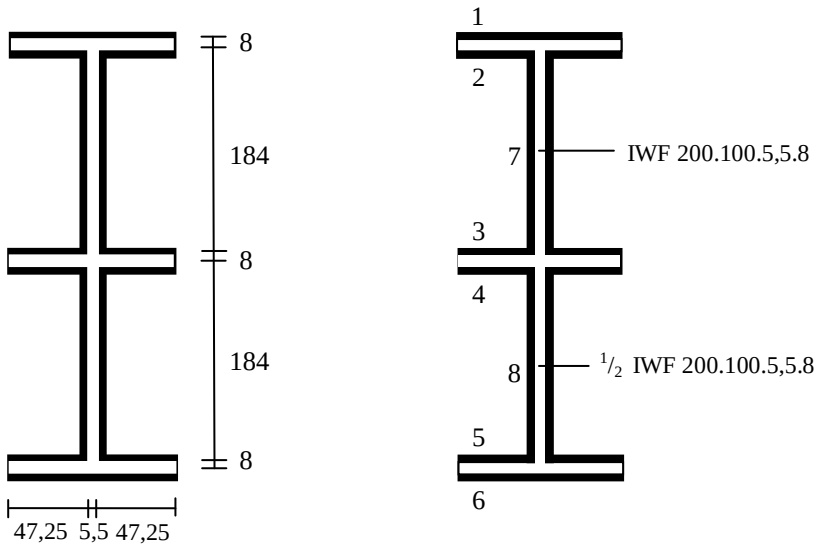


Gambar 3.35 Potongan pada Sambungan 2

Diketahui :

Pu = 6,239 kN

Mu = 4,973 kN.m



Gambar 3.36 Sambungan Las Profil pada Penampang Sambungan 2

- Akibat Geser Langsung

$(R_n)_v = \frac{P_u}{A}$

Dicoba a = 3 mm

A_1 = 100 mm x 3 mm = 300 mm^2

A_2 = 47,25 mm x 3 mm x 2 = 283,5 mm^2

A_3 = 47,25 mm x 3 mm x 2 = 283,5 mm^2

A_4 = 47,25 mm x 3 mm x 2 = 283,5 mm^2

A_5 = 47,25 mm x 3 mm x 2 = 283,5 mm^2

A_6 = 100 mm x 3 mm = 300 mm^2

A_7 = 184 mm x 3 mm x 2 = 1104 mm^2

A_8 = 184 mm x 3 mm x 2 = 1104 mm^2 +

A_{tot} = 3942 mm^2

$(R_n)_v = \frac{P_u}{A}$

$= \frac{6239{,}08\ N}{3942\ mm^2}$

$= 1{,}582\ N/mm^2$

- Akibat Momen

$(R_n)_t = \frac{M_u . C}{I}$

$Ix_1 = \frac{1}{12}$ x 100 x 3^3 + 100 x 3 x 200^2 = $12 . 10^6$ mm^4

$Ix_2 = \frac{1}{12}$ x 47,25 x 3^3 + 47,25 x 3 x 192^2 = $5,226 . 10^6$ mm^4

$Ix_3 = \frac{1}{12}$ x 47,25 x 3^3 + 47,25 x 3 x 192^2 = $5,226 . 10^6$ mm^4

$Ix_4 = \frac{1}{12}$ x 47,25 x 3^3 + 47,25 x 3 x 192^2 = $5,226 . 10^6$ mm^4

$Ix_5 = \frac{1}{12}$ x 47,25 x 3^3 + 47,25 x 3 x 192^2 = $5,226 . 10^6$ mm^4

$Ix_6 = \frac{1}{12}$ x 100 x 3^3 + 100 x 3 x 200^2 = $12 . 10^6$ mm^4

$Ix_7 = \frac{1}{12}$ x 3 x 200^3 + 3 x 200 x 100^2 = $8 . 10^6$ mm^4

$Ix_8 = \frac{1}{12}$ x 3 x 200^3 + 3 x 200 x 100^2 = $8 . 10^6$ mm^4 +

Ix_{tot} = $60,904 . 10^6$ mm^4

$$(R_n)_t = \frac{M_u . C}{I}$$

$$= \frac{4,973 . 10^6 \text{ N.mm} . 200 \text{ mm}}{60,904 . 10^6 \text{ mm}^4}$$

$$= 16,331 \text{ N/mm}^2$$

- Resultan Gaya

$$\phi R_{n\ perlu} = \sqrt{(R_n)_v^{\,2} + (R_n)_t^{\,2}}$$

$$= \sqrt{1,582^2 + 16,331^2}$$

$$= 16,407 \text{ N/mm}^2$$

- Tahanan Las

$\phi R_{nw} = \phi . 0,6 . f_{uw}$

$= 0,75 . 0,6 . 490$ N/mm^2

$= 220,5$ N/mm^2

$\phi R_{n\ perlu} < \phi R_{nw}$

16,407 N/mm^2 < 220,5 N/mm^2 (Oke)

2. Sambungan Baut ke Kolom

- Diketahui :

h = 200 mm

tf = 8 mm

Ø baut (d_b) = 22 mm

Ø lubang (d_l) = 24 mm

Tebal plat (t_p) = 10 mm

Mu = 4,973 kN.m

Pu = 6,239 kN

Direncanakan menggunakan 12 baut (6 buah baut per baris)

Jarak maksimum : Jarak minimum :

S1 < 200 mm S1 > 1,5 . d_b = 33 mm

S1 < (4 . t_p + 100 mm) = 140 mm S > 3 . d_b = 66 mm

S < 200 mm

S < 15 . t_p = 150 mm

Jadi jarak antar baut yang diambil, S1 = 66 mm

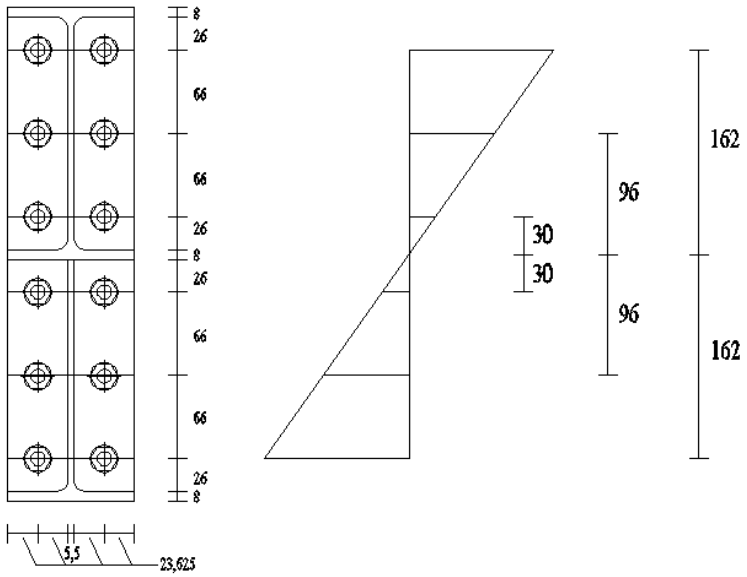
S = 26 mm

- ϕR_{nv} = 0,75 . (0,5 . f_u^b) . m . A_b

  = 0,75 . (0,5 . 825 N/mm^2) .1 . $\frac{1}{4}$. π . 22^2 mm^2

  = 117603,558 N

  = 117,604 kN



Gambar 3.37 Sambungan Baut Profil pada Penampang Sambungan 2

- $Tu = \frac{Mu.y}{\sum y^2}$

y1 = 162 mm y4 = 30 mm

y2 = 96 mm y5 = 96 mm

y3 = 30 mm y6 = 162 mm

$\sum y^2 = 2 . (162^2 + 96^2 + 30^2 + 30^2 + 96^2 + 162^2)$

$= 145440 \text{ mm}^2$

$Tu = \frac{Mu.y}{\sum y^2}$

$= \frac{4{,}973 . 10^6 \text{ N.mm} . 162 \text{ mm}}{145440 \text{ mm}^2}$

$= 5539{,}23 \text{ N}$

$= 5{,}539 \text{ kN}$

- $Vu = \frac{Pu}{n}$

$= \frac{6{,}239 \text{ kN}}{12 \text{ baut}}$

$= 0{,}520 \text{ kN/baut } (R_{uv})$

$R_{uv} < \phi R_{nv}$

0,520 kN < 117,604 kN (Oke)

- Periksa Interaksi Geser dan Tarik

$f_t = (807 - 1{,}5 . f_{uv}) < 621 \text{ Mpa}$

$= (807 - 1{,}5 . \frac{R_{uv}}{A_b}) < 621 \text{ Mpa}$

$= (807 - 1{,}5 . \frac{0{,}490 . 10^3 \text{ N}}{1/4 . \pi . 22^2 \text{ mm}^2}) < 621 \text{ Mpa}$

$= 805{,}065 \text{ Mpa} > 621 \text{ Mpa}$

Karena $f_t > 621$ Mpa, maka digunakan f_t sebesar 621 Mpa.

- $\phi R_{nt} = \phi f_t . A_b$

$= 0{,}75 . 621 \text{ N/mm}^2 . 1/4 . \pi . 22^2 \text{mm}^2$

$= 177046{,}81 \text{ N}$

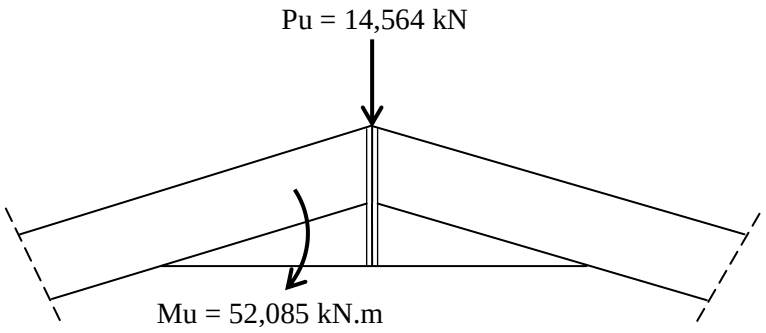
$= 177{,}047 \text{ kN}$

$Tu < \phi R_{nt}$

5,539 kN < 177,047 kN (Oke)

3.5.3 Sambungan 3

1. Sambungan Las pada *End Plate*

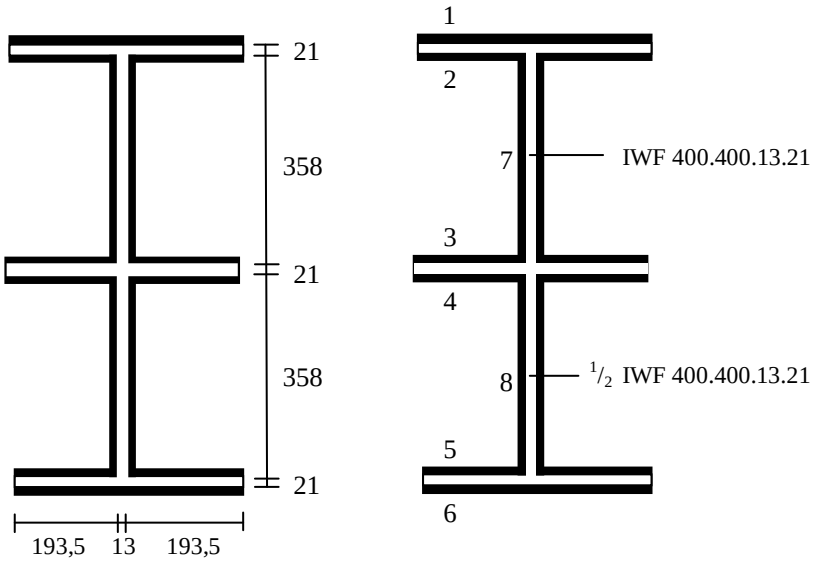


Gambar 3.38 Potongan pada Sambungan 3

Diketahui :

Pu = 14,564 kN

Mu = 52,085 kN.m



Gambar 3.39 Sambungan Las Profil pada Penampang Sambungan 3

- Akibat Geser Langsung

$(R_n)_v = \frac{P_u}{A}$

Dicoba a = 3 mm

A_1 = 400 mm x 3 mm = 1200 mm^2

A_2 = 193,5 mm x 3 mm x 2 = 1161 mm^2

A_3 = 193,5 mm x 3 mm x 2 = 1161 mm^2

A_4 = 193,5 mm x 3 mm x 2 = 1161 mm^2

A_5 = 193,5 mm x 3 mm x 2 = 1161 mm^2

A_6 = 400 mm x 3 mm = 1200 mm^2

A_7 = 358 mm x 3 mm x 2 = 2148 mm^2

A_8 = 358 mm x 3 mm x 2 = 2148 mm^2 +

A_{tot} = 11340 mm^2

$$(R_n)_v = \frac{P_u}{A}$$

$$= \frac{14564{,}12\ N}{11340\ mm^2}$$

$$= 1{,}284\ N/mm^2$$

- Akibat Momen

$$(R_n)_t = \frac{M_u . C}{I}$$

$Ix_1 = \frac{1}{12}$ x 400 x 3^3 + 400 x 3 x 400^2 = 192 . 10^6 mm^4

$Ix_2 = \frac{1}{12}$ x 193,5 x 3^3 + 193,5 x 3 x 379^2 = 83,384 . 10^6 mm^4

$Ix_3 = \frac{1}{12}$ x 193,5 x 3^3 + 193,5 x 3 x 379^2 = 83,384 . 10^6 mm^4

$Ix_4 = \frac{1}{12}$ x 193,5 x 3^3 + 193,5 x 3 x 379^2 = 83,384 . 10^6 mm^4

$Ix_5 = \frac{1}{12}$ x 193,5 x 3^3 + 193,5 x 3 x 379^2 = 83,384 . 10^6 mm^4

$Ix_6 = \frac{1}{12}$ x 400 x 3^3 + 400 x 3 x 400^2 = 192 . 10^6 mm^4

$Ix_7 = \frac{1}{12}$ x 3 x 400^3 + 3 x 400 x 200^2 = 64 . 10^6 mm^4

$Ix_8 = \frac{1}{12}$ x 3 x 400^3 + 3 x 400 x 200^2 = 64 . 10^6 mm^4 +

Ix_{tot} = 845,536 . 10^6 mm^4

$$(R_n)_t = \frac{M_u . C}{I}$$

$$= \frac{52{,}085 . 10^6\ N.mm . 400\ mm}{845{,}536 . 10^6\ mm^4}$$

$$= 24{,}640\ N/mm^2$$

- Resultan Gaya

$$\phi R_{n\ perlu} = \sqrt{(R_n)_v^{\,2} + (R_n)_t^{\,2}}$$

$= \sqrt{1{,}284^2 + 24{,}64^2}$

$= 24{,}673\ \text{N/mm}^2$

- Tahanan Las

$\phi R_{nw} = \phi \,.\, 0{,}6 \,.\, f_{uw}$

$= 0{,}75 \,.\, 0{,}6 \,.\, 490\ \text{N/mm}^2$

$= 220{,}5\ \text{N/mm}^2$

$\phi R_{n\ perlu} < \phi R_{nw}$

$24{,}673\ \text{N/mm}^2 < 220{,}5\ \text{N/mm}^2$ (Oke)

2. Sambungan Baut ke Kolom

- Diketahui :

h = 400 mm

tf = 21 mm

Ø baut (d_b) = 40 mm

Ø lubang (d_l) = 42 mm

Tebal plat (t_p) = 16 mm

Mu = 52,085 kN.m

Pu = 14,564 kN

Direncanakan menggunakan 12 baut (6 buah baut per baris)

Jarak maksimum :	Jarak minimum :
S1 < 200 mm	S1 > 1,5 . d_b = 60 mm
S1 < (4 . t_p + 100 mm) = 164 mm	S > 3 . d_b = 120 mm

S < 200 mm

S < 15 . t_p = 240 mm

Jadi jarak antar baut yang diambil, S1 = 59 mm

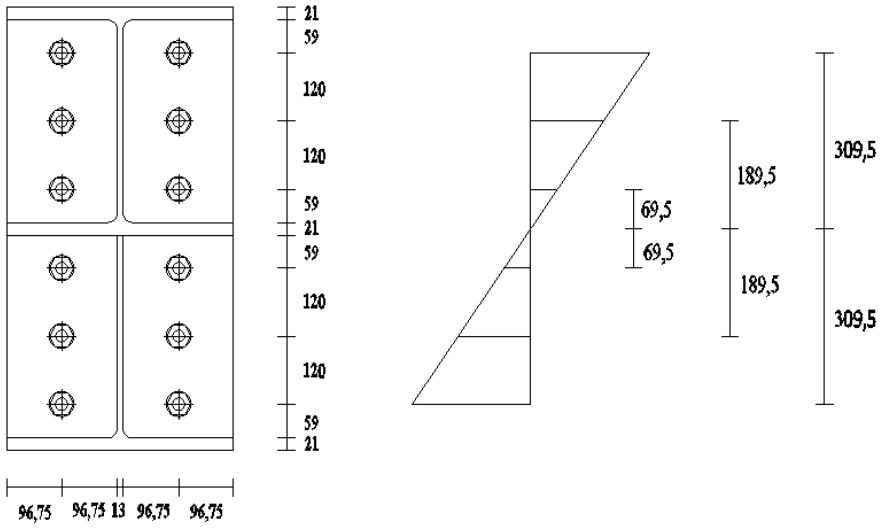
S = 120 mm

- $\phi R_{nv} = 0{,}75 \,.\, (0{,}5 \,.\, f_u^{\,b}) \,.\, m \,.\, A_b$

$= 0{,}75 \,.\, (0{,}5 \,.\, 60\ \text{N/mm}^2) \,.1\, .\, \frac{1}{4} \,.\, \pi \,.\, 40^2\ \text{mm}^2$

$= 28274{,}334\ \text{N}$

$= 28{,}274\ \text{kN}$



Gambar 3.40 Sambungan Baut Profil pada Penampang Sambungan 3

- $Tu = \frac{Mu.y}{\sum y^2}$

  y1 = 309,5 mm y4 = 69,5 mm

  y2 = 189,5 mm y5 = 189,5 mm

  y3 = 69,5 mm y6 = 309,5 mm

  $\sum y^2 = 2 . (309{,}5^2 + 189{,}5^2 + 69{,}5^2 + 69{,}5^2 + 189{,}5^2 + 309{,}5^2)$

  $= 546123 \text{ mm}^2$

  $Tu = \frac{Mu.y}{\sum y^2}$

  $= \frac{52{,}085 . 10^6 \text{ N.mm} . 309{,}5 \text{ mm}}{546123 \text{ mm}^2}$

  = 29517,72 N

  = 29,518 kN

- $Vu = \frac{Pu}{n}$

  $= \frac{14{,}564 \text{ kN}}{12 \text{ baut}}$

  = 1,21 kN/baut (R_{uv})

  $R_{uv} < \phi R_{nv}$

  1,21 kN < 28,274 kN (Oke)

- Periksa Interaksi Geser dan Tarik

  $f_t = (807 – 1{,}5 . f_{uv}) < 621$ Mpa

$= (807 - 1{,}5 \cdot \frac{R_{uv}}{A_b}) < 621$ Mpa

$= (807 - 1{,}5 \cdot \frac{2{,}58 \cdot 10^3 \text{ N}}{1/4 \cdot \pi \cdot 40^2 \text{ mm}^2}) < 621$ Mpa

$= 803{,}92$ Mpa > 621 Mpa

Karena $f_t > 621$ Mpa, maka digunakan f_t sebesar 621 Mpa.

- $\phi R_{nt} = \phi f_t \cdot A_b$

  $= 0{,}75 \cdot 621 \text{ N/mm}^2 \cdot 1/4 \cdot \pi \cdot 40^2 \text{mm}^2$

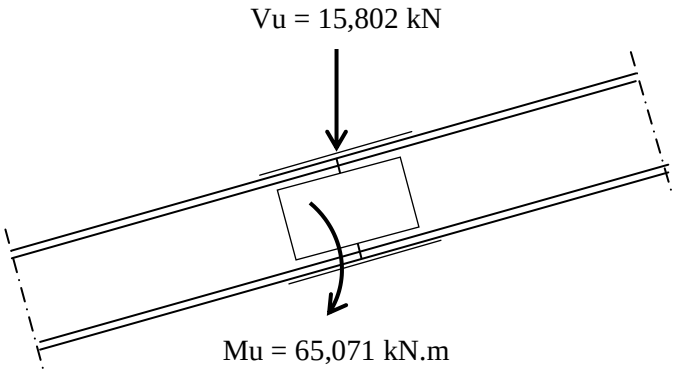
  $= 585278{,}711$ N

  $= 585{,}279$ kN

  $Tu < \phi R_{nt}$

  29,518 kN < 585,279 kN (Oke)

3.5.4 Sambungan 4



Gambar 3.41 Potongan pada Sambungan 4

Diketahui:

Nu = 63,785 kN

Vu = 15,802 kN

Mu = 65,071 kN.m

ø baut (d_b) = 40 mm

ø lubang (d_l) = 42 mm

Tebal plat (t_p) direncanakan sebesar 10 mm

1. Sambungan Baut pada Sayap Profil

Jarak maksimum :

$S1 < 200$ mm

$S1 < (4 . t_p + 100 \text{ mm}) = 140$ mm

$S < 200$ mm

$S < 15 . t_p = 150$ mm

Jarak minimum :

$S1 > 1{,}5 . d_b = 60$ mm

$S > 3 . d_b = 120$ mm

Jadi jarak antar baut yang diambil, S1 = 65 mm

S = 135 mm

- Kekuatan Geser Baut

$R_n = 0{,}5 . f_u^b . A_b$

$= 0{,}5 . 370 \text{ N/mm}^2 . ¼ . \pi . (40 \text{ mm})^2$

$= 232477{,}856$ N

$= 232{,}478$ kN

$R_u \leq \phi R_n$

$R_u = 0{,}75 . 232{,}478$ kN

$R_u = 174{,}358$ kN

- Gaya yang Memikul Pelat Sayap

$S = \frac{Mu}{h}$

$= \frac{65{,}071 . 10^6 \text{ N.mm}}{400 \text{ mm}}$

$= 162677{,}5$ N

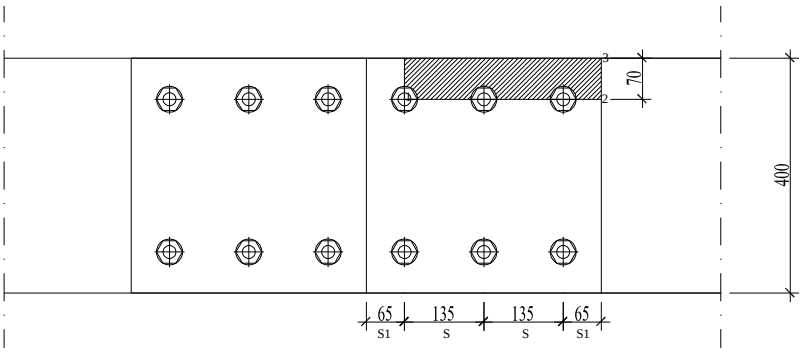
$= 162{,}677$ kN

$n = \frac{S}{Ru}$

$= \frac{162{,}677 \text{ kN}}{174{,}358 \text{ kN}} . 1$ bh

$= 0{,}933$ bh ~ 4 bh

Jika keruntuhan balok pelat penyambung melalui jalur 1,2,3 maka tebal pelat penyambung dapat dicari sebagai berikut:



Gambar 3.42 Sambungan Baut Profil Sayap pada Sambungan 4

A_{gt} = 70 mm . t_{ps}

= 70 mm . t_{ps}

A_{nt} = $(b - \frac{d_l}{2})$. t_{ps}

= $(70\ mm - \frac{42\ mm}{2})$. t_{ps}

= 49 mm . tp_s

A_{gv} = (S1 + S + S) . t_{ps}

= (65 mm + 135 mm +135 mm) . t_{ps}

= 335 mm . t_{ps}

A_{nv} = [(S1 + S + S) – (2,5 . d_l)] . t_{ps}

= [(65 mm + 135 mm +135 mm) – (2,5 . 40 mm)] . t_{ps}

= 230 mm . t_{ps}

Gaya pelat penyangga = F_u = S = 299,255 kN

- Retak Tarik Leleh Geser

$F_u \leq \phi(A_{nt} . f_u + 0{,}6 . A_{gv} . f_y)$

299254,8 N ≤ 0,75.(49 mm . tp_s . 370 N/mm^2 + 0,6 . 335 mm . t_{ps} . 240 N/mm^2)

299254,8 N = 66370 N/mm . t_{ps}

$t_{ps} = \frac{299254{,}8\ N}{66370\ N/mm}$

t_{ps} = 4,509 mm ~ 10 mm

- Retak Geser Tarik Leleh

$F_u \leq \phi(A_{gt} . f_y + 0{,}6 . A_{nv} . f_u)$

299254,8 N ≤ 0,75.(70 mm . t_{ps} . 240 N/mm^2 + 0,6 . 230 mm . t_{ps} . 370 N/mm^2)

299254,8 N = 67860 N/mm . t_{ps}

$t_{ps} = \frac{299254{,}8\ \text{N}}{67860\ \text{N/mm}}$

t_{ps} = 4,410 mm ~ 10 mm

Jadi, diambil tebal pelat sambungan (t_{ps}) sebesar 10 mm

- Kekuatan Tumpu Baut

R_n = 2,4 . d_b . t_{ps} . f_u

= 2,4 . 40 mm . 10 mm . 370 N/mm^2

= 355200 N

= 355,2 kN

R_u = ϕR_n

= 0,75 . 355,2 kN

= 266,4 kN

$R_u \geq \frac{S}{n}$

266,4 kN > 40,669 kN (Oke)

2. Sambungan Baut pada Badan Profil

Direncanakan:

Jumlah baut (n) = 2 buah

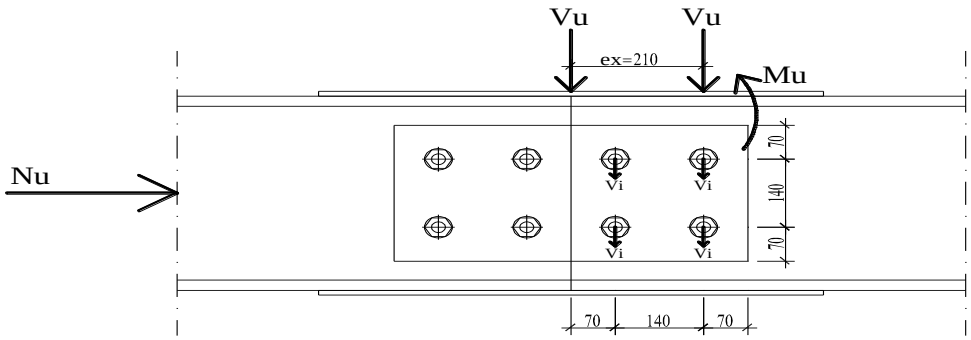
ø baut (d_b) = 40 mm

ø lubang (d_l) = 42 mm

Tebal plat (t_p) = 10 mm

Jarak antar baut, S = 140 mm

S1 = 70 mm



Gambar 3.43 Sambungan Baut Profil Badan pada Sambungan 4

N_s = 63,785 kN

V_s = 15,802 kN

M = V_u . ex

= 15,802 kN . 0,21 m

= 3,318 kN.m

M_s = M_u + M

= 65,071 kN.m + 3,318 kN.m

= 68,389 kN

- N_s dipikul bersama oleh sistem baut, gaya masing-masing baut N_i :

$N_i = \frac{Nu}{n}$

$= \frac{63{,}785\ kN}{4}$

= 15,946 kN

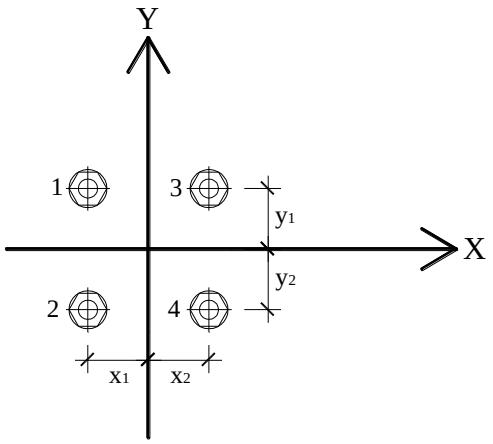
- V_s dipikul bersama oleh sistem baut, gaya masing-masing baut V_i :

$V_i = \frac{Vu}{n}$

$= \frac{15{,}802\ kN}{4}$

= 3,9505 kN

- Momen didistribusikan sesuai posisi baut



Gambar 3.44 Pendistribusian Momen pada Sambungan 4

x_1 = -70 mm

y_1 = 70 mm

x_2 = 70 mm

y_2 = -70 mm

$\sum r_i^2 = \sum x_i^2 + \sum y_i^2$

$= (-70)^2 + 70^2 + 70^2 + (-70)^2$

$= 19600 \text{ mm}^2$

- Gaya akibat M sejajar sumbu x :

$$Fm_1x = \frac{M \,.\, y_1}{\sum r_i^2}$$

$$= \frac{3{,}318 \,.\, 10^6 \text{ N.mm} \,.\, (70 \text{ mm})}{19600 \text{ mm}^2}$$

$$= 11850 \text{ N}$$

$$Fm_2x = \frac{M \,.\, y_2}{\sum r_i^2}$$

$$= \frac{3{,}318 \,.\, 10^6 \text{ N.mm} \,.\, (-70 \text{ mm})}{19600 \text{ mm}^2}$$

$$= -11850 \text{ N}$$

- Gaya akibat M sejajar sumbu y :

$$Fm_1y = \frac{M \,.\, x_1}{\sum r_i^2}$$

$$= \frac{3{,}318 \,.\, 10^6 \text{ N.mm} \,.\, (70 \text{ mm})}{19600 \text{ mm}^2}$$

$$= 11850 \text{ N}$$

$$Fm_2y = \frac{M \,.\, x_2}{\sum r_i^2}$$

$$= \frac{3{,}318 \,.\, 10^6 \text{ N.mm} \,.\, (-70 \text{ mm})}{19600 \text{ mm}^2}$$

$$= -11850 \text{ N}$$

- Resultan gaya-gaya pada setiap baut, Ru :

$$R_u = \sqrt{(Fm_1y + Vi)^2 + (Fm_1x + Ni)^2}$$

$$= \sqrt{(11{,}850 \text{ kN} + 3{,}9505 \text{ kN})^2 + (11{,}850 \text{ kN} + 15{,}946 \text{ kN})^2}$$

$$= 31{,}973 \text{ kN}$$

- Kekuatan Geser Baut

$R_n = 0{,}5 \,.\, f_u^{\,b} \,.\, A_b$

$= 0{,}5 \cdot 370\ N/mm^2 \cdot ¼ \cdot \pi \cdot (40\ mm)^2$

$= 232477{,}856\ N$

$= 232{,}478\ kN$

$R_i \leq \phi R_n$

$R_i = 0{,}75 \cdot 232{,}478\ kN$

$R_i = 174{,}358\ kN$

$R_i \geq R_u$

$174{,}358\ kN > 31{,}973\ kN$ (Oke)

- Kekuatan Tumpu Baut

$R_n = 2{,}4 \cdot d_b \cdot t_{pb} \cdot f_u$

$= 2{,}4 \cdot 40\ mm \cdot t_{pb} \cdot 370\ N/mm^2$

$= 35520\ N/mm \cdot t_{pb}$

$R_u \leq \phi Rn$

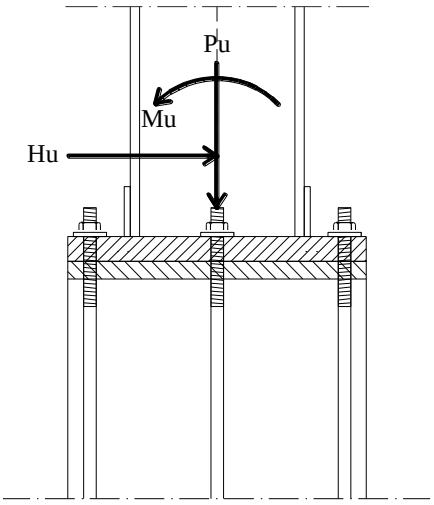
$174{,}358\ kN = 0{,}75 \cdot 35{,}520\ kN \cdot t_{pb}$

$t_{pb} = \frac{174{,}358 \cdot 10^3\ N}{26640\ N/mm} > \frac{tw}{2}$

$= 6{,}545\ mm > \frac{13\ mm}{2}$

$= 6{,}545\ mm \sim 10\ mm > 6{,}5\ mm$ (Oke)

3.5.5 Sambungan A



Gambar 3.45 Potongan pada Sambungan A

Diketahui :

Mu = 30,192 kN.m

Hu = 62,614 kN

Pu = 1903,125 kg + Berat kolom baja

= 1903,125 kg + (136 kg/m . 5,875 m)

= 2702,125 kg

= 27,021 kN

Direncanakan nilai N dan B sebesar :

N = 600 mm

B = 400 mm

- Penetuan Tebal Plat Dasar Sambungan

  Harga b atau n yang terbesar akan digunakan untuk mendapatkan tebal plat dasar yang diperlukan.

  0,80 . b = 0,80 . 400 mm = 320 mm

  0,95 . d = 0,95 . 400 mm = 380 mm

  m = 0,5 . (N – 0,95 . d)

  = 0,5 . (600 mm – 380 mm)

  = 110 mm

  n = 0,5 . (B – 0,80 . b)

  = 0,5 . (400 mm – 320 mm)

  = 40 mm

  $$t = \sqrt{\frac{2 \,.\, Pu \,.\, n^2}{B \,.\, N \,.\, (0{,}9).\, fy}}$$

  $$= \sqrt{\frac{2 \,.\, 2702{,}125\ N \,.\, 40^2\ mm^2}{400\ mm \,.\, 600\ mm \,.\, (0{,}9).\, 240\ N/mm^2}}$$

  $$= 0{,}408\ mm \sim 50\ mm$$

- Cek ukuran luas permukaan kolom terhadap fc’ beton

  $$\left(\frac{P_u}{A_g}\right) + \left(\frac{M_u}{w}\right) \leq 0{,}85 \,.\, fc'$$

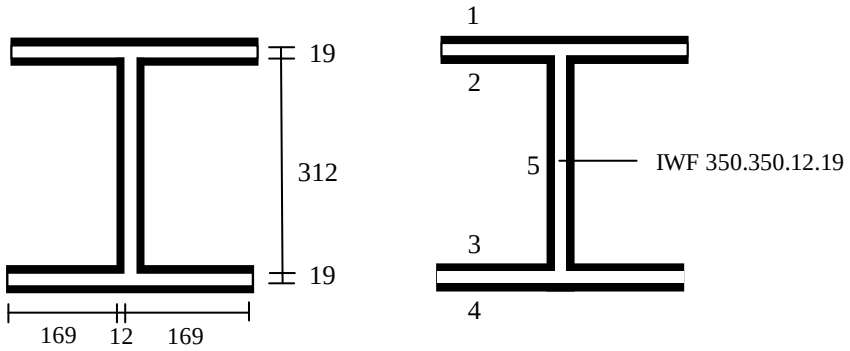
$$\left(\frac{2702{,}125\ \text{N}}{400\ .\ 600\ \text{mm}^2}\right)+\left(\frac{30{,}192\ .\ 10^6\ \text{N.mm}}{\frac{1}{6}.\ 400\ .\ 600^2\ \text{mm}^2}\right)\leq 0{,}85\ .\ 25\ \text{N/mm}^2$$

1,27 N/mm^2 < 21,25 N/mm^2 (Oke)

Sambungan profil ke pelat penyambung dengan menggunakan las.

Gaya geser pada profil (Hu) = 62,614 kN

Direncanakan:



Gambar 3.46 Sambungan Las Profil pada Penampang Sambungan A

- Akibat Geser Langsung

  $(R_n)_v = \frac{P_u}{A}$

  Dicoba a = 5 mm

  A_1 = 350 mm x 5 mm = 1750 mm^2

  A_2 = 169 mm x 5 mm x 2 = 1960 mm^2

  A_3 = 169 mm x 5 mm x 2 = 1960 mm^2

  A_4 = 350 mm x 5 mm = 1750 mm^2

  A_5 = 312 mm x 5 mm x 2 = 3150 mm^2 +

  A_{tot} = 10570 mm^2

  $(R_n)_v = \frac{P_u}{A}$

  $= \frac{2702{,}125\ \text{N}}{10570\ \text{mm}^2}$

  $= 0{,}256\ \text{N/mm}^2$

- Akibat Momen

  $(R_n)_t = \frac{M_u.C}{I}$

$Ix_1 = \frac{1}{12}$ x 350 x 5^3 + 350 x 5 x 350^2 = 214,379 . 10^6 mm^4

$Ix_2 = \frac{1}{12}$ x 169 x 5^3 + 169 x 5 x 331^2 = 92,581 . 10^6 mm^4

$Ix_3 = \frac{1}{12}$ x 169 x 5^3 + 169 x 5 x 331^2 = 92,581 . 10^6 mm^4

$Ix_4 = \frac{1}{12}$ x 350 x 5^3 + 350 x 5 x 350^2 = 214,379 . 10^6 mm^4

$Ix_5 = \frac{1}{12}$ x 5 x 350^3 + 5 x 350 x 175^2 = 71,458 . 10^6 mm^4 +

Ix_{tot} = 685,378 . 10^6 mm^4

$$(R_n)_t = \frac{M_u . C}{I}$$

$$= \frac{30{,}192 \ . 10^4 \ \text{N.mm} \ . 350 \ \text{mm}}{685{,}378 \ . 10^6 \ \text{mm}^4}$$

$$= 15{,}418 \ \text{N/mm}^2$$

- Resultan Gaya

$$\phi R_{n\ perlu} = \sqrt{(R_n)_v^{\,2} + (R_n)_t^{\,2}}$$

$$= \sqrt{0{,}256^2 + 15{,}418^2}$$

$$= 15{,}420 \ \text{N/mm}^2$$

- Tahanan Las

$\phi R_{nw} = \phi$. 0,6 . f_{uw}

= 0,75 . 0,6 . 490 N/mm^2

= 220,5 N/mm^2

$\phi R_{n\ perlu} < \phi R_{nw}$

15,420 N/mm^2 < 220,5 N/mm^2 (Oke)

1. Perencanaan Sepatu Kolom

Dicoba :

Dia. Baut (d) = 25 mm

Jumlah Baut (n) = 6 buah

Mu = 30,192 kN.m

Hu = 62,614 kN

Pu = 19,031 kN

Mutu Baja = BJ 37 $\longrightarrow$ f_y = 2400 kg/cm^2

f_u = 3700 kg/cm^2

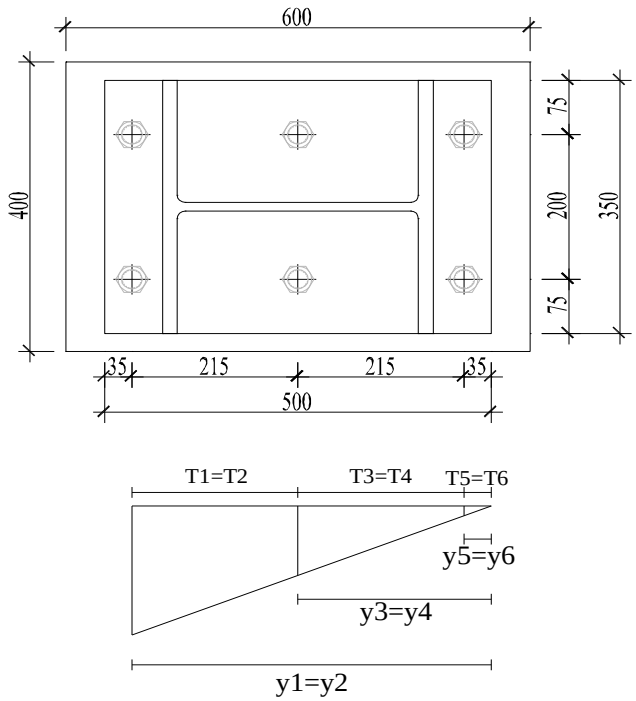
a. Gaya geser terfaktor pada baut lintang (Ru) dipikul dengan besarnya baut.

$$R_{uv} = \frac{H_u}{n}$$

$$= \frac{62{,}614 \text{ kN}}{6 \text{ bh}}$$

$$= 10{,}435 \text{ kN/baut}$$

b. Beban yang dipikul oleh sekelompok baut yang berada pada serat tertarik (daerah tertarik)



Gambar 3.47 Sambungan Baut Profil pada Penampang Sambungan A

- Kekuatan Geser Nominal

$\phi R_n = \phi \,.\, 0{,}5 \,.\, f_u^{\,b} \,.\, m \,.\, A_b$

$= 0{,}75 \,.\, 0{,}5 \,.\, 825 \text{ N/mm}^2 \,.\, 1 \,.\, {}^1\!/_4 \,.\, \pi \,.\, 25^2 \text{ mm}^2$

$= 151864{,}098 \text{ N}$

$= 151{,}864 \text{ kN}$ (Diambil Terkecil)

- Kekuatan Tumpu Nominal

$\phi R_n = \phi \,.\, 2{,}4 \,.\, d_b \,.\, t_p \,.\, f_u^{\,p}$

$= 0{,}75 \,.\, 2{,}4 \,.\, 25 \text{ mm} \,.\, 50 \text{ mm} \,.\, 370 \text{ N/mm}^2$

$= 832500 \text{ N}$

$= 832{,}5 \text{ kN}$

- $\phi R_n = 151{,}864 \text{ kN} \times 6 \text{ baut}$

  $= 911{,}184 \text{ kN}$

  $\phi R_n > Hu$

  $911{,}184 \text{ kN} > 62{,}614 \text{ kN}$ (Oke)

- Gaya Tekan Terfaktor pada Satu Baut Akibat Momen

  $$Rut = \frac{M \,.\, y1}{\sum y^2}$$

  $y1 = y2 = 215 \text{ mm} + 215 \text{ mm} + 35 \text{ mm} = 465 \text{ mm}$

  $y3 = y4 = 215 \text{ mm} + 35 \text{ mm} = 250 \text{ mm}$

  $y5 = y6 = 35 \text{ mm}$

  $\sum y^2 = 2 \,.\, (465^2 + 250^2 + 35^2)$

  $= 559900 \text{ mm}^2$

  $$Rut = \frac{M \,.\, y1}{\sum y^2}$$

  $$= \frac{30{,}192 \,.\, 10^6 \text{ N.mm} \,.\, 465 \text{ cm}}{559900 \text{ mm}^2}$$

  $= 25074{,}62 \text{ N}$

  $= 25{,}074 \text{ kN}$

- Kuat Tarik Baut

  $R_{nt} = 0{,}75 \,.\, f_u^{\,b} \,.\, A_b$

  $= 0{,}75 \,.\, 825 \text{ N/mm}^2 \,.\, \frac{1}{4} \,.\, \pi \,.\, 25^2 \text{ mm}^2$

  $= 303728{,}196 \text{ N}$

  $= 303{,}728 \text{ kN}$

  Sehingga satu baut akan mengalami geser dan tarik secara bersamaan

  $$\left[\frac{R_{uv}}{\phi_v \,.\, R_{nv}}\right]^2 + \left[\frac{R_{ut}}{\phi_t \,.\, R_{nt}}\right]^2 \leq 1{,}0$$

  $$\left[\frac{10{,}435 \text{ kN}}{0{,}75 \,.\, 911{,}184 \text{ kN}}\right]^2 + \left[\frac{25{,}074 \text{ kN}}{0{,}75 \,.\, 303{,}728 \text{ kN}}\right]^2 \leq 1{,}0$$

0,0123 ≤ 1,0 (Oke)

2. Penjangkaran

Untuk menentukan panjang baut angkur yang dibutuhkan, didasarkan pada luas permukaan pelat dan kapasitas baut angkur itu sendiri. Rumus yang digunakan adalah :

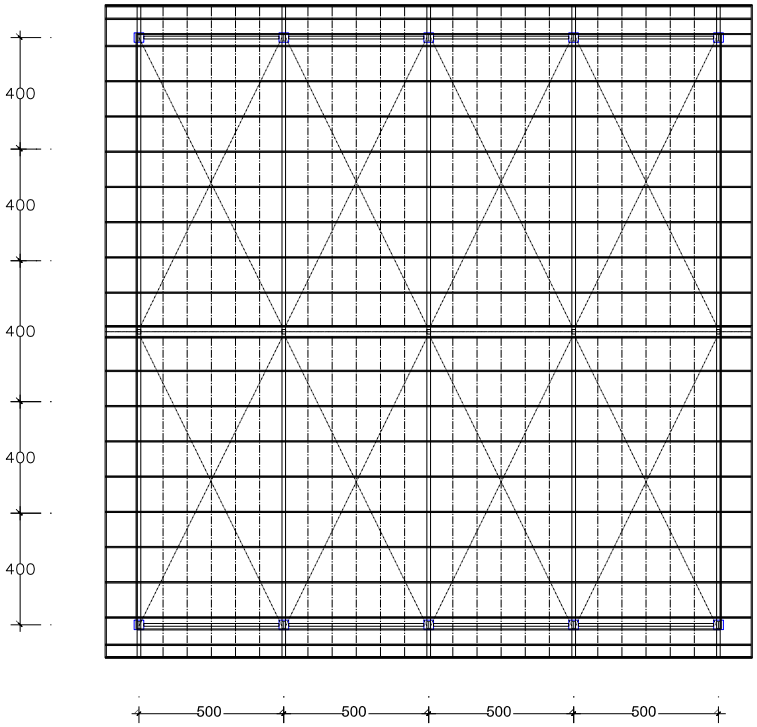
$$L = \sqrt{\frac{A\ pelat}{\pi}}$$

$$= \sqrt{\frac{350\ mm\ .\ 500\ mm}{\pi}}$$

= 236,017 mm

= 23,602 cm ~ 100 cm

3.6 Perhitungan Ikatan Angin



Gambar 3.48 Denah Ikatan Angin

Diketahui data-data sebagai berikut:

Nu = 72,994 kN

Jarak antar *Single Beam* (lk) = 5,00 m

Jarak antar Gording (lg) = 1,50 m

Bentang Portal (l) = 20,0 m

Jumlah *Trave* = 1 buah

E_s = 200000 MPa

Mutu Baja = BJ 37 ⟶ f_y = 240 Mpa

f_u = 370 MPa

3.6.1 Perhitungan Pembebanan

Beban Vertikal (ql) = Berat gording + Berat atap + berat air hujan

= (1,2 . 7,51 kg/m) + (1,2 . 2,65 kg/m) + (1,6 . 20 kg/m)

= 44,192 kg/m

= 0,442 kN/m

$$P_{portal} = \frac{\text{Luas Sayap}}{\text{Luas Profil}} . N_u$$

$$= \frac{21\ mm\ .\ 400\ mm}{21870\ mm^2} . 72{,}994\ kN$$

= 28,036 kN

P’ = (0,01 . P_{portal}) + 0,0025 . n . ql . lk . lg

= (0,01 . 28,036 kN) + 0,0025 . 1 . 0,442 kN/m . 5,0 m . 1,5 m

= 0,288 kN

3.6.2 Bentang Ikatan Angin

Beban Horizontal dari Atap (Q’)

Q’ = 0,0025 . n . ql . lk . lg

= 0,0025 . 1 . 0,442 kN/m . 5,0 m . 1,5 m

= 0, 00828 kN

Syarat Bentang Ikatan Angin

$$\frac{h}{l} \geq \sqrt{\frac{0{,}25\ .Q\prime}{E\ .\ A_{tepi}}}$$

dengan,

A_{tepi} = lk . (2 . lg)

$= 5{,}0\ \text{m} \,.\, (2 \,.\, 1{,}5\ \text{m})$

$= 15\ \text{m}^2$

$$\frac{5{,}0\ \text{m}}{20\ \text{m}} \geq \sqrt{\frac{0{,}25 \,.\, 8{,}28\ \text{N}}{2 \,.\, 10^5\ \text{N/mm}^2 \,.\, 15 \,.\, 10^6\ \text{mm}^2}}$$

0,25 > 0,000000262 (Oke)

Direncanakan menggunakan batang diameter 10 mm = 1 cm

$A_g = \frac{1}{4} \,.\, \pi \,.\, d^2$

$= \frac{1}{4} \,.\, \pi \,.\, (10\ \text{mm})^2$

$= 78{,}539\ \text{mm}^2$

$\varnothing N_n = \varnothing A_g \,.\, f_y$

$= 0{,}9 \,.\, 78{,}539\ \text{mm}^2 \,.\, 240\ \text{N/mm}^2$

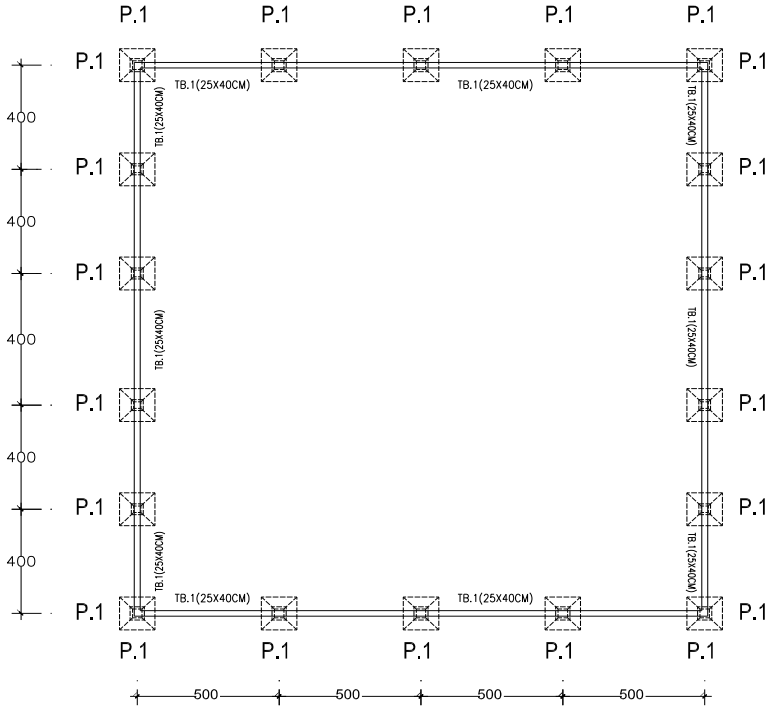
$= 16964{,}6\ \text{N}$

$= 16{,}965\ \text{kN}$

$P' \leq \varnothing N_n$

0,288 kN < 16,965 kN (Oke)

3.7 Perhitungan *Tie Beam*



Gambar 3.49 Denah *Tie Beam*

3.7.1 *Tie Beam* Arah Memanjang

- Diketahui data-data sebagai berikut:

  Ukuran *tie beam* = 300 x 400 mm^2

  Panjang Bentang (L) = 5,00 m

  Mutu Beton = fc' 25 MPa

  Mutu Baja = BJ 37

  Selimut Beton (p) = 30 mm

  Tulangan Pokok (D) = D19 mm

  Tulangan Sengkang (øs) = ø8 mm

  Tinggi Efektif (d) $= h - p - øs - \frac{D}{2}$

  $= 400\ mm - 30\ mm - 8\ mm - \frac{16\ mm}{2}$

  $= 354\ mm$

  Tebal Plesteran = 1,5 cm x 2 sisi = 3 cm

- Pembebanan:

  Berat sendiri *tie beam* = (0,3 m . 0,4 m) . 24 kN/m^3 = 2,88 kN/m

  Berat dinding $^1/_2$ bata = 5,0 m . 2,5 kN/m^2 = 12,5 kN/m

  Berat plesteran = (5,0 m . 0,21 kN/m^2) . 3 = 3,15 kN/m +

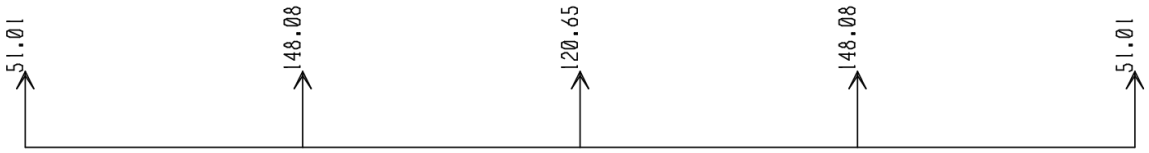
  Beban Mati (W_D) = 18,53 kN/m

  Beban Hidup (W_L) = 0

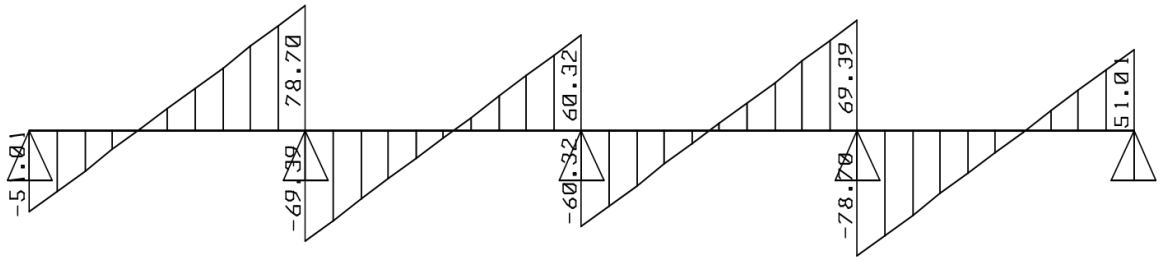
  $W_u = 1{,}4 \cdot W_D$

  $= 1{,}4 \cdot 18{,}53\ kN/m$

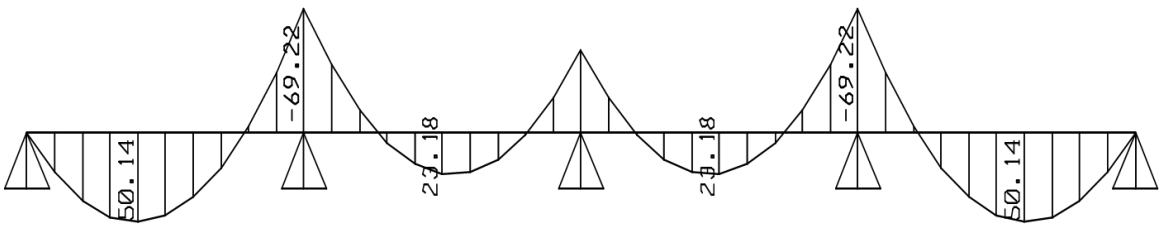
  $= 25{,}942\ kN/m$



Gambar 3.50 Perletakan Gaya Akibat Beban Mati Tie beam Memanjang



Gambar 3.51 Gaya Lintang Akibat Beban Mati Tie beam Memanjang



Gambar 3.52 Gaya Momen Akibat Beban Mati Tie beam Memanjang

1. Tulangan Lapangan

M = 50,14 kN.m

$k = \frac{M_u}{\emptyset . b . d^2}$

$= \frac{50{,}14 . 10^6}{0{,}8 . 300 . 354^2}$

$= 1{,}667$

$\frac{f_y}{1{,}7 . fc'} . \rho^2 - \rho + \frac{M_u}{\emptyset . b . d^2 . f_y} = 0$

$\frac{240}{1{,}7 . 25} . \rho^2 - \rho + \frac{50{,}14 . 10^6}{0{,}8 . 300 . 354^2 . 240} = 0$

$5{,}647\ \rho^2 - \rho + 0{,}006946 = 0$

$\rho = 0{,}006946$

$\rho_{min} = \frac{1{,}4}{f_y}$ atau $\frac{\sqrt{fc'}}{4 . f_y}$

$\rho_{min} = \frac{1{,}4}{f_y} = \frac{1{,}4}{240} = 0{,}00583$ (Diambil Terbesar)

$\rho_{min} = \frac{\sqrt{fc'}}{4 . f_y} = \frac{\sqrt{25}}{4 . 240} = 0{,}00521$

$\rho_{maks} = \frac{0{,}75 . 0{,}85 . fc' . \beta_1}{f_y}\left(\frac{600}{600 + f_y}\right)$

$= \frac{0{,}75 . 0{,}85 . 25 . 0{,}85}{240}\left(\frac{600}{600 + 240}\right)$

$= 0{,}04032$

$As_{min} < As_{pakai} < As_{maks}$

$\rho_{min} . b . d < \rho . b . d < \rho_{maks} . b . d$

$0{,}00583 . 300 . 354 < 0{,}006946 . 300 . 354 < 0{,}04032 . 300 . 354$

$619{,}146\ mm^2 < 737{,}665\ mm^2 < 4281{,}984\ mm^2$

Jadi, $As_{pakai} = 737{,}665\ mm^2 \longrightarrow$ Dipakai tulangan 5D16

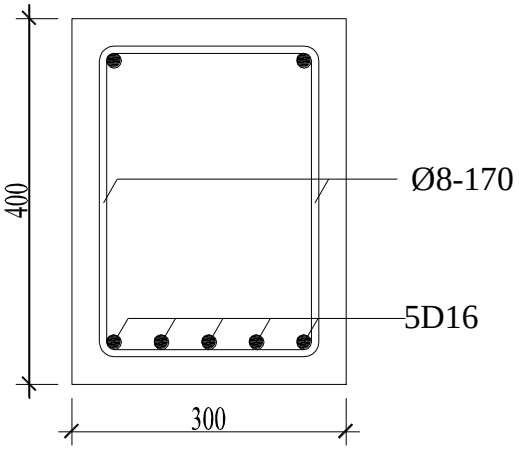
- Kontrol susunan penulangan *tie beam* :

  Dengan, jarak antar tulangan direncanakan = 25 mm

b_{perlu} = (5 x Tul. pokok) + (2 x Selimur beton) + (2 x Tul. sengkang) + (4 x Jarak antar tulangan) < b

= (5 . 16 mm) + (2 . 30 mm) + (2 . 8 mm) + (4 . 25 mm) < 300 mm

= 256 mm < 300 mm (Oke) ⟶ Dapat Dibuat 1 Lapis



Gambar 3.53 Tulangan Lapangan *Tie beam* Arah Memanjang

2. Tulangan Tumpuan

M = 69,22 kN.m

$$k = \frac{M_u}{\emptyset . b . d^2}$$

$$= \frac{69{,}22 . 10^6}{0{,}8 . 300 . 354^2}$$

$$= 2{,}301$$

$$\frac{f_y}{1{,}7 . fc'} \cdot \rho^2 - \rho + \frac{M_u}{\emptyset . b . d^2 . f_y} = 0$$

$$\frac{240}{1{,}7 . 25} \cdot \rho^2 - \rho + \frac{69{,}22 . 10^6}{0{,}8 . 300 . 354^2 . 240} = 0$$

$$5{,}647\ \rho^2 - \rho + 0{,}00958 = 0$$

$$\rho = 0{,}012711$$

$$\rho_{min} = \frac{1{,}4}{f_y} \text{ atau } \frac{\sqrt{fc'}}{4 . f_y}$$

$$\rho_{min} = \frac{1{,}4}{f_y} = \frac{1{,}4}{240} = 0{,}00583 \text{ (Diambil Terbesar)}$$

$\rho_{min} = \frac{\sqrt{f_c'}}{4 \, . \, f_y} = \frac{\sqrt{25}}{4 \, . \, 240} = 0{,}00521$

$\rho_{maks} = \frac{0{,}75 \, . \, 0{,}85 \, . \, fc' \, . \, \beta_1}{f_y} \left(\frac{600}{600 + f_y} \right)$

$= \frac{0{,}75 \, . \, 0{,}85 \, . \, 25 \, . \, 0{,}85}{240} \left(\frac{600}{600 + 240} \right)$

$= 0{,}04032$

$As_{min} < As_{pakai} < As_{maks}$

$\rho_{min} \, . \, b \, . \, d < \rho \, . \, b \, . \, d < \rho_{maks} \, . \, b \, . \, d$

$0{,}00583 \, . \, 300 \, . \, 354 < 0{,}00958 \, . \, 300 \, . \, 354 < 0{,}04032 \, . \, 300 \, . \, 354$

$619{,}146 \text{ mm}^2 < 1017{,}396 \text{ mm}^2 < 4281{,}984 \text{ mm}^2$

Jadi, $As_{pakai} = 1017{,}396 \text{ mm}^2 \longrightarrow$ Dipakai tulangan 7D16

- Kontrol susunan penulangan *tie beam* :

  Dengan, jarak antar tulangan direncanakan = 25 mm

  b_{perlu} = (7 x Tul. pokok) + (2 x Selimut beton) + (2 x Tul. sengkang) + (5 x Jarak antar tulangan) < b

  = (7 . 16 mm) + (2 . 30 mm) + (2 . 8 mm) + (5 . 25 mm) < 300 mm

  = 338 mm > 300 mm (Tidak Oke) ⟶ Tidak Dapat Dibuat 1 Lapis

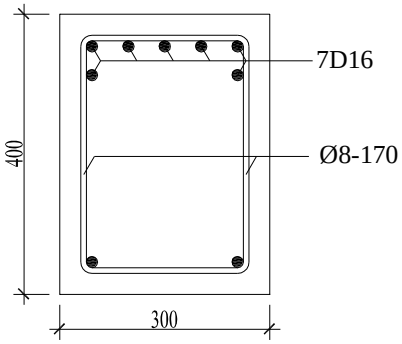
  Sehingga dibuat 2 lapis tulangan = 5D16

  2D16

  b_{perlu} = (5 x Tul. pokok) + (2 x Selimur beton) + (2 x Tul. sengkang) + (4 x Jarak antar tulangan) < b

  = (5 . 16 mm) + (2 . 30 mm) + (2 . 8 mm) + (4 . 25 mm) < 300 mm

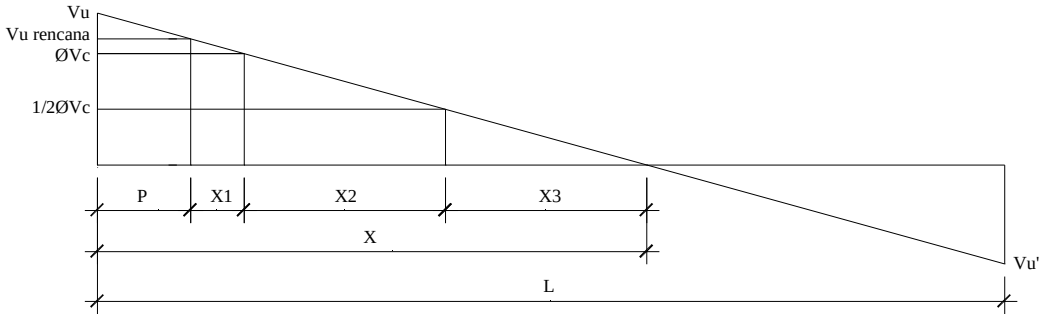
  = 256 mm < 300 mm (Oke)



Gambar 3.54 Tulangan Tumpuan *Tie beam* Arah Memanjang

3. Penulangan Geser

Tumpuan tulangan bagian luar :



Gambar 3.55 Penentuan $Vu_{rencana}$ Penulangan Geser

Diketahui:

Vu = 78,70 kN

Vu'= 51,01 kN

Ukuran kolom = 400 x 600 mm^2

P = d + ½ . b kolom

= 354 mm + 400 mm

= 554 mm

$$X = \frac{Vu}{Vu + Vu'} \cdot L$$

$$= \frac{78{,}70\ kN}{78{,}70\ kN + 51{,}01\ kN} \cdot 5{,}0\ m$$

= 3,033 m

$$Vu_{rencana} = \frac{Vu \cdot (X - P)}{X}$$

$$= \frac{78{,}70\ kN \cdot (3{,}033\ m - 0{,}554\ m)}{3{,}033\ m}$$

= 64,325 kN

$$= \frac{Vu\ rencana}{b \cdot d}$$

$$= \frac{64{,}325 \cdot 10^3\ N}{300\ mm \cdot 354\ mm}$$

= 0,606 N/mm^2

$\emptyset Vc = \emptyset \cdot \frac{1}{6} \cdot \sqrt{fc'}$

$= 0{,}75 \cdot \frac{1}{6} \cdot \sqrt{25}$

$= 0{,}625 \text{ N/mm}^2$

$½\emptyset Vc = \frac{\emptyset Vc}{2}$

$= \frac{0{,}625 \text{ N/mm}^2}{2}$

$= 0{,}3125 \text{ N/mm}^2$

$Vu_{rencana} > ½ \emptyset Vc$

$0{,}606 \text{ N/mm}^2 > 0{,}3125 \text{ N/mm}^2 \longrightarrow$ Perlu Tulangan Geser

$Vs_{perlu} = \frac{V_{u\ rencana}}{\emptyset} - Vc$

$= \frac{0{,}606 \text{ N/mm}^2}{0{,}75} - 0{,}625 \text{ N/mm}^2$

$= 0{,}183 \text{ N/mm}^2$

$Vs_{maks} = \frac{2}{3} \cdot \sqrt{fc'}$

$= \frac{2}{3} \cdot \sqrt{25}$

$= 3{,}333 \text{ N/mm}^2$

$Vs_{perlu} < Vs_{maks}$

$0{,}183 \text{ N/mm}^2 < 3{,}333 \text{ N/mm}^2$ (Oke) $\longrightarrow$ Dimensi Tie beam Oke

- Cek Nilai V_s :

$Vs = \frac{1}{3} \cdot \sqrt{fc'}$

$= \frac{1}{3} \cdot \sqrt{25}$

$= 1{,}667 \text{ N/mm}^2$

$Vs_{perlu} < Vs = \frac{1}{3} \cdot \sqrt{fc'} \cdot b_w \cdot d$

$0{,}183 \text{ N/mm}^2 < 1{,}667 \text{ N/mm}^2$, maka $S_{maks} = \frac{d}{2}$ atau 600 mm

$S_{maks} = \frac{d}{2}$

$= \frac{354 \text{ mm}}{2}$

= 177 mm ~ 170 mm

$$X1 = \frac{(V_{u\ rencana} - \emptyset Vc)\ .\ (X - P)}{V_{u\ rencana}}$$

$$= \frac{(0{,}625\ N/mm^2 - 0{,}606\ N/mm^2)\ .\ (3{,}033\ m - 0{,}554\ m)}{0{,}606\ N/mm^2}$$

= 0,077 m

$$X2 = \frac{(\emptyset Vc - ½\emptyset Vc)\ .\ (X - P - X1)}{\emptyset Vc}$$

$$= \frac{(0{,}625\ N/mm^2 - 0{,}3125\ N/mm^2)\ .\ (3{,}033\ m - 0{,}554\ m - 0{,}077\ m)}{0{,}625\ N/mm^2}$$

= 1,201 m

X3 = (X – P – X1 – X2)

= (3,033 m – 0,554 m – 0,077 m –1,201 m)

= 1,201 m

- Jarak Spasi Tulangan Sengkang Sepanjang d = 0,354 m:

$$Av = \frac{V_s\ .\ b\ .\ d}{f_y}$$

$$= \frac{0{,}183\ N/mm^2\ .\ 300\ mm\ .\ 354\ mm}{240\ N/mm^2}$$

= 80,977 mm^2

$$Av_{per\ meter} = \frac{80{,}977\ mm^2}{0{,}354\ m}$$

= 228,748 mm^2/meter

$$Av_1 = 2\ .\ \frac{1}{4}.\pi\ .\ d^2$$

$$= 2\ .\ \frac{1}{4}.\pi\ .\ 8^2\ mm^2$$

= 100,53 mm^2

$$S = \frac{Av_1}{Av_{per\ meter}}$$

$$= \frac{100{,}53\ mm^2}{228{,}748\ mm^2/meter} \text{ x } 1000$$

= 439,479 mm ~ 450 mm

Karena nilai S > S_{maks}, maka dipakai S sebesar S_{maks} = 170 mm

- Jarak Spasi Tulangan Sengkang Sepanjang X1 = 0,183 m:

$$Av = \frac{1/2 \,.\, V_s \,.\, b \,.\, X1}{f_y}$$

$$= \frac{1/2 \,.\, 0{,}183 \ N/mm^2 \,.\, 300 \ mm \,.\, 183 \ mm}{240 \ N/mm^2}$$

$$= 20{,}931 \ mm^2$$

$$Av_{per\ meter} = \frac{20{,}931 \ mm^2}{0{,}183 \ m}$$

$$= 114{,}377 \ mm^2/meter$$

$$Av_1 = 2 \,.\, \frac{1}{4} . \pi \,.\, d^2$$

$$= 2 \,.\, \frac{1}{4} . \pi \,.\, 8^2 \ mm^2$$

$$= 100{,}53 \ mm^2$$

$$S = \frac{Av_1}{Av_{per\ meter}}$$

$$= \frac{100{,}53 \ mm^2}{114{,}377 \ mm^2/meter} \text{ x } 1000$$

$$= 504{,}226 \ mm \sim 500 \ mm$$

Karena nilai S > S_{maks}, maka dipakai S sebesar S_{maks} = 170 mm

- Jarak Spasi Tulangan Sengkang Sepanjang X2 = 1,201 m:

$$Av_{min} = \frac{1}{3} \,.\, \frac{b \,.\, s}{f_y}$$

$$= \frac{1}{3} \,.\, \frac{300 \ mm \,.\, 1000 \ mm}{240 \ N/mm^2}$$

$$= 416{,}667 \ mm^2$$

$$Av_1 = 2 \,.\, \frac{1}{4} . \pi \,.\, d^2$$

$$= 2 \,.\, \frac{1}{4} . \pi \,.\, 8^2 \ mm^2$$

$$= 100{,}53 \ mm^2$$

$$S = \frac{Av_1}{Av_{per\ meter}}$$

$$= \frac{100{,}53 \ mm^2}{416{,}667 \ mm^2/meter} \text{ x } 1000$$

$$= 241{,}271 \ mm \sim 240 \ mm$$

Karena nilai S > S_{maks}, maka dipakai S sebesar S_{maks} = 170 mm

- Jarak Spasi Tulangan Sengkang Sepanjang X3 = 1,201 m:

$$Av_{min} = \frac{1}{3} . \frac{b . s}{f_y}$$

$$= \frac{1}{3} . \frac{300\ mm . 1000\ mm}{240\ N/mm^2}$$

$$= 416{,}667\ mm^2$$

$$Av_1 = 2 . \frac{1}{4} . \pi . d^2$$

$$= 2 . \frac{1}{4} . \pi . 8^2\ mm^2$$

$$= 100{,}53\ mm^2$$

$$S = \frac{Av_1}{Av_{per\ meter}}$$

$$= \frac{100{,}53\ mm^2}{416{,}667\ mm^2/meter} \times 1000$$

$$= 241{,}271\ mm \sim 240\ mm$$

Karena nilai S > S_{maks}, maka dipakai S sebesar S_{maks} = 170 mm

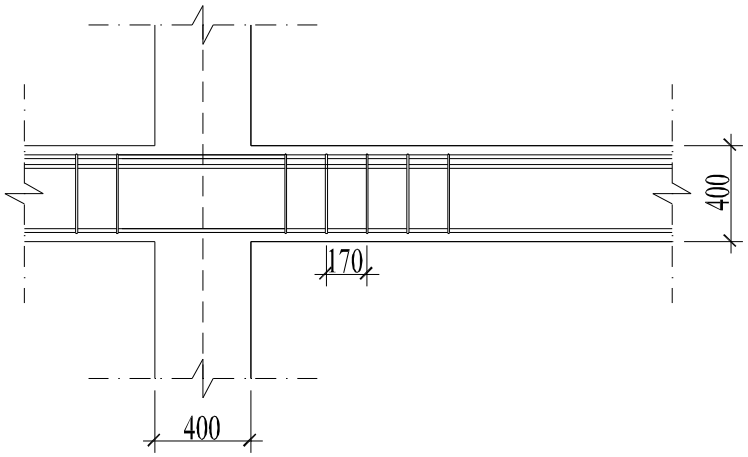
- Kesimpulan

Jadi, sepanjang d = 0,354 m ⟶ Ø8 - 170 mm

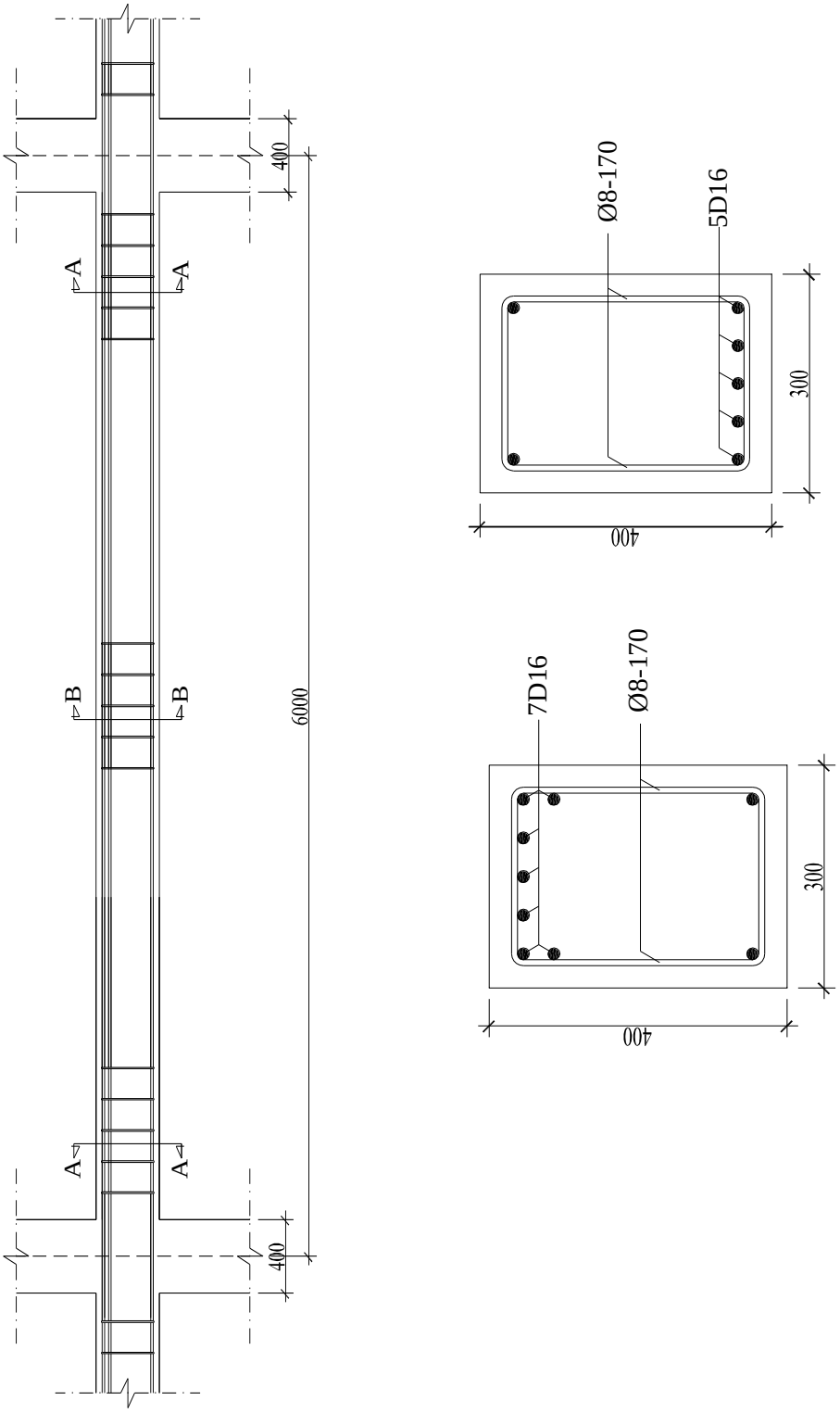
Jadi, sepanjang X1 = 0,183 m ⟶ Ø8 - 170 mm

Jadi, sepanjang X2 = 1,201 m ⟶ Ø8 - 170 mm

Jadi, sepanjang X3 = 1,201 m ⟶ Ø8 - 170 mm



Gambar 3.56 Jarak Sengkang *Tie beam* Arah Memanjang



Gambar 3.57 Penulangan *Tie beam* Arah Memanjang

3.7.2 *Tie beam* Arah Melintang

- Diketahui data-data sebagai berikut:

  Ukuran *Tie beam* = 300 x 400 mm^2

  Panjang Bentang (L) = 4,00 m dan 3,00 m

  Mutu Beton = fc' 25 MPa

  Mutu Baja = BJ 37

  Selimut Beton (p) = 30 mm

  Tulangan Pokok (D) = D19 mm

  Tulangan Sengkang (øs) = ø8 mm

  Tinggi Efektif (d) $= h - p - øs - \frac{D}{2}$

  $= 400\ mm - 30\ mm - 8\ mm - \frac{16\ mm}{2}$

  $= 354\ mm$

  Tebal Plesteran = 1,5 cm x 2 sisi = 3 cm

- Pembebanan:

a. *Tie beam* dengan bentang 5,00 m :

  Berat sendiri *tie beam* = (0,3 m . 0,4 m) . 24 kN/m^3 = 2,88 kN/m

  Berat dinding $^1/_2$ bata = 5 m . 2,5 kN/m^2 = 12,5 kN/m

  Berat plesteran = (5 m . 0,21 kN/m^2) . 3 = 3,15 kN/m +

  Beban Hidup (W_D) = 18,53 kN/m

  Wu = 1,4 . W_D

  = 1,4 . 18,53 kN/m

  = 25,942 kN/m

b. *Tie beam* dengan bentang 4,75 m :

  Berat sendiri *tie beam* = (0,3 m . 0,4 m) . 24 kN/m^3 = 2,88 kN/m

  Berat dinding $^1/_2$ bata = 4,75 m . 2,5 kN/m^2 = 11,87 kN/m

  Berat plesteran = (4,75 m . 0,21 kN/m^2) . 3 = 2,99 kN/m +

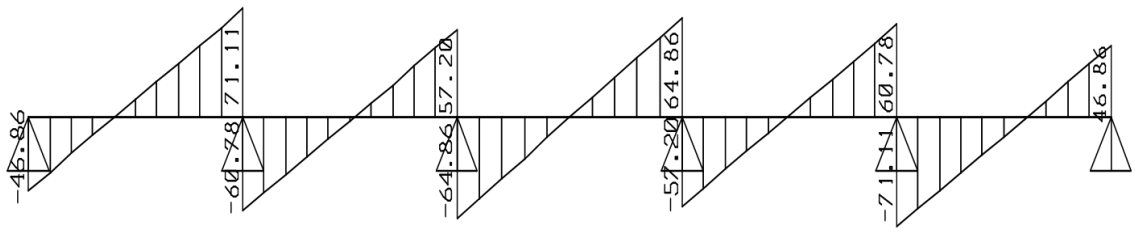
  Beban Mati (W_D) = 17,74 kN/m

  Wu = 1,4 . W_D

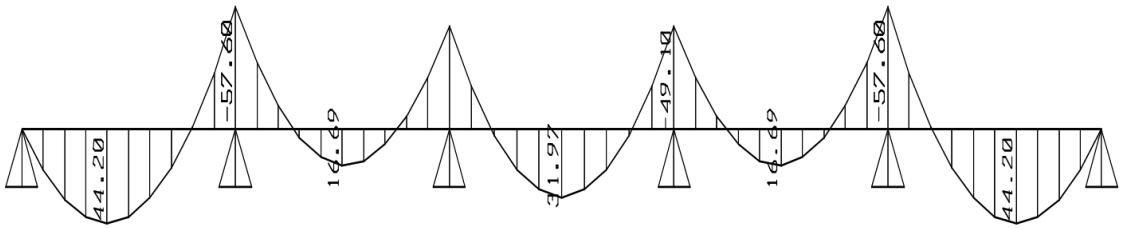
  = 1,4 . 17,74 kN/m

  = 24,836 kN/m

Gambar 3.58 Perletakan Gaya Akibat Beban Mati Tie beam Melintang



Gambar 3.59 Gaya Lintang Akibat Beban Mati Tie beam Melintang



Gambar 3.60 Gaya Momen Akibat Beban Mati Tie beam Melintang

1. Tulangan Lapangan

M = 44,20 kN.m

$$k = \frac{M_u}{\emptyset . b . d^2}$$

$$= \frac{44{,}20 . 10^6}{0{,}8 . 300 . 354^2}$$

$$= 1{,}469$$

$$\frac{f_y}{1{,}7 . fc'} . \rho^2 - \rho + \frac{M_u}{\emptyset . b . d^2 . f_y} = 0$$

$$\frac{240}{1{,}7 . 25} . \rho^2 - \rho + \frac{44{,}20 . 10^6}{0{,}8 . 300 . 354^2 . 240} = 0$$

$5{,}647\ \rho^2 - \rho + 0{,}006123 = 0$

$\rho = 0{,}006123$ (Diambil Terbesar)

$$\rho_{min} = \frac{1{,}4}{f_y} \text{ atau } \frac{\sqrt{fc'}}{4 . f_y}$$

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

$$\rho_{min} = \frac{\sqrt{fc'}}{4 . f_y} = \frac{\sqrt{25}}{4 . 240} = 0{,}00521$$

$$\rho_{maks} = \frac{0{,}75 . 0{,}85 . fc' . \beta_1}{f_y}\left(\frac{600}{600 + f_y}\right)$$

$$= \frac{0{,}75 . 0{,}85 . 25 . 0{,}85}{240}\left(\frac{600}{600 + 240}\right)$$

$$= 0{,}04032$$

Karena $\rho < \rho_{min}$, maka nilai ρ diambil sebesar ρ_{min}

$As_{pakai} < As_{maks}$

$\rho_{min} . b . d < \rho_{maks} . b . d$

$0{,}006123 . 300 . 354 < 0{,}04032 . 300 . 354$

$650{,}263\ mm^2 < 4281{,}984\ mm^2$

Jadi, $As_{pakai} = 650{,}263\ mm^2 \longrightarrow$ Dipakai tulangan 4D16

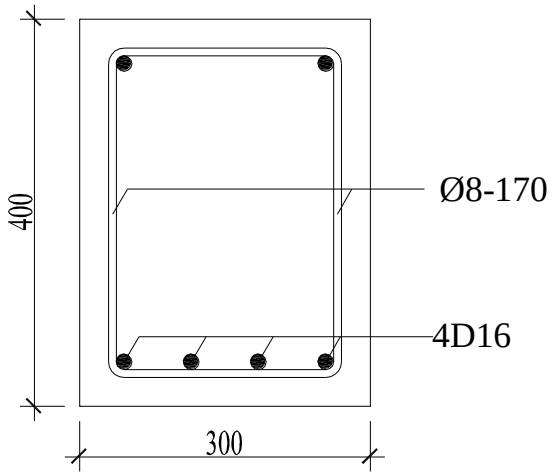
- Kontrol susunan penulangan *tie beam* :

  Dengan, jarak antar tulangan direncanakan = 25 mm

b_{perlu} = (4 x Tul. pokok) + (2 x Selimur beton) + (2 x Tul. sengkang) + (3 x Jarak antar tulangan) < b

= (4 . 16 mm) + (2 . 30 mm) + (2 . 8 mm) + (3 . 25 mm) < 300 mm

= 215 mm < 300 mm (Oke) ⟶ Dapat Dibuat 1 Lapis



Gambar 3.61 Tulangan Lapangan *Tie beam* Arah Melintang

2. Tulangan Tumpuan

M = 57,60 kN.m

$$k = \frac{M_u}{\emptyset \,.\, b \,.\, d^2}$$

$$= \frac{57{,}60 \,.\, 10^6}{0{,}8 \,.\, 300 \,.\, 354^2}$$

$$= 1{,}9152$$

$$\frac{f_y}{1{,}7 \,.\, fc'} \,.\, \rho^2 - \rho + \frac{M_u}{\emptyset \,.\, b \,.\, d^2 \,.\, f_y} = 0$$

$$\frac{240}{1{,}7 \,.\, 25} \,.\, \rho^2 - \rho + \frac{57{,}60 \,.\, 10^6}{0{,}8 \,.\, 300 \,.\, 354^2 \,.\, 240} = 0$$

$5{,}647\ \rho^2 - \rho + 0{,}007979 = 0$

$\rho = 0{,}007979$ (Diambil Terbesar)

$$\rho_{min} = \frac{1{,}4}{f_y} \text{ atau } \frac{\sqrt{fc'}}{4 \,.\, f_y}$$

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

$$\rho_{min} = \frac{\sqrt{f_c'}}{4 \,.\, f_y} = \frac{\sqrt{25}}{4 \,.\, 240} = 0{,}00521$$

$$\rho_{maks} = \frac{0{,}75 \,.\, 0{,}85 \,.\, fc' \,.\, \beta_1}{f_y}\left(\frac{600}{600 + f_y}\right)$$

$$= \frac{0{,}75 \,.\, 0{,}85 \,.\, 25 \,.\, 0{,}85}{240}\left(\frac{600}{600 + 240}\right)$$

$$= 0{,}04032$$

Karena $\rho < \rho_{min}$, maka nilai ρ diambil sebesar ρ_{min}

$As_{pakai} < As_{maks}$

$\rho_{min} \,.\, b \,.\, d < \rho_{maks} \,.\, b \,.\, d$

$0{,}007979 \,.\, 300 \,.\, 354 < 0{,}04032 \,.\, 300 \,.\, 354$

$847{,}369 \text{ mm}^2 < 4281{,}984 \text{ mm}^2$

Jadi, $As_{pakai} = 847{,}369 \text{ mm}^2 \longrightarrow$ Dipakai tulangan 4D16

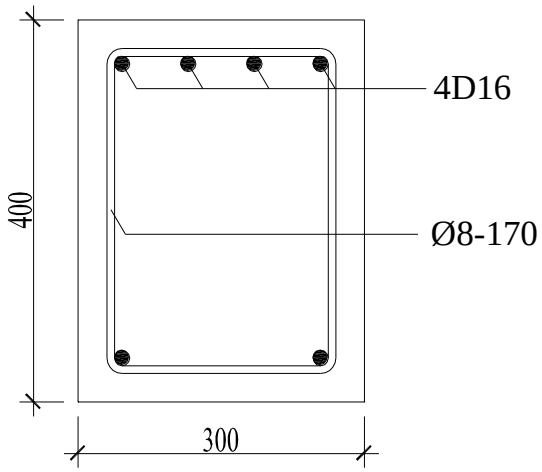
- Kontrol susunan penulangan *tie beam* :

  Dengan, jarak antar tulangan direncanakan = 25 mm

  b_{perlu} = (4 x Tul. pokok) + (2 x Selimur beton) + (2 x Tul. sengkang) + (3 x Jarak antar tulangan) < b

  = (4 . 16 mm) + (2 . 30 mm) + (2 . 8 mm) + (3 . 25 mm) < 300 mm

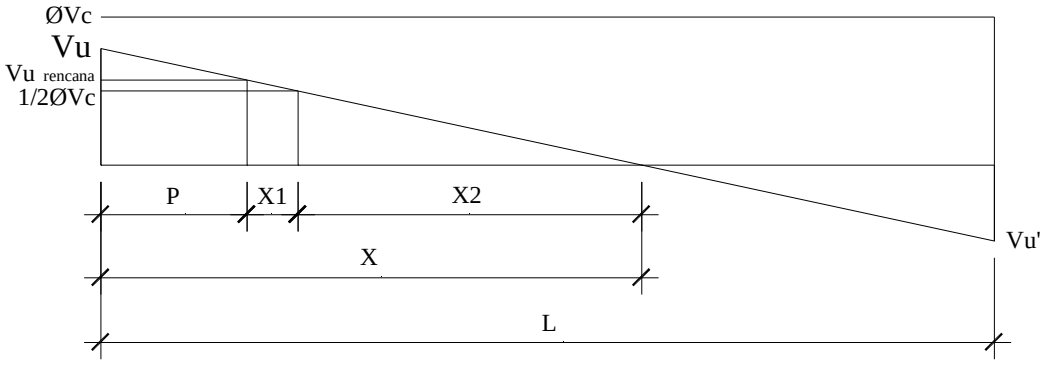
  = 215 mm < 300 mm (Oke) $\longrightarrow$ Dapat Dibuat 1 Lapis



Gambar 3.62 Tulangan Tumpuan *Tie beam* Arah Melintang

3. Penulangan Geser

Tumpuan tulangan bagian luar :



Gambar 3.63 Penentuan $Vu_{rencana}$ Penulangan Geser

Diketahui:

Vu = 71,11 kN

Vu'= 46,86 kN

Ukuran kolom = 400 x 600 mm^2

P = d + ½ . b kolom

= 354 mm + 600 mm

= 654 mm

$$X = \frac{Vu}{Vu + Vu'} \cdot L$$

$$= \frac{71{,}11\ kN}{71{,}11\ kN + 46{,}86\ kN} \cdot 4{,}75\ m$$

= 2,863 m

$$Vu_{rencana} = \frac{Vu \cdot (X - P)}{X}$$

$$= \frac{71{,}11\ kN \cdot (2{,}863\ m - 0{,}654\ m)}{2{,}863\ m}$$

= 54,866 kN

$$= \frac{Vu\ rencana}{b \cdot d}$$

$$= \frac{54{,}866 \cdot 10^3\ N}{300\ mm \cdot 354\ mm}$$

= 0,516 N/mm^2

$\emptyset Vc = \emptyset \cdot \frac{1}{6} \cdot \sqrt{fc'}$

$= 0{,}75 \cdot \frac{1}{6} \cdot \sqrt{25}$

$= 0{,}625\ N/mm^2$

$½\ \emptyset Vc = \frac{\emptyset Vc}{2}$

$= \frac{0{,}625\ N/mm^2}{2}$

$= 0{,}3125\ N/mm^2$

$Vu_{rencana} < \emptyset Vc$

$0{,}516\ N/mm^2 < 0{,}625\ N/mm^2$(Oke) ⟶ Tidak Perlu Tulangan Geser

$X1 = \frac{(V_{u\ rencana} - 1/2.\emptyset Vc) \cdot (X - P)}{V_{u\ rencana}}$

$= \frac{(0{,}516\ N/mm^2 - 0{,}3125\ N/mm^2) \cdot (2{,}863\ m - 0{,}654\ m)}{0{,}516\ N/mm^2}$

$= 0{,}871\ m$

$X2 = (X - P - X1)$

$= (2{,}863\ m - 0{,}654\ m - 0{,}871\ m)$

$= 1{,}34\ m$

- Jarak Spasi Tulangan Sengkang Sepanjang d = 0,354 m:

Karena ½ ØVc < Vu < ØVc, maka dipakai Av_{min}

$Av_{min} = \frac{1}{3} \cdot \frac{b \cdot s}{f_y}$

$= \frac{1}{3} \cdot \frac{300\ mm \cdot 1000\ mm}{240\ N/mm^2}$

$= 416{,}667\ mm^2$

$Av_1 = 2 \cdot \frac{1}{4} \cdot \pi \cdot d^2$

$= 2 \cdot \frac{1}{4} \cdot \pi \cdot 8^2\ mm^2$

$= 100{,}53\ mm^2$

$S = \frac{Av_1}{Av_{per\ meter}}$

$= \frac{100{,}53\ mm^2}{416{,}667\ mm^2/meter}$ x 1000

= 241,271 mm ~ 240 mm

$S_{maks} = \frac{d}{2}$ atau 600 mm

$S_{maks} = \frac{d}{2}$

$= \frac{354\ mm}{2}$

= 177 mm ~ 170 mm

Karena nilai S > S_{maks}, maka dipakai S sebesar S_{maks} = 170 mm

- Jarak Spasi Tulangan Sengkang Sepanjang X1 = 0,871 m:

Karena ½ ØVc < Vu < ØVc, maka dipakai Av_{min}

$Av_{min} = \frac{1}{3} . \frac{b . s}{f_y}$

$= \frac{1}{3} . \frac{300\ mm . 1000\ mm}{240\ N/mm^2}$

= 416,667 mm^2

$Av_1 = 2 . \frac{1}{4} . \pi . d^2$

$= 2 . \frac{1}{4} . \pi . 8^2\ mm^2$

= 100,53 mm^2

$S = \frac{Av_1}{Av_{per\ meter}}$

$= \frac{100{,}53\ mm^2}{416{,}667\ mm^2/meter}$ x 1000

= 241,271 mm ~ 240 mm

$S_{maks} = \frac{d}{2}$ atau 600 mm

$S_{maks} = \frac{d}{2}$

$= \frac{354\ mm}{2}$

= 177 mm ~ 170 mm

Karena nilai S > S_{maks}, maka dipakai S sebesar S_{maks} = 170 mm

- Jarak Spasi Tulangan Sengkang Sepanjang X2 = 1,34 m:

Karena ½ ØVc < Vu < ØVc, maka dipakai Av_{min}

$Av_{min} = \frac{1}{3} . \frac{b . s}{f_y}$

$= \frac{1}{3} . \frac{300\ mm . 1000\ mm}{240\ N/mm^2}$

$= 416{,}667\ mm^2$

$Av_1 = 2 . \frac{1}{4} . \pi . d^2$

$= 2 . \frac{1}{4} . \pi . 8^2\ mm^2$

$= 100{,}53\ mm^2$

$S = \frac{Av_1}{Av_{per\ meter}}$

$= \frac{100{,}53\ mm^2}{416{,}667\ mm^2/meter}$ x 1000

$= 241{,}271\ mm \sim 240\ mm$

$S_{maks} = \frac{d}{2}$ atau 600 mm

$S_{maks} = \frac{d}{2}$

$= \frac{354\ mm}{2}$

$= 177\ mm \sim 170\ mm$

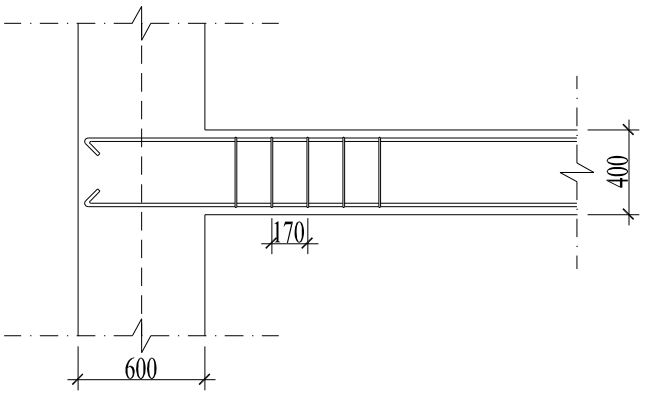
Karena nilai $S > S_{maks}$, maka dipakai S sebesar $S_{maks} = 170$ mm

- Kesimpulan

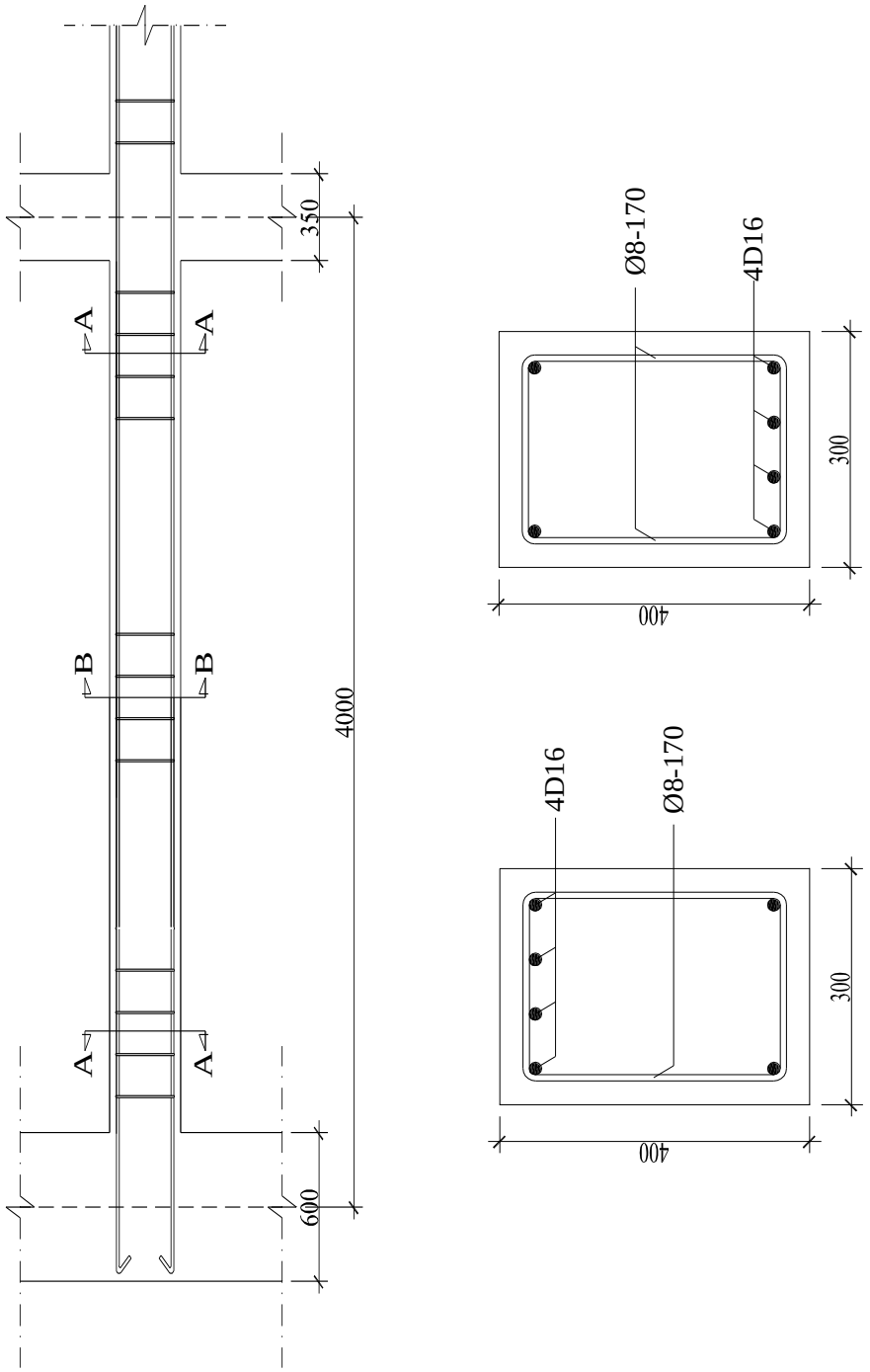
Jadi, sepanjang d = 0,354 m ⟶ Ø8 - 170 mm

Jadi, sepanjang X1 = 0,228 m ⟶ Ø8 - 170 mm

Jadi, sepanjang X2 = 1,54 m ⟶ Ø8 - 170 mm



Gambar 3.64 Jarak Sengkang *Tie beam* Arah Melintang



Gambar 3.65 Penulangan *Tie beam* Arah Melintang

3.8 Perhitungan Pondasi

- Diketahui data-data sebagai berikut:

  Mutu Beton = fc' 25 Mpa

  Mutu Baja = BJ 37

  Kedalaman Pondasi = 1,4 m

  Tebal Pondasi = 0,35 m

  Selimut Beton (p) = 50 mm

  γ beton (γc) = 24 kN/m^3

  γ tanah (γm) = 19,5 kN/m^3

  q_c pada Kedalaman 1,1 m = 31,91 kg/cm^2

3.8.1 Perhitungan Pembebanan

1) Beban Portal
   - Gaya Vertikal ⟶ P_D = 46,880 kN
     P_L = 11,984 kN
   - Gaya Horizontal ⟶ H_D = 9,261 kN
     H_L = 3,231 kN
2) Beban Tie beam = 0,3 m . 0,4 . 5,0 m . 24 kN/m^3 = 14,4 kN
3) Berat Dinding
   - Bata ½ Batu = 5,0 m . 7,375 m . 2,5 kN/m^2 = 92,187 kN
   - Berat Plesteran = (5,0 m . 7,375 m . 0,21 kN/m^2) . 3 = 23,231 kN
4) Berat Kolom Baja = 5,875 m . 1,37 kN/m = 8,049 kN
5) Berat Kolom Beton = 1,5 m . 0,4 m . 0,6 m . 24 kN/m^3 = 8,64 kN
6) Berat Pondasi = 1,5 m . 1,5 m . 0,20 m . 24 kN/m^3 = 10,8 kN
7) Berat Tanah = 1,5 m . 1,5 m . 0,7 m . 19,5 kN/m^3 = 30,712 kN

Beban Total:

P = 46,880 kN + 11,984 kN + 14,4 kN + 92,187 kN + 23,231 kN + 8,049 kN + 8,64 kN + 10,8 kN + 30,712 kN

= 246,883 kN

H = 9,261 kN + 3,231 kN

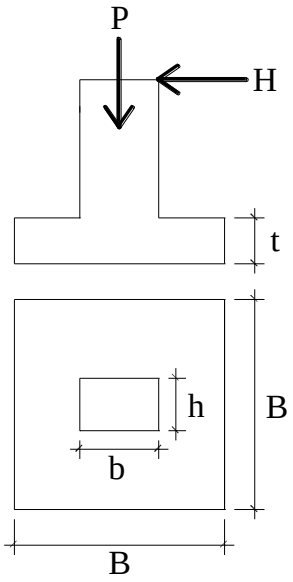
= 12,492 kN

Mx = 0 kN.m

My = H . h

= 12,492 kN . 1,4 m

= 17,488 kN.m



Gambar 3.66 Pondasi Tapak

3.8.2 Menghitung Dimensi Pondasi

1. Daya Dukung Ijin Tanah

Nilai q_c pada Kedalaman 1,4 m = 31,91 kg/cm^2

Direncanakan pondasi bujur sangkar.

$q_{ult} = 5 + 0{,}34 \,.\, (q_c)^2$

$= 5 + 0{,}34 \,.\, (31{,}91 \text{ kg/cm}^2)^2$

$= 15{,}849 \text{ kg/cm}^2$

$= 1584{,}9 \text{ kN/m}^2$

$q_{all} = \frac{q_{ult}}{F}$

$= \frac{1584{,}9 \text{ kN/m}^2}{2{,}5}$

$= 633{,}96 \text{ kN/m}^2$

Mx = 0 kN.m

My = H . h

= 12,492 kN . 1,4 m

= 17,488 kN.m

Agar pada pelat kondisi bekerja tegangan sejenis (tekan), maka ex < $\frac{B}{6}$:

ex = $\frac{M_y}{P}$

= $\frac{17{,}488\ \text{kN.m}}{217{,}963\ \text{kN}}$

= 0,0802 m

ex < $\frac{B}{6}$

0,0802 m < $\frac{B}{6}$

B > 0,0802 m . 6 = 0,481 m

2. Tegangan Netto Ijin Tanah:

Tegangan ijin tanah = 633,96 kN/m^2

Berat sendiri pondasi = (0,35 m . 24 kN/m^3) = 8,4 kN/m^2

Berat pasir urug = (0,05 m . 18 kN/m^3) = 0,9 kN/m^2

Berat lantai kerja = (0,05 m . 22 kN/m^3) = 1,1 kN/m^2 -

σ ijin = 623,56 kN/m^2

$\sigma = \frac{P}{A}\left(1 \pm \frac{6\,.\,ex}{B}\right)$

623,56 kN/m^2 = $\frac{246{,}883\ \text{kN}}{B^2}\left(1 \pm \frac{6\,.\,0{,}0802\ \text{m}}{B}\right)$

623,56 kN/m^2 = $\frac{246{,}883\ \text{kN}}{B^2} \pm \frac{247{,}575\ \text{kN.m}}{B^3}$

B^3 – 0,396 B ± 0,397 = 0

B^3 – 0,396 B + 0,397 = 0

B1 = -0,924 m

B2 = 0,927 m

B3 = -0,003 m

B^3 – 0,396 B – 0,397 = 0

B1 = 0,924 m

B2 = -0,003 m

B3 = 0,927 m

Jadi diambil B sebesar 0,927 m ~1,5 m

3. Kontrol Tegangan Netto Ijin Tanah

$\sigma_{1,2} = \frac{P}{A}\left(1 \pm \frac{6\,.\,ex}{B}\right)$

$\sigma_1 = \frac{P}{A}\left(1 + \frac{6 \,.\, ex}{B}\right)$

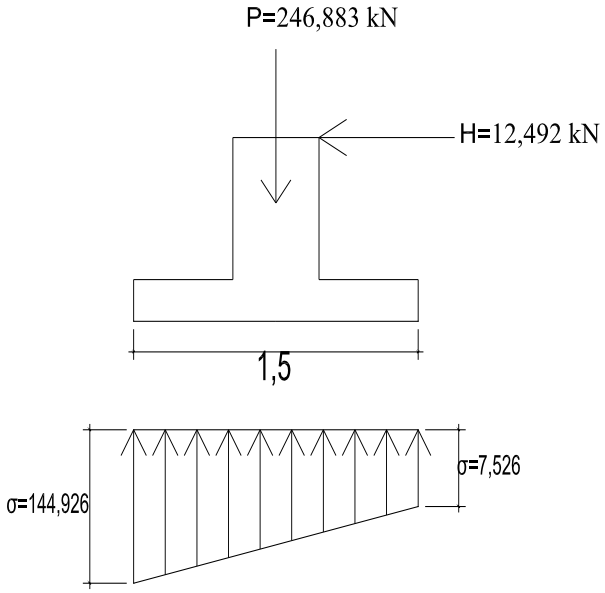
$= \frac{246{,}883 \text{ kN}}{1{,}5^2 \text{ m}^2}\left(1 + \frac{6 \,.\, 0{,}0802 \text{ m}}{1{,}5 \text{ m}}\right)$

$= 144{,}926 \text{ kN/m}^2 < \sigma \text{ ijin} = 623{,}56 \text{ kN/m}^2$ (Oke)

$\sigma_2 = \frac{P}{A}\left(1 - \frac{6 \,.\, ex}{B}\right)$

$= \frac{26{,}883 \text{ kN}}{1{,}5^2 \text{ m}^2}\left(1 - \frac{6 \,.\, 0{,}0802 \text{ m}}{1{,}5 \text{ m}}\right)$

$= 7{,}526 \text{ kN/m}^2 < \sigma \text{ ijin} = 623{,}56 \text{ kN/m}^2$ (Oke)



Gambar 3.67 Diagram Tegangan Kontak

4. Tegangan Netto Ijin Tanah Akibat Beban Terfaktor

Pu = (1,2 . 46,880 kN + 1,6 . 11,984 kN) + 1,2 . (14,4 kN + 92,187 kN + 23,231 kN + 8,049 kN + 8,64 kN + 10,8 kN + 30,712 kN)

= 301,053 kN

Hu = (1,2 . 9,261 kN + 1,6 . 3,231 kN) 9,261 kN + 3,231 kN

= 16,283 kN

$\sigma_{u \text{ netto } 1} = \frac{P_u}{B \,.\, B} + \frac{6 \,.\, H_u \,.\, 2{,}15}{B \,.\, B^2}$

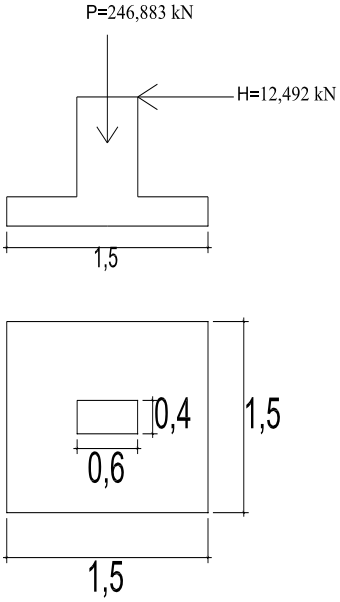
$= \frac{301{,}053}{1{,}5 \,.\, 1{,}5} + \frac{6 \,.\, 16{,}283 \,.\, 2{,}15}{1{,}5 \,.\, 1{,}5^2}$

$= 196{,}038 \text{ kN/m}^2$

$$\sigma_{u\ \text{netto 2}} = \frac{P_u}{B\ .\ B} - \frac{6\ .\ H_u\ .\ 2{,}15}{B\ .\ B^2}$$

$$= \frac{301{,}053\ \text{kN}}{1{,}6\ .\ 1{,}6} - \frac{6\ .\ 16{,}283\ \text{kN}\ .\ 2{,}15}{1{,}6\ .\ 1{,}6^2}$$

$$= 71{,}564\ \text{kN/m}^2$$



Gambar 3.68 Ukuran Pondasi Tapak

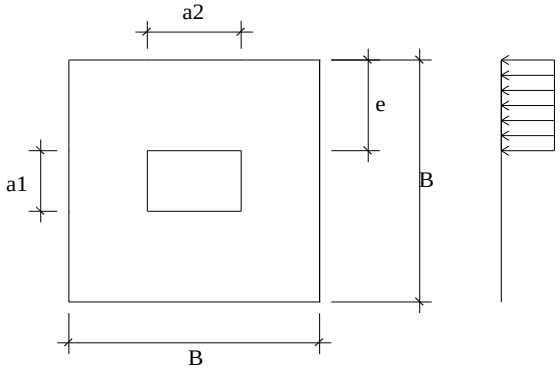
Arah L ⟶ L = B

$$V_u = \frac{\sigma_u\text{netto 1} + \sigma_u\text{netto 2}}{2} . \left(\frac{L - a}{2} - d\right) . 1{,}5$$

$$= \frac{196{,}038\ \text{kN/m}^2 + 71{,}564\ \text{kN/m}^2}{2} . \left(\frac{1{,}5\ \text{m} - 0{,}5\ \text{m}}{2} - 0{,}292\ \text{m}\right) . 1{,}5$$

$$= 41{,}746\ \text{kN}$$

Momen Lentur



Gambar 3.69 Momen Lentur Terhadap Pelat

$$M_u = \left(\frac{1}{2} \cdot q_5 \cdot + \frac{(q_1 - q_5) \cdot \left(\frac{B-a}{2}\right)}{2} \text{ x } \frac{2}{3} \cdot \left(\frac{B-a}{2}\right) \right) \cdot B$$

$$= \left(\frac{1}{2} \cdot q_5 \cdot (0{,}5 \text{ m})^2 + \frac{1}{3} \cdot (q_1 - q_5) \cdot (0{,}5 \text{ m})^2 \right) \cdot B$$

$$q_5 = \frac{q_1 \left(\frac{B-a}{2}\right) + q_2 \left(\frac{B-a}{2}\right)}{B}$$

$$= \frac{196{,}038 \text{ kN/m}^2 \cdot \left(\frac{1{,}5 + 0{,}5}{2}\right) + 71{,}564 \text{ kN/m}^2 \cdot \left(\frac{1{,}5 - 0{,}5}{2}\right)}{1{,}5}$$

$$= 154{,}547 \text{ kN}$$

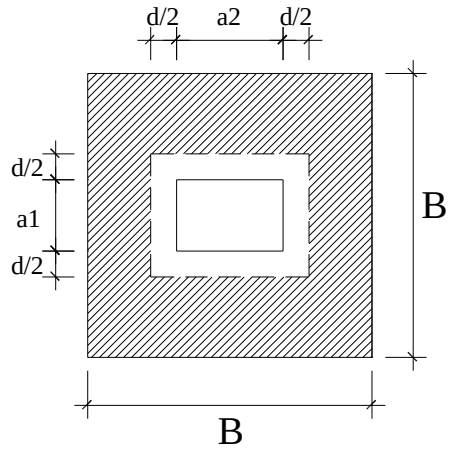
$$M_u = \left(\frac{1}{2} \cdot q_5 \cdot \left(\frac{B-a}{2}\right)^2 + \frac{1}{3} \cdot (q_1 - q_5) \cdot \left(\frac{B-a}{2}\right)^2 \right) \cdot B$$

$$= \left(\frac{1}{2} \cdot 154{,}547 \cdot (0{,}5)^2 + \frac{1}{3} \cdot (196{,}038 - 154{,}547) \cdot (0{,}5)^2 \right) \cdot 1{,}5$$

$$= 34{,}164 \text{ kN.m}$$

3.8.3 Kontrol Kuat Geser

1. Untuk Aksi 2 Arah



Gambar 3.70 Kontrol Tebal Pelat (Terhadap Geser Dua Arah)

Direncanakan pondasi menggunakan diameter tulangan sebesar D16 mm

Tinggi efektif:

$$d = h - p - \frac{1}{2} D$$

$$= 350 \text{ mm} - 50 \text{ mm} - \frac{1}{2} \cdot 16 \text{ mm}$$

$$= 292 \text{ mm}$$

σ_u netto rata-rata = $\frac{\sigma_u \text{netto } 1 + \sigma_u \text{netto } 2}{2}$

$= \frac{196{,}038 \ \text{kN/m}^2 + 71{,}564 \ \text{kN/m}^2}{2}$

$= 133{,}801 \ \text{kN/m}^2$

$V_u = \sigma_u \text{netto rata} - \text{rata } ((B \,.\, B) - (a_1 + d) \,.\, (a_2 + d))$

$= 133{,}801 \ \text{kN/m}^2 \,.\, ((1{,}5^2 \text{m}^2) - (0{,}40 \text{ m} + 0{,}292 \text{ m}).(0{,}50 \text{ m} + 0{,}292 \text{ m}))$

= 227,721 kN

$V_C = \left[1 + \frac{2}{\beta_c}\right] . \frac{\sqrt{fc'} \,.\, b_o \,.\, d}{6}$

Dengan,

$b_o = 2 \,.\, (600 + 246{,}032) + (400 + 246{,}032)$

$= 2338{,}096$ mm

$V_C = \left[1 + \frac{2}{1{,}5}\right] . \frac{\sqrt{25} \ \text{N/mm}^2 \,.\ 2338{,}096 \text{ mm} \,.\, 292 \text{ mm}}{6} . 10^{-3}$

$= 1327{,}519$ kN

$V_C = \frac{1}{3} \,.\sqrt{fc'} \,.\, b_o \,.\, d$

$= \frac{1}{3} \,.\sqrt{25} \ \text{N/mm}^2 .\ 2338{,}096 \text{ mm} \,.\ 292 \text{ mm} \,.\, 10^{-3}$

$= 1137{,}873$ kN

$V_C = \left(\frac{as \,.\, d}{b_o} + 2\right)\left(\frac{\sqrt{fc'} . b_o \,.\, d}{12}\right)$

Dengan nilai as untuk kolom sudut sebesar 20

$V_C = \left(\frac{20 \,.\, 292 \text{ mm}}{2338{,}096 \text{ mm}}\right)\left(\frac{\sqrt{25} \ \text{N/mm}^2 .\ 2338{,}096 \text{ mm} \,.\ 292 \text{ mm}}{12}\right) . 10^{-3}$

$= 710{,}533$ kN ⟶ Diambil Terkecil

$\emptyset Vc = 0{,}75 \,.\, V_c$

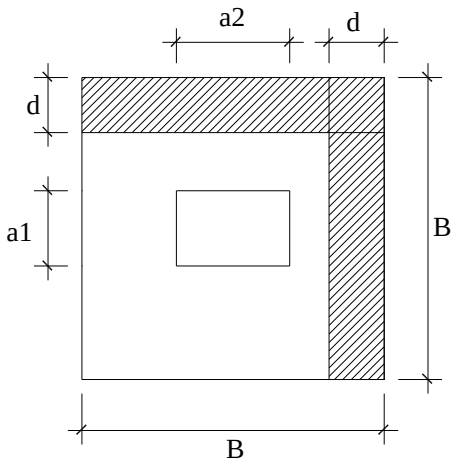
= 0,75 . 710,533 kN

= 532,899 kN

$\emptyset V_C > Vu$

532,899 kN > 227,721 kN (Oke)

2. Untuk Aksi Satu Arah



Gambar 3.71 Kontrol Tebal Pelat (Terhadap Geser Satu Arah)

Arah B Kolom

$$X = \left(\frac{B - a}{2}\right) - d$$

$$= \left(\frac{1{,}5\ \text{m} - 0{,}5\ \text{m}}{2}\right) - 0{,}292\ \text{m}$$

$$= 0{,}208\ \text{m}$$

$$0{,}5\ \text{m} + 2\ .\ d = 0{,}5\ \text{m} + 2\ .\ 0{,}292\ \text{m}$$

$$= 1{,}084\ \text{m}$$

Gaya Geser Total pada Penampang Kritis

$$\sigma_u\text{netto } 3 = \frac{\sigma_u\text{netto } 1\left(\left(\frac{B - a}{2} - d\right) + (0{,}6\ \text{m} + 2d)\right) + \sigma_u\text{netto } 2\left(\frac{B - a}{2} - d\right)}{B}$$

$$= \frac{196{,}038\ \text{kN/m}^2.\left((0{,}208\ \text{m}) + (1{,}084\ \text{m})\right) + 71{,}564\ \text{kN/m}^2.(0{,}208\ \text{m})}{1{,}5\ \text{m}}$$

$$= 178{,}778\ \text{kN}$$

$$\sigma_u\text{netto } 4 = \frac{\sigma_u\text{netto } 1\left(\frac{B - a}{2} - d\right) + \sigma_u\text{netto } 2\left(\left(\frac{B - a}{2} - d\right) + (0{,}6\ \text{m} + 2d)\right)}{B}$$

$$= \frac{196{,}038\ \text{kN/m}^2.(0{,}208\ \text{m}) + 71{,}564\ \text{kN/m}^2.\left((0{,}208\ \text{m}) + (1{,}084\ \text{m})\right)}{1{,}5\ \text{m}}$$

$$= 88{,}824\ \text{kN}$$

$$Vu = \frac{\sigma_u\text{netto } 3 + \sigma_u\text{netto } 1}{2}\ .\ X\ .\ B$$

$$= \frac{178{,}778\ \text{kN/m}^2 + 196{,}038\ \text{kN/m}^2}{2}.\ 0{,}208\ \text{m}\ .1{,}5\ \text{m}$$

$$= 58{,}471\ \text{kN}$$

$$\text{Vc} = \frac{1}{6}\sqrt{f_{c'}}.\ \text{B.d}$$

$$= \frac{1}{6}\sqrt{25}\ \text{N/mm}^2.1600\ \text{mm}\ .292\ \text{mm}\ .10^{-3}$$

$$= 389{,}3\ \text{kN}$$

$$\emptyset\text{Vc} = 0{,}75\ .389{,}3\ \text{kN}$$

$$= 291{,}975\ \text{kN}$$

$$\emptyset\text{Vc} > \text{Vu}$$

$291{,}975\ \text{kN} > 58{,}471\ \text{kN}$ (Oke)

Tebal pelat terhadap geser dua arah dan satu arah Oke, sehingga tebal pelat mencukupi untuk memikul gaya geser tanpa memerlukan tulangan geser.

3.8.4 Penulangan Pondasi

$$\frac{M_u}{\emptyset\ .\ b\ .\ d^2} = \rho\ .f_y\left(1 - \frac{\rho\ .f_y}{1{,}7\ .f_c'}\right)$$

$$\frac{34{,}164\ .10^6\ \text{N.mm}}{0{,}8\ .1600\ .292^2} = \rho.240\ \text{N/mm}^2.\left(1 - \frac{\rho\ .240\ \text{N/mm}^2}{1{,}7\ .25\ \text{N/mm}^2}\right)$$

$$0{,}313 = 240.\rho - 1115{,}3\ .\ \rho^2$$

$$1115{,}3\ .\rho^2 - 240.\rho + 0{,}313 = 0\ \ 768{,}061\ \rho^2 - 192\ \rho + 1{,}48 = 0$$

Rumus abc :

$$\rho_{1,2} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\rho_{1,2} = \frac{-(-240) \pm \sqrt{-240^2 - 4(1115{,}3\ \text{x}\ 0{,}313)}}{2(1115{,}3)}$$

$$\rho_{1,2} = \frac{240 \pm 237{,}073}{2230{,}6}$$

$$\rho_1 = \frac{240 + 237{,}073}{2230{,}6} = 0{,}214$$

$\rho_2 = \frac{240 - 237{,}073}{2230{,}6} = 0{,}00131$ (diambil ρ terkecil)

$\rho = 0{,}00131$

$\rho_{min} = \frac{1{,}4}{f_y}$ atau $\frac{\sqrt{fc'}}{4 \, . \, f_y}$

$\rho_{min} = \frac{1{,}4}{f_y} = \frac{1{,}4}{240} = 0{,}00583$ (Diambil Terbesar)

$\rho_{min} = \frac{\sqrt{f_c'}}{4 \, . \, f_y} = \frac{\sqrt{25}}{4 \, . \, 240} = 0{,}00521$

$\rho_{maks} = \frac{0{,}75 \, . \, 0{,}85 \, . \, fc' \, . \, \beta_1}{f_y} \left(\frac{600}{600 + f_y} \right)$

$= \frac{0{,}75 \, . \, 0{,}85 \, . \, 25 \, . \, 0{,}85}{240} \left(\frac{600}{600 + 240} \right)$

$= 0{,}04032$

Karena $\rho < \rho_{min}$, maka ρ diambil sebesar $\rho_{min} = 0{,}00583$

$As_{perlu} = \rho_{min} \, . \, 1600 \text{ mm} \, . \, d$

$= 0{,}00583 \, . \, 1600 \text{ mm} \, . \, 292 \text{ mm}$

$= 2723{,}776 \text{ mm}^2$

$A_{s1} = \frac{1}{4} \, . \pi . \, D^2$

$= \frac{1}{4} . \pi . \, 16^2 \text{mm}^2$

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

$S = \frac{A_{s1}}{A_s} . \, 1600 \text{ mm}$

$= \frac{201{,}062 \text{ mm}^2}{2723{,}776 \text{ mm}^2} . \, 1600 \text{ mm}$

$= 118{,}107 \text{ mm} \sim 200 \text{ mm}$

Jadi, dipakai tulangan D16-200 mm

3.8.5 Perhitungan Tulangan Pasak

$\emptyset P_n = \emptyset \, . \, 0{,}85 \, . \, fc' . \, Ag$

$= 0{,}65 . \, 0{,}85 . \, 25 \text{N/mm}^2 \, . \, 400 \text{ mm} \, . \, 500 \text{ mm} \, . \, 10^{-3}$

= 3315 kN

$\emptyset P_n > Pu$

3315 kN > 301,053 kN (Oke)

As_{min} = 0,005 . Ag

= 0,005. 400 mm . 600 mm

= 1200 mm^2

$$n = \frac{As}{1/4 \,.\, \pi \,.\, d^2}$$

$$= \frac{1200\ mm^2}{1/4 \,.\, \pi \,.\, 16^2\ mm^2}$$

= 5,968 bh ~ 20 bh

Jadi, dipakai tulangan pasak 20D16

1. Kontrol Panjang Penyaluran Tulangan Pasak

Tulangan pasak harus disalurkan diatas dan dibawah pertemuan kolom dan telapak pondasi.

$$Ldb = 0{,}25 \,.\, fy \,.\, \frac{\text{diameter baut}}{\sqrt{fc}} \geq 0{,}04 \,.\, fy \,.\, \text{diameter baut}$$

$$= 0{,}25 \,.\, 240\ N/mm^2 . \frac{16\ mm}{\sqrt{25} N/mm^2} \geq 0{,}04 \,.\, 240\ N/mm^2 . 16\ mm$$

= 192 mm > 153,6 mm (Oke)

2. Panjang yang Tersedia

L_1 = h – p – (2ø tulangan pondasi) - ø tulangan besi pasak

= 350 mm – 50 mm – (2 . 16 mm) – 16 mm

= 252 mm

L_1 > Ldb

252 mm > 192 mm (Oke)