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Perencanaan Portal Pada Pembangunan ruko Ex Kota Julian
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Bab IV
Perencanaan Struktur Portal

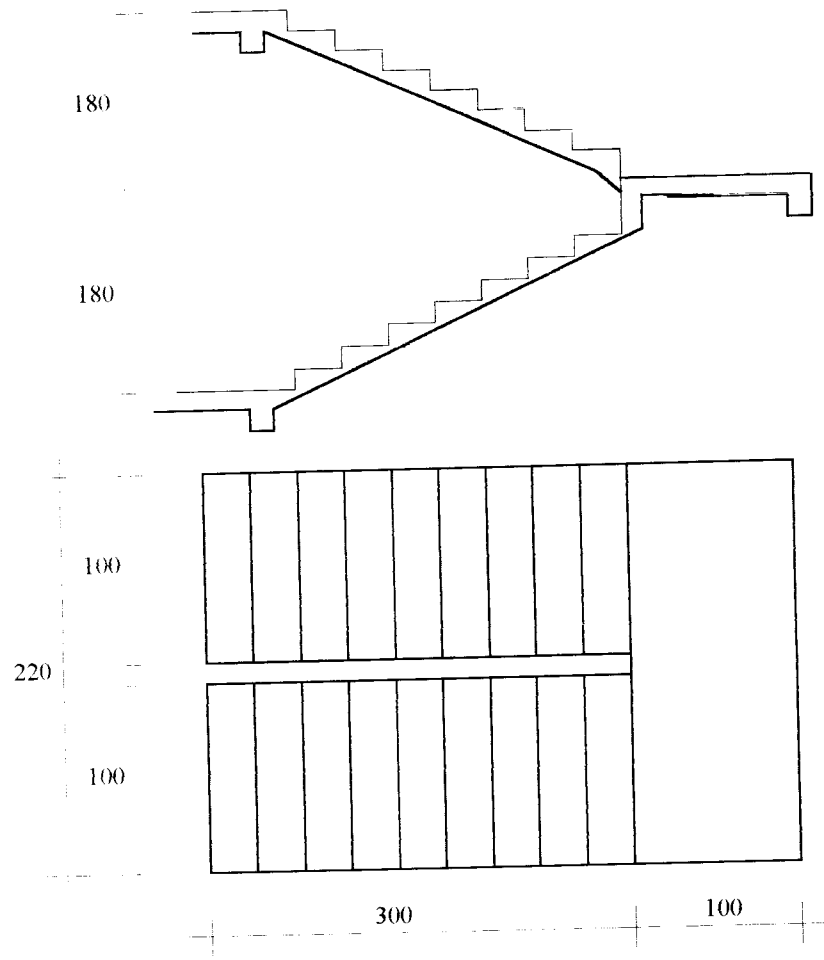
PROGRAM D III TEKNIK SIPIL
JURUSAN PENDIDIKAN TEKNIK BANGUNAN
FAKULTAS PENDIDIKAN TEKNIK DAN KEJURUAN
UNIVERSITAS PENDIDIKAN INDONESIA
2005

BAB IV

PERENCANAAN KONSTRUKSI PORTAL

4.1 Perencanaan Kontruksi Tangga

4.1.1 Ketentuan – ketentuan Tangga



Gambar 4.1 Denah Tangga

- Perbedaan ketinggian antara dua lantai = h = 360 cm
- Jumlah Optrede n_{opt} = (h/18) = 360/18 =20 buah
- Tinggi Optrede = (h/n_{opt}) cm = 360/20 =18 cm
- Tebal plat tangga dan bordes = 15 cm
- Lebar tangga = 2x100 cm

- Panjang datar tangga = 300 cm
- Tinggi bordes h_0 = 360/2 = 180 cm
- Kemiringan tangga, $\alpha = tg^{-1}(180/300) = 30{,}96^0$
- Menentukan antrede sesuai syarat tangga yaitu 57 – 65 cm

  (2 x Opt) + antrede = 65

  (2 x 18,0) + antrede = 65

  Antrede = 65 – (2 x 18) = 29 cm

  Panjang miring tangga $AB = \sqrt{ho^2 + pdt^2} = \sqrt{180^2 + 360^2} = 40{,}25$ Cm

  Panjang miring anak tangga $A = \sqrt{o^2 + a^2} = \sqrt{18^2 + 300^2} = 34{,}985$ Cm

4.1.2 Perhitungan kontruksi tangga

A. Pembebanan

Pembebanan tangga

- Beban Mati :

  Plat tangga = 0,15 .(1/cos 30,96) . 1,0 .24 = 4,201 KN/m

  Trede = (1/2 . 1 . 0,29 . 0,18 . 24) . (1/cos 30,96)

  = 0,731 Untuk 1 m terdapat anak tangga

  100/20 = 5 bh

  Maka : 5 x 0,731 = 3,655 KN/m

  Keramik 0,5 cm = 0,005. 0,17. 1 = 0,0008 KN/m

  Spesi 1 cm = 0,17 . 0,01 .1 = 0,0017 KN/m

  Berat sandaran = 0,250 KN/m

  $W_{DL\,1}$ = 8,1085 KN/m

- Beban hidup untuk tangga :

  $W_{LL\,1} = 3 \cdot 1{,}0 = 3$ KN/m^2

- Beban tangga terfaktor :

  $Wu_1 = 1{,}2\ W_{DL\,1} + 1{,}6\ W_{LL\,1}$

  $Wu_1 = 1{,}2 \cdot 8{,}1085 + 1{,}6 \cdot 3 = 14{,}53$ KN/m

Pembebanan bordes

- Beban Mati :

Plat bordes	= 0,15 . 1 . 24	= 3,60 KN/m
Keramik 0,5 cm	= 0,005 . 0,21 . 1	= 0,001 KN/m
Spesi 1 cm	= 0,01 . 0,17 . 1	= 0,002 KN/m
	$W_{DL\,2}$	= 3,603 KN/m

- Beban hidup untuk tangga :

  $W_{LL\,2} = 3 . 1 = 3$ KN/m^2

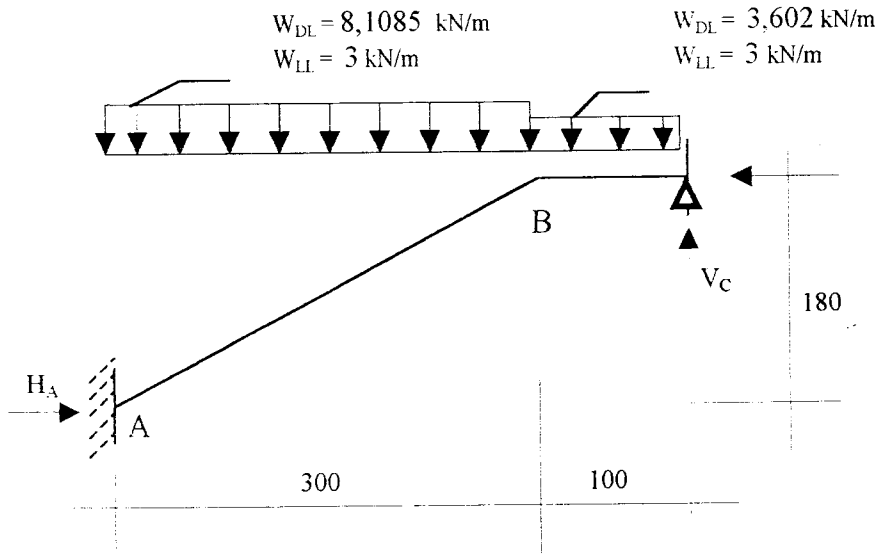
- Beban tangga terfaktor :

  $Wu_2 = 1{,}2\ W_{DL\,1} + 1{,}6\ W_{LL\,1}$

  $Wu_2 = 1{,}2 . 3{,}603 + 1{,}6 . 3 = 9{,}123$ kN/m

B. Analisis Struktur Kontruksi Tangga

Dengan Menggunakan Analisis SAP 2000 Versi 7.42.



Gambar 4.2 Pembebanan pada Tangga

SAP2000 v7.42 File: TANGGA DIKS BETUL KN-m Units PAGE 1
2/19/05 5:14
Alkahfi.dept
LOADCOMBINATION MULTIPLIERS
COMB1 ADD COMB1
MATI 1.2000 STATIC(DEAD)
HIDUP 1.6000 STATIC(LIVE)
SAP2000 v7.42 File: TANGGA DIKS BETUL KN-m Units PAGE 2
2/19/05 5:14
Alkahfi.dept
JOINT DISPLACEMENTS

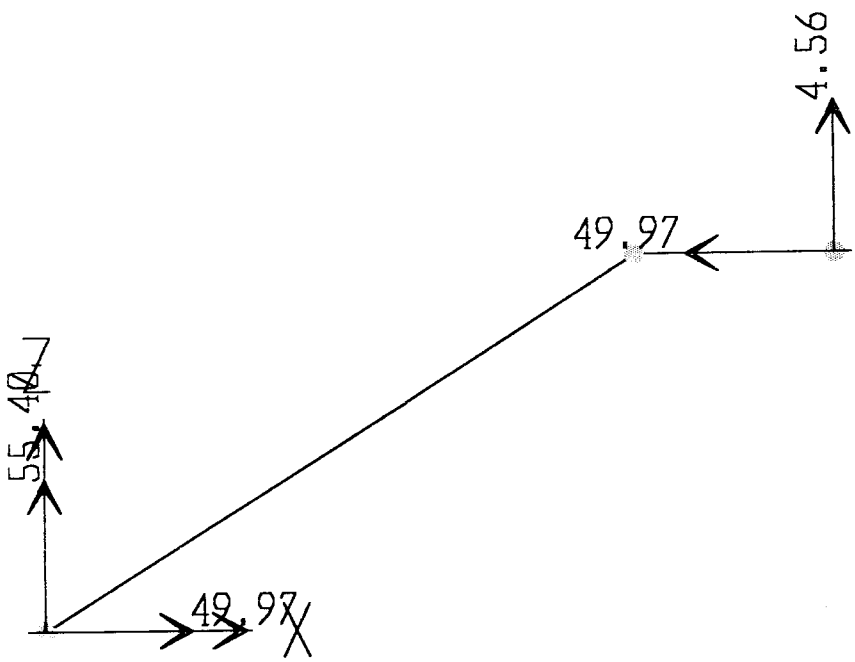
JOINT	LOAD	U1	U2	U3	R1	R2	R3
1	MATI	0	0	0	0	0	0
1	HIDUP	0	0	0	0	0	0
1	COMB1	0	0	0	0	0	0
2	MATI	7.56E+16	0	-7.25E+17	0	0	0
2	HIDUP	3.19E+16	0	-3.06E+17	0	0	0
2	COMB1	1.42E+17	0	-1.36E+18	0	0	0
3	MATI	0	0	0	0	0	0
3	HIDUP	0	0	0	0	0	0
3	COMB1	0	0	0	0	0	0

JOINT REACTIONS

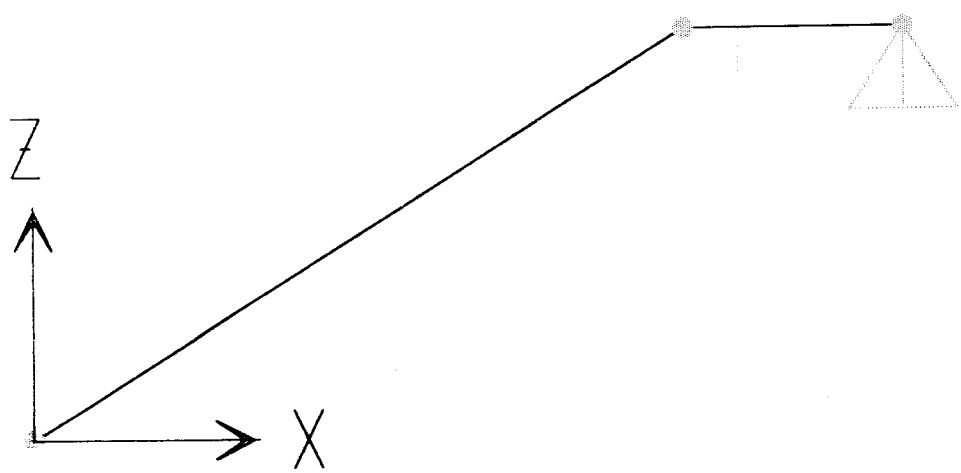
JOINT	LOAD	F1	F2	F3	M1	M2	M3
1	MATI	26.6426	0	30.1697	0	0	0
1	HIDUP	11.2464	0	11.9957	0	0	0
1	COMB1	49.9654	0	55.3967	0	0	0
3	MATI	-26.6426	0	1.8015	0	0	0
3	HIDUP	-11.2464	0	1.5	0	0	0
3	COMB1	-49.9654	0	4.5618	0	0	0

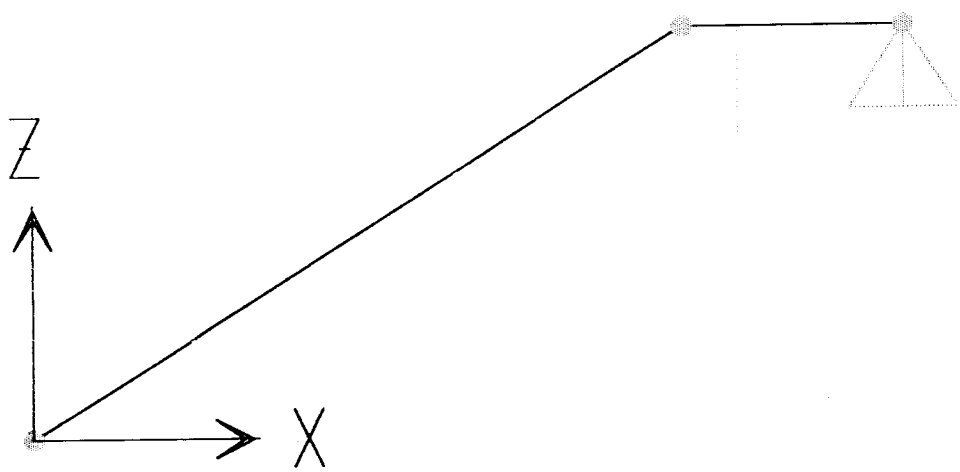
FRAME ELEMENT FORCES

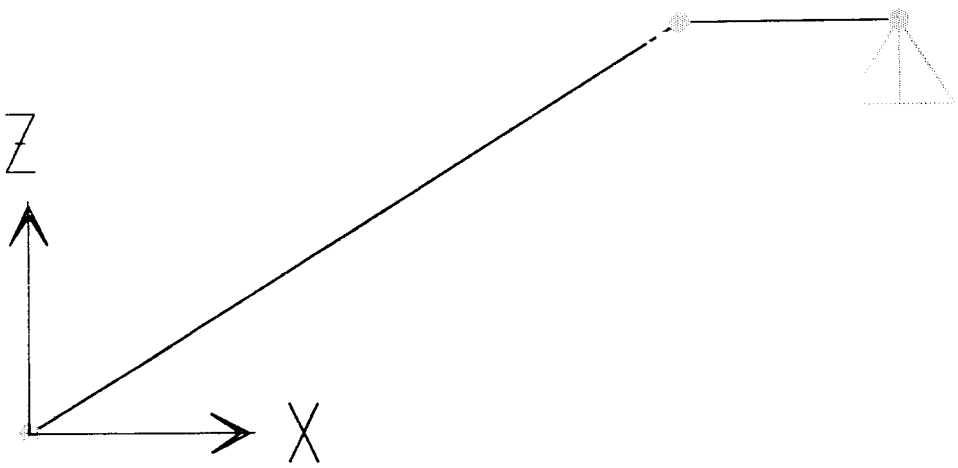
FRAME	LOAD	LOC	P	V2	V3	T	M2	M3
1	MATI							
		0	-38.37	-12.16	0	0	0	0
		1.75	-31.07	0	0	0	0	10.64
		3.5	-23.77	12.16	0	0	0	0
1	HIDUP							
		0	-15.82	-4.5	0	0	0	0
		1.75	-13.12	0	0	0	0	3.94
		3.5	-10.42	4.5	0	0	0	0
1	COMB1							
		0	-71.35	-21.8	0	0	0	0
		1.75	-58.27	0	0	0	0	19.06
		3.5	-45.19	21.8	0	0	0	0
2	MATI							
		0	-26.64	-1.8	0	0	0	0
		2.50E-01	-35.64	7.00E-04	0	0	0	3.38E-01
		5.00E-01	-26.64	0	0	0	0	4.50E-01
		7.50E-01	-26.64 9	7.00E-04	0	0	0	3.38E-01
		1	-26.64	1.8	0	0	0	0
2	HIDUP							
		0	-11.25	-1.5	0	0	0	0
		2.50E-01	-18.25	5.00E-02	0	0	0	2.81E-01
		5.00E-01	-11.25	0	0	0	0	3.75E-01
		7.50E-01	-11.25 7	5.00E-02	0	0	0	2.81E-01
		1	-11.25	1.5	0	0	0	0
2	COMB1							
		0	-49.97	-4.56	0	0	0	0
		2.50E-01	-49.97	-2.28	0	0	0	8.55E-01
		5.00E-01	-49.97	0	0	0	0	1.14
		7.50E-01	-49.97	2.28	0	0	0	8.55E-01
		1	-49.97	4.56	0	0	0	0

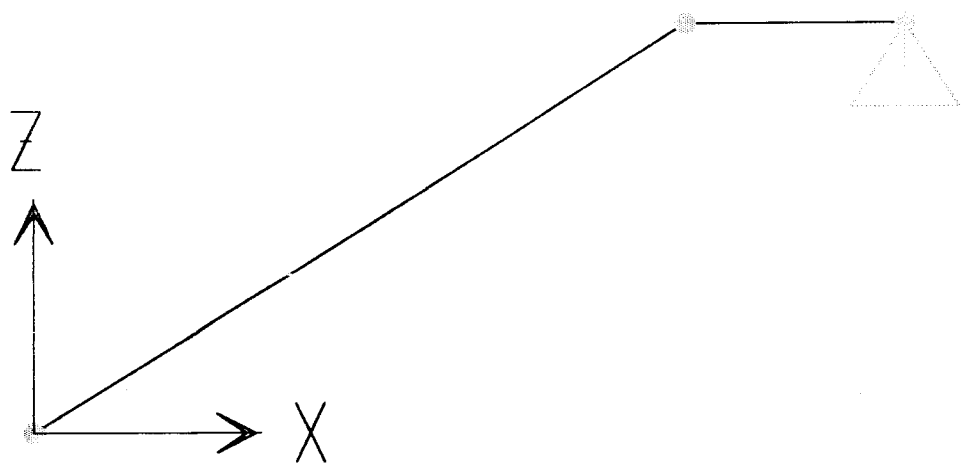


Gambar 4.3 Reaksi Perletakan pada Tangga


Z
X


Z
X


Z
X



Gambar 4.4 Bidang Momen, Gaya Lintang dan Gaya Normal

4.2.3 Perhitungan Tulangan

1. Perhitungan balok tangga

Dimensi balok tangga 15/25

Pembebanan ;

- berat sendiri balok tangga = 0,15 . 0,25 . 24 = 0,90 KN/m

- Beban trapezium plat bordes :

$$q_{ek} = \frac{\left(q\frac{l_x}{3}\right)\left(3-\frac{l_x^2}{l_y^2}\right)}{2} = \frac{\left(9{,}123\frac{1}{3}\right)\left(3-\frac{1^2}{2{,}2^2}\right)}{2} = \underline{4{,}222 \text{ KN/m}}$$

W_u = 5,122 KN/m

W_{LL} = 3 . 1 = 3 KNm

W_U = 1,2 W_{DL} + 1,6 W_{LL} KNm

= 1,2 . 5,122 + 1,6 . 3 = 10,946 KNm

Perhitungan momen dan gaya lintang

Berdasarkan SK SNI T-15-1991-0,3 pasal 3.1.33 perhitungan momen adalah sebagai berikut :

Momen tumpuan :

1/24 . W_u . l^2 = 1/24 . 10,946 . $2{,}2^2$ = 2,207 KNm.

Momen lapangan :

1/16 . W_u . l^2 = 1/16 . 10,946 . $2{,}2^2$ = 3,311 KNm.

Beban Hidup W_{LL}

Perhitungan penulangan akibat lentur :

A. Tulangan tumpuan

M_u = 2,207 KNm.

b = 150 mm

h = 300 mm

p = 25 mm

d = h – p – $Ø_{tul\ sengk}$ – ½ $Ø_{tul\ ut}$

= 250 – 25 – 8 – ½ . 13 = 235,5 mm

ρ_{min} = 0,00583

$Ø_{tul\ sengkang}$ = 8 mm

$Ø_{tul\ ut}$ = 13 mm

ρ_{maks} = 0,03628

$$k_{maks} = \rho_{maks} . f_y . (1 - \frac{0,588.\rho_{maks}.f_y}{f_c})$$

$$k_{maks} = 0,03628 . 240 . (1 - \frac{0,588.0,03628.240}{25}) = 6,924 \text{ Mpa.}$$

$M_{R\ mzks}$ = ø . b . d^2 . k_{maks}

= 0,8 . 150 . $235,5^2$. 6,924 . 10^{-6} = 46,08 KNm.

$M_{R\ maks} > M_u$, maka balok dianalisis sebagai balok bertulang tunggal.

$$k = \frac{Mu}{\phi.b.d^2} = \frac{2,207.10^6}{0,8.150.235,5^2} = 0,331$$

$$\rho = \frac{0,85.fc}{fy}\left(1 - \sqrt{1 - \frac{2.k}{0,85.fc}}\right) = \rho = \frac{0,85.25}{240}\left(1 - \sqrt{1 - \frac{2.0,331}{0,85.25}}\right) = 0,0014$$

$\rho_{min} > \rho < \rho_{maks}$, maka diambil ρ_{min} = 0,00583

$A_S = \rho.b.d$ = 0,00583 . 150 . 235,5 = 205,944 mm^2

Dipakai tulangan 2 Ø 13 = 265,33 mm^2.

A'_s = 0,5 . A_s = 0,5 . 265,33 = 132,66 mm^2. Dipakai 2 Ø 13 = 265,33 mm^2.

Kontrol :

1. Jarak tulangan :

   - Selimut beton = 2 . 25 = 50 mm
   - Sengkang = 2 . 8 = 16 mm
   - Tulangan pokok = 2.13 = 26 mm

   = 92 mm

   Spasi = (150 - 92) = 58 mm > 25 mm. → ok..

2. Kontrol kapasitas balok :

$$a = \frac{A_s.f_y}{0,85.f_c.b} = \frac{205,944.240}{0,85.25.150} = 9,691\ mm$$

M_n = A_S . f_y .(d-a/2) = 205,944 . 240 .(235,5 – 9,691/2)

= 11,4 . 10^6 Nmm.

Ø M_n = 0,8 . 11,4 . 10^6 = 9,12 . 10^6 Nmm > M_u = 2,207 . 10^6 Nmm. → (ok)

B. Tulangan lapangan

$M_u = 3{,}311$ KNm.

$$k = \frac{Mu}{\phi.b.d^2} = \frac{1{,}64.10^6}{0{,}8.150.260{,}5} = 0{,}201$$

$$\rho = \frac{0{,}85.fc}{fy}\left(1 - \sqrt{1 - \frac{2.k}{0{,}85.fc}}\right) = \rho = \frac{0{,}85.25}{240}\left(1 - \sqrt{1 - \frac{2.0{,}201}{0{,}85.25}}\right) = 0{,}00084$$

$\rho_{min} > \rho < \rho_{maks}$, maka diambil $\rho_{min} = 0{,}00583$

$A_S = \rho.b.d = 0{,}00583 \,.150\,.\, 260{,}5 = 227{,}8\ mm^2$

Dipakai tulangan 2 Ø 13 = 265,33 mm^2.

$A'_s = 0{,}5\,.A_s = 0{,}5\,.\, 265{,}33 = 132{,}66\ mm^2$.Dipakai 2 Ø 13 = 265,33 mm^2.

Kontrol :

1. Jarak tulangan :

   - Selimut beton = 2.25 = 50 mm
   - Sengkang = 2.8 = 16 mm
   - Tulangan pokok = 2.13 = 26 mm

   = 92 mm

   Spasi = (150-92) = 58 mm > 25 mm.→ ok..

2. Kontrol kapasitas balok :

$$a = \frac{A_s.f_y}{0{,}85.f_c.b} = \frac{227{,}8.240}{0{,}85.25.150} = 17{,}154\ mm$$

$M_n = A_S\,.\,f_y\,.(d\text{-}a/2) = 265{,}33\,.\,240\,.(260{,}5 - 17{,}154/2)$

$= 13{,}8\,.\,10^6$ Nmm.

Ø $M_n = 0{,}8\,.\,13{,}8\,.\,10^6 = 11{,}018\,.10^6$ Nmm > $M_u = 1{,}64\,.10^6$ Nmm.→ (ok)

C. Tulangan geser

$$V_u = \frac{W_u.l}{.2} = \frac{10{,}946.2{,}2}{.2} = 12{,}04\,KN.$$

❖ Perencanaan sengkang didaerah plastis

Pada perencanaan sengkang penampang kritis untuk geser sejauh d dari perletakan sehingga $V_u = 5{,}96\left(\frac{2{,}2\,.\,0{,}2605}{2{,}2}\right) = 5{,}254$

$V_u/Ø \leq V_c + V_s$ dimana $V_c = 0$

$V_u/Ø \leq V_s$

$V_s = V_u/ø$

$= 5{,}414 / 0{,}6 = 8{,}76$ KN.

Digunakan sengkang Ø 8 ($A_V = 2.1/4 .\pi . 8^2 = 100{,}53$ mm^2)

$s = (A_V .fy . d)/V_s$

$$= \frac{100{,}5.240.260{,}5}{8760} = 717{,}48\, mm$$

Berdasarkan SKSNI 3.14.9-3.3b, bahwa spasi maksimum tidak boleh melebihi nilai – nilai dibawah ini :

Kontrol S_{maks} $= d/4 = 260{,}5/4$ $= 65{,}125$ mm

$= 10 . Ø_{tul\ ut} = 10 . 13$ $= 104$ mm

$= 10 . Ø_{tul\ seng} = 10 . 19$ $= 192$ mm

$= 361{,}125$ mm

$= 2 .h .f_y .A_V / ((A_s + A_s') f_y)$

$= 2 . 300 . 240 . 100{,}5 / ((132{,}7 + 132{,}5) .240)$

$= 227{,}204$ mm.

Dipakai sengkang Ø 8 – 200 mm

$s_{terpakai} = 200$ mm $< s_{maks} = 227{,}204$ mm

$$A_{V\,min} = \frac{b.w}{3.fy} = \frac{150.200}{3.240} = 41{,}66\, mm^2 < A_{V\,min} = 100{,}5 \text{ mm}^2 \rightarrow \text{ok!}$$

Kontrol kapasitas Geser :

$$V_s = \frac{100{,}5.240.260{,}5}{200}.10^6 = 31{,}42\, KN$$

$V_{SR} = Ø . V_s = 0{,}6 . 31{,}42 = 18{,}852$ KN $> Vu = 5{,}254$ KN.

❖ Perencanaan sengkang diluar daerah sendi plastis :

(pada jarak $2 . h = 2 .300 = 600$ mm dari tumpuan)

$V_u = V_{u\,total} - 2.h\,(W)$

$= 5{,}96 - 2 .300\,(5{,}414) = 2{,}712$ KN.

$V_u/ø \leq V_c + V_s$

$V_c = 1/6 . \sqrt{f_c} .b_w . d = 1/6 . \sqrt{25} .150 . 260{,}5 = 32{,}562$ KN.

$V_s = V_u/ø - Vc = 2,712/0,6 - 32,562 = -28,042$ KN.

(berarti tidak diperlukan sengkang)

dipakai jarak sengakang maksimum = d/2 = 260,5/2 = 130,25 mm.

Diambil sengkang dengan jarak 100 mm.

$$V_s = \frac{100,5.240.260,5}{100} = 62,83\ KN$$

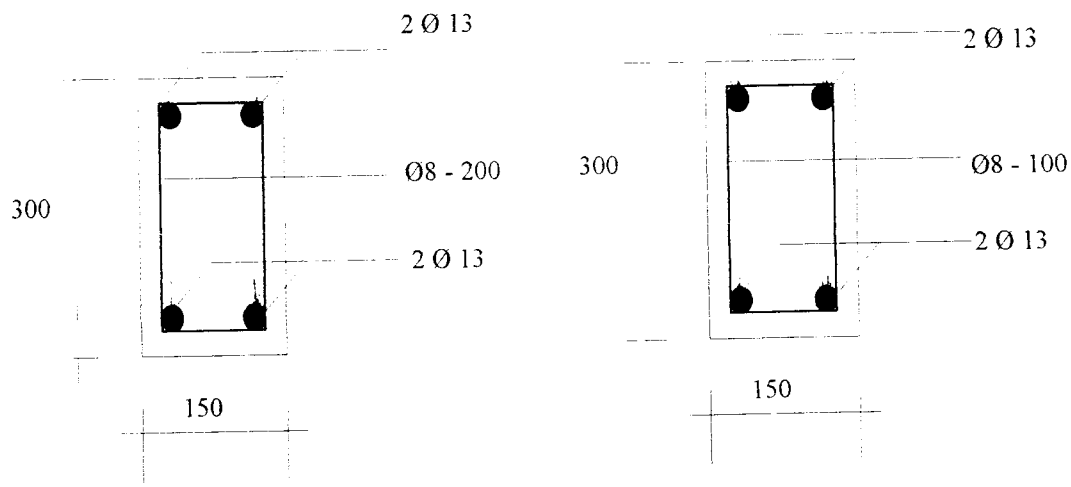
$V_s \leq 2/3 \cdot \sqrt{f_c} \cdot b_w \cdot d = 2/3 \cdot \sqrt{25} \cdot 150 \cdot 260,5 = 130,25$ KN → ok!.

$$A_{V\,min} = \frac{b.w}{3.fy} = \frac{150.100}{3.240} = 20,83\ mm^2 < A_{V\,min} = 100,53\ mm^2 \rightarrow \text{ok!}.$$

Kontrol kapasitas Geser :

$Ø\,(V_c + V_s) = 0,6\,(32,562 + 130,25) = 97,678$ KN > $V_u = 2,712$ KN → ok!

Tulangan tumpuan *Tulangan Lapangan*



Gambar 4.5 Penampang balok bordes

2. Perhitungan plat Tangga

- Tebal plat bordes (h) = 150 mm
- tulangan digunakan = Ø 12 mm
- Tebal selimut beton (P) = 25 mm
- Tinggi efektip plat (d) = $h - p - Ø_{tul\ sengk.}$ = 150 – 25 - 8
  = 117 mm
- Lebar plat (b) = 1000 mm

Mu = 19,06 KNm

Mn = Mu / 0,8 = 19,06/ 0,8 = 23,825 KNm

$$k = \frac{Mn}{bd^2} = \frac{23{,}825.10^6}{1000.117^2} = 1{,}74$$

$$\rho = \frac{0{,}85.fc}{fy}\left(1 - \sqrt{1 - \frac{2.k}{0{,}85.fc}}\right) = 0{,}00757$$

$\rho_{min} < \rho < \rho_{mak}$ maka diambil $\rho_{Perlu} = 0{,}00757$

$A_{stx} = \rho \cdot b \cdot d = 0{,}00757 \cdot 1000 \cdot 117 = 886.4\ mm^2$

Dipakai tulangan Ø 12 mm

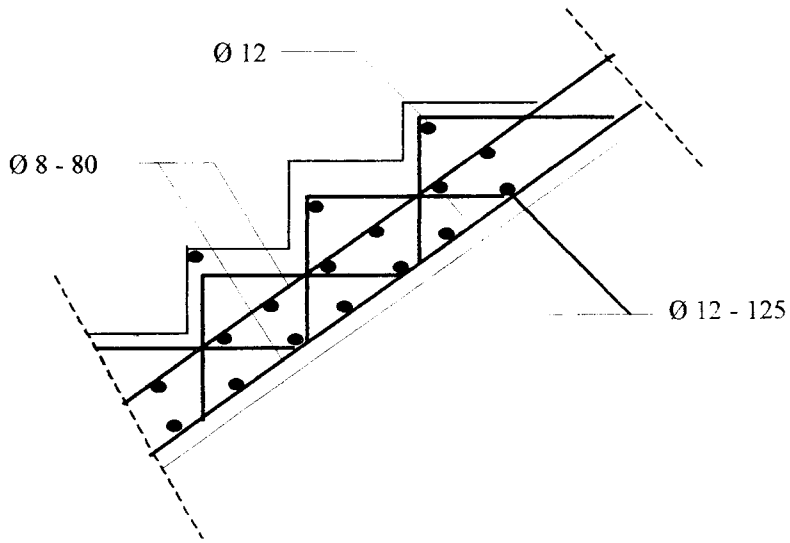
$$\text{Jarak tulangan perlu} = \frac{(\frac{\pi}{4}.12^2.1000)}{886{,}4} = 127{,}527\ mm$$

Maka diambil jarak tulangan (s) = 125 mm.

Kontrol kekuatan plat :

- s = 150 mm < s_{maks} = 3 . h = 3 . 150 = 450 mm
  Luas tulangan (A) Ø 12 mm = 113 mm^2
- $A_s = \frac{113.1000}{125} = 904{,}32\ mm^2 > As_{min} = 0{,}004 \times 150 \times 1000 = 600\ mm^2$
- $a = \frac{A_s.f_y}{0{,}85.f_c.b} = \frac{904{,}32.240}{0{,}85.25.1000} = 10{,}213$ mm.
- $M_n = A_s . f_y . (d - a/2) = 904{,}32.\ 240(117 - 10{,}213/2) = 24{,}285.\ 10^6$ Nmm.
- $Ø\ M_n = 0{,}8 \cdot 24{,}285.10^6 = 19{,}427$ Nmm > $M_u = 19{,}06 \cdot 10^6$ Nmm.

- Luas tulangan bagi :
- A_s = 0,004 . b . h = 0,004 . 1000 . 150 = 600 mm^2. maka digunakan tulangan Ø 8 – 80 = 628 mm^2.



Gambar 4.6 penampang plat tangga

3. Perhitungan plat bordes

- Tebal plat bordes (h) = 150 mm
- tulangan digunakan = Ø 12 mm
- Tebal selimut beton (P) = 25 mm
- Tinggi efektip plat (d) = h – p – $Ø_{tul\ sengk.}$ = 150 – 25 - 8
  = 117 mm
- Lebar plat (b) = 1000 mm

Mu = 0,855 KNm

Mn = Mu / 0,8 = 0,855/ 0,8 = 1,06875 KNm

$$k = \frac{Mn}{bd^2} = \frac{1{,}06875.10^6}{1000.117^2} = 0{,}078$$

$$\rho = \frac{0{,}85.fc}{fy}\left(1 - \sqrt{1 - \frac{2.k}{0{,}85.fc}}\right) = 0{,}00032$$

$\rho_{min} > \rho < \rho_{mak}$, maka diambil ρ_{min} = 0,00583

$A_{stx} = \rho$. b . d = 0,00583 . 1000 . 117 = 682,11 mm^2

Dipakai tulangan Ø 12 mm

Jarak tulangan perlu = $\frac{(\frac{\pi}{4}.12^2.1000)}{682,11}$ =195,72 *mm*

Maka diambil jarak tulangan (s) = 150 mm.

Kontrol kekuatan plat :

- s = 150 mm < s_{maks} = 3 . h = 3 . 150 = 450 mm

  Luas tulangan (A) Ø 12 mm = 113 mm^2

- $A_s = \frac{113.1000}{150}$ = 753,33 mm^2 > As_{min} = 0,004 x 150 x 1000 = 600 mm^2

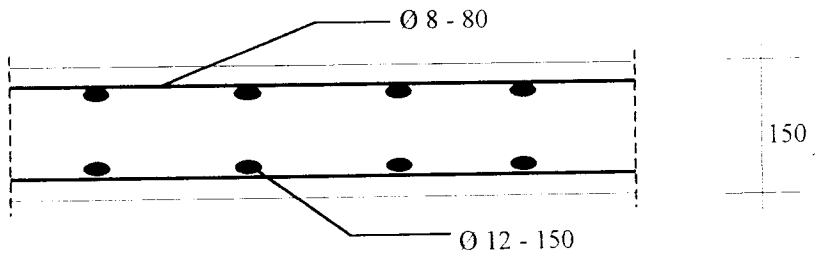
- $a = \frac{A_s.f_y}{0,85.f_c.b} = \frac{753,33.240}{0,85.25.1000}$ = 8,508 mm.

- $M_n = A_s .f_y .(d - a/2)$ = 753,33. 240(117 – 8,508/2) = 20,384. 10^6 Nmm.

- Ø M_n = 0,8 . 20,384.10^6 = 16,307 Nmm > M_u = 0,855 . 10^6 Nmm.

- Luas tulangan bagi :

- A_s = 0,004 . b . h = 0,004 . 1000 . 150 = 600 mm^2. maka digunakan tulangan Ø 8 – 80 = 628 mm^2.



Gambar 4.7 penulangan plat bordes

4. Perhitungn Pondasi Tangga

Type pondasi yang direncanakan pada tangga ini adalah pondasi jalur (pondasi telapak).

Menentukan daya dukung pondasi :

Data – data tanah :

Berat isi tanah (γ) = 14,5 KN/m^3

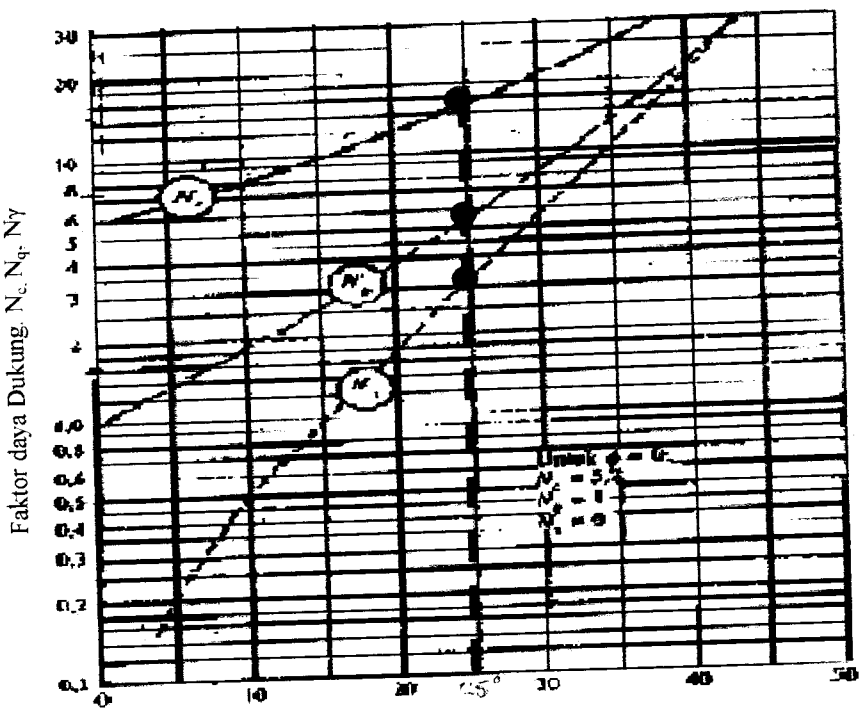
Kohesi tanah (c) = 15 KN/m^3

Sudut geser (Ø) = 25^0

Safety faktor (SF) = 20 KN/m^3

Maka untuk menentukan nilai N_c, N_q, N_γ dari sudut geser (Ø) dapat dilihat dari tabel daya dukung Terzaghi dibawah ini.

Tabel TERZAGHI



Gambar 4.8 Tabel Terzaghi

Maka dari tabel daya dukung terzaghi tersebut diperoleh :

$N_c = 15,5$

$N_q = 5,4$

$N_\gamma = 3,25$

Dengan lebar rencana pondasi = 1,2 m

Kedalaman Rencana pondasi = 1,0 m

Daya dukung tanah untuk pondasi telapak :

$q_{ult} = c \cdot N_c + \gamma \cdot d_p \cdot N_q + 0,5 \cdot \gamma \cdot B \cdot N_\gamma$

$= 15 \cdot 15,5 + 14,5 \cdot 1 \cdot 5,4 + 0,5 \cdot 14,5 \cdot 1,2 \cdot 3,25$

$= 339,075 \text{ KN/m}^2$

Daya dukung izin

$$q_a = \frac{q_{ult}}{SF} = \frac{339,075}{3} = 113,025 KN/m^2 = 0,113 \text{ Mpa}$$

Menntukan ukuran pondasi :

Tebal pondasi direncanakan (t) = 0,25 m

Panjang pondasi (L) = 1,2 m

Tinggi kolom pondasi (hk) = 1 m

Lebar pondasi (B) = 1,2 m

Lebar kolom = 0,25 m

Pembebanan pondasi :

Berat tanah	= d . g	= 1 . 20	= 20	KN/m^2
Berat telapak pondasi	= t . γc	= 0,25 . 24	= 6	KN/m^2
Berat kolom pondasi	= h .γc	= 0,35 . 24	= 8,4	KN/m^2
		q	= 34,4	KN/m^2
		q	= 0,0344	N/m^2

Gaya aksial yang bekerja :

$P_u = R_{AV}$ + DL (akibat kolom pondasi)

$= 55,4 + 0,25. 1 . 24$

$= 61,4$ KNm.

Momen lentur yang bekerja :

$M_u = - M_{AB} + R_{AH} . d$

$= - 19.06 + (49,97 . 1)$

$= 30,91$ KNm.

Eksentrisitas :

$$e = \frac{M_u}{P_u}$$

$$= \frac{30,91}{61,4} = 0,503 \text{ m} = 503 \text{ mm}.$$

Luas perlu untuk pondasi :

$$A_{perlu} = \frac{P_u}{q_{netto}}\left(1+\frac{6e}{L}\right)$$

$$L . B = \frac{61400}{(0,113-0,0344)}\left(1+\frac{6.503}{L}\right)$$

$$L . B = 781170,48\left(1+\frac{3018}{L}\right)$$

$$\frac{1200.L}{\left(1+\frac{3018}{L}\right)} = 781170,48 \qquad \text{Dengan B = 1,2 m = 1200 mm}$$

$$\frac{L}{\left(1+\frac{3018}{L}\right)} = \frac{781170,48}{1200} = 650,975$$

$$\left(1+\frac{3018}{L}\right) = \frac{L}{650,975}$$

$$1 = \frac{L}{650,975} - \frac{3018}{L}$$

$$1 = \frac{L^2.(650,975.3018)}{650,975.L}$$

$650,975.L = L^2 - 1964643,766$

$L^2 - 650,975.L - 1964643,766 = 0$

$(L + 1113,469) . (L - 1764,444)$

$L = - 1113,469 \quad L = 1764,444$

Maka L dapat dengan menggunakan L terbesar yaitu :

L = 1764,444 mm = 1,764 m

Luas perlu = 1,2 . 1,764 = 2,11 m^2

Luas tersedia = 1,2 . 1,8 = 2,16 m^2 > luas perlu = 2,11 m^2 → *Aman*

*M*enghitung tegangan tanah yang terjadi :

$$q_{1\text{-}2} = \frac{P}{A} \pm \frac{M}{W} = \frac{61,4}{2,16} \pm \frac{30,91}{1/6.1.1,8^2}$$

$q_{1\text{-}2}$ = 28,426 ± 57,24

q_1 = 28,426 + 57,24 = 85,666 KN/m^2 = 0,0856 Mpa < 0,113 Mpa

q_2 = 28,426 - 57,2 = -28,814 KN/m^2 = - 0,0288 Mpa < 0,113 Mpa

Menentukan tebal telapak pondasi berdasarkan kriteria geser :

Selimut beton (p) = 40 mm

Tebal pondasi (t) = 250 mm

Dipakai tulangan Ø 16 mm

Tinggi efektif : d = 250 – 40 – ½ . 16 = 202 mm.

Kontrol tebal plat pondasi terhadap gaya geser :

q_c = ½ (q_1 + q_2)

q_c = ½ (0,08856 + 0,0288) = 0,0572

$$q_v = q_c + \left(\frac{0,5.l + d}{1/2.L}\right)(q_1 - q_2)$$

$$q_v = 0,0572 + \left(\frac{0,5.250 + 202}{600}\right)(0,0856 + 0,0288) = 0,119 \text{ Mpa.}$$

V_u = 0,5 (q_a + q_v) . L . (0,5.L – (0,5.l + d))

= 0,5 (0,113 + 0,119) . 1200. (0,5.1200 – (0,5.250 + 202))

= 38493 N

$V_{n\ perlu} = V_u / ø$ = 38493 / 0,6 = 64155 N.

$V_{n\ actual}$ = 1/6. $\sqrt{fc'}$. B . d

= 1/6. $\sqrt{25'}$. 1200 . 202

= 202000 N

$V_{n\ actual}$ = 202000 N > $V_{n\ perlu}$ = 64155 N → tebal plat aman terhadap geser.

Peninjauan Momen Lentur :

$$M_u = ½ \left(\frac{q_1 + q_2}{2}\right).L.(0{,}5.L - 0{,}5l)^2$$

$$= \left(\frac{0{,}0856 + 0{,}0288}{2}\right).1200.(0{,}5.1200 - 0{,}5.250)^2.10^{-6} = 15{,}486 \text{ KNm.}$$

$M_n = M_u / ø = 15{,}86 / 0{,}8 = 19{,}358$ KNm

$$k = \frac{Mn}{bd^2} = \frac{19{,}358}{1{,}2.0{,}202^2} = 395{,}357 \text{ KN/m} = 0{,}395 \text{ Mpa.}$$

$$\rho = \frac{0{,}85.fc}{fy}\left(1 - \sqrt{1 - \frac{2.k}{0{,}85.fc}}\right)$$

$$\rho = \frac{0{,}85.25}{240}\left(1 - \sqrt{1 - \frac{2.0{,}395}{0{,}85.25}}\right) = 0{,}00166$$

$\rho_{min} > \rho < \rho_{mak}$, maka diambil $\rho_{min} = 0{,}00583$

$A_{stx} = 0{,}00583 \ .\ 1200 \ .\ 202 = 1413{,}2 \text{ mm}^2$

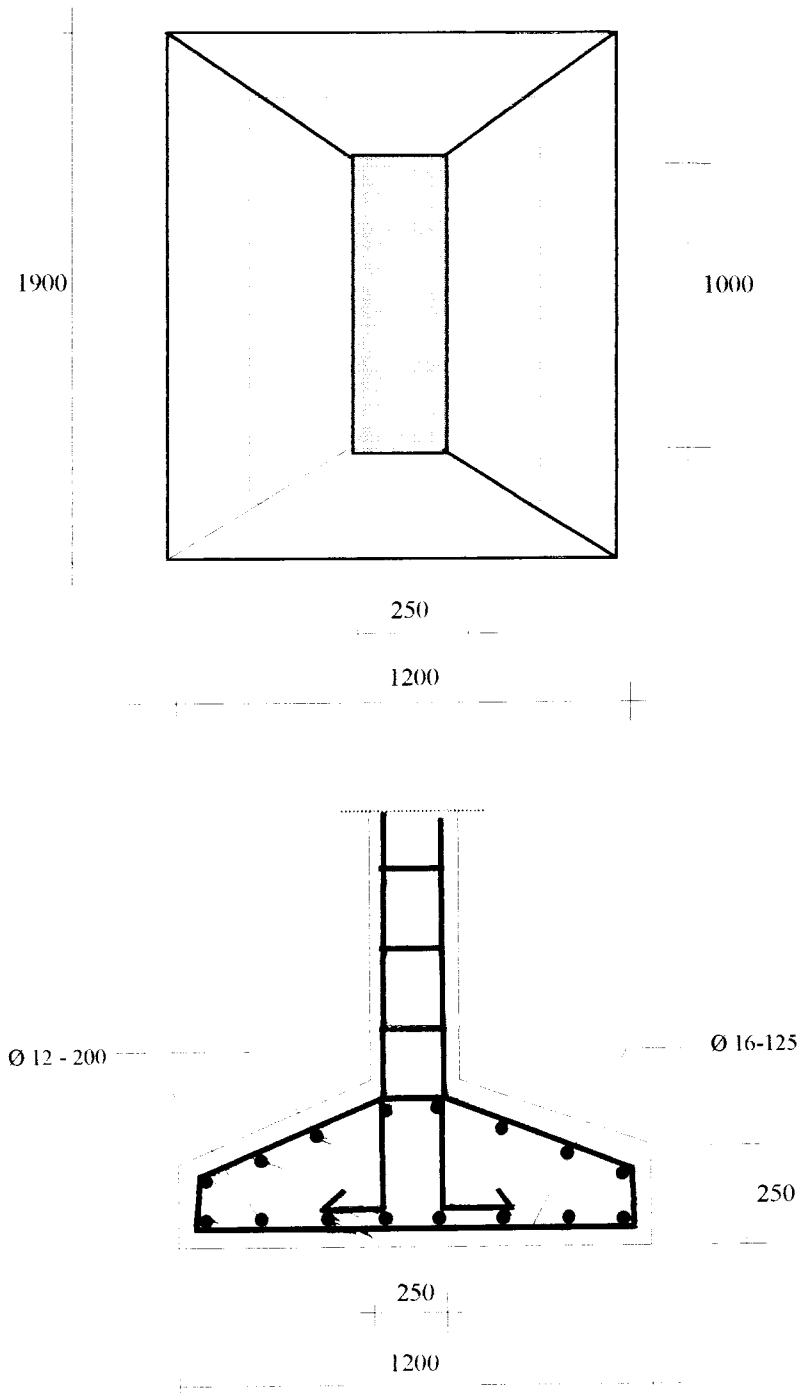
Dipakai tulangan Ø 16 – 125 (1607,68 mm^2)

Luas tulangan bagi :

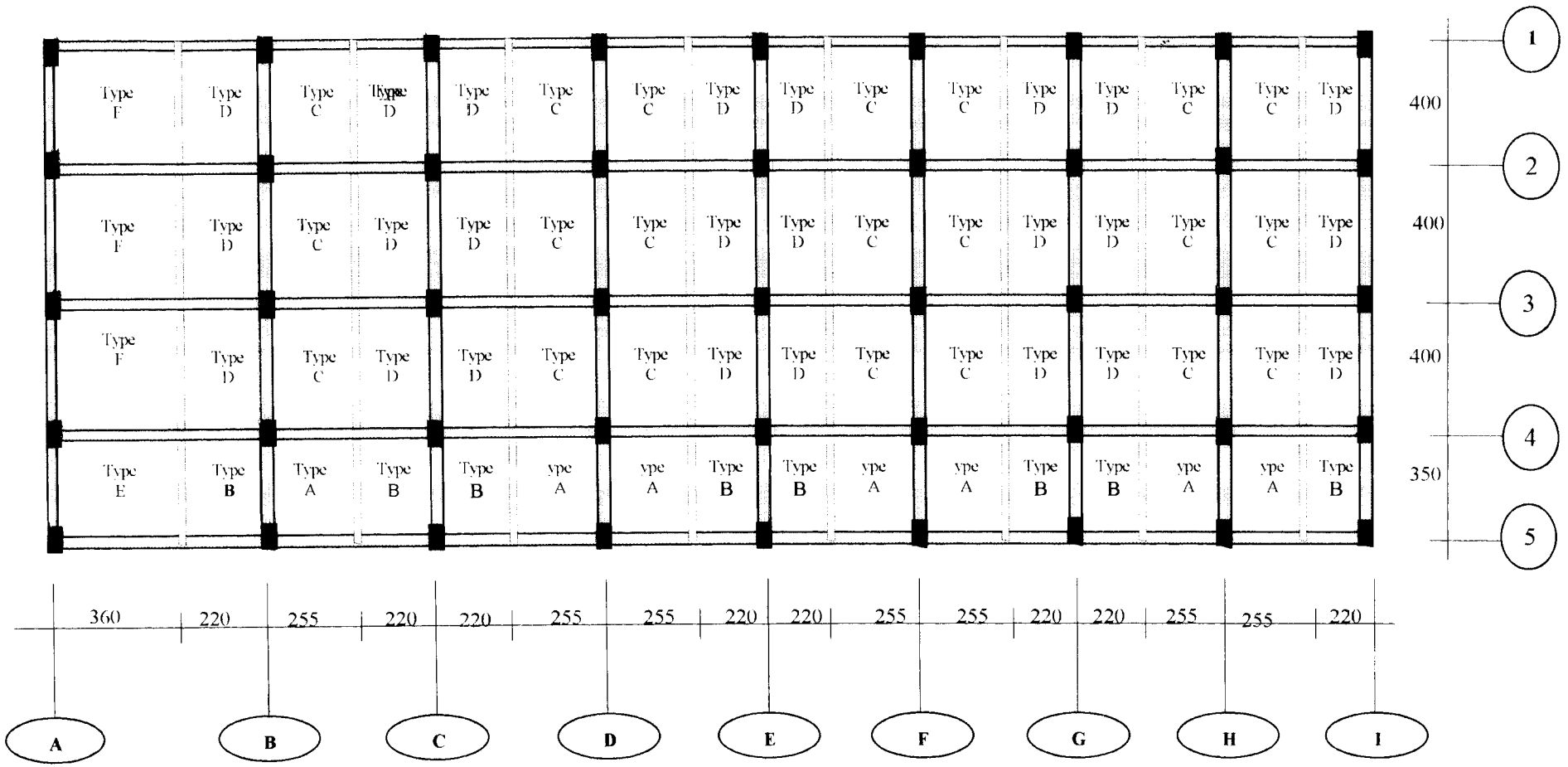
$A_s = 0{,}002 \ .\ b \ .\ d$

$= 0{,}002 \ .\ 1200.\ 202 = 484{,}8$ mm2

Digunakan tulangan Ø 12 – 200 (565 mm^2).



Gambar 4.9 Penulangan pondasi tangga



Gambar 4.10 Denah Plat Atap dan Plat Lantai

4.2 Perencanaan plat

Pembebanan plat

1. Plat type A
2. Plat type B
3. Plat type C
4. Plat type D
5. Plat type E
6. Plat type F

A. Pembebanan plat atap beton

- Beban hidup (LL) :

  Bebab hidup atap Ruko = 1,00 KN/m^2

  LL = 1,00 KN/m^2

- Beban mati (DL) :

  - Berat sendiri plat : 0,1 x 24 = 2,400 KN/m^2
  - Berat langit-langit penggantung : 0,11 x 0,7 = 0,180 KN/m^2
  - Berat genangan air hujan 0,5 cm : 0,05 x 10 = 0,500 KN/m^2
  - Berat lapisan aspal dan pasir 0,2 cm : 0,02 x 14 = 0,280 KN/m^2

  DL = 3,360 KN/m^2

$Wu = 1,2\ q_{DL} + 1,6\ q_{LL}$

$= 1,2\ (3,36) + 1,6\ (1)$

$= 5,632$ KN/m^2

B. Pembebanan plat lantai beton

- Beban hidup (LL) :

  Beban lantai Ruko = 2,50 KN/m^2

  LL = 2,50 KN/m^2

- Beban mati (DL) :

  - Berat sendiri plat : 0,13 x 24 = 3,120 KN/m^2
  - Berat langit-langit penggantung : 0,11 x 0,7 = 0,180 KN/m^2

Berat finising lantai keramik :

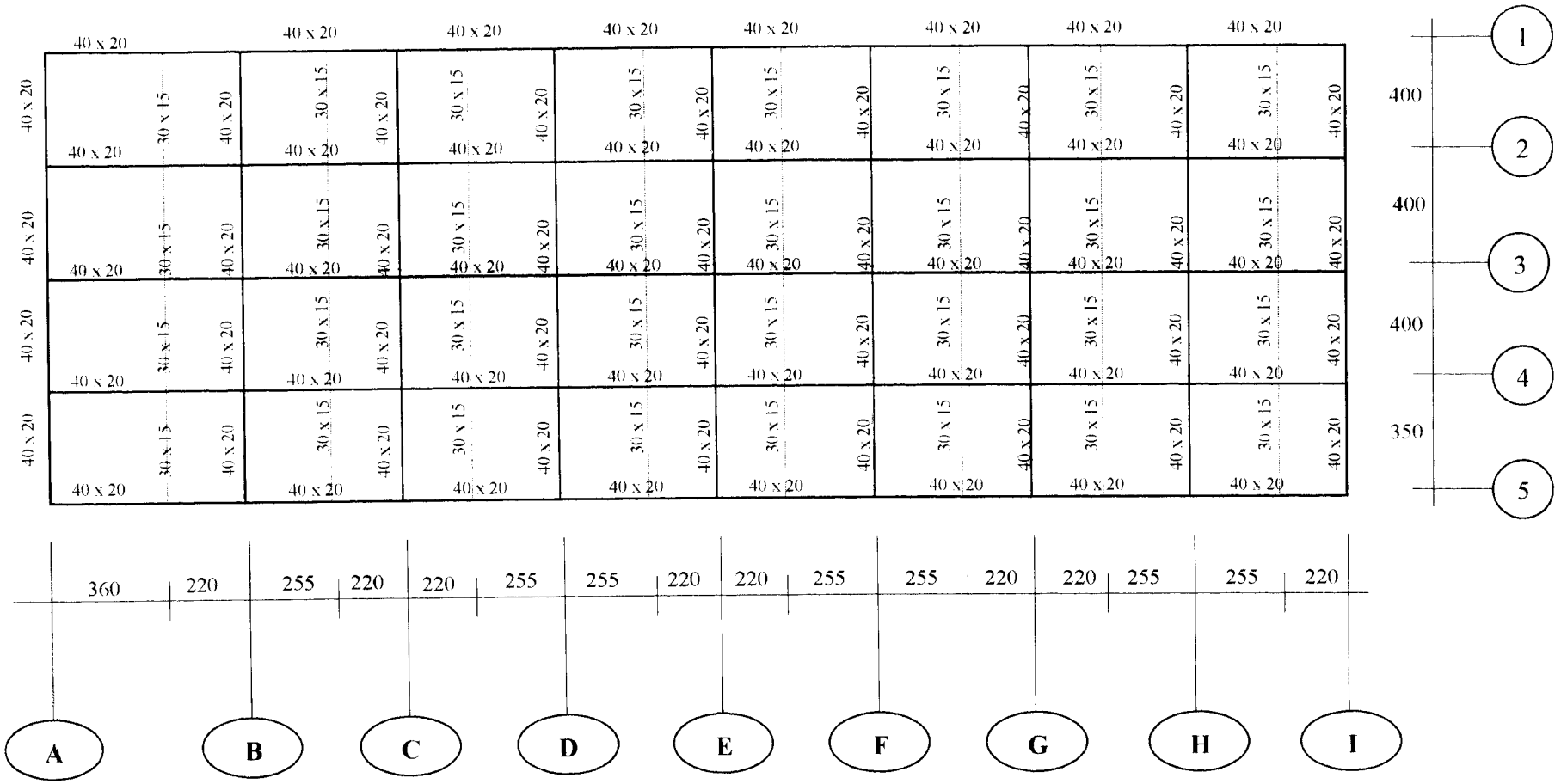
- Spesi 2 cm : 0,02 x 21 KN/m^3 = 0,420 KN/m^2
- Tegel keramik 0,5 cm : 0,005 x 24 = 0,120 KN/m^2

DL = 3,840 KN/m^2

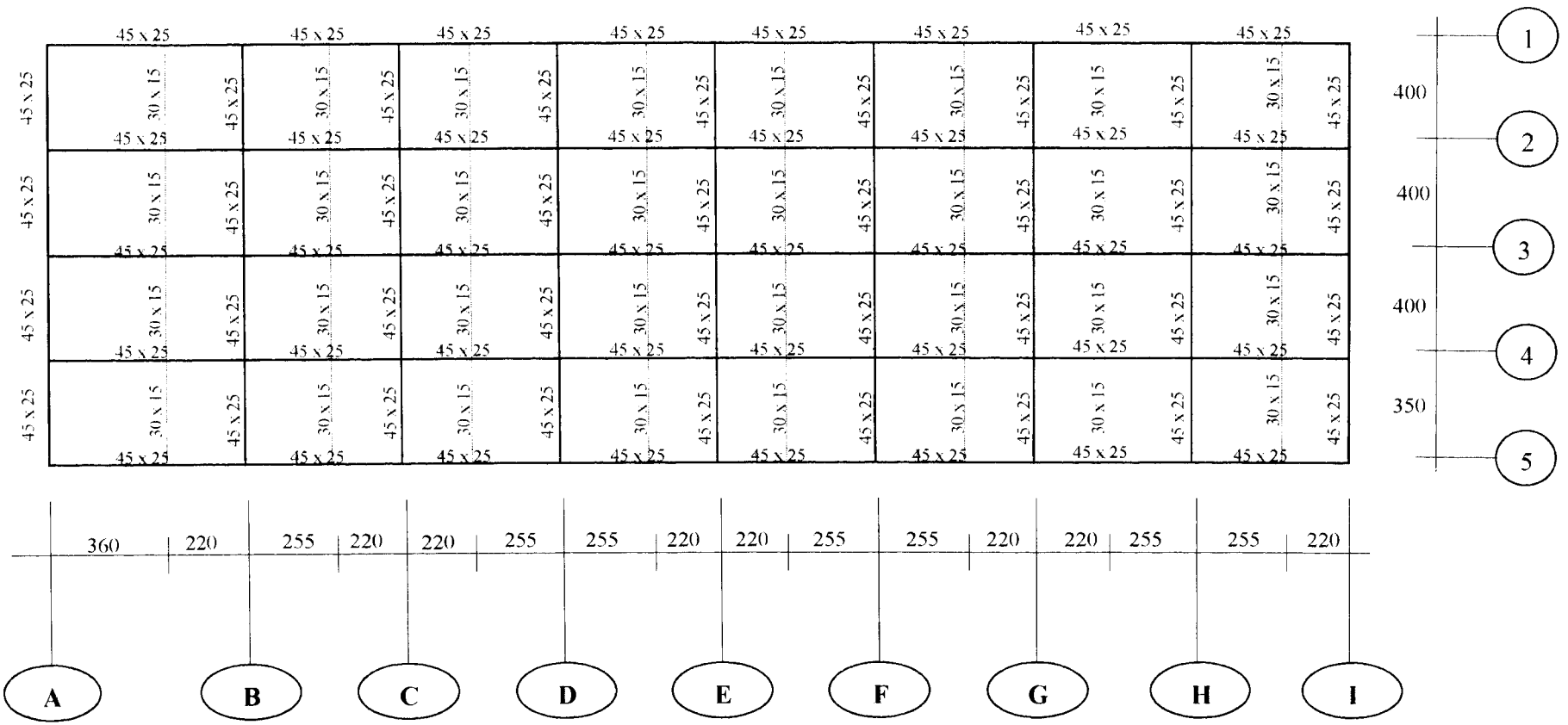
$Wu = 1,2\ q_{DL} + 1,6\ q_{LL}$

$= 1,2\ (3,84) + 1,6\ (2,5)$

$= 8,608$ KN/m^2



Gambar 4.11 Rencana Pembalokan Atap



Gambar 4.12 Rencana Pembalokan Lantai 2 dan 3

4.3 Perhitungan Balok Anak (lantai)

1. Dimensionering Penampang Balok

Tinggi penampang balok diambil nilai antara 1/10 L sampai 1/15 L. pada balok ini dipilih nilai tinggi balok 1/15 L = 1/15 . 400 = 26,66 cm, diambil 30 cm, sedangkan lebar balok diambil nilai ½ . 30 = 15 cm.

2. Pembebanan Balok Anak

a. Baban merata terfaktor akibat balok sendiri balok anak

qba =1,2 (0,30 – 0,10) . 0,15 . 24 = 0,864 KN/m

b. Beban akibat beban pelat

q_{2DL} = 3,84 KN/m^2

q_{2LL} = 2,5 KN/m^2

Wu = 1,2 q_{2DL} + 1,6 q_{2LL}

= 1,2 . 3,84 + 1,6 . 2,5

= 8,608 KN/m^2

Pembebanan pada balok anak berasal dari beban pelat lantai yang berupa beban segitiga dan trapesium. Pada perhitungan pembebanan ini, diambil bentang terpanjang dari balok anak ini.

Penbebanan balok anak A_S D Bentang 2-3

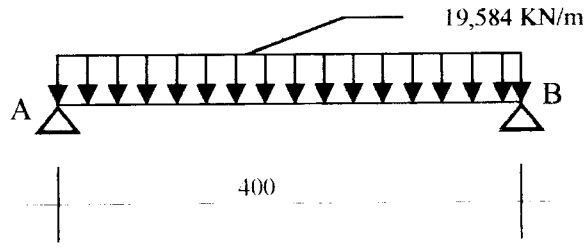
Beban Trapesium $q_{eq} = \dfrac{\left(q\dfrac{lx}{3}\right)\left(3-\dfrac{lx^2}{ly^2}\right)}{2}$

$$q_{eq} = \frac{\left(8{,}608.\frac{2{,}55}{3}\right)\left(3-\frac{2{,}55^2}{4{,}00^2}\right)}{2} = 9{,}486 \text{ KN/m}$$

Beban merata (q) :

- berat sendiri balok anak = (0,3 – 0,1) . 0,15 . 24 = 0,720 KN/m
- Berat Plat ⏢ qeq = 9,488 x 2 = 18,976 KN/m

W_{eq} = 19,584 KN/m



Gambar 4.13 Skema Pembebanan balok anak

3. Reaksi tumpuan dan momen ultimit

RA = RB = ½ ql

= ½ . (19,584) . 4 = 39,168 KN

Momen tumpuan negatif :

M_{TA}^{-} M_{TB}^{-} = -1/12 .q_{eq}.L^2

= -1/12 (19,584). 4^2

= - 26,112 KNm

momen lapangan :

M_l^{+} = 1/24 ql^2

= 1/24 . (19,584) . 4^2

= 13,056 KNm.

4. Perhitungan Tulangan

A. Tulangan Tumpuan

M_u = 19,584 KNm.

b = 150 mm

h = 300 mm

p = 30 mm

d = h – p – $Ø_{tul\ seng}$ – ½ $Ø_{tul\ ut}$

= 300 – 25 – 8 - ½ . 13

= 260,5 mm

d` = h – d = 300 – 260,5 = 39,5 mm.

$Ø_{tul\ seng}$ = 8 mm

$Ø_{tul\ ut}$ = 13 mm

ρ_{maks} = 0,0402

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

$$\rho_b = \frac{0{,}85.\beta.f'c}{fy}\left(\frac{600}{600+fy}\right)$$

$$\rho_b = \frac{0{,}85.0{,}85.25}{240}\left(\frac{600}{600+240}\right) = 0{,}0537$$

$\rho_{maks} = 0{,}75.\rho_b$

$= 0{,}75 \,.\, 0{,}0537 = 0.0402$

$$k_{maks} = \rho_{maks} \,.\, f_y \,.\, (1 - \frac{0{,}588.\rho_{maks}.f_y}{24})$$

$$k_{maks} = 0.0402 \,.\, 240 \,.\, (1 - \frac{0{,}588.0.0402.240}{25}) = 9{,}638 \text{ MPa}$$

$M_{R\,maks} = \text{ø} \,.\, b \,.\, d^2.k_{maks}$

$= 0{,}8 \,.\, 150. \, 260{,}5^2. \, 9{,}638 \,.\, 10^{-6}$

$= 78{,}484$ KNm.

$M_{R\,maks} = 78{,}484$ KNm. $> M_u = 19{,}584$ KNm., maka balok dianalisis sebagai balok bertulangan tunggal.

$$k = \frac{Mu}{\phi.b.d^2} = \frac{19{,}584.10^6}{0{,}8.150.260{,}5^2} = 2{,}405$$

$$\rho = \frac{0{,}85.f_C}{f_y}\left(1 - \sqrt{1 - \frac{2k}{0{,}85.f_C}}\right) = \frac{0{,}85.25}{240}\left(1 - \sqrt{1 - \frac{2.2{,}405}{0{,}85.25}}\right)$$

$\rho = 0{,}0108$

$\rho_{mak} > \rho_{perlu} > \rho_{min}$, maka diambil $\rho_{min} = 0{,}0108$

$A_s = \rho \,.\, b \,.\, d = 0{,}0108 \,.\, 150. \, 260{,}5 = 422{,}618 \text{ mm}^2$

Dipakai tulangan 4 Ø 13 = 530,66 mm^2

$A'_s = 0{,}5 \,.\, A_s = 0{,}5 \,.\, 530{,}66 = 265{,}33 \text{ mm}^2$. Dipakai 2 Ø 13 = 265,33 mm^2

Kontrol :

1. Jarak tulangan :

- Selimut beton	= 2 .25	= 50 mm
- Sengkang	= 2 . 8	= 16 mm
- Tulangan Pokok	= 2 . 13	= 26 mm
		= 92 m

Spasi = (150 - 92)/1 = 58 mm > 25 mm .....O.k

2. Kontrol kapasitas balok

$$A = \frac{A_s . f_y}{0{,}85 . f_c . b} = \frac{422{,}613.240}{0{,}85.25.150} = 31{,}82 \text{ mm}$$

$M_n = A_s . f_y . (d-a/2)$

$= 422{,}613 . 240 . (260{,}5 - 19{,}584/2)$

$= 24{,}808 . 10^6$ Nmm

$\emptyset M_n \; 0{,}8 . 24{,}808 . 10^6 = 19{,}846 . 10^6$ Nmm $> M_u = 19584 . 10^6$ Nmm

B. Tulangan Lapangan

$M_u = 13{,}056$ KNm $= 13{,}056 . 10^6$ Nmm.

Balok berpenampang T, dengan data :

b = 150 mm, h = 300 mm, t = 130 mm, d' = 39,5 mm.

Lebar fens (bf) diambil dari nilai – nilai terkecil dari nialai-nilai berikut :

- bf = ¼ . l = ¼ . 4000 = 1000 mm
- bf = b + 16t = 150 + 16 . 130 = 2280 mm
- bf = b + ln = 150 + 3700 = 2850 mm

dipakai lebar flens (bf) = 1000 mm.

Diperiksa apakah balok berprilaku sebagai balok T persegi atau balok T murni, dengan menganggap seluruh flens dalam keadaan desak.

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

$$\rho_b = \frac{0{,}85.\beta.f'c}{fy}\left(\frac{600}{600+fy}\right)$$

$$\rho_b = \frac{0{,}85.0{,}85.25}{240}\left(\frac{600}{600+240}\right) = 0{,}0537$$

$\rho_{maks} = 0{,}75.\rho_b$

$= 0{,}75 . 0{,}0537$

$= 0.0402$

$Mn = 0{,}85 . fc' . b . t (d-½ . t)$

$= 0{,}85 . 25 . 1000 . 130 (260{,}5 -½ . 130)$

$= 540{,}068 . 10^6$ Nmm.

Ø Mn = 0,8 . 540,068 .10^6 = 432,055.10^6 KNm > Mu = 13,056 KNm.

(maka balok berprilaku sebagai balok T persegi dengan lebar balok b = bf = 100 mm).

Maka perencanaan tulangan dilakukan seperti balaok persegi, menurut ρ yang diperlukan :

$$k = \frac{Mu}{\phi.b.d^2} = \frac{13{,}056 \cdot 10^6}{0{,}8.1000.260{,}5^2} = 1{,}6$$

$$\rho = \frac{0{,}85.f_C}{f_y}.\left(1-\sqrt{1-\frac{2k}{0{,}85.f_C}}\right) = \frac{0{,}85.25}{240}.\left(1-\sqrt{1-\frac{2.1{,}6}{0{,}85.25}}\right)$$

ρ = 0,00693

$\rho_{perlu} < \rho_{min}$, **maka diambil** ρ_{min} = 0,00693

$A_s = \rho . b . d = 0{,}00693 . 150 . 260{,}5 = 270{,}789$ mm^2.

Maka digunakan A_s terbesar.

Dipakai 3 Ø 13 = 397,995 mm^2

As' = 0,5 . A_s = 0,5 . 397,995 = 198,997 mm^2.

Dipakai 2 Ø 13 = 265,33 mm^2

Kontrol :

3. Jarak tulangan :

-	Selimut beton	= 2 .25	= 50 mm
-	Sengkang	= 2 . 8	= 16 mm
-	Tulangan Pokok	= 2 . 13	= 26 mm
			= 92 mm

Spasi = (150 - 92)/2 = 29 mm > 25 mm .....O.k

4. Kontrol kapasitas balok

$$a = \frac{A_s.f_y}{0{,}85.f_c.b} = \frac{402.240}{0{,}85.25.150} = 30{,}268 \text{ mm}$$

$M_n = A_s . f_y . (d-a/2)$

$= 402 . 240 .(260{,}5 - 30{,}268/2)$

$= 23{,}668 . 10^6$ Nmm

$ØM_n = 0{,}8 . 23{,}668 .10^6 = 18{,}934 . 10^6$ Nmm > $M_u = 13{,}355 . 10^6$ Nmm

C. Tulangan Geser

V_u = 39,168 KN.

- Perencanaan sengkang di daerah berpotensi sendi plastis

pada perencanaan sengkan penampang kritis un tuk geser sejauh dari perletakan sehingga V_u= 39,168 . $\left(\frac{4-0,2605}{4}\right)$ = 36,617 KN

$V_u / \phi \leq V_c + V_c$ dimana $V_c = 0$

$V_u / \phi \leq V_s$

$V_s = V_u / \phi$

$= 36,617 / 0,6 = 61,028$ KN.

Digunakan sengkang Ø 8 (Av = 2 .1/4 . π . 8^2 = 100,48 mm^2)

$S = (A_v . f_y . d)/V_s$

$= \frac{100,8.240.260,5}{61028} = 102,936$ mm.

Berdasarkan SKSNI 3.14.9-3.3b, bahwa sepasi maksimum tidak boleh melebihi nilai-nilai dibawah ini :

Kontrol S_{maks} = d/4 = 260,5 /4 = 65,125 mm

= 10 . $Ø_{tul.ut}$ = 10 . 13 = 130 mm

= 24 . $Ø_{tul.seng.}$ = 24 . 8 = 192 mm

= 387,125 mm

Dipakai sengkang Ø 8 – 100 mm.

$S_{terpakai}$ = 65 mm < S_{maks} = 65,125 mm.

$A_{v\,min} = \frac{b.w}{3.f_y} = \frac{150.100}{3.240} = 20,833\ mm^2 < A_{v\,min} = 100.48\ mm^2 \rightarrow$ ok.

Kontrol kapasitas Geser :

$V_s = \frac{100,48.240.260,5}{65}.10^{-3} = 96,646$ KN

$V_{SR} = \phi . V_s = 0,6 . 96,646 = 57,987$ KN > V_u = 39,168 KN.

- Perencanaan sengkang diluar sendi plastis :

(pada jarak 2 . h = 2 . 300 = 600 mm dari tumpuan)

$V_u = V_{u\,total} - 2 \cdot h \cdot (W)$

$= 39{,}168 - 0{,}6 \cdot (19{,}584) = 27{,}417$ KN.

$V_u / \phi \leq V_c + V_s$

$V_c = 1/6 \sqrt{f'_c}\, b_w \cdot d = 1/6 \cdot \sqrt{25} \cdot 150 \cdot 260{,}5 = 32{,}562$ KN

$V_s = V_u / \phi - V_c = 27{,}417 / 0{,}6 - 32{,}562 = 13{,}133$ KN.

Dipakai jarak sengkang maksimum = d/2 = 260,5/2 = 130,25 mm.

Diambil sengkang dengan jarak 100 mm.

$V_s = \frac{100{,}48.240.260{,}5}{100} = 39{,}262$ KN

$V_s < 2/3 \cdot \sqrt{f'_c} \cdot b_w \cdot d = 2/3 \cdot \sqrt{25} \cdot 150 \cdot 260{,}5 = 130{,}25$ KN. → ok.

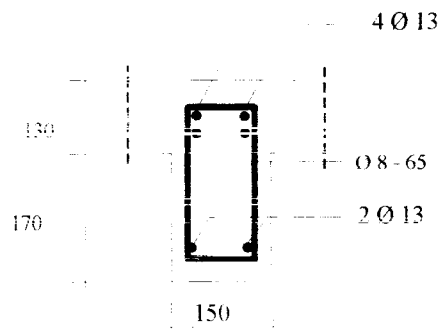
$A_{v\,min} = \frac{b.w}{3.f_y} = \frac{150.100}{3.240} = 20{,}833\ mm^2 < A_{v\,min} = 100{,}53\ mm^2$ → ok.

Kontrol kapasitas Geser :

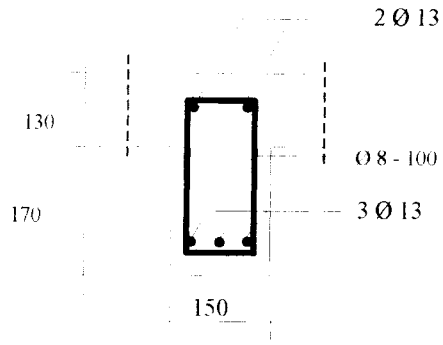
$\phi (V_c + V_s) = 0{,}6\ (39{,}262 + 130{,}25) = 101{,}707$ KN > 27,417 KN.→ ok.

Rencana Balok Anak (lantai 2 dan 3)

Tulangan Tumpuan



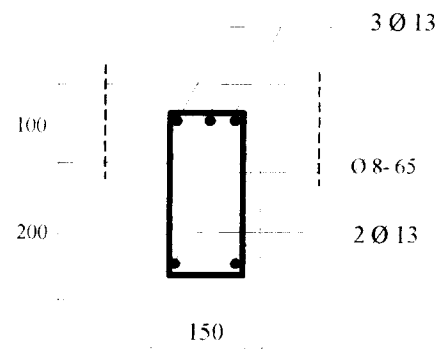
Tulangan Lapangan



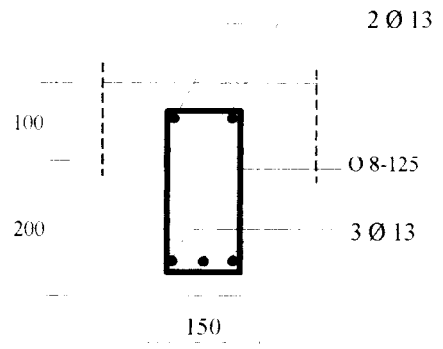
Gambar 4.14 Rencana Penulangan Balok Anak Lantai 2 dan 3

Rencana Balok Anak (Lantai Atap)

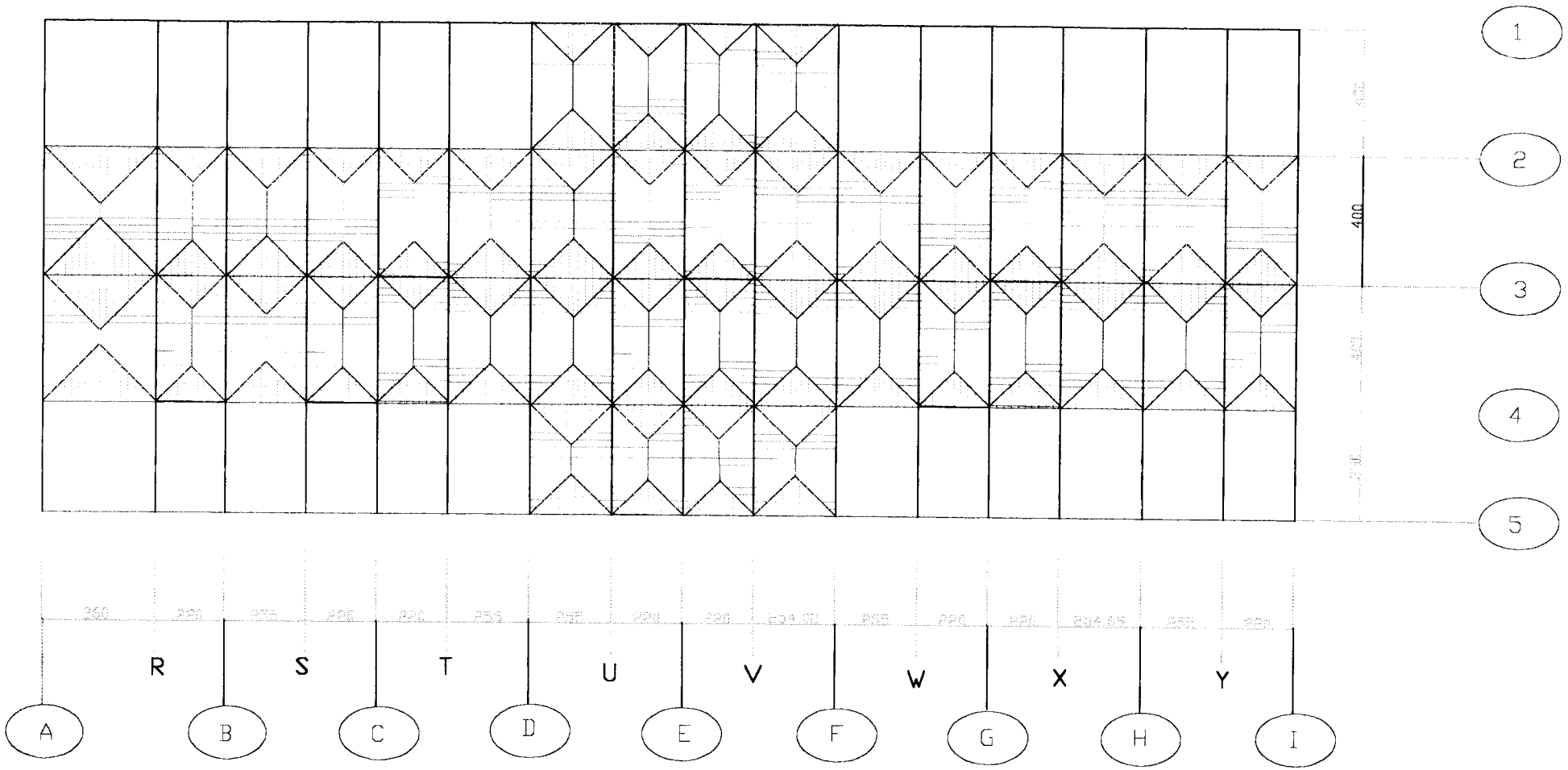
Tulangan Tumpuan



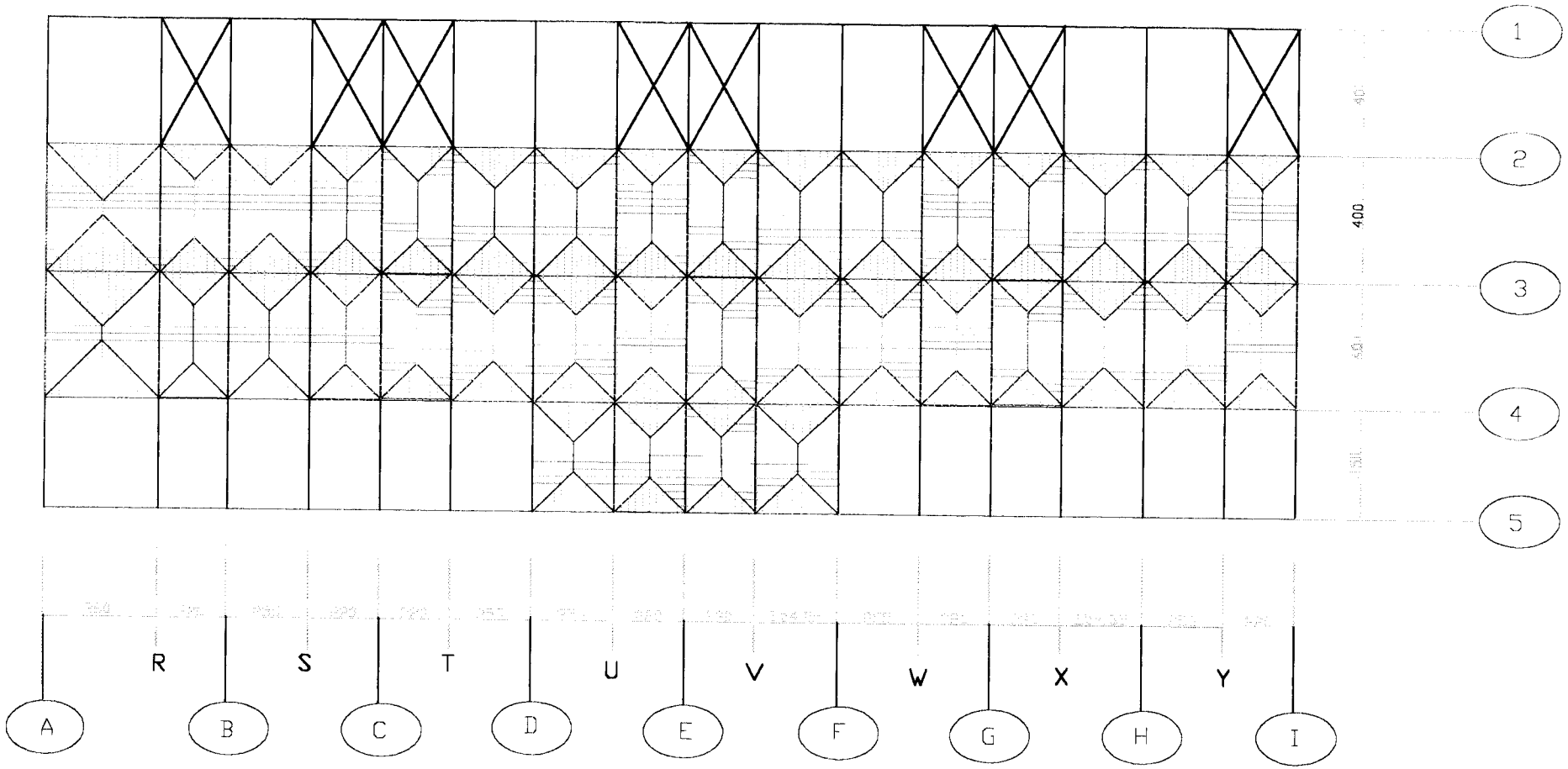
Tulangan Lapangan



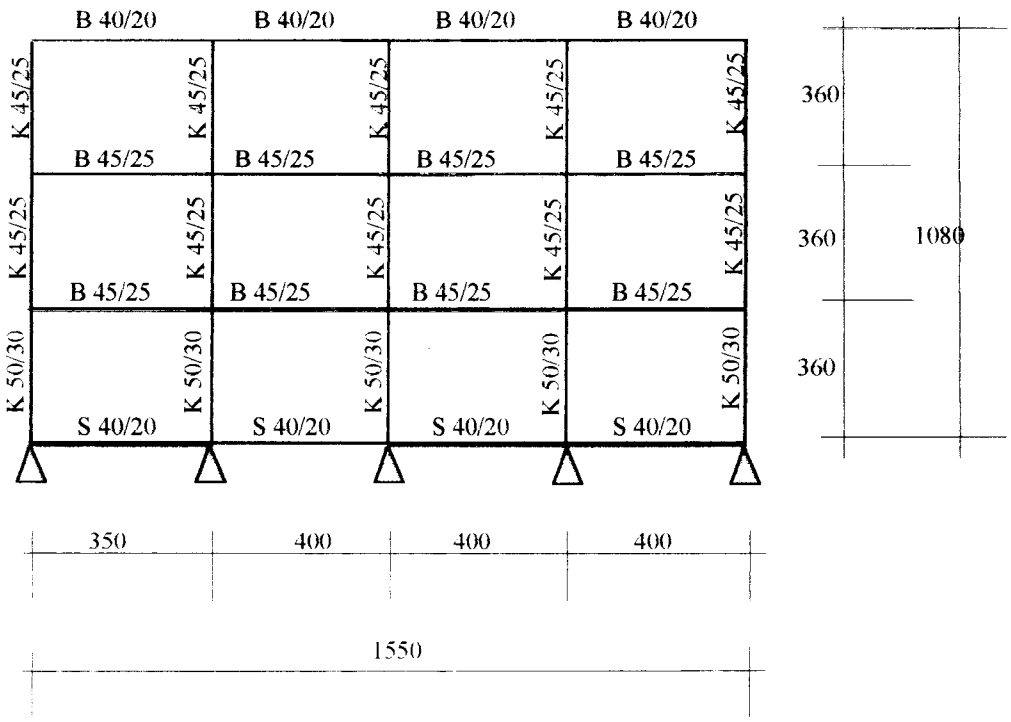
Gambar 4.15 Rencana Penulangan Balok Anak Lantai Atap



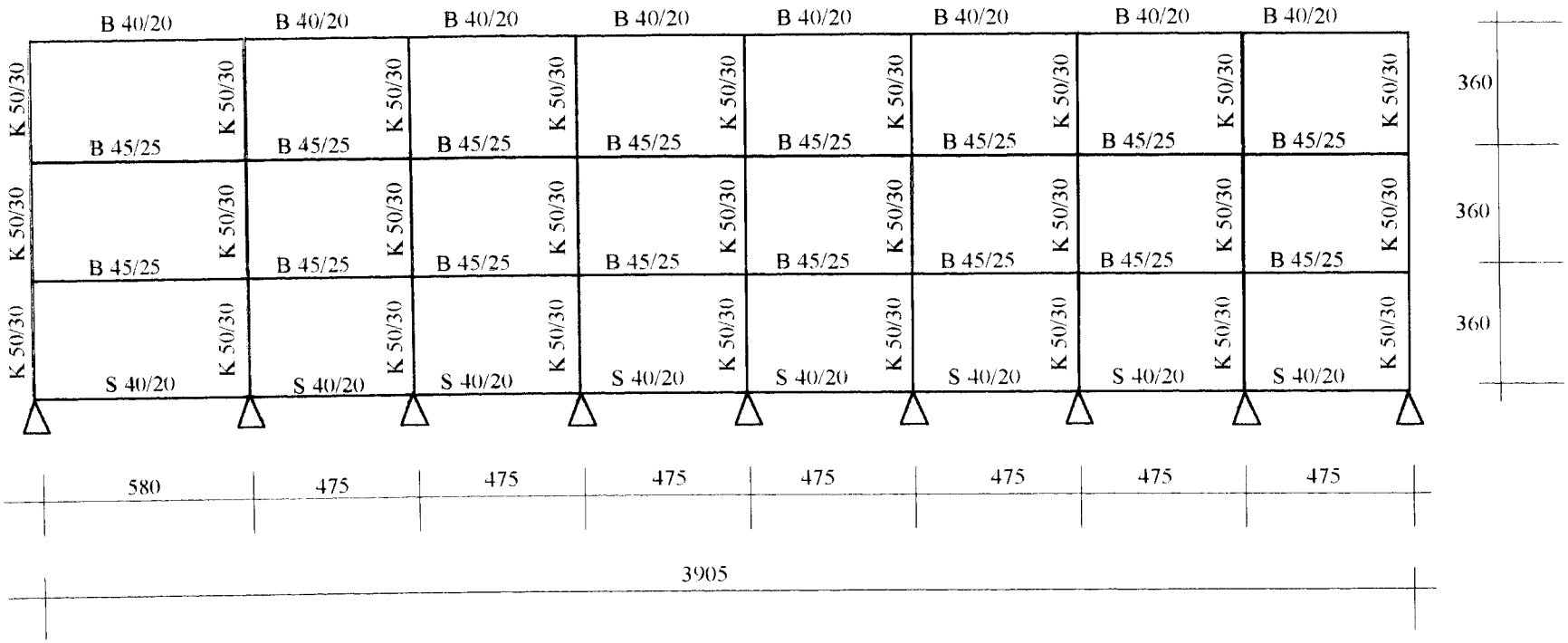
Gambar 4.16a Rencana Pembebanan Portal Lanatai Atap



Gambar 4.16b Rencana Pembebanan Portal Lanatal 1 & 2



Gambar 4.17 Portal melintang As E



Gambar 4.18 Portal memanjang As 3

4.4 Analisis Struktur Portal

4.4.1 Dimensionering Penampang Balok

Tinggi penampang balok lantai Atap diambil nilai antara 1/10 L sampai 1/15 L. pada balok ini dipilih nilai tinggi balok 1/15 L = 1/15 . 580 = 38,6 cm, diambil 40 cm, sedangkan lebar balok diambil nilai ½ . 40 = 20 cm,

Dan untuk tinggi penampang balok induk lantai 2 dan 3 diambil nilai tinggi balok 1/15 L = 1/14 . 580 = 41,42 cm, diambil 45 cm, sedangkan lebar balok diambil nilai ½ . 45 = 22,5 cm, diambil 25 cm.

4.4.2 Pembebanan Balok Induk Pada Plat Atap (100 mm)

- Beban Mati

q_1 = Berat sendiri balok induk berupa beban merata

= (0,4 – 0,1).0,20.24 = 1,44 KN/m

q_2 = Berat sendiri balok anak akibat beban merata

= (0,3 – 0,1).0,15.24 = 0,72 KN/m

q_3 = Berat sendiri plat atap berupa beban merata

= 3,36 KN/m

- Beban Hidup

q_4 = Beban hidup pada plat atap

= 1,00 KN/m

Perhitungan beban $q_{ekivalen}$ didapat dengan menggunakan

a. Rumus q_{ek} Segi tiga, yaitu :

q_{ek} = 1/3 . q . lx

b. Rumus q_{ek} Trapesium, yaitu :

$$q_{ek} = \frac{(q.\frac{lx}{3})(3-\frac{lx^2}{ly^2})}{2}$$

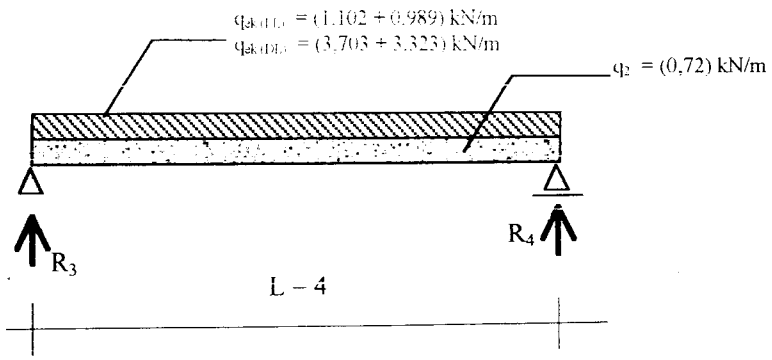
Untuk mempermudah perhitungan beban $q_{ekivalen}$ ini dihitung secara tabelaris sebagai berikut.

Type Plat	lx (m)	ly (m)	q_3 (mati)	q_4 (hidup)	q_{ek} Beban Mati (KN/m)		q_{ek} Beban Hidup (KN/m)	
					Δ	▱	Δ	▱
A	2,55	3,50	3,36	1,0	2,856	3,526	0,850	1,050
B	2,20	3,50	3,36	1,0	2,464	3,209	0,733	0,955
C	2,55	4,00	3,36	1,0	2,856	3,703	0,850	1,102
D	2,20	4,00	3,36	1,0	2,464	3,323	0,733	0,989
E	3,50	3,60	3,36	1,0	3,920	4,030	1,166	1,196
F	3,60	4,00	3,36	1,0	4,032	4,150	1,333	1,460

Tabel 4.2 Beban $q_{ekivalen}$ pada plat atap

Perhitungan Reaksi perletakan pada balok Atap

As u Bentang 3 - 4



*Gambar 4.19 Reaksi perletakan **As u Bentang 3 - 4***

Keterangan :

q_{ek} = Beban trapesium plat lantai type C + D

Beban mati

$\Sigma M_4 = 0$

$- R_{u3}.l - (q_{ek\,(DL)} + q_2) . l . (½ .l) = 0$

$- R_{u3}.4 - (7,026 + 0,72) . 4 . (½ .4) = 0$

$- 4R_{u3} - 61,968 = 0$

$$R_{u3} = \frac{61,968}{4} = 15,492 \text{ KN}$$

$R_{u3} = R_{u4z}$

Beban Hidup

$\Sigma M_4 = 0$S

$- R_{u3}.1 - (q_{ek\ (LL)}) . 1 . (½ .1) = 0$

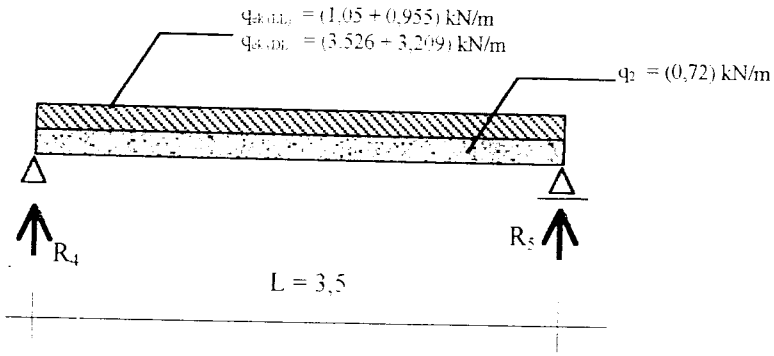
$- R_{u3}.4 - (2,091) . 4 . (½ .4) = 0$

$- 4R_{u3} - 16,728 = 0$

$$R_{u3} = \frac{16,728}{4} = 4,182 \text{ KN}$$

$R_{u3} = R_{..}$

As u Bentang 4 - 5



*Gambar 4.20 Reaksi perletakan **As u Bentang 4 - 5***

Keterangan :

q_{ek} = Beban trapesium plat lantai type A + B

Beban mati

$\Sigma M_4 = 0$

$- R_{u4}.1 - (q_{ek\ (DL)} + q_2) . 1 . (½ .1) = 0$

$- R_{u4}.3,5 - (6,735 + 0,72) . 3,5 . (½ .3,5) = 0$

$- 3,5R_{u4} - 45,662 = 0$

$$R_{u4} = \frac{45,662}{3,5} = 13,046 \text{ KN} \qquad R_{u4} = R_{u5}$$

Beban Hidup

$\Sigma M_4 = 0$

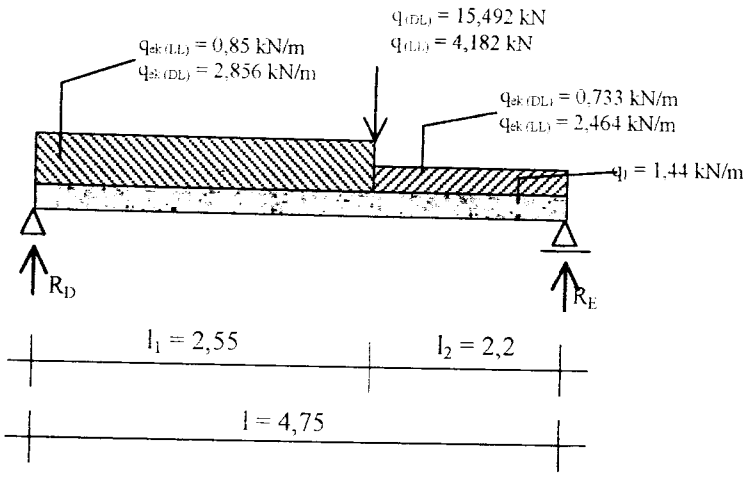
$- R_{u3}.1 - (q_{ek\ (LL)}) . 1 . (½ .1) = 0$

$- R_{u3}.3,5 - (2,005) . 3,5 . (½ . 3,5) = 0$

$- 3,5R_{u3} - 12,28 = 0$

$$R_{u3} = \frac{12,28}{3,5} = 3,508 \text{ KN} \qquad R_{u4} = R_{u5}$$

As 1 Bentang D – E



Gambar 4.21 Reaksi perletakan ***As 1 Bentang D - E***

Keterangan :

P_{DL} $= R_{1u} = R_{3u}$ (Bentang 3 - 4 (Balok Anak)) $= 15,492$ KN

P_{LL} $= R_{1u} = R_{3u}$ (Bentang 3 - 4 (Balok Anak)) $= 4,182$ KN

$q_{ek} (l_1)$ = Beban segi tiga plat lantai type C

$q_{ek} (l_2)$ = Beban segi tiga plat lantai type D

Beban mati

$\Sigma M_{1E} = 0$

$-R_{1D}.l - q_{ek} . l_2 (½ . l_2) - q_{ek} . l_1 (½ l_1 . l_2) - q_1 . . l - P . l_2 = 0$

$-R_{1D}.4,75 - 2,464. 2,2 (½ .2,2) - 2,856. 2,55 (3,475) - 1,44 .4,75 - 15,492. 2,2 = 0$

$- 4,75 R_{1D} - 72,265 = 0$

$$R_{1D} = \frac{72,265}{4,75} = 15,214 \text{ KN}$$

$\Sigma V_{ID} = 0$

$R_{ID} + R_{IE} - q_{ek} . l_2 - q_{ek} . l_1 - q_l . l - P = 0$

$R_{ID} + R_{IE} - 2,464. 2,2 - 2,856. 2,55 - 1,44 .4,75 - 15,492 = 0$

$R_{ID} + R_{IE} - 35,035 = 0$

$R_{IE} = 35,035 - R_{ID} = 35,035 - 15,214 = 19,821$ KN

Beban Hidup

$\Sigma M_{IE} = 0$

$- R_{ID}.l - q_{ek} . l_2 (½ . l_2) - q_{ek} . l_1 (½ l_1 . l_2) - P . l_2 = 0$

$- R_{ID} .4,75 - 0,733 . 2,2 (½ .2,2) - 0,85 , 2,55 (3,475) - 4,182 . 2,2 = 0$

$- 4,75 R_{ID} - 18,506 = 0$

$$R_{ID} = \frac{18,506}{4,75} = 3,896 \text{ KN}$$

$\Sigma V_{ID} = 0$

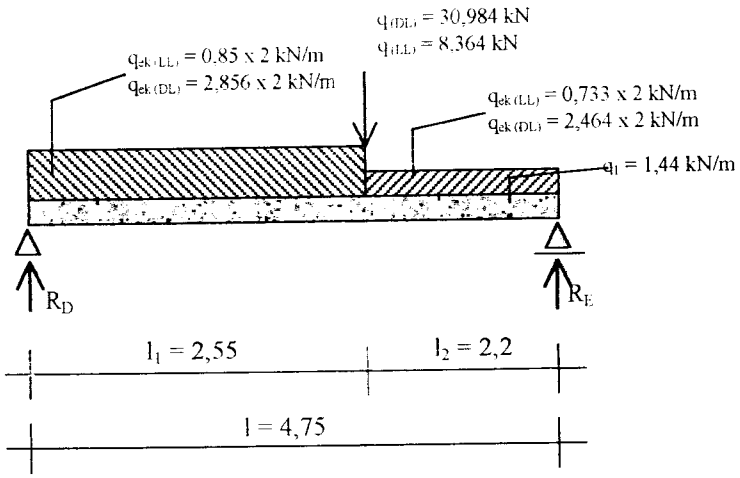
$R_{ID} + R_{IE} - q_{ek} . l_2 - q_{ek} . l_1 - P = 0$

$R_{ID} + R_{IE} - 0,733 . 2,2 - 0,85 , 2,55 - 4,182 = 0$

$R_{ID} + R_{IE} - 7,9625 = 0$

$R_{IE} = 7,9625 - R_{ID} = 7,9625 - 3,896 = 4,066$ KN

As 3 Bentang D - E



*Gambar 4.22 Reaksi perletakan **As 3 Bentang D - E***

Keterangan :

P_{DL} = ($R_{u3\ (Bentang\ 3\text{-}4\ \ (Balok\ Anak)}$ X 2)

= 15,492 x 2 = 30,984 KN

P_{LL} = ($R_{u3\ (Bentang\ 3\text{-}4\ \ (Balok\ Anak)}$ X 2)

= 4,1182 x2 = 8,364 KN

q_{ek} (l_1) = Beban segi tiga plat lantai type C x 2

q_{ek} (l_2) = Beban segi tiga plat lantai type D x 2

Beban mati

$\Sigma M_{3E} = 0$

$-R_{3D}.l - q_{ek} . l_2 (½ . l_2) - q_{ek} . l_1 (½ l_1 . l_2) - q_1 . l - P . l_2 = 0$

$-R_{3D}.4,75 - 4,928. 2,2 (½ .2,2) - 5,712. 2,55 (3,475) - 1,44 .4,75 - 30,984. 2,2 = 0$

$- 4,75\ R_{3D} - 137,546 = 0$

$$R_{3D} = \frac{137,546}{4,75} = 28,957 \text{ KN}$$

$\Sigma V_{3D} = 0$

$R_{3D} + R_{3E} - q_{ek} . l_2 - q_{ek} . l_1 - q_1 . l - P = 0$

$R_{3D} + R_{3E} - 4,928 . 2,2 - 5,712 , 2,55 - 1,44 . 4,75 - 30,984 = 0$

$R_{3D} + R_{3E} - 63,232 = 0$

$R_{3E} = 63,232 - R_{3D} = 63,232 - 28,957 = 34,274$ KN

Beban Hidup

$\Sigma M_{4E} = 0$

$- R_{3D}.l - q_{ek} . l_2 (½ . l_2) - q_{ek} . l_1 (½ l_1 . l_2) - P . l_2 = 0$

$- R_{3D} .4,75 - 1,466 . 2,2 (½ .2,2) - 1,7 , 2,55 (3,475) - 8,364 . 2,2 = 0$

$- 4,75\ R_{3D} - 37,013 = 0$

$$R_{3D} = \frac{37,013}{4,75} = 7,792 \text{ KN}$$

$\Sigma V_{3D} = 0$

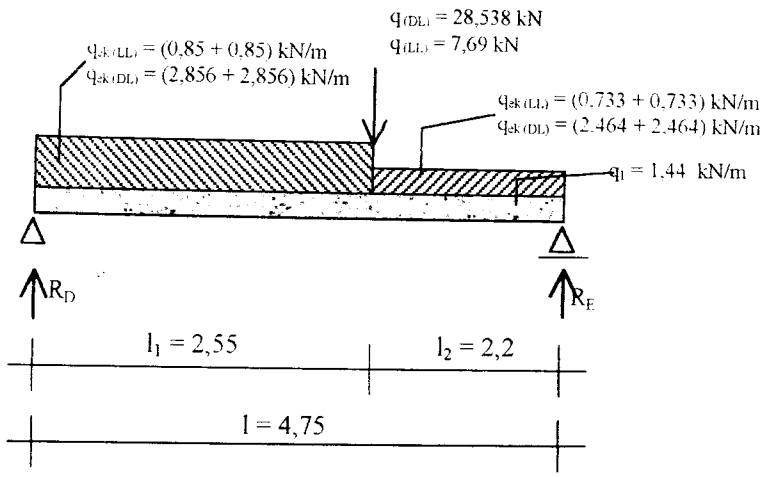
$R_{3D} + R_{3E} - q_{ek} . l_2 - q_{ek} . l_1 - P = 0$

$R_{3D} + R_{3E} - 1,466 . 2,2 - 1,7 , 2,55 - 8,364 = 0$

$R_{3D} + R_{3E} - 15{,}924 = 0$

$R_{3E} = 15{,}25 - R_{3D} = 15{,}924 - 7{,}792 = 8{,}132$ KN

As 4 Bentang D – E



Gambar 4.23 Reaksi perletakan ***As 4 Bentang D - E***

Keterangan :

P_{DL} $= (R_{u4\ (Bentang\ 3\text{-}4\ (Balok\ Anak)} + R_{u4\ (Bentang\ 4\text{-}5\ (Balok\ Anak))})$

$= 15{,}492 + 13{,}046 = 28{,}538$ KN

P_{LL} $= (R_{u4\ (Bentang\ 3\text{-}4\ (Balok\ Anak)} + R_{u4\ (Bentang\ 4\text{-}5\ (Balok\ Anak))})$

$= 4{,}182 + 3{,}508 = 7{,}69$ KN

q_{ek} (l_1) = Beban segi tiga plat lantai type A + C

q_{ek} (l_2) = Beban segi tiga plat lantai type B + D

Beban mati

$\Sigma M_{4E} = 0$

$-R_{4D}.l - q_{ek} . l_2 (\frac{1}{2} . l_2) - q_{ek} . l_1 (\frac{1}{2} l_1 . l_2) - q_1 . . l - P . l_2 = 0$

$-R_{4D}.4{,}75 - 4{,}928. 2{,}2 (\frac{1}{2} .2{,}2) - 5{,}712. 2{,}55 (3{,}475) - 1{,}44 .4{,}75 - 28{,}538. 2{,}2 = 0$

$- 4{,}75\ R_{4D} - 132{,}163 = 0$

$$R_{4D} = \frac{132{,}163}{4{,}75} = 27{,}824 \text{ KN}$$

$\Sigma V_{4D} = 0$

$R_{4D} + R_{4E} - q_{ek} \cdot l_2 - q_{ek} \cdot l_1 - q_l \cdot l - P = 0$

$R_{4D} + R_{4E} - 4{,}928 \cdot 2{,}2 - 5{,}712 \cdot 2{,}55 - 1{,}44 \cdot 4{,}75 - 28{,}538 = 0$

$R_{4D} + R_{4E} - 60{,}785 = 0$

$R_{4E} = 60{,}785 - R_{4D} = 60{,}785 - 27{,}824 = 32{,}96$ KN

Beban Hidup

$\Sigma M_{4E} = 0$

$- R_{4D} \cdot l - q_{ek} \cdot l_2 (\frac{1}{2} \cdot l_2) - q_{ek} \cdot l_1 (\frac{1}{2} l_1 \cdot l_2) - P \cdot l_2 = 0$

$- R_{4D} \cdot 4{,}75 - 1{,}466 \cdot 2{,}2 (\frac{1}{2} \cdot 2{,}2) - 1{,}7 \cdot 2{,}55 (3{,}475) - 7{,}69 \cdot 2{,}2 = 0$

$- 4{,}75 R_{4D} - 35{,}53 = 0$

$$R_{4D} = \frac{35{,}53}{4{,}75} = 7{,}48 \text{ KN}$$

$\Sigma V_{4D} = 0$

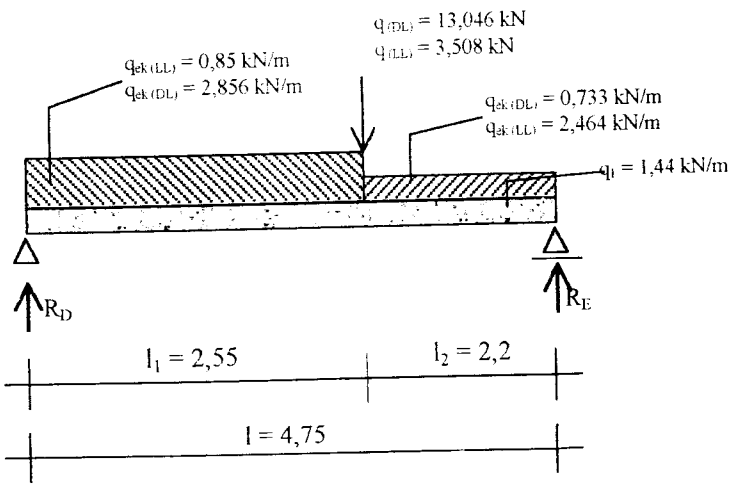
$R_{4D} + R_{4E} - q_{ek} \cdot l_2 - q_{ek} \cdot l_1 - P = 0$

$R_{4D} + R_{4E} - 1{,}466 \cdot 2{,}2 - 1{,}7 \cdot 2{,}55 - 7{,}69 = 0$

$R_{4D} + R_{4E} - 15{,}25 = 0$

$R_{4E} = 15{,}25 - R_{4D} = 15{,}25 - 7{,}48 = 7{,}56$ KN

As 5 Bentang D - E



Gambar 4.24 Reaksi perletakan ***As 5 Bentang D - E***

Keterangan :

P_{DL} = $R_{u5\ (Bentang\ 4\ -\ 5\ (Balok\ Anak)}$ = 13,046

P_{LL} = $R_{u5\ (Bentang\ 4\ -\ 5\ (Balok\ Anak)}$ = 3,508

q_{ek} (l_1) = Beban segi tiga plat lantai type A

q_{ek} (l_2) = Beban segi tiga plat lantai type B

Beban mati

$\Sigma M_{5E} = 0$

$-R_{5D}.l - q_{ek} . l_2 (½ . l_2) - q_{ek} . l_1 (½l_1 . l_2) - q_1 . l - P . l_2 = 0$

$-R_{5D}.4,75 - 2,464. 2,2 (½ .2,2) - 2,856. 2,55 (3,475) - 1,44 .4,75 - 13,046. 2,2 = 0$

$- 4,75\ R_{5D} - 66,812 = 0$

$$R_{5D} = \frac{66,812}{4,75} = 14,066 \text{ KN}$$

$\Sigma V_{5D} = 0$

$R_{5D} + R_{5E} - q_{ek} . l_2 - q_{ek} . l_1 - q_1 . l - P = 0$

$R_{5D} + R_{5E} - 2,464. 2,2 - 2,856. 2,55 - 1.44 .4,75 - 13,046 = 0$

$R_{5D} + R_{5E} - 32,59 = 0$

$R_{5E} = 32,59 - R_{5D} = 32,59 - 14,066 = 18,524$ KN

Beban Hidup

$\Sigma M_{5E} = 0$

$- R_{5D}.l - q_{ek} . l_2 (½ . l_2) - q_{ek} . l_1 (½l_1 . l_2) - P . l_2 = 0$

$- R_{5D} .4,75 - 0,733 . 2,2 (½ .2,2) - 0,85 , 2,55 (3,475) - 3,508 . 2,2 = 0$

$- 4,75\ R_{5D} - 17,023 = 0$

$$R_{5D} = \frac{17,023}{4,75} = 3,584 \text{ KN}$$

$\Sigma V_{5D} = 0$

$R_{5D} + R_{5E} - q_{ek} . l_2 - q_{ek} . l_1 - P = 0$

$R_{5D} + R_{5E} - 0,733 . 2,2 - 0,85 , 2,55 - 3,508 = 0$

$R_{5D} + R_{5E} - 7,2885 = 0$

$R_{5E} = 7,2885 - R_{5D} = 7,2885 - 3,584 = 3,704$ KN

Pembebanan pada balok induk atap (Melintang)

Bentang 3 - 4 As E

- Beban merata (q) :
  - b. Akibat beban mati
    - Beban plat trapezium type D = (3,323) x 2 = 6,646 KN/m
  - c. Akibat beban hidup
    - Beban hidup plat trapezium Type D = 0,989 x 2 = 1,898 KN/m

- Beban pada Joint E3
  - a. Beban mati
    - Berat Reaksi perletakan $R_{E3\,(DL)}$ x 2 = 34,274 x 2 = 68,548 KN
  - b. Beban hidup
    - Berat Reaksi perletakan $R_{E3\,(LL)}$ x 2 = 8,132 x 2 = 16,264 KN

Bentang 4 - 5 As E

- Beban merata (q) :
  - b. Akibat beban mati
    - Beban plat trapezium type B = 3,209 x 2 = 6,418 KN/m
  - c. Akibat beban hidup
    - Beban hidup plat trapezium Type B = 0,955 x 2 = 1,110 KN/m

- Beban pada Joint E4
  - a. Beban mati
    - Berat Reaksi perletakan $R_{E4\,(DL)}$ x 2 = 32,96 x 2 = 65,820 KN
  - b. Beban hidup
    - Berat Reaksi perletakan $R_{E4\,(LL)}$ x 2 = 7,56 x 2 = 15,120 KN

- Beban pada Joint E5
  - a. Beban mati
    - Berat Reaksi perletakan $R_{5E\,(DL)}$ x 2 = 18,524 x 2 = 37,048 KN

b. Beban hidup

- Berat Reaksi perletakan $R_{5E\,(LL)}$ x 2 = 3,704 x 2 = 7,408 KN

- Beban pada Joint E1

a. Beban mati

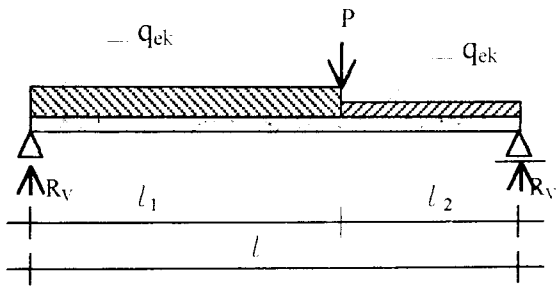
- Berat Reaksi perletakan $R_{1E\,(DL)}$ x 2 = 19,821 x 2 = 39,642 KN

b. Beban hidup

- Berat Reaksi perletakan $R_{1E\,(LL)}$ x 2 = 4,066 x 2 = 8,132 KN

Pembebanan pada balok induk atap (Memanjang)

Bentang A - B As 3



- Beban merata (q) :

a. Akibat beban mati

- Berat sendiri plat segi Δ type D (l_2) = 2,464 . 2 = 4,928 KN/m
- Berat sendiri plat segi Δ type F (l_1) = 4,032 . 2 = 8,064 KN/m

b. Akibat beban hidup

- Berat sendiri plat segi Δ type D (l_2) = 2 . 0,733 = 1,466 KN/m
- Berat sendiri plat segi Δ type F (l_1) = 2 . 1,333 = 2,666 KN/m

- Beban terpusat

a. Beban mati

- Berat sendiri balok anak = (0,3 – 0,1) . 0,15 . 24 .4 = 2,880 KN

- Berat sendiri plat trapesium type D = ½ (3,323) . 2 . 2 = 6,646 KN
- Berat sendiri plat trapesium type F = ½ (4,15) . 2 . 2 = 8,300 KN

= 17,826 KN

b. Beban hidup

- Berat sendiri plat trapesium type D = ½ (0,989) . 2 . 2 = 1,979 KN
- Berat sendiri plat trapesium type F = ½ (1,46) . 2 . 2 = 2,920 KN

= 4,899 KN

- Beban pada Joint 3A

a. Beban mati

- Berat sendiri balok induk = (0,4 – 0,1) . 0,2 . 24 .4 = 5,760 KN
- Berat sendiri Plat trapesium type F = ½ (4,15) . 2 . 2 = 8,300 KN

= 14,06 KN

b. Beban hidup

- Beban hidup plat trapesium Type F = ½ (1,46) . 2 . 2 = 2,920 KN

Bentang B - C As 3

- Beban merata (q) :

a. Akibat beban mati

- Berat sendiri plat segi Δ type D (l_2) = 2,464 . 2 = 4,928 KN/m
- Berat sendiri plat segi Δ type C (l_1) = 2,856 . 2 = 5,712 KN/m

b. Akibat beban hidup

- Berat sendiri plat segi Δ type D (l_2) = 2 . 0,733 = 1,466 KN/m
- Berat sendiri plat segi Δ type C (l_2) = 2 . 0,85 = 1,700 KN/m

- Beban terpusat

a. Beban mati

- Berat sendiri balok anak = (0,3 – 0,1) . 0,15 . 24 .4 = 2,880 KN
- Berat sendiri plat trapesium type D = ½ (3,323) . 2 . 2 = 6,646 KN
- Berat sendiri plat trapesium type C = ½ (3,703) . 2 . 2 = 7,406 KN

= 16,932 KN

b. Beban hidup

- Berat sendiri plat trapesium type D = ½ (0,989) . 2 .2 = 1,978 KN
- Berat sendiri plat trapesium type C = ½ (1,102) . 2 . 2 = 2,204 KN

= 4,182 KN

- Beban pada Joint 3B

a. Beban mati

- Berat sendiri balok induk = (0,4 – 0.1) . 0,2 . 24 .4 = 5,760 KN
- Berat sendiri Plat trapesium type C = ½ (3,703) . 2 . 2 = 7,406 KN
- Berat sendiri Plat trapesium type D = ½ (3,323) . 2 . 2 = 6,646 KN

=19,812 KN

b. Beban hidup

- Beban hidup plat trapesium Type D = ½ (0,989) . 2 = 0,989 KN
- Beban hidup plat trapesium Type C = ½ (1,102) . 2 = 1,102 KN

= 2,891 KN

- Beban pada Joint 3C

a. Beban mati

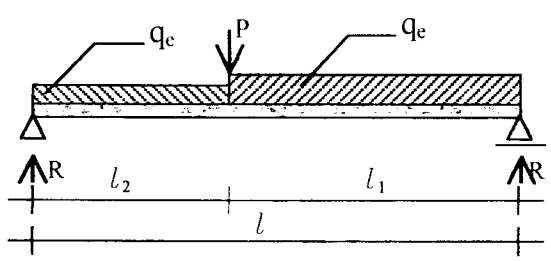
- Berat sendiri balok induk = (0,4 – 0,1) . 0,2 . 24 .4 = 5,7600 KN
- Berat sendiri Plat trapesium type D = ½ (3,323) . 4 . 2 = 13,292 KN

= 19,052 KN

b. Beban hidup

- Beban hidup plat trapesium Type D = ½ (0,989) . 4 . 2 = 3,956 KN

Bentang C – D As 3



- Beban merata (q) :
  a. Akibat beban mati
     - Berat sendiri plat segi Δ type D (l_2) = 2,464 . 2 = 4,928 KN/m
     - Berat sendiri plat segi Δ type C (l_1) = 2,856 . 2 = 5,712 KN/m
  b. Akibat beban hidup
     - Berat sendiri plat segi Δ type D (l_2) = 2 . 0,733 = 1,466 KN/m
     - Berat sendiri plat segi Δ type C (l_1) = 2 . 0,85 = 1,700 KN/m

- Beban terpusat
  a. Beban mati
     - Berat sendiri balok anak = (0,3 – 0,1) . 0,15 . 24 .4 = 2,880 KN
     - Berat sendiri plat trapesium type D = ½ (3,323) . 2 . 2 = 6,646 KN
     - Berat sendiri plat trapesium type C = ½ (3,703) . 2 . 2 = 7,406 KN

       = 16,932 KN
  b. Beban hidup
     - Berat sendiri plat trapesium type D = ½ (0,989) . 2 . 2 = 1,978 KN
     - Berat sendiri plat trapesium type C = ½ (1,102) . 2 . 2 = 2,204 KN

       = 4,182 KN

- Beban pada Joint 3D
  a. Beban mati
     - Berat sendiri balok induk = (0,4 – 0,1) . 0,2 . 24 .4 = 5,760 KN
     - Berat sendiri Plat trapesium type C = ½ (3,703) . 4 . 2 = 14,812 KN

       = 20,572 KN
  b. Beban hidup
     - Beban hidup plat trapesium Type C = ½ (1,102) . 4 . 2 = 4,408 KN

- Beban pada Joint 3I
  a. Beban mati
     - Berat sendiri balok induk = (0,4 – 0,1) . 0,2 . 24 .4 = 5,760 KN

- Berat sendiri Plat trapesium type D = ½ (3,323) . 2 . 2 = 6,646 KN

= 12,406 KN

b. Beban hidup

- Beban hidup plat trapesium Type D = ½ (0,989) . 2 . 2 = 1,978 KN

Keterangan :

Berat sendiri balok induk pada beban merata tidak dihitung, untuk As yang ditinjau karena sudah dihitung oleh program SAP itu sendiri.

Resume Pembebabnan melintang

As E Bentang	Beban Pada Batang				Beban Pada Joint	
	Beban Merata		Beban Terpusat		Beban Terpusat	
	Mati	Hidup	Mati	Hidup	Mati	Hidup
1 – 2	6,646	1,898	-	-	39,642	8,132
					68,548	16,264
2 – 3	6,646	1,898	-	-	68,548	16,264
3 – 4	6,646	1,898	-	-	65,820	15,120
4 – 5	6,418	1,110	-	-	37,048	7,408

Tabel 4.3 Resume Pembebanan Balok Atap Melintang

Keterangan :

Joint D2 = Joint D3

Resume Pembebanan Memanjang

As 3 Bentang	Beban Pada Batang				Beban Pada Joint	
	Beban Merata		Beban Terpusat		Beban Terpusat	
	Mati	Hidup	Mati	Hidup	Mati	Hidup
A - B	l_1 = 8,064 l_2 = 4,928	l_1 = 2,666 l_2 = 1,466	17.826	4,899	14,06	2,920
B - C	l_1 = 5,712 l_2 = 4,928	l_1 = 1,700 l_2 = 1,466	16,932	4,182	19,812	2,891
C - D	l_1 = 5,712 l_2 = 4,928	l_1 = 1,700 l_2 = 1,466	16,932	4,182	19,052	3,956
D - E	l_1 = 5,712 l_2 = 4,928	l_1 = 1,700 l_2 = 1,466	16,932	4,182	20,572	4,408
E - F	l_1 = 5,712 l_2 = 4,928	l_1 = 1,700 l_2 = 1,466	16,932	4,182	19,052	3,956
F - G	l_1 = 5,712 l_2 = 4,928	l_1 = 1,700 l_2 = 1,466	16,932	4,182	20,572	4,408
G - H	l_1 = 5,712 l_2 = 4,928	l_1 = 1,700 l_2 = 1,466	16,932	4,182	19,052	3,956
H - I	l_1 = 5,712 l_2 = 4,928	l_1 = 1,700 l_2 = 1,466	16,932	4,182	20,572	4,408
					12,406	1,978

Tabel 4.4 Resume Pembebanan Balok Atap Memanjang

Keterangan :

Joint 3C = Joint 3E = Joint 3G

Joint 3D = Joint 3F = Joint 3H

4.4.3 Pembebanan Balok Induk Pada Plat Lantai (130 mm), lantai 2 dan 3

- Beban Mati

q_1 = Berat sendiri balok induk berupa beban merata

= (0,45 – 0,13).0,25.24 = 1,92 KN/m

q_2 = Berat sendiri balok anak akibat beban merata

= (0,30 – 0,13).0,15. 24 = 0,612 KN/m

q_3 = Berat sendiri plat lantai berupa beban merata

= 3,84 KN/m

- Beban Hidup

q_4 = Beban hidup pada plat atap

= 2,5 KN/m

Perhitungan beban $q_{ekivalen}$ didapat dengan menggunakan

a. Rumus q_{ek} Segi tiga, yaitu :

$q_{ek} = 1/3 \cdot q \cdot lx$

b. Rumus q_{ek} Trapesium, yaitu :

$$q_{ek} = \frac{(q.\frac{lx}{3})(3-\frac{lx^2}{ly^2})}{2}$$

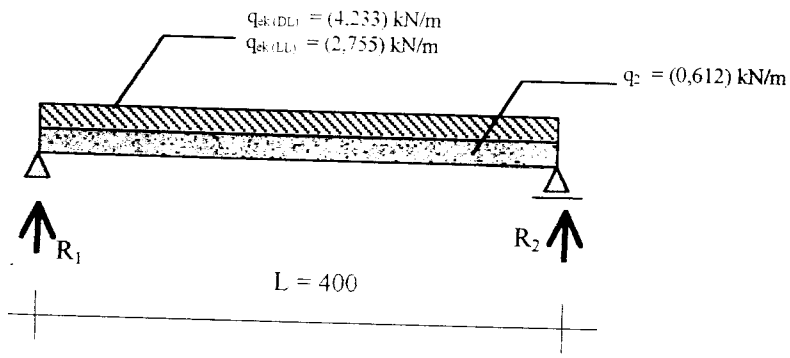
Untuk mempermudah perhitungan beban $q_{ekivalen}$ ini dihitung secara tabelaris sebagai berikut.

Type Plat	lx (m)	ly (m)	q_3 (mati)	q_4 (hidup)	q_{ek} Beban Mati (KN/m)		q_{ek} Beban Hidup (KN/m)	
					Δ	⏢	Δ	⏢
A	2,55	3,50	3,84	2,5	3,264	4,030	2,125	2,623
B	2,2	3,50	3,84	2,5	2,816	3,667	1,833	2,387
C	2,55	4,00	3,84	2,5	3,264	4,233	2,125	2,755
D	2,20	4,00	3,84	2,5	2,816	3,800	1,833	2,472
E	3,50	3,60	3,84	2,5	4,480	4,603	2,920	3,000
F	3,60	4,00	3,84	2,5	4,608	5,046	3,000	3,285

Tabel 4.5 Beban $q_{ekivalen}$ pada plat atap

Perhitungan reaksi perletakan pada balok lantai

As u Bentang 1 - 2



Gambar 4.25 Reaksi perletakan ***As u Bentang 1 - 2***

Keterangan :

q_{ek} = Beban trapesium plat lantai type C

Beban mati

$\Sigma M_2 = 0$

$- R_{u1}.l - (q_{ek\ C\ (DL)} + q_2) . 1 . (½ .l) = 0$

$- R_{u1}.4 - (4,233 + 0,612) . 4 . (½ .4) = 0$

$- 4R_{u1} - 39,624 = 0$

$$R_{u1} = \frac{39,624}{4} = 9,906 \text{ KN}$$

$R_{u1} = R_{u2}$

Beban Hidup

$\Sigma M_2 = 0$

$- R_{u1}.l - (q_{ek\ C\ (LL)}) . 1 . (½ .l) = 0$

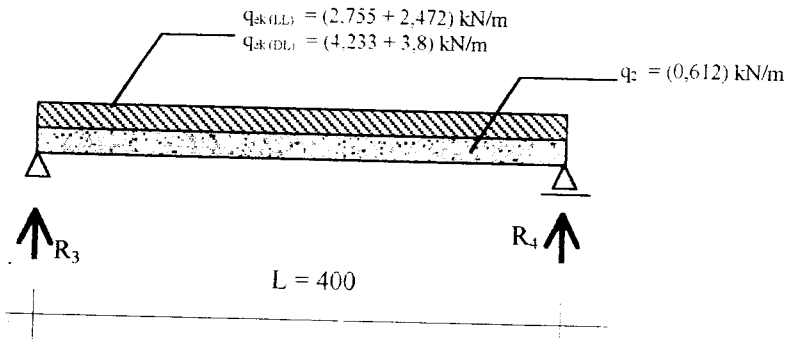
$- R_{u1}.3,5 - (2,755) . 4 . (½ . 4) = 0$

$- 4R_{u1} - 22,04 = 0$

$$R_{u1} = \frac{22,04}{4} = 5,51 \text{ KN}$$

$R_{u1} = R_{u2}$

As u Bentang 3 - 4



Gambar 4.26 Reaksi perletakan ***As u Bentang 3 - 4***

Keterangan :

q_{ek} = Beban trapesium plat lantai type C + D

Beban mati

$\Sigma M_4 = 0$

$- R_{u3}.l - (q_{ek\,(DL)} + q_2) \,.\, l \,.\, (\tfrac{1}{2}.l) = 0$

$- R_{u3}.4 - (8{,}033 + 0{,}612) \,.\, 4 \,.\, (\tfrac{1}{2}.4) = 0$

$- 4R_{u3} - 69{,}160 = 0$

$$R_{u3} = \frac{69{,}160}{4} = 17{,}290 \text{ KN}$$

$R_{u3} = R_{u4}$

Beban Hidup

$\Sigma M_4 = 0$

$- R_{u3}.l - (q_{ek\,(LL)}) \,.\, l \,.\, (\tfrac{1}{2}.l) = 0$

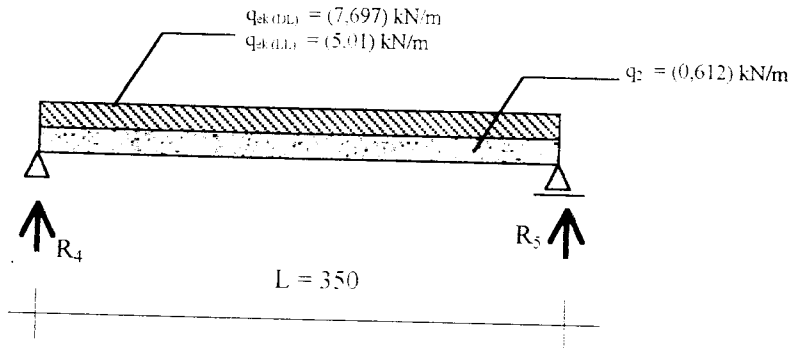
$- R_{u3}.4 - (5{,}227) \,.\, 4 \,.\, (\tfrac{1}{2}.4) = 0$

$- 4R_{u3} - 41{,}816 = 0$

$$R_{u3} = \frac{41{,}816}{4} = 10{,}454 \text{ KN}$$

$R_{u3} = R_{u4}$

As u Bentang 4 - 5



Gambar 4.27 Reaksi perletakan ***As u Bentang 4 - 5***

Keterangan :

q_{ek} = Beban trapesium plat lantai type A + B

Beban mati

$\Sigma M_5 = 0$

$- R_{u4}.l - (q_{ek\ A\ (DL)} + q_{ek\ B\ (DL)} + q_2) . l . (½ .l) = 0$

$- R_{u4}.3,5 - (4,03 + 3,667 + 0,612) . 3,5 . (½ .3,5) = 0$

$- 3,5R_{u4} - 51,554 = 0$

$$R_{u4} = \frac{51,554}{3,5} = 14,73 \text{ KN}$$

$R_{u4} = R_{u5}$

Beban Hidup

$\Sigma M_4 = 0$

$- R_{u5}.l - (q_{ek\ B\ (LL)} + q_{ek\ B\ (LL)}) . l . (½ .l) = 0$

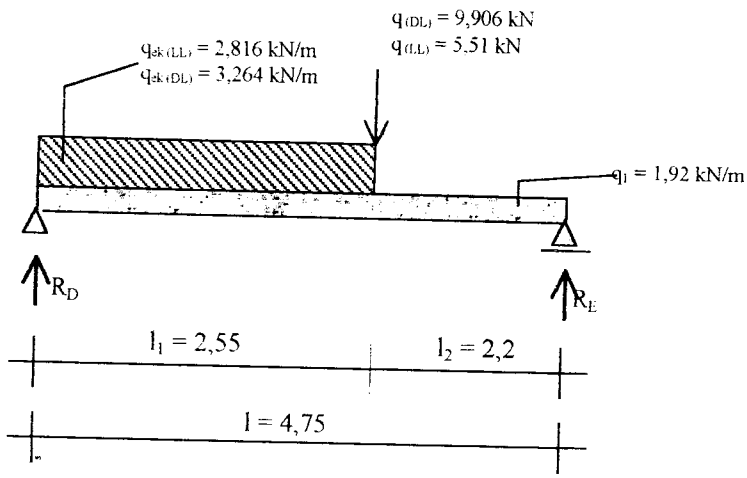
$- R_{u5}.3,5 - (2,623 + 2,387) . 3,5 . (½ . 3,5) = 0$

$- 3,5R_{u5} - 30,741 = 0$

$$R_{u5} = \frac{30,741}{3,5} = 8,783 \text{ KN}$$

$R_{u4} = R_{u5}$

As 1 Bentang D – E



Gambar 4.28 Reaksi perletakan ***As 1 Bentang D - E***

Keterangan :

P_{DL} = R_{1u} = $R_{3u\ (Bentang\ 3-4\ (Balok\ Anak)}$ = 9,906 KN

P_{LL} = R_{1u} = $R_{3u\ (Bentang\ 3-4\ (Balok\ Anak)}$ = 5,51 KN

q_{ek} (l_1) = Beban segi tiga plat lantai type C

Beban mati

$\Sigma M_{1E} = 0$

$-R_{1D}.l - q_{ek} . l_1 (\frac{1}{2} l_1 . l_2) - q_1 . l - P . l_2 = 0$

$-R_{1D}.4,75 - 3,264. 2,55 (3,475) - 1,92 .4,75 - 9,906. 2,2 = 0$

$- 4,75 R_{1D} - 59,836 = 0$

$$R_{1D} = \frac{59,836}{4,75} = 12,6 \text{ KN}$$

$\Sigma V_{1D} = 0$

$R_{1D} + R_{1E} - q_{ek} . l_1 - q_1 . l - P = 0$

$R_{1D} + R_{1E} - 3,264. 2,55 - 1,92 .4,75 - 9,906 = 0$

$R_{1D} + R_{1E} - 27,35 = 0$

$R_{1E} = 27,35 - R_{1D} = 27,35 - 9,906 = 14,749$ KN

Beban Hidup

$\Sigma M_{1E} = 0$

$- R_{1D}.l - q_{ek} . l_1 (\frac{1}{2} l_1 . l_2) - P . l_2 = 0$

$- R_{1D} .4,75 - 2,125 , 2,55 (3,475) - 5,51 . 2,2 = 0$

$4,75\ R_{1D} - 30,952 = 0$

$$R_{1D} = \frac{30,952}{4,75} = 6,516 \text{ KN}$$

$\Sigma V_{1D} = 0$

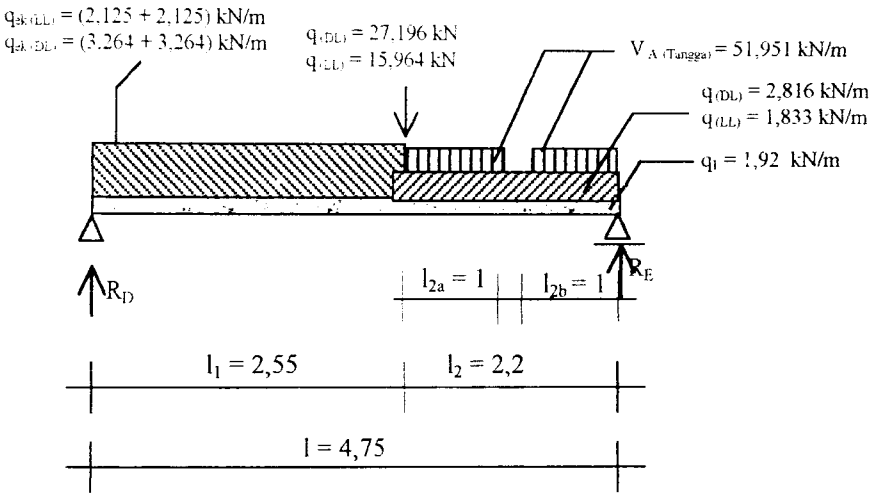
$R_{1D} + R_{1E} - q_{ek} . l_1 - P = 0$

$R_{1D} + R_{1E} - 2,125 , 2,55 - 5,51 = 0$

$R_{1D} + R_{1E} - 10,928 = 0$

$R_{1E} = 10,928 - R_{1D} = 10,928 - 6,516 = 4,13$ KN

As 2 Bentang D – E



*Gambar 4.29 Reaksi perletakan **As 4 Bentang D - E***

Keterangan :

P_{DL} = ($R_{u2\ (Bentang\ 1-2\ (Balok\ Anak)}$ + R_{u2} = $R_{u3\ (Bentang\ 3-4\ (Balok\ Anak)}$)

= 17,290 + 9,906 = 27,196 KN

P_{DL} = ($R_{u2\ (Bentang\ 1-2\ (Balok\ Anak)}$ + R_{u2} = $R_{u3\ (Bentang\ 3-4\ (Balok\ Anak)}$)

= 10,454 + 5,51 = 15,964 KN

q_{ek} (l_1) = Beban segi tiga plat lantai type D + C

q_{ek} (l_2) = Beban segi tiga plat lantai type D

Beban mati

$\Sigma M_{2E} = 0$

$-R_{2D}.l - q_{ek} . l_2 (½ . l_2) - V_A . l_{2b} (l_2 - ½l_{2b}) - V_A . l_{2b} (½l_{2a}) - q_{ek} . l_1 (½l_1 . l_2) - q_1 . l - P . l_2 = 0$

$- R_{2D}.4,75 - 2,816. 2,2 (½ .2,2) - 51,951 . 1 (1,7) - 51,951 . 1 (0,5) - 6,528 . 2,55 (3,475) - 1,92 . 4,75 - 27,196 . 2,2 = 0$

$- 4,75 R_{2D} - 247,772 = 0$

$$R_{2D} = \frac{247,772}{4,75} = 52,162 \text{ KN}$$

$\Sigma V_{2D} = 0$

$R_{2D} + R_{2E} - q_{ek} . l_2 - V_A . l_{2b} - V_A . l_{2b} - q_{ek} . l_1 - q_1 . l - P = 0$

$R_{2D} + R_{2E} - 2,816.2,2 - 51,951 .1 - 51,95 .1 - 6,528 .2,55 - 1,92 .4,75 - 27,196 = 0$

$R_{2D} + R_{2E} - 160,999 = 0$

$R_{2E} = 160,999 - R_{4D} = 160,999 - 52,162 = 108,837$ KN

Beban Hidup

$\Sigma M_{2E} = 0$

$- R_{2D}.l - q_{ek} . l_2 (½ . l_2) - q_{ek} . l_1 (½l_1 . l_2) - P . l_2 = 0$

$- R_{2D} . 4,75 - 1,833 . 2,2 (½ .2,2) - 4,25 . 2,55 (3,475) - 15,964 . 2,2 = 0$

$- 4,75 R_{2D} - 77,216 = 0$

$$R_{2D} = \frac{77,216}{4,75} = 16,256 \text{ KN}$$

$\Sigma V_{2D} = 0$

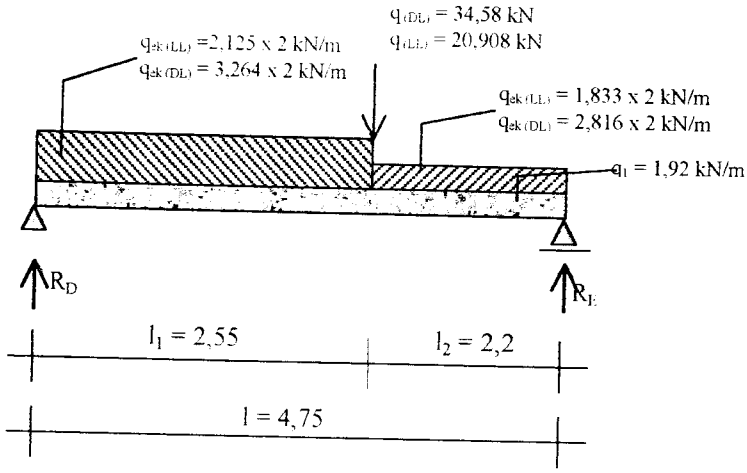
$R_{2D} + R_{2E} - q_{ek} . l_2 - q_{ek} . l_1 - P = 0$

$R_{2D} + R_{2E} - 1,833 . 2,2 - 4,25 . 2,55 - 15,964 = 0$

$R_{2D} + R_{2E} - 30,834 = 0$

$R_{2E} = 30,834 - R_{2D} = 30,834 - 15,578 = 19,431$ KN

As 3 Bentang D - E



*Gambar 4.30 Reaksi perletakan **As 3 Bentang D - E***

Keterangan :

P_{DL} = ($R_{u3\,(Bentang\ 3\text{-}4\ (Balok\ Anak)}$ x 2)

= 17,29 x 2 = 34,58 KN

P_{LL} = ($R_{u3\,(Bentang\ 3\text{-}4\ (Balok\ Anak)}$ x 2)

= 10,454 x2 = 20,908 KN

q_{ek} (l_1) = Beban segi tiga plat lantai type C x 2

q_{ek} (l_2) = Beban segi tiga plat lantai type D x 2

Beban mati

$\Sigma M_{3E} = 0$

$-R_{3D}.l - q_{ek} . l_2 (½ . l_2) - q_{ek} . l_1 (½ l_1 . l_2) - q_1 . . l - P . l_2 = 0$

$-R_{3D}.4,75 - 5,632. 2,2 (½ .2,2) - 6,528. 2,55 (3,475) - 1,92 .4,75 - 34,58. 2,2 = 0$

$- 4,75\ R_{3D} - 149,755 = 0$

$$R_{3D} = \frac{149,755}{4,75} = 31,527 \text{ KN}$$

$\Sigma V_{3D} = 0$

$R_{3D} + R_{3E} - q_{ek} . l_2 - q_{ek} . l_1 - q_1 . . l - P = 0$

$R_{3D} + R_{3E} - 5,632 . 2,2 - 6,528 , 2,55 - 1,92 . 4,75 - 34,58 = 0$

$R_{3D} + R_{3E} - 72,737 = 0$

$R_{3E} = 72,737 - R_{3D} = 72,737 - 31,527 = 41,209$ KN

Beban Hidup

$\Sigma M_{4E} = 0$

$- R_{3D}.l - q_{ek} . l_2 (\frac{1}{2} . l_2) - q_{ek} . l_1 (\frac{1}{2} l_1 . l_2) - P . l_2 = 0$

$- R_{3D} .4,75 - 3,666 . 2,2 (\frac{1}{2} .2,2) - 4,25 , 2,55 (3,475) - 20,908 . 2,2 = 0$

$- 4,75 R_{3D} - 92,53 = 0$

$$R_{3D} = \frac{92,53}{4,75} = 19,48 \text{ KN}$$

$\Sigma V_{3D} = 0$

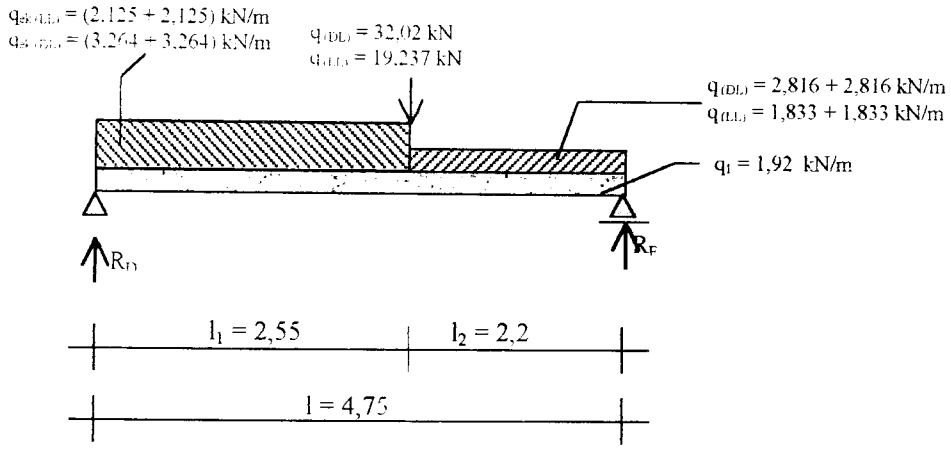
$R_{3D} + R_{3E} - q_{ek} . l_2 - q_{ek} . l_1 - P = 0$

$R_{3D} + R_{3E} - 3,666 . 2,2 - 4,55 , 2,55 - 20,908 = 0$

$R_{3D} + R_{3E} - 40,576 = 0$

$R_{3E} = 40,576 - R_{3D} = 40,576 - 19,48 = 21,096$ KN

As 4 Bentang D – E



Gambar 4.31 Reaksi perletakan ***As 4 Bentang D – E***

Keterangan :

P_{DL} = ($R_{u4\ (Bentang\ 3 - 4\ (Balok\ Anak)}$ + $R_{u4\ (Bentang\ 4 - 5\ (Balok\ Anak))}$)

= 17,290 + 14,73 = 32,02 KN

P_{LL} = ($R_{u4\ (Bentang\ 3 - 4\ (Balok\ Anak)}$ + $R_{u4\ (Bentang\ 4-5\ (Balok\ Anak))}$)

= 10,454 + 8,783 = 19,237 KN

q_{ek} (l_1) = Beban segi tiga plat lantai type A + C

q_{ek} (l_2) = Beban segi tiga plat lantai type D + B

Beban mati

$\Sigma M_{4E} = 0$

$-R_{4D}.l - q_{ek} . l_2 (½ . l_2) - q_{ek} . l_1 (½l_1 . l_2) - q_{1} . l - P . l_2 = 0$

$-R_{4D}.4,75 - 5,632. 2,2 (½ .2,2) - 6,528 . 2,55 (3,475) - 1,92 .4,75 - 32,02. 2,2 = 0$

$- 4,75 R_{4D} - 151,04 = 0$

$$R_{4D} = \frac{151,04}{4,75} = 31,8 \text{ KN}$$

$\Sigma V_{4D} = 0$

$R_{4D} + R_{4E} - q_{ek} . l_2 - q_{ek} . l_1 - q_{1} . l - P = 0$

$R_{4D} + R_{4E} - 5,632. 2.2 - 6,528 . 2,55 - 1,92 .4,75 - 32,02 = 0$

$R_{4D} + R_{4E} - 70,176 = 0$

$R_{4E} = 171,666 - R_{4D} = 171,666 - 70,176 = 38,376$ KN

Beban Hidup

$\Sigma M_{4E} = 0$

$- R_{4D}.l - q_{ek} . l_2 (½ . l_2) - q_{ek} . l_1 (½l_1 . l_2) - P . l_2 = 0$

$- R_{4D} . 4,75 - 3,666 . 2,2 (½ .2,2) - 4,246 . 2,55 (3,475) - 19,237 . 2,2 = 0$

$- 4,75 R_{4D} - 88,818 = 0$

$$R_{4D} = \frac{88,818}{4,75} = 18,698 \text{ KN}$$

$\Sigma V_{4D} = 0$

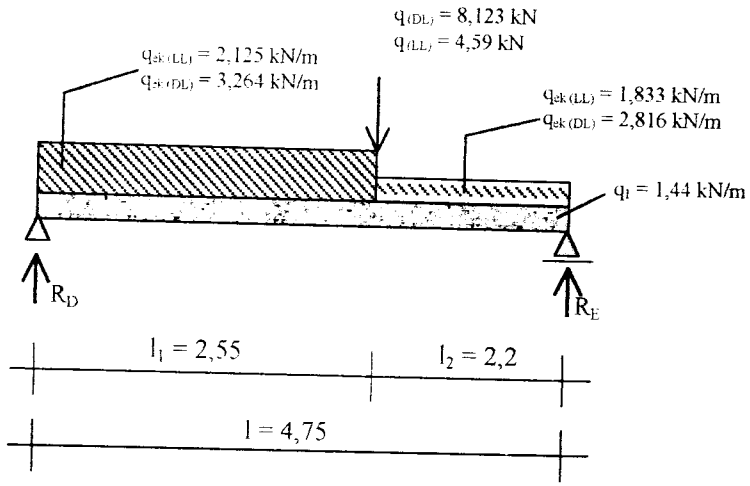
$R_{4D} + R_{4E} - q_{ek} . l_2 - q_{ek} . l_1 - P = 0$

$R_{4D} + R_{4E} - 3,666 . 2,2 - 4,246 . 2,55 - 19,237 = 0$

$R_{4D} + R_{4E} - 38,129 = 0$

$R_{4E} = 15,25 - R_{4D} = 38,129 - 19,237 = 19,431$ KN

As 5 Bentang D – E



Gambar 4.32 Reaksi perletakan ***As 5 Bentang D - E***

Keterangan :

P_{DL} = $R_{u5\ (Bentang\ 4-5\ (Balok\ Anak)}$ = 14,73 KN

P_{LL} = $R_{u5\ (Bentang\ 4-5\ (Balok\ Anak)}$ = 8,783 KN

q_{ek} (l_1) = Beban segi tiga plat lantai type A

q_{ek} (l_2) = Beban segi tiga plat lantai type B

Beban mati

$\Sigma M_{5E} = 0$

$-R_{5D}.l - q_{ek} . l_2 (½. l_2) - q_{ek} . l_1 (½l_1. l_2) - q_1 . l - P . l_2 = 0$

$-R_{5D}.4,75 - 2,816. 2,2 (1,1) - 3,264. 2,55 (3,475) - 1,92 .4,75 - 14,73 . 2,2 = 0$

$- 4,75\ R_{5D} - 77,264 = 0$

$$R_{5D} = \frac{77,264}{4,75} = 16,266 \text{ KN}$$

$\Sigma V_{5D} = 0$

$R_{5D} + R_{5E} - q_{ek} . l_2 - q_{ek} . l_1 - q_1 . l - P = 0$

$R_{5D} + R_{5E} - 2,816 . 2,2 - 3,264. 2,55 - 1,92 .4,75 - 14,73 = 0$

$R_{5D} + R_{5E} - 36,29 = 0$

$R_{5E} = 36,29 - R_{5D} = 36,29 - 16,266 = 20,163$ KN

Beban Hidup

$\Sigma M_{5E} = 0$

$- R_{5D}.l - q_{ek} . l_2 (l_2) - q_{ek} . l_1 (\frac{1}{2} l_1 . l_2) - P . l_2 = 0$

$- R_{5D} .4,75 - 1,833 , 2,2 (1,1) - 2,125 , 2,55 (3,475) - 8,783 . 2,2 = 0$

$- 4,75 R_{5D} - 42,588 = 0$

$$R_{5D} = \frac{42,588}{4,75} = 8,966 \text{ KN}$$

$\Sigma V_{5D} = 0$

$R_{5D} + R_{5E} - q_{ek} . l_2 - q_{ek} . l_1 - P = 0$

$R_{5D} + R_{5E} - 1,833 . 2,2 - 2,125 . 2,55 - 8,783 = 0$

$R_{5D} + R_{5E} - 18,234 = 0$

$R_{5E} = 18,234 - R_{5D} = 18,234 - 8,966 = 9,268$ KN

Pembebanan pada balok induk atap (Melintang)

Bentang 3 - 4 As E

- Beban merata (q) :
  a. Akibat beban mati
     - Beban plat trapezium type D = 3,8 x 2 = 7,60 KN/m
     - Beban Dinding = 2,5 x 3,6 = 9,00 KN/m

     = 16,60 KN/m
  b. Akibat beban hidup
     - Beban hidup plat trapezium Type D = 2.472 x 2 = 4,944 KN/m

- Beban pada Joint E3
  a. Beban mati
     - Berat Reaksi perletakan $R_{E3\,(DL)}$ x 2 = 41,209 x 2 = 82,418 KN/m
     - Beban Dinding = 2,5 x 3,6 x 4,75 = 42,75 KN/m

     =125,168 KN/m
  b. Beban hidup
     - Berat Reaksi perletakan $R_{E3\,(LL)}$ x 2 = 21,096 x 2 = 42,192 KN/m

Bentang 4 - 5 As E

- Beban merata (q) :
  a. Akibat beban mati
     - Beban plat trapezium type B = 3,667 x 2 = 7,334 KN/m
     - Berat dinding = 2,5 x 3,6 = 9,000 KN/m
     =16,334 KN/m
  b. Akibat beban hidup
     - Beban hidup plat trapezium Type B = 2,387 x 2 = 4,774 KN/m

- Beban pada Joint E4
  a. Beban mati
     - Berat Reaksi perletakan $R_{E4\,(DL)}$ x 2 = 38,378 x 2 = 76,752 KN
     - Beban Dinding = 2,5 x 3,6 x 4,75 = 42,75 KN
     =119,502 KN
  b. Beban hidup
     - Berat Reaksi perletakan $R_{E4\,(LL)}$ x 2 = 19,431 x 2 = 38,863 KN

- Beban pada Joint E5
  a. Beban mati
     - Berat Reaksi perletakan $R_{5E\,(DL)}$ x 2 = 20,165 x 2 = 40,326 KN
     - Beban Dinding = 2,5 x 3,6 x 4,75 = 42,75 KN
     = 83,076 KN
  b. Beban hidup
     - Berat Reaksi perletakan $R_{5E\,(LL)}$ x 2 = 9,268 x 2 = 18,536 KN

- Beban pada Joint E1
  a. Beban mati
     - Berat Reaksi perletakan $R_{1E\,(DL)}$ x 2 = 14,79 x 2 = 29,498 KN
     - Beban Dinding = 2,5 x 3,6 x 4,75 = 42,75 KN
     = 72,248 KN

b. Beban hidup

- Berat Reaksi perletakan $R_{1E\,(LL)}$ x 2 = 4,413 x 2 = 8,826 KN

- Beban pada Joint E2

a. Beban mati

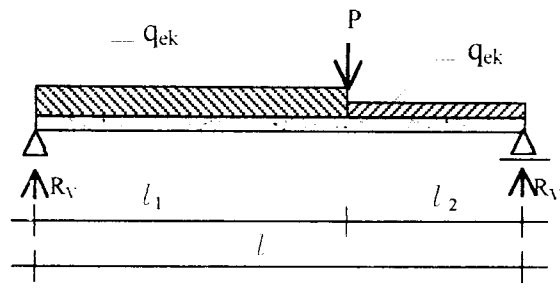
- Berat Reaksi perletakan $R_{2E\,(DL)}$ x 2 = 108,837 x 2 =217,674 KN

b. Beban hidup

- Berat Reaksi perletakan $R_{2E\,(LL)}$ x 2 = 14,578 x 2 = 29,156 KN

Pembebanan pada balok induk atap (memanjang)

Bentang A-B As 3



- Beban merata (q) :

a. Akibat beban mati

- Berat sendiri plat segi Δ type D = 2,816 . 2 = 5,632 KN/m
- Berat sendiri dinding = 2,5 x 3,6 = 9,000 KN/m

l_2 =14,632 KN/m

- Berat sendiri plat segi Δ type F = 4,608 . 2 = 9,216 KN/m
- Berat sendiri dinding = 2,5 x 3,6 = 9,000 KN/m

l_1 =18,216 KN/m

b. Akibat beban hidup

- Beban hidup plat segi Δ type D (l_2) = 2 . 1,833 = 3,666 KN/m
- Beban hidup plat segi Δ type F (l_1) = 2 . 3 = 6,000 KN/m

- Beban terpusat

  a. Beban mati

  - Berat sendiri balok anak = (0,30 – 0,13) . 0,15 . 24 .4 = 2,448 KN
  - Berat sendiri plat trapesium type D = ½ (3,8) . 2 . 2 = 7,600 KN
  - Berat sendiri plat trapesium type F = ½ (5,046) . 2 . 2 = 10,092 KN

  = 20,140 KN

  b. Beban hidup

  - Berat sendiri plat trapesium type D = ½ (2,472) . 2 . 2 = 4,944 KN
  - Berat sendiri plat trapesium type F = ½ (3,285) . 2 . 2 = 6,570 KN

  = 11,514 KN

- Beban pada Joint 3A

  a. Beban mati

  - Berat sendiri balok induk = (0,45 – 0,13) . 0,25 . 24 .4 = 7,680 KN
  - Berat sendiri Plat trapesium type F = ½ (5,046) . 2 . 2 = 10,092 KN
  - Berat sendiri dinding = 2,5 x 3,6 x 4 = 36,000 KN

  = 53,772 KN

  b. Beban hidup

  - Beban hidup plat trapesium Type F = ½ (3,285) . 2 . 2 = 6,570 KN

Bentang B - C As 3

- Beban merata (q) :

  a. Akibat beban mati

  - Berat sendiri plat segi Δ type D = 2,816 . 2 = 5,632 KN/m
  - Berat sendiri dinding = 2,5 x 3,6 = 9,000 KN/m

  l_2 =14,632 KN/m

  - Berat sendiri plat segi Δ type C = 3,264 . 2 = 6,528 KN/m
  - Berat sendiri dinding = 2,5 x 3,6 = 9,000 KN/m

  l_1 =15,528 KN/m

b. Akibat beban hidup

- Berat sendiri plat segi Δ type D (l_2) = 2 . 1,833 = 3,666 KN/m
- Berat sendiri plat segi Δ type C (l_1) = 2 . 2,125 = 4,250 KN/m

- Beban terpusat

a. Beban mati

- Berat sendiri balok anak = (0,30 – 0,13) . 0,15 . 24 .4 = 2,448 KN
- Berat sendiri plat trapesium type D = ½ (3,8) . 2 . 2 = 7,600 KN
- Berat sendiri plat trapesium type C = ½ (4,233) . 2 . 2 = 8,466 KN

= 18,514 KN

b. Beban hidup

- Berat sendiri plat trapesium type D = ½ (2,472) . 2 . 2 = 4,944 KN
- Berat sendiri plat trapesium type C = ½ (2,755) . 2 . 2 = 5,510 KN

= 10,454 KN

- Beban pada Joint 3B

a. Beban mati

- Berat sendiri balok induk = (0,45 – 0,13) . 0,25 . 24 .4 = 7,680 KN
- Berat sendiri Plat trapesium type C = ½ (4,233) . 2 . 2 = 8,466 KN
- Berat sendiri Plat trapesium type D = ½ (3,8) . 2 . 2 = 7,600 KN
- Berat sendiri dinding = 2,5 x 3,6 x 4 = 36,00 KN

= 59,746 KN

b. Beban hidup

- Beban hidup plat trapesium Type D = ½ (2,472) . 2 . 2 = 4,944 KN
- Beban hidup plat trapesium Type C = ½ (2,755) . 2 . 2 = 5,510 KN

= 10,454 KN

- Beban pada Joint 3C

a. Beban mati

- Berat sendiri balok induk = (0,45 – 0,13) . 0,25 . 24 .4 = 7,680 KN
- Berat sendiri Plat trapesium type D = ½ (3,8) . 4 . 2 = 15,20 KN

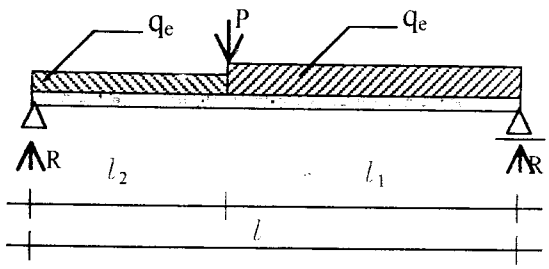
- Berat sendiri dinding = 2,5 x 3,6 x 4 = 36,00 KN

= 58,88 KN

b. Beban hidup

- Beban hidup plat trapesium Type D = ½ (2,472) . 4 . 2 = 9,888 KN

Bentang C – D As 3



- Beban merata (q) :

a. Akibat beban mati

- Berat sendiri plat segi Δ type D = 2,816 . 2 = 5,632 KN/m
- Berat sendiri dinding = 2,5 x 3,6 = 9,000 KN/m

l_2 =14,632 KN/m

- Berat sendiri plat segi Δ type C = 3,264 . 2 = 6,528 KN/m
- Berat sendiri dinding = 2,5 x 3,6 = 9,000 KN/m

l_1 =15,528 KN/m

b. Akibat beban hidup

- Berat sendiri plat segi Δ type D (l_2) = 2 . 1,833 = 3,666 KN/m
- Berat sendiri plat segi Δ type C (l_1) = 2 . 2,125 = 4,250 KN/m

- Beban terpusat

a. Beban mati

- Berat sendiri balok anak = (0,30 – 0,13) . 0,15 . 24 .4 = 2,448 KN
- Berat sendiri plat trapesium type D = ½ (3,8) . 2 . 2 = 7,600 KN
- Berat sendiri plat trapesium type C = ½ (4,233) . 2 . 2 = 8,466 KN

=18,514 KN

b. Beban hidup

- Berat sendiri plat trapesium type D = ½ (2,472) . 2 . 2 = 4,944 KN
- Berat sendiri plat trapesium type C = ½ (2,755) . 2 . 2 = 5,510 KN

= 10,454 KN

- Beban pada Joint 3D

a. Beban mati

- Berat sendiri balok induk = (0,45 – 0,13) . 0,25 . 24 .4 = 7,680 KN
- Berat sendiri Plat trapesium type C = ½ (4,233) . 4 . 2 = 16,932 KN
- Berat sendiri dinding = 2,5 x 3,6 x 4 = 36,00 KN

= 60,612 KN

b. Beban hidup

- Beban hidup plat trapesium Type C = ½ (2,755) . 4 . 2 = 11,020 KN

- Beban pada Joint 3I

a. Beban mati

- Berat sendiri balok induk = (0,45 – 0,13) . 0,25 . 24 .4 = 7,680 KN
- Berat sendiri Plat trapesium type D = ½ (3,8) . 2 . 2 = 7,600 KN
- Berat sendiri dinding = 2,5 x 3,6 x 4 = 36,00 KN

= 51,28 KN

b. Beban hidup

- Beban hidup plat trapesium Type D = ½ (2,472) . 2 . 2 = 4,944 KN

Keterangan :

Berat sendiri balok induk pada beban merata tidak dihitung, untuk As yang ditinjau karena sudah dihitung oleh program SAP itu sendiri.

Resume Pembebanan Portal Melintang Lantai 2 dan 3

As E Bentang	Beban Pada Batang				Beban Pada Joint	
	Beban Merata		Beban Terpusat		Beban Terpusat	
	Mati	Hidup	Mati	Hidup	Mati	Hidup
1 – 2	9,00	-	-	-	72,248	8,826
2 – 3	16,60	4,944	-	-	217,674	29,156
3 – 4	16,60	4,944	-	-	125,168	42,192
4 – 5	16,433	4,774	-	-	119,502	38,863
					83,076	18,536

Tabel 4.6 Resume Pembebanan Balok Lantai Melintang

Resume Pembebanan Portal Memanjang Lantai 2 dan 3

As 3 Bentang	Beban Pada Batang				Beban Pada Joint	
	Beban Merata		Beban Terpusat		Beban Terpusat	
	Mati	Hidup	Mati	Hidup	Mati	Hidup
A - B	$l_1 = 18,216$ $l_2 = 14,632$	$l_1 = 6,00$ $l_2 = 3,666$	20,140	11,514	53,772	6,570
					59,746	10,454
B - C	$l_1 = 15,528$ $l_2 = 14,632$	$l_1 = 4,25$ $l_2 = 3,666$	18,514	10,454		
					58,88	9,888
C - D	$l_1 = 15,528$ $l_2 = 14,632$	$l_1 = 4,25$ $l_2 = 3,666$	18,514	10,454		
					60,612	11,02
D - E	$l_1 = 15,528$ $l_2 = 14,632$	$l_1 = 4,25$ $l_2 = 3,666$	18,514	10,454		
					58,88	9,888
E - F	$l_1 = 15,528$ $l_2 = 14,632$	$l_1 = 4,25$ $l_2 = 3,666$	18,514	10,454		
					60,612	11,02
F - G	$l_1 = 15,528$ $l_2 = 14,632$	$l_1 = 4,25$ $l_2 = 3,666$	18,514	10,454		
					58,88	9,888
G - H	$l_1 = 15,528$ $l_2 = 14,632$	$l_1 = 4,25$ $l_2 = 3,666$	18,514	10,454		
					60,612	11,02
H - I	$l_1 = 15,528$ $l_2 = 14,632$	$l_1 = 4,25$ $l_2 = 3,666$	18,514	10,454		
					51,28	4,944

Tabel 4.7 Resume Pembebanan Balok Lantai Memanjang

4.4.4 Perhitungan Beban Gempa

A. Portal Melintang As D

Lanatai Atap

- Beban hidup tereduksi, (15,5 . 4,75) . 0,336 . 1 = 24,738 KN
- Beban Plafond, (15,5 . 4,75) . 0,18 = 13,252 KN
- Beban Plat atap, (15,5 . 4,75) . 24 . 0,1 = 176,70 KN
- Beban Genangan Air 5 cm, (15,5 . 4,75) . 0,05 . 10 = 36,812 KN
- Beban Lap (Aspal + Spasi) 2 cm,
  = (15,5 . 4,75) . 0,02 . 14 = 20,615 KN
- Beban Balok Anak (0,3-0,1) . 0,15 . 15,5 . 24 = 11,160 KN
- Beban Balok Induk (0,4-0,1) . 0,20 . 15,5 . 24 = 22,320 KN

Wi = 305,597 KN

Lanatai 3 dan 2

- Beban hidup tereduksi, (15,5 . 4,75) . 0,384 . 2,5 = 70,680 KN
- Beban Plafond, (15,5 . 4,75) . 0,18 = 13,252 KN
- Beban Plat atap, (15,5 . 4,75) . 24 . 0,13 = 229,71 KN
- Beban Kolom, (0,45 . 0,25) . 3,6 . 5 . 24 = 48,600 KN
- Berat dinding, 15,5 . 2,5 . 3,6 = 139,50 KN
- Spesi tebal 1,5 cm (15,5 . 4,75) . 0,15 . 0,21 = 2,320 KN
- Beban Tegel Kramik 0,5 cm (15,5 . 4,75). 0,05 . 0,17 = 0,625 KN
- Beban Balok Anak, (0,35-0,13) . 0,20 . 15,5 . 24 = 16,368 KN
- Beban Balok Induk, (0,45-0,13) . 0,25 . 15,5 . 24 = 29,760 KN

Wi = 550,815 KN

Beban total Portal melintang

$Wt = W_{Atap} + W_{i\,2} + W_{i\,3}$

= 305,597 + 550,815 + 550,815

= 1407,227 KN

Gaya Gempa untuk portal melintang

V = C . I . k .Wt

Dimana :

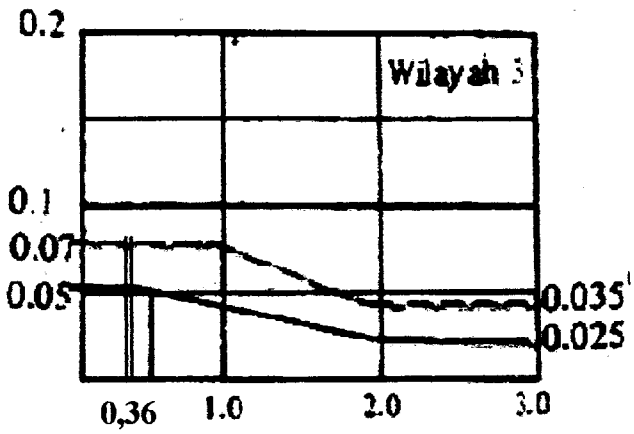
C = Koefisien dasar gempa.

I = Faktor keamanan 1,5 (untuk bangunan Ruko)

K = Faktor jenis struktur 1,0 (Portal beton bertulang)

Waktu getar alami gedung struktur

T = $0,06 . H^{3/4} = 0,06 . (10,8)^{3/4} = 0,36$ detik



Gambar 4.33 Koefisien Dasar Gempa Portal Melintang

Dari tabel koefisien tanah gempa untuk wilayah gempa 3, pada struktur tanah lunak didapat C = 0,07 ; maka gaya geser genpa adalah :

V = C . I . k . Wt

= 0,07 . 1,5 . 1 . 1407,227

= 147,458 KN Beban gempa terdistribusi

$$F = \frac{\left(\frac{W_i.h}{\sum W_i.h}\right).V}{(JumlahPortal)}$$

Jumlah portal melintang sebayak 5 portal.

No	Lantai	W_i	h_i	$W_i \cdot h_i$	$\frac{W_i.h_i}{\sum W_i.h_i}$	V	F (KN)
1	Atap	305,597	10,8	3300,4	0,357	147,458	10,545
2	3	550,815	7,2	3965,9	0,429	147,458	12,671
3	2	550,815	3,6	1982,9	0,214	147,458	6,336
				9249,25			

Table 4.8 Gaya Gempa untuk Portal Melintang

B. Portal Memanjang As 3

Lanatai Atap

- Beban hidup tereduksi, (39,5 . 4,75) . 0,336 . 1 = 41,731 KN
- Beban Plafond, (39,05 . 4) . 0,18 = 28,116 KN
- Beban Plat atap, (39,05 . 4) . 24 . 0,1 = 374,88 KN
- Beban Genangan Air 5 cm, (39,05 . 4) . 0,05 . 10 = 78,100 KN
- Beban Lap (Aspal + Spasi) 2 cm, (39,05 . 4) . 0,02 . 14 = 43,736 KN
- Beban Balok Anak (0,3-0,1) . 0,15 . (8 . 4) . 24 = 23,040 KN
- Beban Balok Induk (0,4-0,1) . 0,20 . (8 . 4) . 24 = 44,712 KN

Wi = 634,315 KN

Lanatai 3 dan 2

- Beban hidup tereduksi, (39,05 . 4) . 0,384 . 2,5 = 149,952 KN
- Beban Plafond, (39,05 . 4) . 0,18 = 28,116 KN
- Beban Plat atap, (39,05 . 4) . 24 . 0,13 = 487,344 KN
- Beban Kolom, (0,45 . 0,25 . 9) . 3,6 . 24 = 87,480 KN
- Berat dinding, 39,05 . 2,5 . 3,6 = 351,450 KN
- Spesi tebal 1,5 cm, (39,05 . 4) . 0,15 . 0,21 = 4,920 KN
- Beban Tegel Kramik 0,5 cm (39,05 . 4). 0,05 . 0,17 = 1,328 KN
- Beban Balok Anak, (0,35-0,13) . 0,20 . 15,5 . 24 = 33,792 KN
- Beban Balok Induk, (0,45-0,13) . 0,25 . 15,5 . 24 = 74,976 KN

Wi = 1219,36 KN

Beban total Portal memanjang

Wt $= W_{Atap} + W_{i\,2} + W_{i\,3}$

$= 634{,}315 + 1219{,}36 + 1219{,}36$

$= 3073{,}035$ KN

Gaya Gempa untuk portal melintang

V $= C \,.\, I \,.\, k \,.\, Wt$

Dimana :

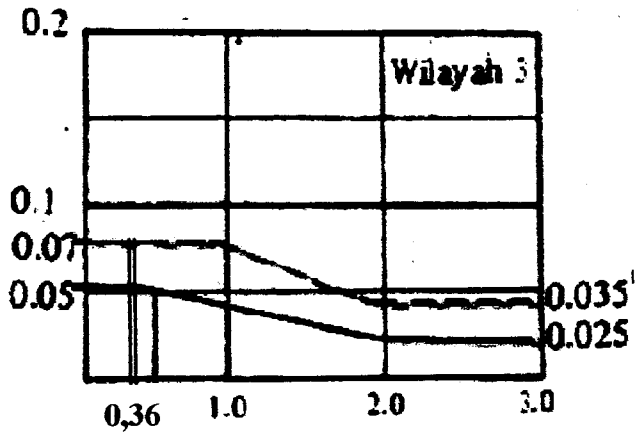
C = Koefisien dasar gempa.

I = Faktor keamanan 1,5 (untuk bangunan Ruko)

K = Faktor jenis struktur 1,0 (Portal beton bertulang)

Waktu getar alami gedung struktur

T $= 0{,}06 \,.\, H^{3/4} = 0{,}06 \,.\, (10{,}8)^{3/4} = 0{,}36$ detik



Gambar 4.34 Koefisien Dasar Gempa Portal Memanjang

Dari table koefisien tanah gempa untuk wilayah gempa 3, pada struktur tanah lunak didapat C = 0,07 ; maka gaya geser genpa adalah :

V $= C \,.\, I \,.\, k \,.\, Wt$

$= 0{,}07 \,.\, 1{,}5 \,.\, 1 \,.\, 3073{,}035$

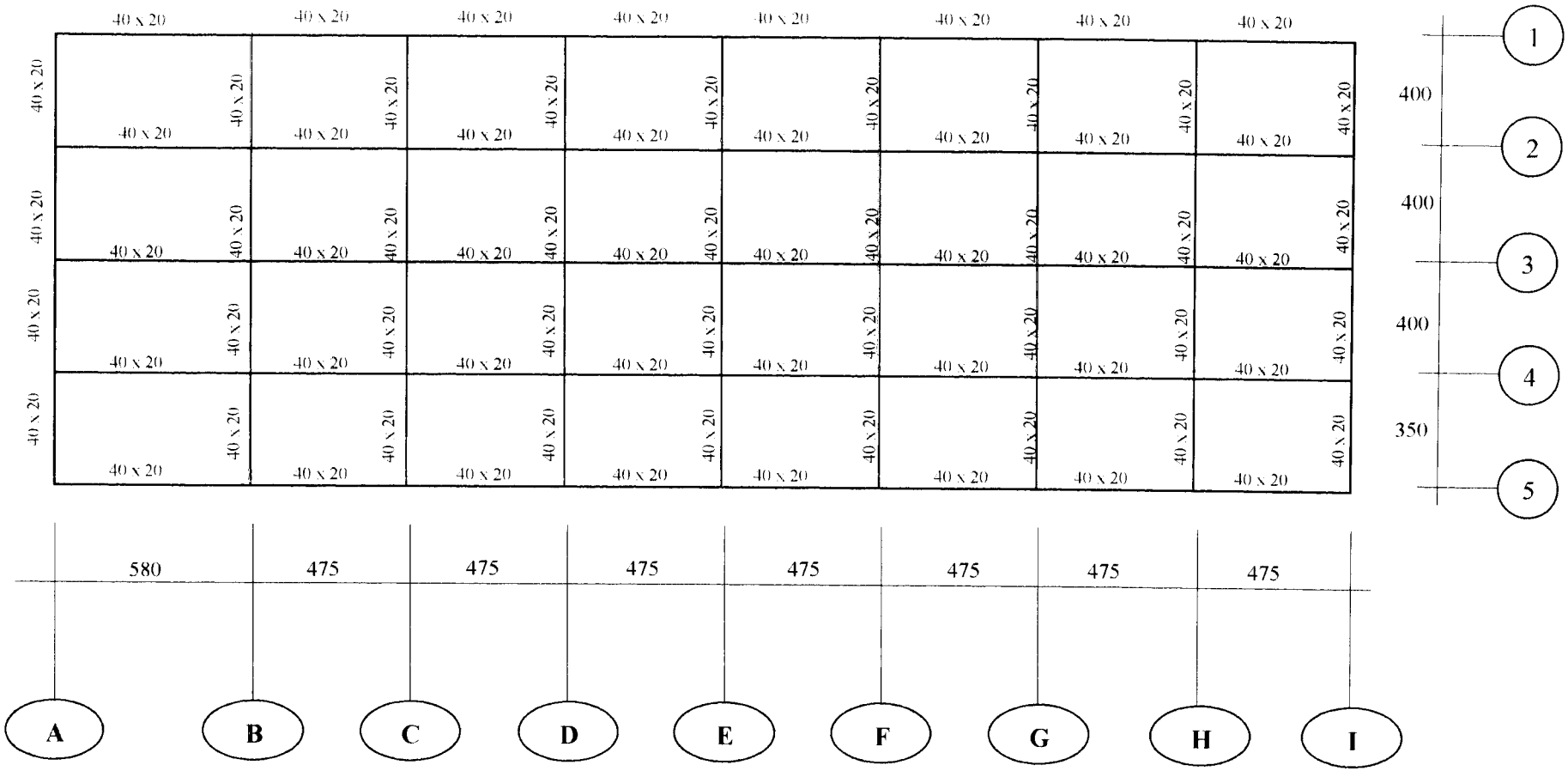
$= 322{,}668$ KN Beban gempa terdistribusi

$$F = \frac{\left(\frac{W_i.h}{\sum W_i.h}\right).V}{(JumlahPortal)}$$

Jumlah portal memanjang sebayak 9 portal.

No	Lantai	W_i	h_i	$W_i \cdot h_i$	$\frac{W_i.h_i}{\sum W_i.h_i}$	V	F (KN)
1	Atap	634,315	10,8	6.850,602	0,342	322,668	12,268
2	3	1219,36	7,2	8.779,392	0,439	322,668	15,722
3	2	1219,36	3,6	4.389,696	0,219	322,668	7,861
				20.019,690			

Tabel 4.9 Gaya Gempa untuk Portal Memanjang



Gambar 4.35 Denah Sloof

4.4.5 Pembebanan Sloof

Pembebanan Sloof Arah Melintang **(As D)**

- Beban Merata (q)

  a. Beban mati

  - Berat sendiri Dinding = 2,5 . 3,6 = 9,00 KN/m

  b. Beban hidup

  - Beban hidup = 0 KN/m

- Beban pada joint As D

  a. Beban mati

  - Berat sendiri sloof = (0,4 . 0,2) . 24 . 4,75 = 9,12 KN/m
  - Berat sendiri dinding = 2,5 x 3,6 x 4,75 = 42,75 KN/m

  = 51,87 KN/m

  b. Beban hidup

  - Beban hidup = 0 KN/m

Pembebanan Sloof Arah Memanjang **(As 3)**

- Beban merata (q)

  a. Beban mati

  - Berat sendiri dinding = 2,5 . 3,6 = 9,00 KN/m

  b. Beban hidup

  - Berat hidup = 0 KN/m

- Beban pada joint As 3

  a. Beban mati

  - Berat sendiri sloof = (0,4 . 0,2) . 24 . 4,75 = 9,120 KN/m
  - Berat sendiri dinding = 2,5 x 3,6 x 4 = 36,00 KN/m

  = 45,12 KN/m

  b. Beban hidup

  - Beban hidup = 0 KN/m

Keterangan :

Berat sendiri Sloof pada beban merata tidak dihitung, untuk As yang ditinjau karena sudah dihitung oleh program SAP itu sendiri.

Analisis struktur portal dilakukan dengan bantuan SAP 2000 dengan menggunakan kombinasi pembebanan sebagai berikut :

a. Kombinasi 1 : 1,2 Beban Mati + 1,6 Beban Hidup
b. Kombinasi 2 : 1,2 Beban Mati + 1,6 Beban Hidup Pola 1
c. Kombinasi 3 : 1,2 Beban Mati + 1,6 Beban Hidup Pola 2
d. Kombinasi 4 : 1,05 (Beban Mati + Beban Hidup + Beban Gempa)
e. Kombinasi 5 : 1,05 (Beban Mati + Beban Hidup Pola 1 + Beban Gempa)
f. Kombinasi 6 : 1,05 (Beban Mati + Beban Hidup Pola 2 + Beban Gempa)

Dengan bantuan SAP 2000 tersebut didapat bidang gaya lintang, normal momen dan reaksi perletakan. Untuk perhitungan selanjutnya maka output dari SAP tersebut dapat digunakan sebagai data dalam perencanaan selanjutnya. Data yang diambil dari SAP merupakan kombinasi terbesar dari berbagai beban kombinasi yang berada diatas. Adapun output dari analisis SAP dapat dilihat dalam lampiran.

4.5 Perhitungan Balok Induk

4.5.1 Dimensionering Penampang Balok

tinggi Penampang balok pada portal melintang diambil nilai antara 1/10 *l* sampai 1/15 *l*. Untuk perencanaan balok induk ini dipilih dari nilai bentang terpanjang yaitu 580 cm, maka tinggi balok induk yang direncanakan nya yaitu 1/15 *l* = 1/15 . 580 = 38,6 cm, diambil 40 cm, sedangkan lebar balok diambil nilai ½ . 40 = 20 cm, untuk balok induk lantai Atap.

Dan untuk tinggi penampang balok induk lantai 2 dan 3 diambil nilai tinggi balok 1/14L = 1/14 . 580 = 41,42 cm, diambil 45 cm, sedangkan lebar balok diambil nilai ½ . 45 = 22,5 cm, diambil 25 cm.

Perencanaan balok induk ini mengacu pada tata cara perhitungan Struktur Beton Untuk Bangunan Gedung SNI T-15-1991-0,3. dengan mutu material yang digunakan

- Mutu beton f'_c = 25 Mpa
- Mutu baja f_y = 400 Mpa untuk tulangan pokok
- Mutu baja f_y = 240 Mpa untuk tulangan geser

4.5.2 Perhitungan Tulangan Pokok Balok induk

Kasus balok 17 pada portal mememanjang diambil nilai momen terbesar dari hasil analisis SAP 2000 versi 7.4 yaitu sebagai berikut :

Mu^- = 106,21 kNm

Mu^+ = 71,02 kNm

Perhitungan penulangan akibat lentur

A. Tulangan Tumpuan

M_u = 106,21 KNm.

b = 250 mm

h = 450 mm

p = 25 mm

d = $h - p - Ø_{tul\ seng} - ½\ Ø_{tul\ ut}$

= 450 – 25 – 10 - ½ . 19 = 405,5 mm

$Ø_{tul\ seng}$ = 10 mm

$Ø_{tul\ ut}$ = 22 mm

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

$$\rho_b = \frac{0,85.\beta.f'c}{fy}\left(\frac{600}{600+fy}\right)$$

$$\rho_b = \frac{0,85.0,85.25}{240}\left(\frac{600}{600+400}\right) = 0,02709$$

$\rho_{maks} = 0,75.\rho_b$

$= 0,75 \cdot 0,02709$

$= 0.02032$

$$k_{maks} = \rho_{maks} \cdot f_y \cdot \left(1 - \frac{0,588.\rho_{maks}.f_y}{24}\right)$$

$$k_{maks} = 0.0402 \cdot 400 \cdot \left(1 - \frac{0,588.0.02032.400}{25}\right) = 6,569 \text{ MPa}$$

$M_{R\ maks} = ø \cdot b \cdot d^2.k_{maks}$

$= 0,8 \cdot 250. 405,5^2. 6,569 . 10^{-6}$

$= 217,629$ KNm.

$M_{R\ maks}$ = 217,629 KNm. > M_u = 106,21 KNm., maka balok dianalisis sebagai balok bertulangan tunggal.

$$k = \frac{Mu}{\phi.b.d^2} = \frac{106,21.10^6}{0,8.250.404^2} = 3,23$$

$$\rho = \frac{0,85.f_c}{f_y}\left(1 - \sqrt{1 - \frac{2k}{0,85.f_c}}\right) = \frac{0,85.25}{400}\left(1 - \sqrt{1 - \frac{2..3,23}{0,85.25}}\right)$$

$\rho = 0,0088$

$\rho_{mak} > \rho_{perlu} > \rho_{min}$, maka diambil ρ_{perlu} = 0,0089

$A_s = \rho \cdot b \cdot d = 0,0088 \cdot 250 \cdot 405,5 = 912$ mm^2

Dipakai tulangan 4 Ø 19 = 1133,54 mm^2

Berdasarkan hasil perhtiungn diatas, secara teoritis tulangan tekan tidak diperlukan tetapi dengan pertimbangan struktur, maka tulangan tekan diperlukan untuk :

a. Meningkatkan momen tahanan penampang karena penampang terbatas,
b. Meningkatkan kapasitas rotasi penampang yang berkaitan dengan peningkatan daktilitas penampang,
c. Meningkatkan kekakuan penampang, sehingga dapat mengurangi defleksi struktur,
d. Dapat mencakup kemungkinan adanya momen yang berubah tanda, akibat gaya luar yang bekerja pada struktur tak tetap seperti beban horizontal gempa yang dapat meyebabkan momen - momen internal berubah tanda.

As' = 0,5 . As = 0,5 .1133,54 = 566,77 mm^2

Dipakai 2 Ø 19 = 566,77 mm^2

Kontrol :

1. Jarak tulangan :

- Selimut beton	= 2 .25	= 50 mm
- Sengkang	= 2 . 10	= 20 mm
- Tulangan Pokok	= 4 . 19	= 76 mm
		= 146 mm

Spasi = (250 - 146)/2 = 34,666 mm > 25 mm .....O.k

Jadi tulangan tarik dipasang dalam satu lapis

Tinggi efektif aktual balok :

$d = h - p - Ø_{tul\ seng} - ½\ Ø_{tul\ ut}$

= 450 – 25 – 10 - ½ 19 = 405,5 mm

Kontrol kapasitas balok sebelum diberi tulangan :

$$a = \frac{A_s.f_y}{0,85.f_c.b} = \frac{1133,54.400}{0,85.25.250} = 85,349 \text{ mm}$$

$M_n = A_s . f_y . (d-a/2)$

= 1139,82 . 400 . (405,5 – 85,349/2)

= 164,511 . 10^6 Nmm

$ØM_n$ = 0,8 . 164,511 . 10^6 = 131,609 . 10^6 Nmm > M_u = 106,21 . 10^6 Nmm

Cek tulangan baja tarik maupun tekan dimana telah mencapai leleh, maka ditetapkan $As_2 = As'$

As $= 4\ \text{Ø}\ 19 = 1133{,}54\ mm^2$

As' $= 2\ \text{Ø}\ 19 = 566{,}77\ mm^2$

$$a = \frac{(A_s. - As').fy}{0{,}85.f_c'.b} = \frac{(1133{,}54 - 566{,}77).400}{0{,}85.25.250} = 42{,}674\ mm$$

Tentukan letak garis netral

$a = \beta_1 . c \Rightarrow \beta_1 = 0{,}85$

$$c = \frac{a}{\beta_1} = \frac{42{,}674}{0{,}85} = 50{,}20$$

Tentukan tulangan baja tekan

$$\varepsilon_{s'} = \frac{c - d'}{c}(0{,}003) = \frac{50{,}204 - 43}{50{,}204}(0{,}003) = 0{,}00043$$

Tentukan tulangan baja tarik

$$\varepsilon_s = \frac{d - c}{c}(0{,}003) = \frac{405{,}5 - 50{,}204}{50{,}204}(0{,}003) = 0{,}02$$

$\varepsilon_s > \varepsilon_{s'}$ maka tulangan baja tarik sudah meluluh tetapi tulangan baja tekan belum

Tentukan garis netral dengan keseimbangan gaya – gaya Horizontal

$(0{,}85 . fc . b . \beta) .c^2 + (600 . As' - As . f_y). c - 600 . d' . As' = 0$

$(0{,}85 . 25 . 250 . 0.85) .c^2 + (600 . 566{,}77 - 1133{,}54 . 400) . c - 600 . 44{,}5 . 566{,}77 = 0$

$4303{,}125\ c^2 - 113354\ c - 15132756 = 0$

$c^2 - 26{,}342\ c - 3516{,}69 = 0$

$c^2 - 26{,}342\ c = 3516{,}69$

$c^2 - 26{,}342\ c + (\frac{1}{2}(26{,}342))^2 = 3516{,}69 + (\frac{1}{2}(26{,}342))^2$

$c^2 - 26{,}342\ c + 173{,}475 = 3516{,}69 + 173{,}475 = 3690{,}165$

$(c - 13{,}171)^2 = 3690{,}165$

$c - 13{,}171 = \sqrt{3690{,}165} = 60{,}746$

$c = 60{,}746 + 13{,}171 = 73{,}917$

$a = \beta . c = 0{,}85 . 73{,}917 = 62{,}83\ mm$

Cek tulangan baja yang terjadi :

$$fs' = \frac{600(c-d')}{c} = \frac{600(73{,}917-44{,}5)}{73{,}917} = 238{,}784 \text{ Mpa} \leq f_y = 400 \text{ Mpa}$$

N_{D1} = 0,85 . fc . a . b

= 0,85 . 25 . 62,83 . 250 . 10^{-3}

= 333,784 kN

N_{D2} = As' . f_s'

= 566,77 . 238,784

= 135,335 kN

N_D = N_{D1} + N_{D2}

= 333,83 + 135,335 = 469,16 kN

N_T = As . f_y

= 1133,54 . 400 = 453,816 kN

$N_D = N_T$ (seimbang) ok!

M_{n1} = N_{D1} .z_1 = N_{D1} . (d – a/2)

= 333,784 . (405,5 – 62,83/2) = 124,863 kNm

M_{n2} = N_{D2} .z_2 = N_{D2} . (d – d')

= 135,335 . (405,5 – 44,5) = 48,855 kNm

M_n = M_{n1} + M_{n2}

= 119,457 + 48,855 = 173,718 kNm

ϕM_n = 0,8 . 173,718 = 138,974 kNm

ϕM_n = 138,98 kNm > M_u = 106,21 kNm.

Cheking pada tulangan baja tarik :

As' . f_s = As_2 . f_y

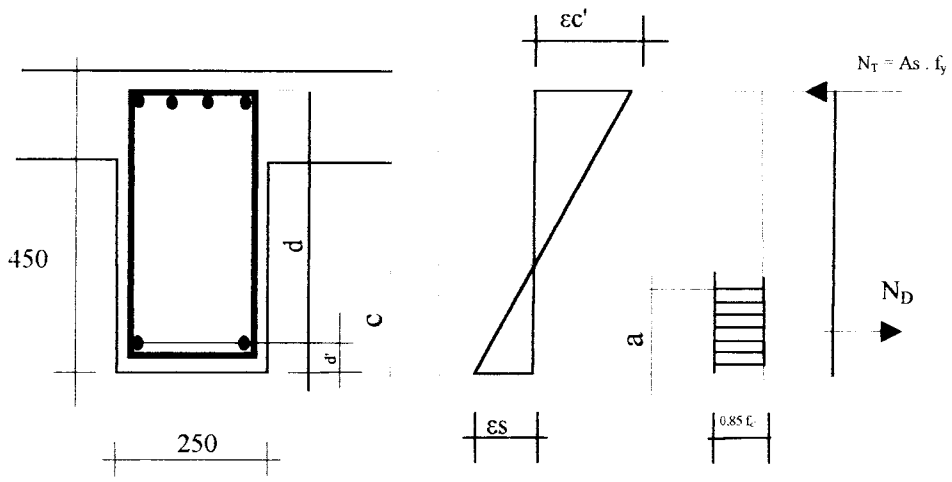
$$As_2 = \frac{As'.fs'}{fy} = \frac{566{,}77.238{,}784}{400} = 338{,}339 \text{ mm}^2.$$

As_1 = As . As_2 = 1133,54 – 338,339 = 795,2 mm^2.

Syarat :

As_1/b.d = 795,2 / 250 . 405,5 = 0,00784

$\rho = 0{,}0078 \geq \rho_{min} = 0{,}0035 \rightarrow$ Ok



Gambar 4.3 Diagram regangan dan tegangan Penampang tumpuan balok induk

B. Tulangan Lapangan

M_u = 71,02 KNm = 71,02 . 10^6 Nmm.

Balok berpenampang T, dengan data :

b = 250 mm, h = 450 mm, t = 130 mm, d' = 44,5 mm.

Lebar flens (bf) diambil dari nilai – nilai terkecil dari nialai-nilai berikut :

- bf = ¼ . l = ¼ . 4750 = 1187,5 mm
- bf = b + 16t = 250 + 16 . 130 = 2330 mm
- bf = b + ln = 250 + 4500 = 4750 mm

dipakai lebar flens (bf) = 1187,5 mm.

Diperiksa apakah balok berprilaku sebagai balok T persegi atau balok T murni, dengan menganggap seluruh flens dalam keadaan desak.

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

$$\rho_b = \frac{0,85.\beta.f'c}{fy}\left(\frac{600}{600+fy}\right)$$

$$\rho_b = \frac{0,85.0,85.25}{240}\left(\frac{600}{600+400}\right) = 0,0271$$

$\rho_{maks} = 0,75.\rho_b$

$= 0,75 . 0,0271$

= 0.0203

Mn = 0,85 . fc' . b . t (d-½ . t)

= 0,85 . 25 . 250 . 130 (407 - ½ . 130)

= 236,193 . 10^6 Nmm.

Ø Mn = 0,8 . 236,193 .10^6 = 188,955 .10^6 KNm > Mu = 71,02 KNm.

(maka balok berprilaku sebagai balok T persegi dengan lebar balok b = bf = 1187,5 mm).

Maka perencanaan tulangan dilakukan seperti balaok persegi, menurut ρ yang diperlukan :

$$k = \frac{Mu}{\phi.b.d^2} = \frac{71{,}02 \cdot 10^6}{0{,}8.250.407^2} = 2{,}144$$

$$\rho = \frac{0{,}85.f_C}{f_y}.\left(1 - \sqrt{1 - \frac{2k}{0{,}85.f_C}}\right) = \frac{0{,}85.25}{240}.\left(1 - \sqrt{1 - \frac{2.2{,}144}{0{,}85.25}}\right)$$

ρ = 0,0057

$\rho_{perlu} > \rho_{min}$, maka diambil ρ_{perlu} = 0,0057

A_s = ρ . b . d = 0,0057 . 250 . 407 = 579,98 mm^2.

Maka digunakan A_s terbesar.

Dipakai 3 Ø 19 = 850,153 mm^2

As' = 0,5 . A_s = 0,5 . 850,153 = 425,076 mm^2.

Dipakai 2 Ø 19 = 566,77 mm^2

Kontrol :

Jarak tulangan :

-	Selimut beton	= 2 .25	= 50 mm
-	Sengkang	= 2 . 10	= 20 mm
-	Tulangan Pokok	= 3 . 19	= 57 mm
			= 127 mm

Spasi = (250 - 127)/2 = 61,5 mm > 25 mm .....O.k

Tinggi efektif aktual balok :

d = h – p – $Ø_{tul\ seng}$ – ½ $Ø_{tul\ ut}$

= 450 – 25 – 10 - ½ . 19

= 405,5

Kontrol kapasitas balok sebelum diberi tulangan :

$$a = \frac{A_s.f_y}{0,85.f_c.b} = \frac{850,155.400}{0,85.25.250} = 64,011 \text{ mm}$$

$M_n = A_s \cdot f_y \cdot (d-a/2)$

$= 803,8 \cdot 400 \cdot (405,5 - 64,011/2)$

$= 127,011 \cdot 10^6$ Nmm

$\emptyset M_n = 0,8 \cdot 127,011 \cdot 10^6 = 101,608 \cdot 10^6$ Nmm $> M_u = 71,02 \cdot 10^6$ Nmm

Cek tulangan baja tarik maupun tekan dimana telah mencapai leleh, maka ditetapkan $As_2 = As'$

As $= 4 \emptyset 16 = 850,155$ mm^2

As' $= 2 \emptyset 16 = 566,77$ mm^2

$$a = \frac{(A_s. - As').fy}{0,85.f_c'.b} = \frac{(850,155 - 566,77).400}{0,85.25.250} = 21,337 \text{ mm}$$

Tentukan letak garis netral

$a = \beta_1 \cdot c \Rightarrow \beta_1 = 0,85$

$$c = \frac{a}{\beta_1} = \frac{21,337}{0,85} = 25,102$$

Tentukan tulangnan baja tekan

$$\varepsilon_{s'} = \frac{c-d'}{c}(0,003) = \frac{25,102-44,5}{21,102}(0,003) = -0,00275$$

Tentukan tulangnan baja tarik

$$\varepsilon_s = \frac{d-c}{c}(0,003) = \frac{405,5-21,102}{21,102}(0,003) = 0.0546$$

$\varepsilon_s > \varepsilon_{s'}$ maka tulangan baja tarik sudah meluluh tetapi tulangan baja tekan belum

Tentukan garis netral dengan keseimbangan gaya – gaya Horizontal :

$(0,85 \cdot fc \cdot b \cdot \beta) .c^2 + (600 \cdot As' - As .f_y). c - 600 \cdot d' \cdot As' = 0$

$(0,85 \cdot 25 \cdot 250 \cdot 0.85) .c^2 + (600 \cdot 566,77) - 850,155 \cdot 400) \cdot c - 600 \cdot 44,5. 566,77 = 0$

$4303,125\ c^2 - 18526\ c - 15132759 = 0$

$c^2 - 4,305\ c - 3516,16 = 0$

$c^2 - 4{,}305\ c = 3516{,}15$

$c^2 - 4{,}305\ c + (\ ½\ (4{,}305))^2 = 3516{,}15 + (\ ½\ (4{,}305))^2$

$c^2 - 4{,}305\ c + 4{,}633 = 3516{,}15 + 4{,}633 = 3520{,}796$

$(c - 2{,}153^2 = 3520{,}796$

$c - 2{,}153 = \sqrt{3520{,}796} = 59{,}336$

$c = 59{,}336 + 2{,}153 = 61{,}488$

$a = \beta\ .\ c = 0{,}85\ .\ 59{,}31 = 50{,}414$ mm

Cek tulangan baja yang terjadi :

$$fs_s' = \frac{600(c - d')}{c} = \frac{600(61{,}88 - 44{,}5)}{61{,}488} = 165{,}765 \text{ Mpa} \leq f_y = 400 \text{ Mpa}$$

$N_{D1} = 0{,}85\ .\ fc\ .\ a\ .\ b$

$= 0{,}85\ .\ 25\ .\ 52{,}265\ .\ 250\ .\ 10^{-3}$

$= 277{,}657$ kN

$N_{D2} = As'\ .\ f_s'$

$= 566{,}77\ .\ 165$

$= 93{,}952$ kN

$N_D = N_{D1} + N_{D2}$

$= 277{,}657 + 93{,}952 = 371{,}609$ kN

$N_T = As\ .\ f_y$

$= 850{,}155\ .\ 400 = 340{,}062$ kN

$N_D = N_T$ (seimbang) ok!

$M_{n1} = N_{D1}\ .z_1 = N_{D1}\ .\ (d - a/2)$

$= 277{,}657\ .\ (405{,}5 - 52{,}265/2) = 105{,}056$ kNm

$M_{n2} = N_{D2}\ .z_2 = N_{D2}\ .\ (d - d')$

$= 93{,}652\ .\ (405{,}5 - 44{,}5) = 33{,}822$ kNm

$M_n = M_{n1} + M_{n2}$

$= 105{,}056 + 33{,}822 = 138{,}878$ kNm

$\phi M_n = 0{,}8\ .\ 138{,}878 = 111{,}103$ kNm

$\phi M_n = 111{,}878$ kNm $> M_u = 71{,}02$ kNm.

Cheking pada tulangan baja tarik :

$As' \cdot f_s = As_2 \cdot f_y$

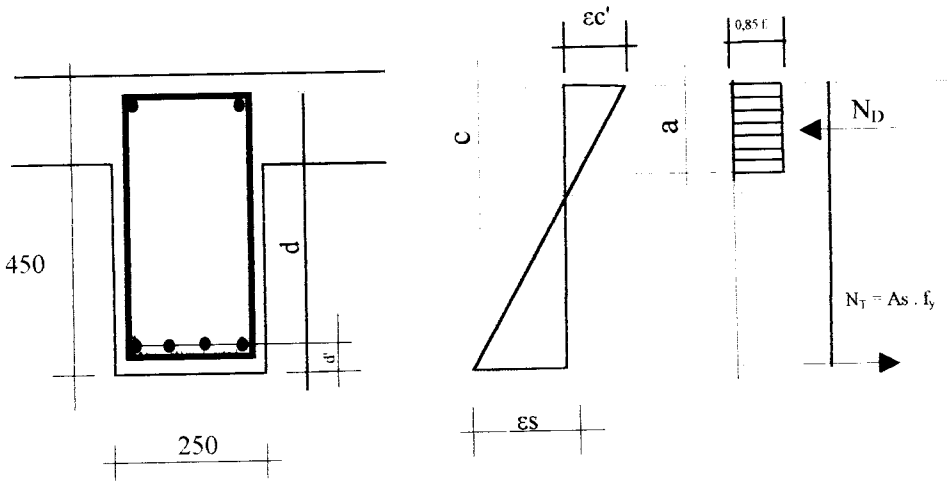
$$As_2 = \frac{As'.fs'}{fy} = \frac{566,77.165,768}{400} = 234,88 \text{ mm}^2.$$

$As_1 = As \cdot As_2 = 850,155 - 234,88 = 615,275 \text{ mm}^2.$

Syarat :

$As_1/b.d = 615,275 / 250 \cdot 405,5 = 0,00606$

$\rho = 0,00606 \geq \rho_{min} = 0,0035 \rightarrow$ Ok



Gambar 4.33 diagram regangan dan tegangan Penampang lapangan balok induk

C. Tulangan Geser

Dari hasil ananlisa program SAP untuk portal memanjang pada balok 17 didapat V_u = 105,26 kN

- **Perencanaan sengkang di daerah berpotensi sendi plastis**

  $V_u / \phi \leq V_c + V_c$ dimana $V_c = 0$

  $V_u / \phi \leq V_s$

  $V_s = V_u / \phi$

  $= 105,26 / 0,6 = 175,433$ KN.

  Digunakan sengkang Ø 10 ($Av = 2 . 1/4 . \pi . 10^2 = 157$ mm^2)

  $S = (A_v . f_y . d)/V_s$

  $$= \frac{157.240.405,5}{175433} = 87,094 \text{ mm.}$$

  Berdasarkan SKSNI 3.14.9-3.3b, bahwa sepasi maksimum tidak boleh melebihi nilai-nilai dibawah ini :

  Kontrol S_{maks} $= d/4 = 405,5/4$ $= 101,375$ mm

  $= 10 . Ø_{tul.ut}$ $= 10 . 19$ $= 190$ mm

  $= 24 . Ø_{tul.seng.}$ $= 24 . 10$ $= 240$ mm

  $= 531,375$ mm

  Dipakai sengkang Ø 10 – 75 mm.

  $S_{terpakai} = 75$ mm $< S_{maks} = 101,375$ mm.

  $$A_{v\,min} = \frac{b.w}{3.f_y} = \frac{250.75}{3.240} = 26,042 \text{ mm}^2 < A_{v\,min} = 157 \text{ mm}^2 \rightarrow \text{ok.}$$

  Kontrol kapasitas Geser :

  $$V_s = \frac{157.240.405,5}{75}.10^{-3} = 203,723 \text{ KN}$$

  $V_{SR} = \phi . V_s = 0,6 . 203,723 = 122,233$ KN $> V_u = 105,26$ KN.

- **Perencanaan sengkang diluar sendi plastis :**

  (Pada jarak 2 . h = 2 . 300 = 600 mm dari tumpuan)

  $V_u / \phi \leq V_c + V_s$

  $V_c = 1/6 . \sqrt{f_c} . b_w . d = 1/6 . \sqrt{25} . 250 . 405,5 = 84,79$ KN.

  $V_s = V_u / \phi - V_c = 105,26 / 0,6 - 84,79 = 77,15$ KN.

Digunakan Sengkang ϕ_P 10 (2 . $A_{s1} = \frac{1}{4} . \pi . 10^2 = 157\ mm^2$)

$S = A_V . f_y . d / V_s$

$= 157 . 240 . 405,5 / 77150 = 198,045$ mm

Diambil sengkang dengan jarak 150 mm.

$$V_s = \frac{157.240.405,5}{150} = 101,861 KN.$$

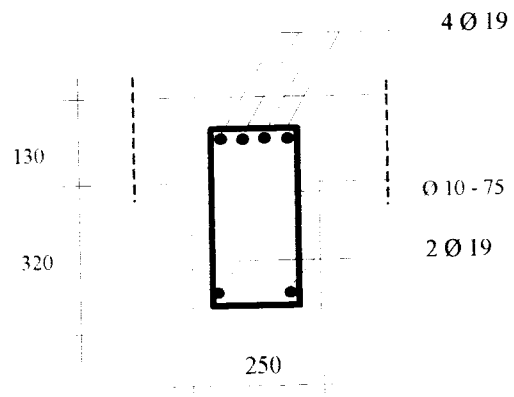
$V_s \leq 2/3 . \sqrt{f_c} . b_w . d = 2/3 . \sqrt{25} . 250 . 405,5 = 337,916$ KN. → ok.

$$A_{v\ min} = \frac{b.w}{3.f_y} = \frac{250.150}{3.240} = 52,08\ mm^2 < A_{v\ min} = 157\ mm^2 \rightarrow \text{ok.}$$

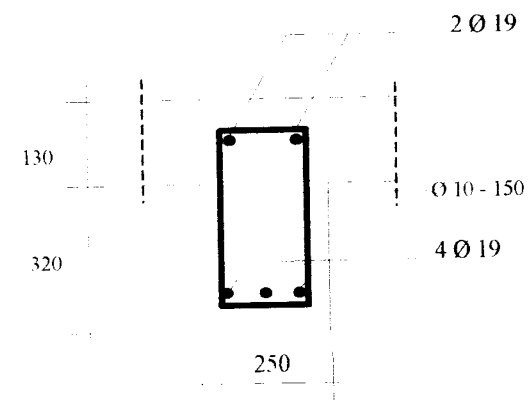
Kontrol kapasitas Geser :

$\phi (V_c + V_s) = 0,6 (84,79 + 101,861) = 111,99$ KN > 105,26 KN.→ ok.

Tulangan tumpuan



Tulangan lapangan



Gambar 4.36 Rencana Penulangan Balok Induk Lantai

Tabel 4.10 Perhitungan Tulangan Tumpuan Balok Induk Portal Melintang

f_y (Mpa) 400 | f_c (Mpa) 25 | ρ_{min} 0,0035 | ρ_{max} 0,027 | k_{max} 6,569

Lantai	No. Balok & Sloof	Dimensi b (mm)	Dimensi h (mm)	defektif (mm)	Mu (KNm)	Analisis	k	ρ_{perlu}	ρ_{pakai}	As Perlu (mm^2)	As tarik Dipakai Jumlah	As tarik Dipakai (mm^2)	As tekan Dipakai Jumlah	As tekan Dipakai (mm^2)	d_{aktual} (mm)	Kap. Balok Tanpa Tulangan a (mm)	Kap. Balok Tanpa Tulangan Mn (KNm)	Kap. Balok Tanpa Tulangan ø Mn (kNm)	Cek tul. Baja setelah diberi tulangan c (mm)	Cek tul. Baja setelah diberi tulangan a (mm)	Cek tul. Baja setelah diberi tulangan fs' (Mpa)	Cek tul. Baja setelah diberi tulangan ND (kN)	Cek tul. Baja setelah diberi tulangan ø Mn (KNm)	Cek
Lt. 1 (Sloof)	1	200	400	355.5	17.47	Tul. Tunggal	0.864	0.0022	0.0035	249	2 D 13 =	265.3	2 D 13 =	265.3	355.5	24.972	36.405	29.124	57.692	49.038	137.198	239.02	64.241	ok
	2	200	400	355.5	17.47	Tul. Tunggal	0.864	0.0022	0.0035	249	2 D 13 =	265.3	2 D 13 =	265.3	355.5	24.972	36.405	29.124	57.692	49.038	137.198	239.02	64.241	ok
	3	200	400	355.5	17.47	Tul. Tunggal	0.864	0.0022	0.0035	249	2 D 13 =	265.3	2 D 13 =	265.3	355.5	24.972	36.405	29.124	57.692	49.038	137.198	239.02	64.241	ok
	4	200	400	355.5	13.38	Tul. Tunggal	0.662	0.0017	0.0035	249	2 D 13 =	265.3	2 D 13 =	265.3	355.5	24.972	36.405	29.124	57.692	49.038	137.198	239.02	64.241	ok
Lt. 2	5	250	450	403.5	15.69	Tul. Tunggal	0.482	0.0012	0.0035	353	3 D 13 =	398	2 D 13 =	265.33	403.5	29.967	61.851	49.481	58.095	49.381	140.408	299.25	90.2	ok
	6	250	450	403.5	32.56	Tul. Tunggal	1.000	0.0026	0.0035	353	3 D 13 =	398	2 D 13 =	265.33	403.5	29.967	61.851	49.481	58.095	49.381	140.408	299.25	90.2	ok
	7	250	450	403.5	43.48	Tul. Tunggal	1.335	0.0035	0.0035	353	3 D 13 =	398	2 D 13 =	265.33	403.5	29.967	61.851	49.481	58.095	49.381	140.408	299.25	90.2	ok
	8	250	450	403.5	35.33	Tul. Tunggal	1.085	0.0028	0.0035	353	3 D 13 =	398	2 D 13 =	265.33	403.5	29.967	61.851	49.481	58.095	49.381	140.408	299.25	90.2	ok
Lt. 3	9	250	450	403.5	16.52	Tul. Tunggal	0.507	0.0013	0.0035	353	3 D 13 =	398	2 D 13 =	265.33	403.5	29.967	61.851	49.481	58.095	49.381	140.408	299.25	90.2	ok
	10	250	450	403.5	28.73	Tul. Tunggal	0.882	0.0023	0.0035	353	3 D 13 =	398	2 D 13 =	265.33	403.5	29.967	61.851	49.481	58.095	49.381	140.408	299.25	90.2	ok
	11	250	450	403.5	44.46	Tul. Tunggal	1.365	0.0035	0.0036	363	3 D 13 =	398	2 D 13 =	265.33	403.5	29.967	61.851	49.481	58.095	49.381	140.408	299.25	90.2	ok
	12	250	450	403.5	33.12	Tul. Tunggal	1.017	0.0026	0.0035	353	3 D 13 =	398	2 D 13 =	265.33	403.5	29.967	61.851	49.481	58.095	49.381	140.408	299.25	90.2	ok
Atap	13	200	400	355.5	12.17	Tul. Tunggal	0.602	0.0015	0.0035	249	2 D 13 =	265.3	2 D 13 =	265.3	355.5	24.972	36.405	29.124	57.692	49.038	137.198	239.02	64.241	ok
	14	200	400	355.5	16.42	Tul. Tunggal	0.812	0.0021	0.0035	249	2 D 13 =	265.3	2 D 13 =	265.3	355.5	24.972	36.405	29.124	57.692	49.038	137.198	239.02	64.241	ok
	15	200	400	355.5	18.4	Tul. Tunggal	0.910	0.0023	0.0035	249	2 D 13 =	265.3	2 D 13 =	265.3	355.5	24.972	36.405	29.124	57.692	49.038	137.198	239.02	64.241	ok
	16	200	400	355.5	12.02	Tul. Tunggal	0.594	0.0015	0.0035	249	2 D 13 =	265.3	2 D 13 =	265.3	355.5	24.972	36.405	29.124	57.692	49.038	137.198	239.02	64.241	ok

Tabel 4.11 Perhitungan Tulangan Lapangan Balok Induk Portal Melintang

f_y (Mpa)	f_c (Mpa)	ρ_{min}	ρ_{max}	k_{max}
400	25	0.0035	0.027	6.569

Lantai	No. Balok & Sloof	Dimensi b (mm)	Dimensi h (mm)	defektif (mm)	Mu (KNm)	Analisis	k	ρ_{perlu}	ρ_{pakai}	As Perlu (mm^2)	As tarik Dipakai Jumlah	As tarik Dipakai (mm^2)	As tekan Dipakai Jumlah	As tekan Dipakai (mm^2)	d_{aktual} (mm)	Kap. Balok Tanpa Tulangan a (mm)	Kap. Balok Tanpa Tulangan Mn (KNm)	Kap. Balok Tanpa Tulangan ø Mn (kNm)	Cek tul. Baja setelah diberi tulangan c (mm)	Cek tul. Baja setelah diberi tulangan a (mm)	Cek tul. Baja setelah diberi tulangan fs' (Mpa)	Cek tul. Baja setelah diberi tulangan ND (kN)	Cek tul. Baja setelah diberi tulangan ø Mn (KNm)	Cek
Lt. 1 (Sloof)	1	200	400	355.5	8.74	Tul. Tunggal	0.432	0.00109	0.0035	249	2 D 13 =	265.3	2 D 13 =	265.3	355.5	24.972	36.405	29.124	57.692	49.038	137.20	245	64.241	ok
	2	200	400	355.5	8.74	Tul. Tunggal	0.432	0.00109	0.0035	249	2 D 13 =	265.3	2 D 13 =	265.3	355.5	24.972	36.405	29.124	57.692	49.038	137.20	245	64.241	ok
	3	200	400	355.5	8.74	Tul. Tunggal	0.432	0.00109	0.0035	249	2 D 13 =	265.3	2 D 13 =	265.3	355.5	24.972	36.405	29.124	57.692	49.038	137.20	245	64.241	ok
	4	200	400	355.5	6.69	Tul. Tunggal	0.331	0.00083	0.0035	249	2 D 13 =	265.3	2 D 13 =	265.3	355.5	24.972	36.405	29.124	57.692	49.038	137.20	245	64.241	ok
Lt. 2	5	250	450	405.5	15.88	Tul. Tunggal	0.483	0.00122	0.0035	355	3 D 13 =	398	2 D 13 =	265.33	405.5	29.967	62.169	49.736	57.845	49.168	138.42	298	90.205	ok
	6	250	450	405.5	23.21	Tul. Tunggal	0.706	0.00179	0.0035	355	3 D 13 =	398	2 D 13 =	265.33	405.5	29.967	62.169	49.736	57.845	49.168	138.42	298	90.205	ok
	7	250	450	405.5	29.90	Tul. Tunggal	0.909	0.00232	0.0035	355	3 D 13 =	398	2 D 13 =	265.33	405.5	29.967	62.169	49.736	57.845	49.168	138.42	298	90.205	ok
	8	250	450	405.5	26.05	Tul. Tunggal	0.792	0.00202	0.0035	355	3 D 13 =	398	2 D 13 =	265.33	405.5	29.967	62.169	49.736	57.845	49.168	138.42	298	90.205	ok
Lt. 3	9	250	450	405.5	18.12	Tul. Tunggal	0.551	0.00140	0.0035	355	3 D 13 =	398	2 D 13 =	265.33	405.5	29.967	62.169	49.736	57.845	49.168	138.42	298	90.205	ok
	10	250	450	405.5	25.13	Tul. Tunggal	0.764	0.00195	0.0035	355	3 D 13 =	398	2 D 13 =	265.33	405.5	29.967	62.169	49.736	57.845	49.168	138.42	298	90.205	ok
	11	250	450	405.5	32.22	Tul. Tunggal	0.980	0.00251	0.0035	355	3 D 13 =	398	2 D 13 =	265.33	405.5	29.967	62.169	49.736	57.845	49.168	138.42	298	90.205	ok
	12	250	450	405.5	29.07	Tul. Tunggal	0.884	0.00226	0.0035	355	3 D 13 =	398	2 D 13 =	265.33	405.5	29.967	62.169	49.736	57.845	49.168	138.42	298	90.205	ok
Atap	13	200	400	355.5	16.58	Tul. Tunggal	0.820	0.00209	0.0035	249	2 D 13 =	265.3	2 D 13 =	265.3	355.5	24.972	36.405	29.124	57.692	49.038	137.20	245	64.241	ok
	14	200	400	355.5	14.60	Tul. Tunggal	0.722	0.00184	0.0035	249	2 D 13 =	265.3	2 D 13 =	265.3	355.5	24.972	36.405	29.124	57.692	49.038	137.20	245	64.241	ok
	15	200	400	355.5	14.47	Tul. Tunggal	0.716	0.00182	0.0035	249	2 D 13 =	265.3	2 D 13 =	265.3	355.5	24.972	36.405	29.124	57.692	49.038	137.20	245	64.241	ok
	16	200	400	355.5	11.77	Tul. Tunggal	0.582	0.00148	0.0035	249	2 D 13 =	265.3	2 D 13 =	265.3	355.5	24.972	36.405	29.124	57.692	49.038	137.20	245	64.241	ok

Tabel 4.12 Perhitungan Tulangan Geser Balok Induk Portal Melintang

f_y (Mpa) 240 f_c (Mpa) 25

Lantai	No. Balok & Sloof	Dimensi b mm	Dimensi h mm	defektif mm	V_U KNm	Tul. Geser di Daerah Sendi Plastis: V_S mm	A_V mm^2	S mm	S_{pakai} mm	Tulangan Terpasang	Kontrol: A_V min mm^2	Cek	ϕ Vs KN	Cek	Tulangan Geser di Luar Sendi Plastis: Vc KN	Vs KN	Av mm2	S mm	S_{Pakai} mm	Tulangan Terpasang	Kontrol: Av min mm^2	Cek	Vs KN	ϕ (Vc + Vs) KN	Cek
Lt. 1 (Sloof)	1	200	400	355.5	26.21	43.68	100.5	196.25	100	D8 - 100	27.778	Ok	51.44	Ok	59.25	-18.93	100.5	453	250	D 8 - 250	69.44	Ok	34.292	56.13	Ok
	2	200	400	355.5	26.21	43.68	100.5	196.25	100	D8 - 100	27.778	Ok	51.44	Ok	59.25	-18.93	100.5	453	250	D 8 - 250	69.44	Ok	34.292	56.13	Ok
	3	200	400	355.5	26.21	43.68	100.5	196.25	100	D8 - 100	27.778	Ok	51.44	Ok	59.25	-18.93	100.5	453	250	D 8 - 250	69.44	Ok	34.292	56.13	Ok
	4	200	400	355.5	22.93	38.22	100.5	224.32	100	D8 - 100	27.778	Ok	51.44	Ok	59.25	-23.97	100.5	358	250	D 8 - 250	69.44	Ok	34.292	56.13	Ok
Lt. 2	5	250	450	405.5	30.12	50.20	100.5	194.80	100	D10 - 100	34.722	Ok	58.67	Ok	84.479	-38.14	100.5	256	250	D 8 - 250	86.81	Ok	39.115	74.16	Ok
	6	250	450	405.5	65.33	108.88	157.0	140.33	100	D10 - 100	34.722	Ok	91.68	Ok	84.479	16.03	100.5	610	250	D 8 - 250	86.81	Ok	39.115	74.16	Ok
	7	250	450	405.5	62.23	103.72	157.0	147.32	100	D10 - 100	34.722	Ok	91.68	Ok	84.479	11.26	100.5	869	250	D 8 - 250	86.81	Ok	39.115	74.16	Ok
	8	250	450	405.5	53.27	88.78	157.0	172.10	100	D10 - 100	34.722	Ok	91.68	Ok	84.479	-2.53	100.5	3872	250	D 8 - 250	86.81	Ok	39.115	74.16	Ok
Lt. 3	9	250	450	405.5	29.63	49.38	157.0	309.40	100	D10 - 100	34.722	Ok	91.68	Ok	84.479	-38.89	100.5	251	250	D 8 - 250	86.81	Ok	39.115	74.16	Ok
	10	250	450	405.5	66.65	111.08	157.0	137.55	100	D10 - 100	34.722	Ok	91.68	Ok	84.479	18.06	100.5	541	250	D 8 - 250	86.81	Ok	39.115	74.16	Ok
	11	250	450	405.5	60.45	100.75	157.0	151.65	100	D10 - 100	34.722	Ok	91.68	Ok	84.479	8.52	100.5	1148	250	D 8 - 250	86.81	Ok	39.115	74.16	Ok
	12	250	450	405.5	54.17	90.28	157.0	169.24	100	D10 - 100	34.722	Ok	91.68	Ok	84.479	-1.14	100.5	8573	250	D 8 - 250	86.81	Ok	39.115	74.16	Ok
Atap	13	200	400	355.5	27.3	45.50	100.5	188.42	100	D8 - 100	27.778	Ok	51.44	Ok	59.25	-17.25	100.5	497	250	D 8 - 250	69.44	Ok	34.292	56.13	Ok
	14	200	400	355.5	27.42	45.70	100.5	187.59	100	D8 - 100	27.778	Ok	51.44	Ok	59.25	-17.07	100.5	502	250	D 8 - 250	69.44	Ok	34.292	56.13	Ok
	15	200	400	355.5	26.58	44.30	100.5	193.52	100	D8 - 100	27.778	Ok	51.44	Ok	59.25	-18.36	100.5	467	250	D 8 - 250	69.44	Ok	34.292	56.13	Ok
	16	200	400	355.5	19.77	32.95	100.5	260.18	100	D8 - 100	27.778	Ok	51.44	Ok	59.25	-28.83	100.5	297	250	D 8 - 250	69.44	Ok	34.292	56.13	Ok

Tabel 4.13 Perhitungan Tulangan Tumpuan Balok Induk Portal Memanjang

f_y (Mpa)	f_c (Mpa)	ρ_{min}	ρ_{max}	k_{max}
400	25	0,0035	0,027	6.569

Lantai	No. Balok & Sloof	Dimensi b (mm)	Dimensi h (mm)	defektif (mm)	Mu (KNm)	Analisis	k	ρ_{hitung}	ρ_{pakai}	As Perlu (mm^2)	As tarik Dipakai Jumlah	As tarik Dipakai (mm^2)	As tekan Dipakai Jumlah	As tekan Dipakai (mm^2)	d_{aktual} (mm)	Kap. Balok Tanpa Tulangan a (mm)	Kap. Balok Tanpa Tulangan Mn (KNm)	Kap. Balok Tanpa Tulangan ø Mn (kNm)	Cek tul. Baja setelah diberi tulangan c (mm)	Cek tul. Baja setelah diberi tulangan a (mm)	Cek tul. Baja setelah diberi tulangan fs' (Mpa)	Cek tul. Baja setelah diberi tulangan ND (kN)	Cek tul. Baja setelah diberi tulangan ø Mn (KNm)	Cek
Lt. 1 Sloof	1	200	400	354	47.95	Tul. Tunggal	2.391	0.0064	0.0064	453	4 D 13 =	531	2 D 13 =	265.33	354	49.94	69.84	55.873	62.31	52.97	171.51	271	70.25	ok
	2	200	400	355.5	32.16	Tul. Tunggal	1.590	0.0041	0.0041	292	3 D 13 =	398	2 D 13 =	265.33	355.5	37.46	53.61	42.891	58.47	49.70	143.33	249	65.33	ok
	3	200	400	355.5	32.16	Tul. Tunggal	1.590	0.0041	0.0041	292	3 D 13 =	398	2 D 13 =	265.33	355.5	37.46	53.61	42.891	58.47	49.70	143.33	249	65.33	ok
	4	200	400	355.5	32.16	Tul. Tunggal	1.590	0.0041	0.0041	292	3 D 13 =	398	2 D 13 =	265.33	355.5	37.46	53.61	42.891	58.47	49.70	143.33	249	65.33	ok
	5	200	400	355.5	32.16	Tul. Tunggal	1.590	0.0041	0.0041	292	3 D 13 =	398	2 D 13 =	265.33	355.5	37.46	53.61	42.891	58.47	49.70	143.33	249	65.33	ok
	6	200	400	355.5	32.16	Tul. Tunggal	1.590	0.0041	0.0041	292	3 D 13 =	398	2 D 13 =	265.33	355.5	37.46	53.61	42.891	58.47	49.70	143.33	249	65.33	ok
	7	200	400	355.5	32.16	Tul. Tunggal	1.590	0.0041	0.0041	292	3 D 13 =	398	2 D 13 =	265.33	355.5	37.46	53.61	42.891	58.47	49.70	143.33	249	65.33	ok
	8	200	400	355.5	32.16	Tul. Tunggal	1.590	0.0041	0.0041	292	3 D 13 =	398	2 D 13 =	265.33	355.5	37.46	53.61	42.891	58.47	49.70	143.33	249	65.33	ok
Lt. 2	9	250	450	400.5	106.26	Tul. Tunggal	3.312	0.0091	0.0091	911	4 D 19 =	1134	2 D 19 =	566.77	400.5	85.35	162.24	129.795	73.92	62.83	238.78	469.12	137.10	ok
	10	250	450	402	62.49	Tul. Tunggal	1.933	0.0051	0.0051	513	5 D 13 =	663	3 D 13 =	398.00	402	49.94	100.04	80.029	62.31	52.97	171.51	350	104.05	ok
	11	250	450	402	64.79	Tul. Tunggal	2.005	0.0053	0.0053	533	5 D 13 =	663	3 D 13 =	398.00	402	49.94	100.04	80.029	62.31	52.97	171.51	350	104.05	ok
	12	250	450	402	65.22	Tul. Tunggal	2.018	0.0053	0.0053	533	5 D 13 =	663	3 D 13 =	398.00	402	49.94	100.04	80.029	62.31	52.97	171.51	350	104.05	ok
	13	250	450	402	64.66	Tul. Tunggal	2.001	0.0053	0.0053	533	5 D 13 =	663	3 D 13 =	398.00	402	49.94	100.04	80.029	62.31	52.97	171.51	350	104.05	ok
	14	250	450	402	65.23	Tul. Tunggal	2.018	0.0053	0.0053	533	5 D 13 =	663	3 D 13 =	398.00	402	49.94	100.04	80.029	62.31	52.97	171.51	350	104.05	ok
	15	250	450	402	65.26	Tul. Tunggal	2.019	0.0053	0.0053	533	5 D 13 =	663	3 D 13 =	398.00	402	49.94	100.04	80.029	62.31	52.97	171.51	350	104.05	ok
	16	250	450	402	56.28	Tul. Tunggal	1.741	0.0045	0.0045	452	5 D 13 =	663	3 D 13 =	398.00	402	49.94	100.04	80.029	62.31	52.97	171.51	350	104.05	ok
Lt. 3	17	250	450	405.5	106.21	Tul. Tunggal	3.230	0.0088	0.0088	892	4 D 19 =	1134	2 D 19 =	566.77	405.5	85.35	164.51	131.609	73.92	62.83	238.78	469.12	138.98	ok
	18	250	450	402	63.49	Tul. Tunggal	1.964	0.0052	0.0052	523	3 D 16 =	603	2 D 16 =	401.92	402	45.39	91.47	73.176	62.31	52.97	171.51	350	104.24	ok
	19	250	450	402	64.95	Tul. Tunggal	2.010	0.0053	0.0053	533	3 D 16 =	603	2 D 16 =	401.92	402	45.39	91.47	73.176	62.31	52.97	171.51	350	104.24	ok
	20	250	450	402	65.41	Tul. Tunggal	2.024	0.0053	0.0053	533	5 D 13 =	663	3 D 13 =	398.00	402	49.94	100.04	80.029	62.31	52.97	171.51	350	104.05	ok
	21	250	450	402	64.49	Tul. Tunggal	1.995	0.0052	0.0053	533	5 D 13 =	663	3 D 13 =	398.00	402	49.94	100.04	80.029	62.31	52.97	171.51	350	104.05	ok
	22	250	450	402	65.04	Tul. Tunggal	2.012	0.0053	0.0053	533	5 D 13 =	663	3 D 13 =	398.00	402	49.94	100.04	80.029	62.31	52.97	171.51	350	104.05	ok
	23	250	450	402	64.47	Tul. Tunggal	1.995	0.0052	0.0053	533	5 D 13 =	663	3 D 13 =	398.00	402	49.94	100.04	80.029	62.31	52.97	171.51	350	104.05	ok
	24	250	450	402	54.71	Tul. Tunggal	1.693	0.0044	0.0044	442	5 D 13 =	663	3 D 13 =	398.00	402	49.94	100.04	80.029	62.31	52.97	171.51	350	104.05	ok
Lt. Atap	25	200	400	354	51.58	Tul. Tunggal	2.572	0.0069	0.0069	489	5 D 13 =	663	3 D 13 =	398.00	354	62.43	85.64	68.516	62.31	52.97	171.51	293	75.88	ok
	26	200	400	355.5	29.94	Tul. Tunggal	1.481	0.0038	0.0038	270	3 D 13 =	398	2 D 13 =	265.33	355.5	37.46	53.61	42.891	58.47	49.70	143.33	249	65.33	ok
	27	200	400	355.5	30.37	Tul. Tunggal	1.502	0.0039	0.0039	277	3 D 13 =	398	2 D 13 =	265.33	355.5	37.46	53.61	42.891	58.47	49.70	143.33	249	65.33	ok
	28	200	400	355.5	30.77	Tul. Tunggal	1.522	0.0040	0.0040	284	3 D 13 =	398	2 D 13 =	265.33	355.5	37.46	53.61	42.891	58.47	49.70	143.33	249	65.33	ok
	29	200	400	355.5	30.00	Tul. Tunggal	1.484	0.0038	0.0038	270	3 D 13 =	398	2 D 13 =	265.33	355.5	37.46	53.61	42.891	58.47	49.70	143.33	249	65.33	ok
	30	200	400	355.5	30.47	Tul. Tunggal	1.507	0.0039	0.0039	277	3 D 13 =	398	2 D 13 =	265.33	355.5	37.46	53.61	42.891	58.47	49.70	143.33	249	65.33	ok
	31	200	400	355.5	29.70	Tul. Tunggal	1.469	0.0038	0.0038	270	3 D 13 =	398	2 D 13 =	265.33	355.5	37.46	53.61	42.891	58.47	49.70	143.33	249	65.33	ok
	32	200	400	355.5	25.72	Tul. Tunggal	1.272	0.0033	0.0035	249	3 D 13 =	398	2 D 13 =	265.33	355.5	37.46	53.61	42.891	58.47	49.70	143.33	249	65.33	ok

Tabel 4.14 Perhitungan Tulangan Lapangan Balok Induk Portal Memanjang

fy (Mpa)	*fc (Mpa)*	*ρmin*	*mak*	*Kmaks*
400	*25*	*0.0035*	*0,027*	*6.569*

Lantai	No. Balok & Sloof	Dimensi b (mm)	Dimensi h (mm)	defektif (mm)	Mu (KNm)	Analisis	k	ρ_{hitung}	ρ_{pakai}	As Perlu (mm^2)	As tarik Dipakai: Jumlah	As tarik Dipakai (mm^2)	As tekan Dipakai: Jumlah	As tekan Dipakai (mm^2)	daktual (mm)	Kap. Balok Tanpa Tulangan: a (mm)	Mn (KNm)	ø Mn (kNm)	Cek tul. Baja telah leleh: c (mm)	a (mm)	fs' (Mpa)	ND (kN)	ø Mn (KNm)	Cek
Lt. 1 Sloof	1	200	400	355.5	23.97	Tul. Tunggal	1.185	0.0031	0.0035	248.85	3 D 13 =	398	2 D 13 =	265	355.5	37.458	53.61	42.891	45.157	38.383	8.730	165.45	44.47	ok
	2	200	400	355.5	16.08	Tul. Tunggal	0.795	0.0020	0.0035	248.85	3 D 13 =	398	2 D 13 =	265	355.5	37.458	53.61	42.891	45.157	38.383	8.730	165.45	44.47	ok
	3	200	400	355.5	16.08	Tul. Tunggal	0.795	0.0020	0.0035	248.85	3 D 13 =	398	2 D 13 =	265	355.5	37.458	53.61	42.891	45.157	38.383	8.730	165.45	44.47	ok
	4	200	400	355.5	16.08	Tul. Tunggal	0.795	0.0020	0.0035	248.85	3 D 13 =	398	2 D 13 =	265	355.5	37.458	53.61	42.891	45.157	38.383	8.730	165.45	44.47	ok
	5	200	400	355.5	16.08	Tul. Tunggal	0.795	0.0020	0.0035	248.85	3 D 13 =	398	2 D 13 =	265	355.5	37.458	53.61	42.891	45.157	38.383	8.730	165.45	44.47	ok
	6	200	400	355.5	16.08	Tul. Tunggal	0.795	0.0020	0.0035	248.85	3 D 13 =	398	2 D 13 =	265	355.5	37.458	53.61	42.891	45.157	38.383	8.730	165.45	44.47	ok
	7	200	400	355.5	16.08	Tul. Tunggal	0.795	0.0020	0.0035	248.85	3 D 13 =	398	2 D 13 =	265	355.5	37.458	53.61	42.891	45.157	38.383	8.730	165.45	44.47	ok
	8	200	400	355.5	16.08	Tul. Tunggal	0.795	0.0020	0.0035	248.85	3 D 13 =	398	2 D 13 =	265	355.5	37.458	53.61	42.891	45.157	38.383	8.730	165.45	44.47	ok
Lt. 2	9	250	450	407	67.2	Tul. Tunggal	2.028	0.0053	0.0054	549.45	3 D 19 =	850.16	2 D 19 =	566.77	407	64.012	127.52	102.017	61,488	52,265	165,768	371,609	111,878	ok
	10	250	450	403.5	45.38	Tul. Tunggal	1.394	0.0036	0.0036	363.15	3 D 13 =	398	2 D 13 =	265	403.5	29.967	61.85	49.481	45.157	38.383	8.730	206.23	63.36	ok
	11	250	450	403.5	45.47	Tul. Tunggal	1.396	0.0036	0.0036	363.15	3 D 13 =	398	2 D 13 =	265	403.5	29.967	61.85	49.481	45.157	38.383	8.730	206.23	63.36	ok
	12	250	450	403.5	45.24	Tul. Tunggal	1.389	0.0036	0.0036	363.15	3 D 13 =	398	2 D 13 =	265	403.5	29.967	61.85	49.481	45.157	38.383	8.730	206.23	63.36	ok
	13	250	450	403.5	45.23	Tul. Tunggal	1.389	0.0036	0.0036	363.15	3 D 13 =	398	2 D 13 =	265	403.5	29.967	61.85	49.481	45.157	38.383	8.730	206.23	63.36	ok
	14	250	450	403.5	45.21	Tul. Tunggal	1.388	0.0036	0.0036	363.15	3 D 13 =	398	2 D 13 =	265	403.5	29.967	61.85	49.481	45.157	38.383	8.730	206.23	63.36	ok
	15	250	450	403.5	44.96	Tul. Tunggal	1.381	0.0036	0.0035	353.06	3 D 13 =	398	2 D 13 =	265	403.5	29.967	61.85	49.481	45.157	38.383	8.730	206.23	63.36	ok
	16	250	450	403.5	45.52	Tul. Tunggal	1.398	0.0036	0.0036	363.15	3 D 13 =	398	2 D 13 =	265	403.5	29.967	61.85	49.481	45.157	38.383	8.730	206.23	63.36	ok
Lt. 3	17	250	450	407	71.02	Tul. Tunggal	2.144	0.0057	0.0057	579.98	3 D 19 =	850.16	2 D 16 =	401.92	407	64.012	127.52	102.017	61,488	52,265	165,768	371,609	111,878	ok
	18	250	450	403.5	49.23	Tul. Tunggal	1.512	0.0039	0.0039	393.41	3 D 16 =	603	2 D 16 =	402	402	45.393	91.47	73.176	48.123	40.905	45.172	235.46	71.52	ok
	19	250	450	403.5	48.85	Tul. Tunggal	1.500	0.0039	0.0039	393.41	3 D 16 =	603	2 D 16 =	402	402	45.393	91.47	73.176	48.123	40.905	45.172	235.46	71.52	ok
	20	250	450	403.5	48.53	Tul. Tunggal	1.490	0.0039	0.0038	383.33	3 D 13 =	398	2 D 13 =	265	403.5	29.967	61.85	49.481	45.157	38.383	8.730	206.23	63.36	ok
	21	250	450	403.5	48.5	Tul. Tunggal	1.489	0.0039	0.0038	383	3 D 13 =	398	2 D 13 =	265	403.5	29.967	61.85	49.481	45.157	38.383	8.730	206.23	63.36	ok
	22	250	450	403.5	48.46	Tul. Tunggal	1.488	0.0039	0.0038	383	3 D 13 =	398	2 D 13 =	265	403.5	29.967	61.85	49.481	45.157	38.383	8.730	206.23	63.36	ok
	23	250	450	403.5	48.16	Tul. Tunggal	1.479	0.0038	0.0038	383	3 D 13 =	398	2 D 13 =	265	403.5	29.967	61.85	49.481	45.157	38.383	8.730	206.23	63.36	ok
	24	250	450	403.5	48.57	Tul. Tunggal	1.492	0.0039	0.0038	383	3 D 13 =	398	2 D 13 =	265	403.5	29.967	61.85	49.481	45.157	38.383	8.730	206.23	63.36	ok
Lt. Atap	25	200	400	355.5	36.38	Tul. Tunggal	1.799	0.0047	0.0047	334	3 D 13 =	398	2 D 13 =	265	355.5	37.458	53.61	42.891	45.157	38.383	8.730	165.45	44.47	ok
	26	200	400	355.5	25.02	Tul. Tunggal	1.237	0.0032	0.0035	249	3 D 13 =	398	2 D 13 =	265	355.5	37.458	53.61	42.891	45.157	38.383	8.730	165.45	44.47	ok
	27	200	400	355.5	24.82	Tul. Tunggal	1.227	0.0032	0.0035	249	3 D 13 =	398	2 D 13 =	265	355.5	37.458	53.61	42.891	45.157	38.383	8.730	165.45	44.47	ok
	28	200	400	355.5	24.62	Tul. Tunggal	1.218	0.0031	0.0035	249	3 D 13 =	398	2 D 13 =	265	355.5	37.458	53.61	42.891	45.157	38.383	8.730	165.45	44.47	ok
	29	200	400	355.5	24.6	Tul. Tunggal	1.217	0.0031	0.0035	249	3 D 13 =	398	2 D 13 =	265	355.5	37.458	53.61	42.891	45.157	38.383	8.730	165.45	44.47	ok
	30	200	400	355.5	24.58	Tul. Tunggal	1.216	0.0031	0.0035	249	3 D 13 =	398	2 D 13 =	265	355.5	37.458	53.61	42.891	45.157	38.383	8.730	165.45	44.47	ok
	31	200	400	355.5	24.43	Tul. Tunggal	1.208	0.0031	0.0035	249	3 D 13 =	398	2 D 13 =	265	355.5	37.458	53.61	42.891	45.157	38.383	8.730	165.45	44.47	ok
	32	200	400	355.5	24.7	Tul. Tunggal	1.222	0.0031	0.0035	249	3 D 13 =	398	2 D 13 =	265	355.5	37.458	53.61	42 891	45.157	38.383	8.730	165.45	44.47	ok

Tabel 4.14 Perhitungan Tulangan Geser Balok Induk Portal Memanjang

f_y (Mpa) 240 f_c (Mpa) 25

Lantai	No. Balok & Sloof	Dimensi b mm	Dimensi h mm	defektif mm	Vu KNm	Tul. Geser di Daerah Sendi Plastis Tulangan: Vs mm	Av mm²	Smak mm	S Pakai mm	Tulangan Terpasang	Kontrol: Av min mm²	Cek	øVs KN	Cek	Tulangan Geser di Luar Sendi Plastis: Vc KN	Vs KN	Av mm²	S mm	Spakai mm	Tulangan Terpasang	Kontrol: Av min mm²	Cek	Vs KN	ø (Vc + Vs) KN	Cek
Lt. 1 Sloof	1	200	400	354	49.60	82.667	100.5	103.268	100	D 8 - 100	27.778	Ok	51.22	Ok	59.00	17.31	100.48	493.2	250	D8 - 250	69.44	Ok	20.49	47.69	ok
	2	200	400	355.5	40.62	67.700	100.5	126.632	100	D 8 - 100	27.778	Ok	51.44	Ok	59.25	3.24	100.48	2644.1	250	D8 - 250	69.44	Ok	20.58	47.90	Ok
	3	200	400	355.5	40.62	67.700	100.5	126.632	100	D 8 - 100	27.778	Ok	51.44	Ok	59.25	3.24	100.48	2644.1	250	D8 - 250	69.44	Ok	20.58	47.90	Ok
	4	200	400	355.5	40.62	67.700	100.5	126.632	100	D 8 - 100	27.778	Ok	51.44	Ok	59.25	3.24	100.48	2644.1	250	D8 - 250	69.44	Ok	20.58	47.90	Ok
	5	200	400	355.5	40.62	67.700	100.5	126.632	100	D 8 - 100	27.778	Ok	51.44	Ok	59.25	3.24	100.48	2644.1	250	D8 - 250	69.44	Ok	20.58	47.90	Ok
	6	200	400	355.5	40.62	67.700	100.5	126.632	100	D 8 - 100	27.778	Ok	51.44	Ok	59.25	3.24	100.48	2644.1	250	D8 - 250	69.44	Ok	20.58	47.90	Ok
	7	200	400	355.5	40.62	67.700	100.5	126.632	100	D 8 - 100	27.778	Ok	51.44	Ok	59.25	3.24	100.48	2644.1	250	D8 - 250	69.44	Ok	20.58	47.90	Ok
	8	200	400	355.5	40.62	67.700	100.5	126.632	100	D 8 - 100	27.778	Ok	51.44	Ok	59.25	3.24	100.48	2644.1	250	D8 - 250	69.44	Ok	20.58	47.90	Ok
Lt. 2	9	250	450	400.5	105.31	175.517	157	85.980	75	D 10 - 75	26.042	Ok	120.73	Ok	83.44	78.58	157	192.0	150	D10 - 150	52.08	Ok	60.36	86.28	Ok
	10	250	450	402	78.63	131.050	157	115.585	100	D 10 - 100	34.722	Ok	90.88	Ok	83.75	37.22	100.48	260.5	250	D8 - 250	86.81	Ok	23.27	64.21	Ok
	11	250	450	402	75.80	126.333	157	119.900	100	D 10 - 100	34.722	Ok	90.88	Ok	83.75	32.87	100.48	295.0	250	D8 - 250	86.81	Ok	23.27	64.21	Ok
	12	250	450	402	76.52	127.533	157	118.772	100	D 10 - 100	34.722	Ok	90.88	Ok	83.75	33.97	100.48	285.4	250	D8 - 250	86.81	Ok	23.27	64.21	Ok
	13	250	450	402	75.92	126.533	157	119.710	100	D 10 - 100	34.722	Ok	90.88	Ok	83.75	33.05	100.48	293.3	250	D8 - 250	86.81	Ok	23.27	64.21	Ok
	14	250	450	402	76.50	127.500	157	118.803	100	D 10 - 100	34.722	Ok	90.88	Ok	83.75	33.94	100.48	285.6	250	D8 - 250	86.81	Ok	23.27	64.21	Ok
	15	250	450	402	75.74	126.233	157	119.995	100	D 10 - 100	34.722	Ok	90.88	Ok	83.75	32.77	100.48	295.8	250	D8 - 250	86.81	Ok	23.27	64.21	Ok
	16	250	450	402	79.27	132.117	157	114.651	100	D 10 - 100	34.722	Ok	90.88	Ok	83.75	38.20	100.48	253.8	250	D8 - 250	86.81	Ok	23.27	64.21	Ok
Lt. 3	17	250	450	405.5	105.26	175.433	157	87.094	75	D 10 - 75	26.042	Ok	122.23	Ok	84.48	77.46	157	197.3	150	D10 - 150	52.08	Ok	101.86	111.80	Ok
	18	250	450	402	75.73	126.217	100.5	76.807	100	D 8 - 100	34.722	Ok	58.17	Ok	83.75	32.76	100.48	295.9	250	D8 - 250	86.81	Ok	23.27	64.21	Ok
	19	250	450	402	76.58	127.633	100.5	75.954	100	D 8 - 100	34.722	Ok	58.17	Ok	83.75	34.07	100.48	284.6	250	D8 - 250	86.81	Ok	23.27	64.21	Ok
	20	250	450	402	75.98	126.633	100.5	76.554	100	D 8 - 100	34.722	Ok	58.17	Ok	83.75	33.14	100.48	292.5	250	D8 - 250	86.81	Ok	23.27	64.21	Ok
	21	250	450	402	76.66	127.767	100.5	75.875	100	D 8 - 100	34.722	Ok	58.17	Ok	83.75	34.19	100.48	283.6	250	D8 - 250	86.81	Ok	23.27	64.21	Ok
	22	250	450	402	76.04	126.733	100.5	76.494	100	D 8 - 100	34.722	Ok	58.17	Ok	83.75	33.23	100.48	291.7	250	D8 - 250	86.81	Ok	23.27	64.21	Ok
	23	250	450	402	79.27	132.117	100.5	73.377	100	D 8 - 100	34.722	Ok	58.17	Ok	83.75	38.20	100.48	253.8	250	D8 - 250	86.81	Ok	23.27	64.21	Ok
	24	250	450	402	50.49	84.150	100.5	115.203	100	D 8 - 100	34.722	Ok	58.17	Ok	83.75	-6.07	100.48	1596.3	250	D8 - 250	86.81	Ok	23.27	64.21	Ok
Lt. Atap	25	200	400	354	35.27	58.783	100.5	145.225	100	D 8 - 100	27.778	Ok	51.22	Ok	59.00	-4.74	100.48	1801.6	250	D8 - 250	69.44	Ok	20.49	47.69	Ok
	26	200	400	355.5	34.06	56.767	100.5	151.021	100	D 8 - 100	27.778	Ok	51.44	Ok	59.25	-6.85	100.48	1251.5	250	D8 - 250	69.44	Ok	20.58	47.90	Ok
	27	200	400	355.5	34.43	57.383	100.5	149.398	100	D 8 - 100	27.778	Ok	51.44	Ok	59.25	-6.28	100.48	1365.0	250	D8 - 250	69.44	Ok	20.58	47.90	Ok
	28	200	400	355.5	34.25	57.083	100.5	150.183	100	D 8 - 100	27.778	Ok	51.44	Ok	59.25	-6.56	100.48	1307.3	250	D8 - 250	69.44	Ok	20.58	47.90	Ok
	29	200	400	355.5	34.50	57.500	100.5	149.095	100	D 8 - 100	27.778	Ok	51.44	Ok	59.25	-6.17	100.48	1388.8	250	D8 - 250	69.44	Ok	20.58	47.90	Ok
	30	200	400	355.5	34.38	57.300	100.5	149.615	100	D 8 - 100	27.778	Ok	51.44	Ok	59.25	-6.36	100.48	1348.4	250	D8 - 250	69.44	Ok	20.58	47.90	Ok
	31	200	400	355.5	35.67	59.450	100.5	144.204	100	D 8 - 100	27.778	Ok	51.44	Ok	59.25	-4.37	100.48	1960.4	250	D8 - 250	69.44	Ok	20.58	47.90	Ok

4.5.3 Perhitungan Panjang Tulangan Daerah Tarik Tekan pada balok

Diketahui (dari analisa SAP 2000):

$Mu_{tumpuan}$ = 106,21 KNm

ϕ Mu = 132,762 KNm

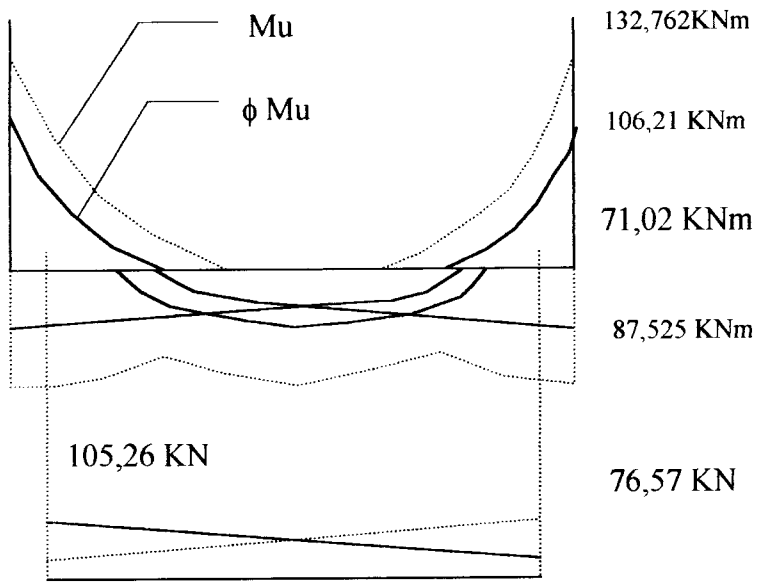
$Mu_{lapangan}$ = 71,020 KNm

ϕ Mu = 87,525 KNm

Vu_{mak} = 105,26 KN

Vu_{min} = 76,57 KN

Dapat digambarkan bidang momen dan gaya geser terfaktor sebagai berikut :



Gambar 4.39 Bidang Momen dan Gaya Terfaktor Balok

a. Perhitungan Tulangan Momen Positif

Tulangan 4 D 16 (Mn = 803,84)

- **Titik balik Kondisi x_1 = 4,1625 m**

$$V_{u1} = 76,57 + \frac{(5,55 - 4,1625)}{5,55} . (105,26 + 76,57) = 122,027 \text{ KN}$$

$L_a = 12\ d_b \geq d$

$L_a = 12 . 25 = 300$ mm < d = 405,5 mm

Dipakai L_a = 405,5 mm

- **Titik balik kondisi x_2 = 1,3875 m**

$$V_{u1} = 76,57 + \frac{(5,55 - 1,3875)}{5,55} . (105,26 + 76,57) = 212,942 \text{ KN}$$

$L_a = 12\ d_b \geq d$

$L_a = 12 . 15 = 5665 \text{ mm} < d = 300 \text{ mm}$

Dipakai $L_a = 405,5$ mm

b. Perhitungan Tulangan Momen Negatif

- **Kapasitas momen :**

Tulangan ϕ 4 D 19 = 0,8 . 1133,540 = 906,832 KNm.

Tulangan ϕ 2 D 19 = 0,8 . 566,770 = 453,416 KNm.

Tulangan ϕ 2 D 19 = 0,8 . 566,770 = 453,416 KNm.

- **Letak pemutusan tulangan momen neganif**

4 D 19 dipasang sampai jarak (ln – ¾ ln) = (5,8 – 4,1625) = 155 m.

2 D 19 dipasang sampai jarak (¼ ln + d) = (1,3875 + 0,4055) = 155 m.

2 D 19 dipasang sampai ujung balok.

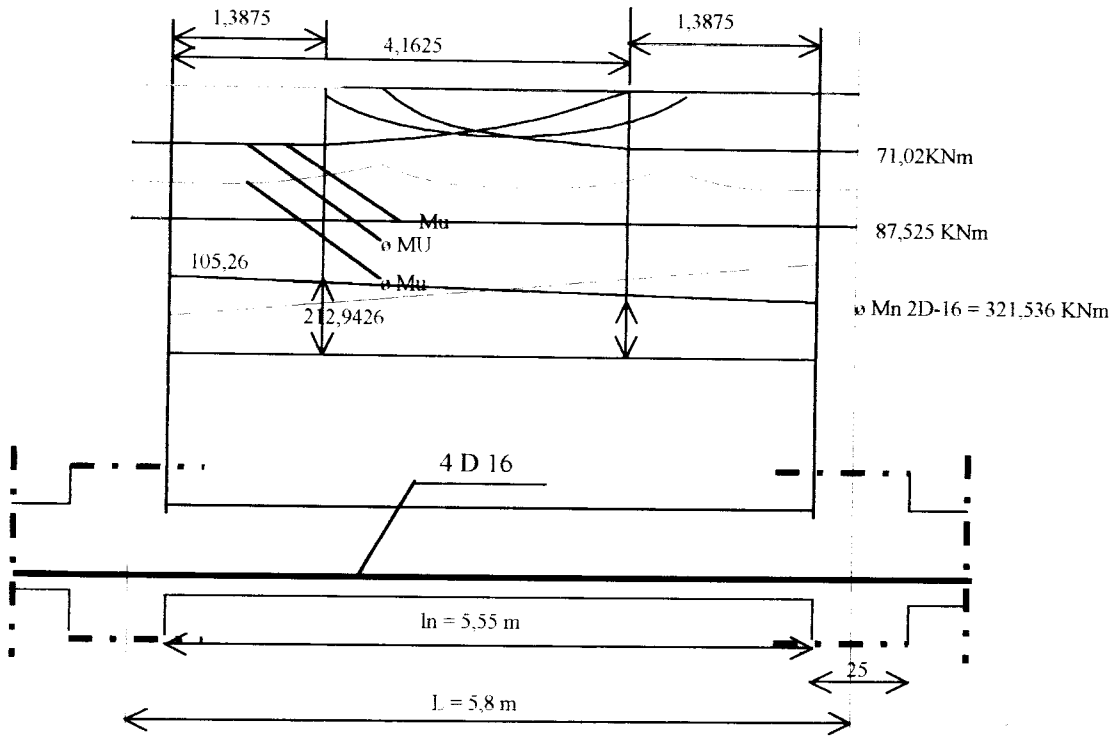
- **Titik balik kondisi x_1 = 1,3875 m**

$$V_{u1} = 76,57 + \frac{(5,55 - 1,3875)}{5,55} . (105,26 + 76,57) = 212,942 \text{ KN}$$

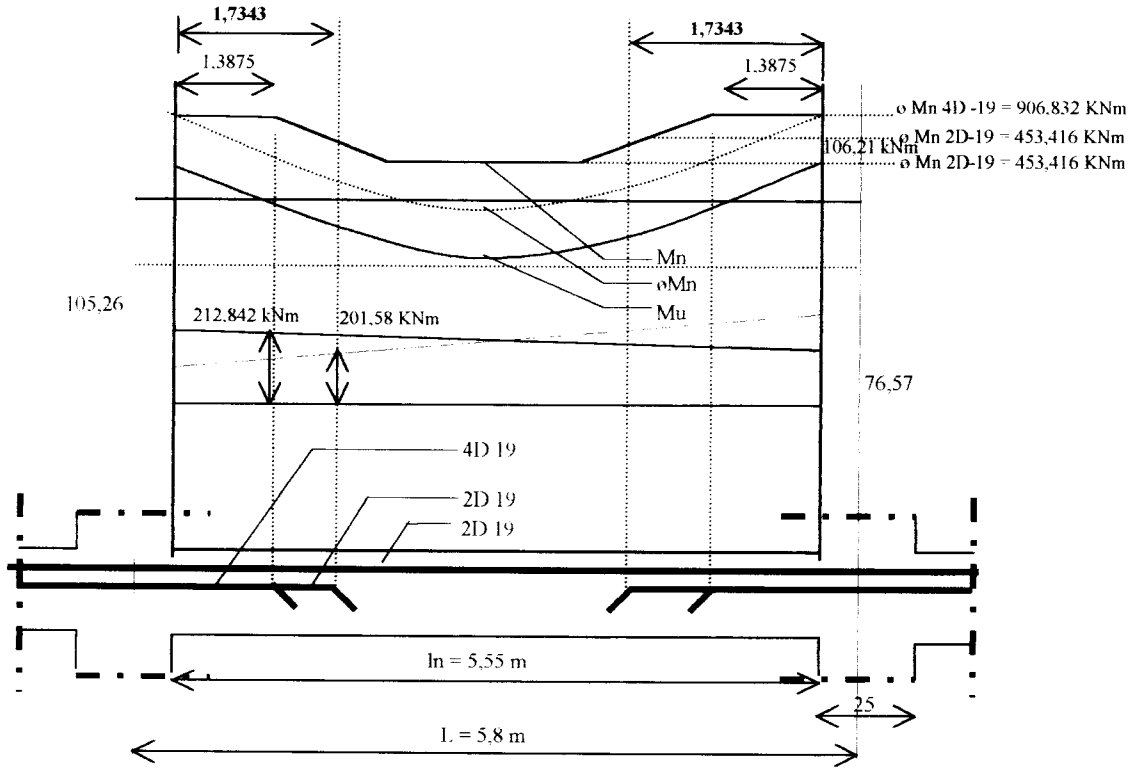
- **Titik balik kondisi x_2 = 1,7343 m**

$$V_{u2} = 76,57 + \frac{(5,55 - 1,7343)}{5,55} . (105,26 + 76,57) = 201,580 \text{ KN}$$

Untuk lebih jelasnya hasil perhitungan diatas dapat digambarkan pada diagram dibawah ini :



Gambar 4.40 Bidang Selimut Momen Tulangan Lapangan



Gambar 4.41 Bidang Selimut Momen Tulangan Tumpuan

4.6. Perhitungan Kolom

Perhitungan kolom dilakukan dengan cara biaksial, yaitu dengan mermperhitungkan gaya-gaya yang bekerja pada arah-x dan arah-y yang menghasilkan gaya aksial dan momen rencana sesuai dengan Pedoman Ketahanan Gempa untuk Rumah dan Gedung Pasal 3.3.2.

Gaya aksial dan momen diambil dari hasil output analisis struktur portal dengan menggunakan program SAP 2000 versi 7.42.

Dengan memperhatikan syarat-syarat struktur daktilitas penuh, kolom desain dengan memperhatikan prinsip "Kolom Kuat dan Balok Lemah" dengan maksud agar kapasitas kolom lebih besar dari kapasitas baloknya, sehingga menjamin kolom tetap berdiri apabila beban melampaui beban rencana serta menjamin sendi plastis terjadi pada balok terlebih dahulu.

Perencanaan penulangan kolom ini dibantu dengtan grafik rasio penulangan kolom dari W.C,Vis dan Gideon Kusuma dan Tabel Perhitungan Beton Bertulang.

4.6.1 PerhitunganTulangan Kolom

A. Menghitung kolom portal melintang

Pada portal melintang diambil kasus batang 26, kolom 4 Lantai 1 dengan momen dan gaya normal sebagai berikut:

Pu = 991,67 kN

Mu = 97,30 kNm

Kontrol kapasiatas Ag (Luas penampang kolom)

ρ_t = 3 % (Trial & error)

$$e = \frac{M_{u.x}}{P_{u.x}} = \frac{97,30}{991,67} = 0,09812 \text{ m}$$

P_0 = Ag [0,85 .f'c (1 – Pg) + fy. Pg]

= Ag [0,85 .25 (1 – 0,003) + 400. 0,003] dengan P_n (maks) = 0,8 P_0

ø P_n = P_u

$$\frac{P_u}{\phi} = P_n \qquad \text{ø} = 0,65$$

P_u = 0,65 . 0,8 Ag [0,85 .25 (1 – 0,003) + 400. 0,003]

0,991 = 18,2447 Ag

Ag = 0,0543 m^2

Ag = b x h ≥ 0,0543 m^2

Direncanakan kolom dengan h = 300 cm, b = 500 cm

Maka Ag = 0,3 x 0,5 = 0,15 m^2 ≥ 0,0543 m^2 ok

Ukuran kolom sesuai dengan rencana awal yaitu dengan ukuran Kolom 300/500

A_{gr} = b . h = 500 . 300 = 150000 mm^2

e/h = 0,09812/0,3 = 0,326

$$K = \frac{P_u}{0,65.A_{gr}.0,85.f'_c} = \frac{991670}{0,65.150000.0,85.25} = 0,475$$

L = K . (e/h) = 0,475 . 0,326 = 0,155

Dari diagram grafik untuk perencanaan kolom , dengan mengambil K sebagai sumbu vertikal dan L sebagai sumbu horizontal, dan dihitung 2 (dua) sisi maka diperoleh:

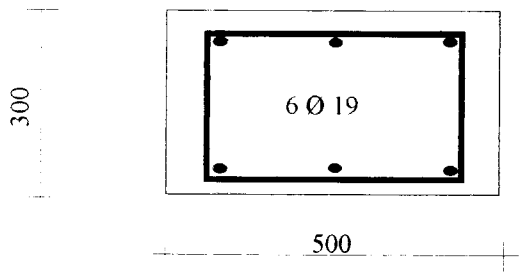
r = 0,0075 β = 1 untuk f'_c = 25 Mpa

Rasio tulangan :

ρ = r . β = 0, 0075 . 1 = 1,5 %

A_s = ρ . A_{gr} = 0,0075 . 150000 = 1125 mm^2.

Digunakan tulangan 6 D 19 = 1700,31 mm^2



Gambar 4.42 Tulangan longitudinal kolom melintang

Cheking jarak tulangan kearah - X :

Selimut beton 2 . 25 = 50 mm

Sengkang 2 . 10 = 20 mm

Tul. Pokok $3 . 19 = 57$ mm

$= 127$ mm

$s = (500 - 127)/2 = 186{,}5$ mm. > 25 mm...OK.

Cheking jarak tulangan kearah - Y :

Cheking: $2 . 25 = 50$ mm

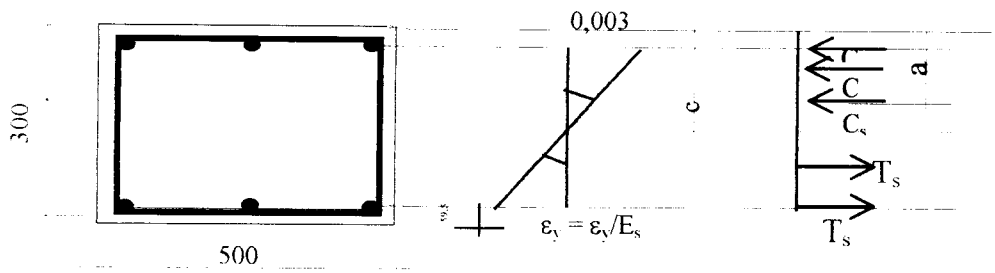
Sengkang: $2 . 10 = 20$ mm

Tul. Pokok: $2 . 19 = 38$ mm

$= 108$ mm

$s = (300 - 108)/1 = 192$ mm. > 25 mm...OK.

Kontrol Kapasitas Kolom:



Gambar 4.43 Penampang kolom, diagram regangan dan tegangan dalam keadaan seimbang kolom melintang

A_s $= 3$ D $19 = 850{,}155$ mm^2

A'_s $= 3$ D $19 = 850{,}155$ mm^2

$$c_b = \frac{600.d}{600 + fy} = \frac{600.255{,}5}{600 + 400} = 153{,}3 \text{ mm}$$

$a_b = 0{,}85 . c_b = 0{,}85 . 153{,}3 = 130{,}305$ mm

$f'_s = 600 (c_b - d') / c_b = 600 (153{,}3 - 44{,}5) / 153{,}3 = 425{,}831$ Mpa $< f_y = 400$ Mpa digunakan $f'_y = 400$ Mpa

$C_c = a_b . b . 0{,}85 . f_c = 130{,}305 . 500 . 0{,}85 . 25 . 10^{-3} = 1384{,}5$ kN

$C_{s1} = A_s . (f'_y - 0{,}85 . f'_c) = 850{,}155 . (400 - 0{,}85 . 25) . 10^{-3} = 321{,}996$ kN

$T_s = A_s . f'_s = 850{,}155 . 400 . 10^{-3} = 340{,}062$ kN

$P_{n.b} = (C_c + C_{s1}) - (T_s)$

$= (1384{,}5 + 321{,}996) - (340{,}062) = 1366{,}191$ kN.

$P_{U,b}$ = 0,85 . 1366,191 = 888,024 kNm

M_c = C_c . (h/2 – a_b/2) = 1384,5 (150 – 130,305/2). 10^{-3} = 117,47 kNm

M_{cs1} = C_{s1} . (h /2 – d') = 321,996 (150 – 44,5) . 10^{-3} = 33,97 kNm

M_{Ts} = T_s . (d – h/2) = 340,062 . (255,5 –150) 10^{-3} = 35,876 kNm

$M_{n,b}$ = M_C + M_{cs1} + M_{Ts}

= 117,47 + 33,97 + 35,876 = 187,316 kNm.

$M_{u,b}$ = 0,65 . $M_{n,b}$ = 0,65 . 187,316 = 121,755 kNm.

e_b = $\frac{M_{n,b}}{P_{n,b}} = \frac{187316}{1366191}$ = 161,303 mm >e = 98,12 mm

P_n = $\frac{A_s.f_y}{(e/d-d')+0,5} + \frac{b.h.f'_c}{(3.h.e)/d^2+1,18}$

= $\frac{850,155.400}{(161,191/255,5-44,5)+0,5} + \frac{300.500.25}{(3.300.161,303)/255,5^2+1,18}$

= 2268,936 + 1309,677 = 1578,613 kN

$P_{u\ Rancang}$ = 0,65 . 1578,613 = 1026,98 kN > P_u = 991,67 kN ..... Ok

M_n = $P_{u,R}$. e = 1026,98 . 0,161303 = 165,2 kNm.

$M_{U,Rancang}$ = 0,65 . 165,2 = 107,38 kNm > M_U = 97,3 kNm ..... Ok

B. Menghitung kolom pada portal memanjang

Pada batang 45 kolom 5 lantai 1

Pu = 572,32 kN

Mu = 33,52 kNm

h = 500 mm

b = 300 mm

e = $\frac{M_{u,x}}{P_{u,x}} = \frac{33,52}{572,32}$ = 0,0635 m

e/h = 0,0635/0,5 = 0,127

K = $\frac{P_u}{0,65.A_{gr}.0,85.f'_c} = \frac{572320}{0,65.150000.0,85.25}$ = 0,276

L = K . (e/h) = 0,275 . 0,127 = 0,035

Dari diagram grafik untuk perencanaan kolom , dengan mengambil K sebagai sumbu vertikal dan L sebagai sumbu horizontal, dan dihitung 2 (dua) sisi maka diperoleh:

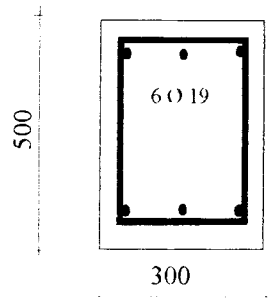
r = 0,0065 β = 1 untuk f'_c = 25 Mpa

Rasio tulangan :

$\rho = r \cdot \beta = 0,0065 \cdot 1 = 0,65\%$

$A_s = \rho \cdot A_{gr} = 0,0065 \cdot 150000 = 975\ mm^2$.

Digunakan tulangan 6 D 19 = 1700,31 mm^2



Gambar 4.42 Tulangan longitudinal kolom memanjang

Cheking jarak tulangan kearah - X :

Selimut beton 2 . 25 = 50 mm

Sengkang 2 . 10 = 20 mm

Tul. Pokok 3 . 19 = 57 mm

= 127 mm

s = (300 – 127)/2 = 96 mm. > 25 mm...OK.

Cheking jarak tulangan kearah - Y :

Cheking: 2 . 25 = 50 mm

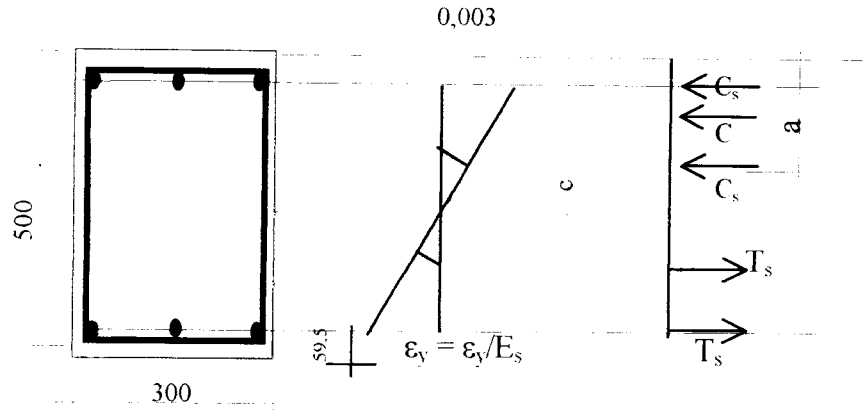
Sengkang: 2 . 10 = 20 mm

Tul. Pokok: 2 . 19 = 38 mm

= 108 mm

s = (300 – 108)/1 = 192 mm. > 25 mm...OK.

Kontrol Kapasitas Kolom:



Gambar 4.43 Penampang kolom, diagram regangan dan tegangan dalam keadaan seimbang portal memanjang

A_s = 3 D 19 = 850,155 mm^2

A'_s = 3 D 19 = 850,155 mm^2

$c_b = \frac{600.d}{600 + fy} = \frac{600.455,5}{600 + 400} = 273,3$ mm

a_b = 0,85 . c_b = 0,85 . 273,3 = 232,305 mm

f'_s = 600 (c_b-d') / c_b = 600 (273,3 – 44,5) / 273,3 = 412,305 Mpa < f_y = 400 Mpa digunakan f'_y = 400 Mpa

C_c = a_b b . 0,85. f_c = 232,305 . 300 . 0,85 . 25 . 10^{-3} = 1480,944 kN

C_{s1} = A_s . (f'_y - 0,85 . f'_c) = 850,155. (400 – 0,85 . 25) . 10^{-3} = 321,996 kN

T_s = A_s . f'_s = 850,155 . 400 .10^{-3} = 340,062 kN

$P_{n,b}$ = (C_c + C_{s1}) – (T_s)

= (1480,344 + 321,996) – (340,062) = 1462,872 kN.

$P_{U,b}$ = 0,85 . 1462,872 = 950,867 kNm

M_c = C_c (h/2 – a_b/2) = 1480,944 (250 – 232,305/2). 10^{-3} = 198,22 kNm

M_{cs1} = C_{s1} . (h /2 – d') = 321,996 (250 – 44,5) . 10^{-3} = 66,17 kNm

M_{Ts} = T_s . (d – h/2) = 340,062 . (455,5 – 250) 10^{-3} = 62,182 kNm

$M_{n,b}$ = M_C + M_{cs1} + M_{Ts}

= 198,22 + 66,17 + 62,182 = 332,572 kNm.

$M_{u,b}$ = 0,65 . $M_{n,b}$ = 0,65 . 332,572 = 216,172 kNm.

$e_b = \frac{M_{n,b}}{P_{n,b}} = \frac{332572}{1462872} = 231{,}443$ mm >e = 63,5 mm

$P_{n.} = \frac{A_s.f_y}{(e/d - d') + 0{,}5} + \frac{b.h.f'_c}{(3.h.e)/d^2 + 1{,}18}$

$= \frac{850{,}155.400}{(231{,}443/455{,}5 - 44{,}5) + 0{,}5} + \frac{300.500.25}{(3.500.231{,}443)/454{,}5^2 + 1{,}18}$

$= 319{,}907 + 1312{,}565 = 1632{,}474$ kN

$P_{u\ Rancang} = 0{,}65\ .\ 1632{,}474 = 1061{,}108$ kN > $P_u = 572{,}32$ kN ..... Ok

$M_n = P_{u,R}\ .\ e = 1061{,}108\ .\ 0{,}231 = 247{,}116$ kNm.

$M_{U,Rancang} = 0{,}65\ .\ 247{,}116 = 159{,}325$ kNm > $M_U = 33{,}52$ kNm ..... Ok A_s

$$A_{v\,min} = \frac{b_w.s}{3.fy} = \frac{450.250}{3.240} = 156{,}25 \text{ mm}$$

Kontrol Kapasitas geser :

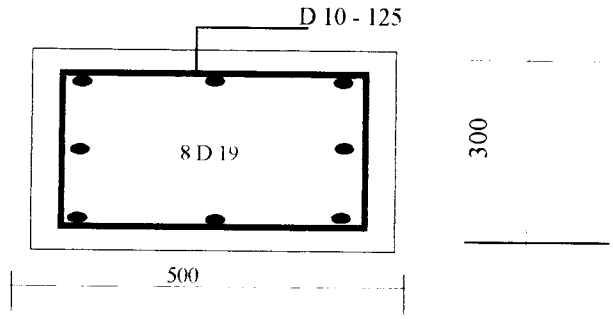
$$V_S = \frac{157{,}14.240.255{,}5}{250}.10^{-3} = 38{,}543 \text{ kN}$$

$$V_{sR} = \varnothing\,(V_s + V_C) = 0{,}6\,.\,(38{,}543 + 95{,}812)$$

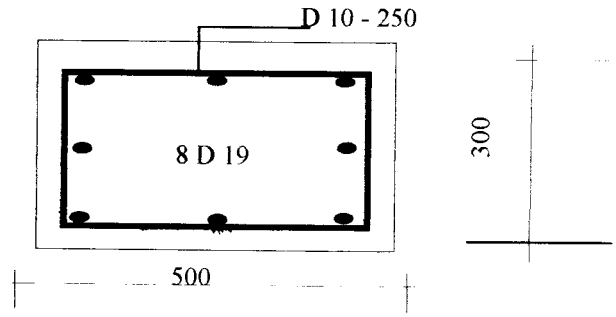
$$= 80{,}613 > V_U = 9{,}40 \text{ kN} \ldots\ldots\ldots\ldots\ldots\text{Ok}$$

jadi tulangn kolom yang dibutuhkan adalah 8D 19

Penulangan pada daerah plastis



Penulangan pada daerah luar plastis



Gambar 4.46 Penampang Kolom pada Daerah Plastis dan Luar Plastis

4.6.2 Tulangan Geser

Dari hasil analisa struktur portal (Portal melintang) untuk batang 20 kolom 4 lantai 1 diperoleh :

$V_U = 9{,}4$ kN

- Penulangan geser di daerah sendi plastis :

$V_{U/}\phi = 0 + v_s$

$v_s = \frac{9{,}4}{0{,}6} = 15{,}667$ kN

$1/3\ \sqrt{f'c}\ .b\ .\ d = 1/3\ \sqrt{25}\ .450\ .\ 255{,}5 = 191{,}625$ kN > Vs maka $S_{maks} = d/2$

Dipakai sengkang D 10 ($2A_{s1} = ¼\ .\pi\ .\ 10^2 = 78{,}5$ mm^2), Av = 157

$s = (A_v\ .\ f_y\ .\ d)/V_s$

$= \frac{157.240.255{,}5}{15667} = 615$ mm,

Kontrol $s_{maks} = d/2 = 225{,}5/2 = 127{,}75$ mm

$= 8.\ \varnothing_{tul.ul} = 8.\ 19 = 152$ mm

$= 24\ .\ \varnothing_{tul.\ sengkang} = 240$ mm

dipakai tulangan sengkang D 10 - 125 mm

Kontrol kapasitas geser:

$Ø\ V_n > V_u$, $ØV_n = Ø\ V_s$

$Ø\ V_s > V_u$

$Ø\ V_s = (Ø\ A_v\ .\ fy\ d/s)$

$Ø\ V_s = (0{,}6\ .\ 157{,}14\ .\ 240\ .\ 255{,}5/100).10^{-3}$

$= 46{,}251$ kN > $V_u = 9{,}4$ kN.....ok

- Penulangan geser diluar sendi plastis :

$V_c = \frac{1}{6}\sqrt{f'_c}b_w.d = \frac{1}{6}\sqrt{25}.450.255{,}5 = 95{,}812$ kN

$V_s = \frac{V_u}{Ø} - V_c = \frac{9{,}4}{0{,}6} - 95{,}812 = -80{,}145$ kN

Berarti tidak diperlukan sengkang

Digunakan sengkang minimum D10 – 250

($2A_{s1} = ¼\ .\pi\ .\ 10^2 = 78{,}5$)

Tabel 4.16 Perhitungan Kolom Portal Melintang

fy (Mpa) 400 *fc (Mpa)* 25

Lantai	No. Kolom	Dimensi b	Dimensi h	defektif	Agr	Mu	Pu	e	e/h	K	L	r	β	ρ	As	As Dipakai			Cheking Jarak Tul. S (mm)	
		mm	mm	mm	$(mm)^2$	KNm	KN	m							$(mm)^2$	Jml	D	$(mm)^2$	arah x	arah y
Lt. 1	1	500	300	255.5	150000	47.80	380.42	0.12565	0.41884	0.18361	0.07690	0.0075	1	0.008	1125	6	19	1700	186.5	192
	2	500	300	255.5	150000	61.80	837.10	0.31847	1.06158	0.11488	0.12195	0.0075	1	0.008	1125	6	19	1700	186.5	192
	3	500	300	255.5	150000	59.90	896.47	0.99860	3.32866	0.04819	0.16040	0.0075	1	0.008	1125	6	19	1700	186.5	192
	4	500	300	255.5	150000	97.30	991.67	0.09812	0.32706	0.47863	0.15654	0.0075	1	0.008	1125	6	19	1700	186.5	192
	5	500	300	255.5	150000	83.40	472.72	0.09358	0.31193	0.27955	0.08720	0.0075	1	0.008	1125	6	19	1700	186.5	192
Lt. 2	6	500	300	257	150000	75.80	238.01	0.54273	1.80908	0.08360	0.15123	0.0065	1	0.007	975	6	16	1206	191	198
	7	500	300	257	150000	54.20	579.19	0.06682	0.22273	0.43269	0.09637	0.0065	1	0.007	975	6	16	1206	191	198
	8	500	300	257	150000	92.80	534.55	0.17360	0.57868	0.25800	0.14930	0.0065	1	0.007	975	6	16	1206	191	198
	9	500	300	257	150000	80.60	497.07	0.55183	1.83945	0.08431	0.15509	0.0065	1	0.007	975	6	16	1206	191	198
	10	500	300	257	150000	84.70	279.00	0.07383	0.24609	0.40403	0.09943	0.0065	1	0.007	975	6	16	1206	191	198
Lt. 3	11	350	250	208.5	87500	99.70	99.84	0.16215	0.64860	0.41128	0.26676	0.0065	1	0.007	568.75	6	13	796	120.5	154
	12	350	250	208.5	87500	94.00	173.20	0.50882	2.03528	0.13416	0.27304	0.0065	1	0.007	568.75	6	13	796	120.5	154
	13	350	250	208.5	87500	96.40	174.69	0.17643	0.70570	0.39113	0.27602	0.0065	1	0.007	568.75	6	13	796	120.5	154
	14	350	250	208.5	87500	82.50	162.14	0.30358	1.21434	0.23085	0.28033	0.0065	1	0.007	568.75	6	13	796	120.5	154
	15	350	250	208.5	87500	80.90	90.13	0.89759	3.59037	0.07457	0.26775	0.0065	1	0.007	568.75	6	13	796	120.5	154

Tabel 4.17 Perhitungan Kolom Portal Memanjang

fy (Mpa) 400 *fc (Mpa)* 25

Lantai	No. Kolom	Dimensi b	Dimensi h	defektif	Agr	Mu	Pu	e	e/h	K	L	r	β	ρ	As	As Dipakai			Cheking Jarak Tul. S (mm)	
		mm	mm	mm	$(mm)^2$	KNm	KN	m							$(mm)^2$	Jml	D	$(mm)^2$	arah x	arah y
Lt. 1	1	300	500	455.5	150000	60.59	436.53	0.13880	0.2775983	0.2106932	0.05849	0.0065	1	0.0065	975	6	19	1700.3	96	373
	2	300	500	455.5	150000	36.73	648.43	0.18152	0.3630418	0.1224977	0.04447	0.0065	1	0.0065	975	6	19	1700.3	96	373
	3	300	500	455.5	150000	35.29	551.40	#DIV/0!	#DIV/0!	0	#DIV/0!	0.0065	1	0.0065	975	6	19	1700.3	96	373
	4	300	500	455.5	150000	35.66	580.35	0.05664	0.113289	0.3129677	0.03546	0.0065	1	0.0065	975	6	19	1700.3	96	373
	5	300	500	455.5	150000	33.52	572.32	0.05050	0.1009994	0.1830275	0.01849	0.0065	1	0.0065	975	6	19	1700.3	96	373
	6	300	500	455.5	150000	35.36	580.06	0.26712	0.5342334	0.0550564	0.02941	0.0065	1	0.0065	975	6	19	1700.3	96	373
	7	300	500	455.5	150000	9.22	572.08	0.06400	0.1280015	0.2661357	0.03407	0.0065	1	0.0065	975	6	19	1700.3	96	373
	8	300	500	455.5	150000	8.89	578.91	0.06257	0.1251491	0.1538027	0.01925	0.0065	1	0.0065	975	6	19	1700.3	96	373
	9	300	500	455.5	150000	14.46	356.67	0.17467	0.3493369	0.0469478	0.01640	0.0065	1	0.0065	975	6	19	1700.3	96	373
Lt. 2	10	300	500	457	150000	46.07	253.80	0.06145	0.1228914	0.2801086	0.03442	0.005	1	0.005	750	6	16	1205.8	99	382
	11	300	500	457	150000	19.15	379.21	0.05736	0.1147114	0.1632531	0.01873	0.005	1	0.005	750	6	16	1205.8	99	382
	12	300	500	457	150000	19.94	318.66	0.16502	0.330035	0.0482896	0.01594	0.005	1	0.005	750	6	16	1205.8	99	382
	13	300	500	457	150000	19.4	338.24	0.05857	0.1171373	0.2762329	0.03236	0.005	1	0.005	750	6	16	1205.8	99	382
	14	300	500	457	150000	18.63	333.48	0.05587	0.1117308	0.1609557	0.01798	0.005	1	0.005	750	6	16	1205.8	99	382
	15	300	500	457	150000	13.02	338.09	0.16723	0.3344516	0.0474787	0.01588	0.005	1	0.005	750	6	16	1205.8	99	382
	16	300	500	457	150000	13.18	333.40	0.06096	0.1219184	0.2799686	0.03413	0.005	1	0.005	750	6	16	1205.8	99	382
	17	300	500	457	150000	12.4	335.94	0.03851	0.0770209	0.1631807	0.01257	0.005	1	0.005	750	6	16	1205.8	99	382
	18	300	500	457	150000	26.53	205.01	0.14811	0.2962296	0.0482606	0.01430	0.005	1	0.005	750	6	16	1205.8	99	382
Lt. 3	19	250	350	308.5	87500	43.9	75.16	0.01612	0.0460475	0.4733435	0.02180	0.005	1	0.005	437.5	6	13	795.99	77	241
	20	250	350	308.5	87500	30.47	114.07	0.03953	0.1129488	0.2758578	0.03116	0.005	1	0.005	437.5	6	13	795.99	77	241
	21	250	350	308.5	87500	16.99	97.27	0.16024	0.457822	0.0765766	0.03506	0.005	1	0.005	437.5	6	13	795.99	77	241
	22	250	350	308.5	87500	16.51	100.05	0.01536	0.0438756	0.4789947	0.02102	0.005	1	0.005	437.5	6	13	795.99	77	241
	23	250	350	308.5	87500	16.45	98.37	0.03691	0.105461	0.2779594	0.02931	0.005	1	0.005	437.5	6	13	795.99	77	241
	24	250	350	308.5	87500	14.81	99.99	0.13915	0.3975795	0.0836013	0.03324	0.005	1	0.005	437.5	6	13	795.99	77	241
	25	250	350	308.5	87500	14.83	92.55	0.04054	0.1158334	0.2951116	0.03418	0.005	1	0.005	437.5	6	13	795.99	77	241
	26	250	350	308.5	87500	14.06	101.04	0.12941	0.3697381	0.1696269	0.06272	0.005	1	0.005	437.5	6	13	795.99	77	241
	27	250	350	308.5	87500	26.61	58.62	0.45394	1.2969732	0.0485027	0.06291	0.005	1	0.005	437.5	6	13	795.99	77	241

Tabel 4.17 Perhitungan Tulangan Geser Kolom Portal Melintang

f_y *(Mpa)* f_c *(Mpa)*

240 *25*

Lantai	No. Kolom	Dimensi		defektif	Vu	Tul Geser di Daerah Sendi Plastis				Kontrol				Tulangan Geser di Luar sendi Plastis					Kontrol				
		b	h			Vu/ ø	Av	S	Tulangan	Av min		ø vs		Vc	Vs	Av	S	Tulangan	Av min		Vs	ø (Vs + Vc)	
		mm	mm	mm	mm	kN	mm^2	mm	$f_p - S_{pakai}$	mm^2	Cek	kN	Cek	kN	kN	mm^2	mm	$f_p - S_{pakai}$	mm^2	Cek	kN	kN	Cek
Lt. 1	1	500	300	255.5	5.06	8.433	157	1142	125	86.81	Ok	46.2108	Ok	106	-98.03	157	250	250	173.611	ok	38.5	86.98	ok
	2	500	300	255.5	11.02	18.367	157	1508	125	86.81	Ok	46.2108	Ok	106	-100.08	157	250	250	173.611	ok	38.5	86.98	ok
	3	500	300	255.5	10.34	17.233	157	960	125	86.81	Ok	46.2108	Ok	106	-96.43	157	250	250	173.611	ok	38.5	86.98	ok
	4	500	300	255.5	9.4	15.667	157	615	125	86.81	Ok	46.2108	Ok	106	-90.79	157	250	250	173.611	ok	38.5	86.98	ok
	5	500	300	255.5	9.49	15.817	157	1109	125	86.81	Ok	46.2108	Ok	106	-97.78	157	250	250	173.611	ok	38.5	86.98	ok
Lt. 2	6	500	300	257	6.02	10.033	157	2343	125	86.81	Ok	46.482	Ok	107	-102.95	157	250	250	173.611	ok	38.7	87.49	ok
	7	500	300	257	5.21	8.683	157	562	125	86.81	Ok	46.482	Ok	107	-89.85	157	250	250	173.611	ok	38.7	87.49	ok
	8	500	300	257	6.09	10.150	157	954	125	86.81	Ok	46.482	Ok	107	-96.93	157	250	250	173.611	ok	38.7	87.49	ok
	9	500	300	257	6.61	11.017	157	1665	125	86.81	Ok	46.482	Ok	107	-101.27	157	250	250	173.611	ok	38.7	87.49	ok
	10	500	300	257	8.05	13.417	157	527	125	86.81	Ok	46.482	Ok	107	-88.72	157	250	250	173.611	ok	38.7	87.49	ok
Lt. 3	11	350	250	208.5	3.83	6.383	157	713	125	60.76	Ok	37.7101	Ok	61	-49.80	157	250	250	121.528	ok	31.4	55.34	ok
	12	350	250	208.5	2.48	4.133	157	1196	125	60.76	Ok	37.7101	Ok	61	-54.25	157	250	250	121.528	ok	31.4	55.34	ok
	13	350	250	208.5	3.49	5.817	157	497	125	60.76	Ok	37.7101	Ok	61	-45.00	157	250	250	121.528	ok	31.4	55.34	ok
	14	350	250	208.5	3.94	6.567	157	586	125	60.76	Ok	37.7101	Ok	61	-47.40	157	250	250	121.528	ok	31.4	55.34	ok
	15	350	250	208.5	5.76	9.600	157	818	125	60.76	Ok	37.7101	Ok	61	-51.21	157	250	250	121.528	ok	31.4	55.34	ok

Tabel 4.18 Perhitungan Tulangan Geser Kolom Portal Memanjang

f_y (Mpa) f_c (Mpa)

240 25

Lantai	No. Kolom	Dimensi		defektif	Vu	Tul Geser di Daerah Sendi Plastis				Kontrol				Tulangan Geser di Luar sendi Plastis					Kontrol				
		b	h			Vu/ ø	Av	S	Tulangan	Av min		ø vs		Vc	Vs	Av	S	Tulangan	Av min		Vs	ø (Vs + Vc)	
		mm	mm	mm	mm	kN	mm^2	mm	$f_p - S_{pakai}$	mm^2	Cek	kN	Cek	kN	kN	mm^2	mm	$f_p - S_{pakai}$	mm^2	Cek	kN	kN	Cek
Lt. 1	1	300	500	455.5	24.52	40.87	157	420	250	104.17	Ok	41.19	Ok	114	-73	157	250	250	104.167	ok	68.7	109.5	ok
	2	300	500	455.5	23.15	38.58	157	412	250	104.17	Ok	41.19	Ok	114	-72	157	250	250	104.167	ok	68.7	109.5	ok
	3	300	500	455.5	14.73	24.55	157	578	250	104.17	Ok	41.19	Ok	114	-84	157	250	250	104.167	ok	68.7	109.5	ok
	4	300	500	455.5	15.53	25.88	157	445	250	104.17	Ok	41.19	Ok	114	-75	157	250	250	104.167	ok	68.7	109.5	ok
	5	300	500	455.5	14.52	24.20	157	947	250	104.17	Ok	41.19	Ok	114	-96	157	250	250	104.167	ok	68.7	109.5	ok
	6	300	500	455.5	15.36	25.60	157	1002	250	104.17	Ok	41.19	Ok	114	-97	157	250	250	104.167	ok	68.7	109.5	ok
	7	300	500	455.5	1.78	2.97	157	699	250	104.17	Ok	41.19	Ok	114	-89	157	250	250	104.167	ok	68.7	109.5	ok
	8	300	500	455.5	14.85	24.75	157	1740	250	104.17	Ok	41.19	Ok	114	-104	157	250	250	104.167	ok	68.7	109.5	ok
	9	300	500	455.5	14.97	24.95	157	4881	250	104.17	Ok	41.19	Ok	114	-110	157	250	250	104.167	ok	68.7	109.5	ok
Lt. 2	10	300	500	457	25.00	41.67	157	665	250	104.17	Ok	41.33	Ok	114	-88	157	250	250	104.167	ok	68.9	109.9	ok
	11	300	500	457	10.87	18.12	157	1622	250	104.17	Ok	41.33	Ok	114	-104	157	250	250	104.167	ok	68.9	109.9	ok
	12	300	500	457	5.92	9.87	157	4633	250	104.17	Ok	41.33	Ok	114	-111	157	250	250	104.167	ok	68.9	109.9	ok
	13	300	500	457	6.37	10.62	157	712	250	104.17	Ok	41.33	Ok	114	-90	157	250	250	104.167	ok	68.9	109.9	ok
	14	300	500	457	5.92	9.87	157	1745	250	104.17	Ok	41.33	Ok	114	-104	157	250	250	104.167	ok	68.9	109.9	ok
	15	300	500	457	6.22	10.37	157	4761	250	104.17	Ok	41.33	Ok	114	-111	157	250	250	104.167	ok	68.9	109.9	ok
	16	300	500	457	5.81	9.68	157	673	250	104.17	Ok	41.33	Ok	114	-89	157	250	250	104.167	ok	68.9	109.9	ok
	17	300	500	457	5.94	9.90	157	1661	250	104.17	Ok	41.33	Ok	114	-104	157	250	250	104.167	ok	68.9	109.9	ok
	18	300	500	457	15.18	25.30	157	5040	250	104.17	Ok	41.33	Ok	114	-111	157	250	250	104.167	ok	68.9	109.9	ok
Lt. 3	19	250	350	308.5	17.82	29.70	157	3918	250	86.81	Ok	27.90	Ok	64	-61	157	250	250	86.806	ok	46.5	66.5	ok
	20	250	350	308.5	10.28	17.13	157	1200	250	86.81	Ok	27.90	Ok	64	-55	157	250	250	86.806	ok	46.5	66.5	ok
	21	250	350	308.5	2.11	3.52	157	4500	250	86.81	Ok	27.90	Ok	64	-62	157	250	250	86.806	ok	46.5	66.5	ok
	22	250	350	308.5	2.23	3.72	157	470	250	86.81	Ok	27.90	Ok	64	-40	157	250	250	86.806	ok	46.5	66.5	ok
	23	250	350	308.5	2.17	3.62	157	1174	250	86.81	Ok	27.90	Ok	64	-54	157	250	250	86.806	ok	46.5	66.5	ok
	24	250	350	308.5	2.05	3.42	157	3918	250	86.81	Ok	27.90	Ok	64	-61	157	250	250	86.806	ok	46.5	66.5	ok
	25	250	350	308.5	1.55	2.58	157	466	250	86.81	Ok	27.90	Ok	64	-39	157	250	250	86.806	ok	46.5	66.5	ok
	26	250	350	308.5	1.78	2.97	157	459	250	86.81	Ok	27.90	Ok	64	-39	157	250	250	86.806	ok	46.5	66.5	ok

4.6.3 Perhitungan Interaksi Kolom

Diketahui :

Perhitungan kolom : 300 mm x 450 mm

Ukuran kolom : 135000 mm

Tulangan terpasang : 8 buah D 19

Fc : 25 Mpa

Fy : 400 Mpa

As_1 = 3 D 19 = 850,155 mm^2 ⟶ d_1 = 44,5 mm

As_2 = 2 D 19 = 566,77 mm^2 ⟶ d_2 = 150 mm

As_3 = 3 D 19 = 850,155 mm^2 ⟶ d_3 = 255,5 mm

As total = 2267,08 mm^2

Perhitungan pada kondisi c = 300 mm

a = 0,85 . c

= 0,85 . 300 = 255 mm

s_1 = 0,003 . (c – d_1) / c

= 0,003 . (300 – 44,5) / 300

= 0,00255

s_2 = 0,003 . (c – d_2) /c

= 0,003 . (300 – 150) / 300

= 0,0015

s_3 = 0,003 . (c –d_3) / c

= 0,003 . (300 – 255,5) / 300

= 0,000445

s_1 > 0,002, maka

c_{s1} = fy .As1

= 400 .0,850155

= 340,062 kN

s_2 < 0,002, maka

c_{s2} = s_2 . Es . As_2

= 0,0015 . 200000 . 0,56677

= 170,031 kN

$s_3 < 0{,}002$, maka

$c_{s3} = s_3 \cdot Es \cdot As_3$

$= 0{,}000445 \cdot 200000 \cdot 850{,}155$

$= 75{,}663$ kN

$c_{si} = cs_1 + cs_2 + cs_3$

$= 340{,}062 + 170{,}031 + 75{,}663$

$= 585{,}756$ kN

$c_c = 0{,}85 \cdot f_c \cdot a \cdot b$

$= 0{,}85 \cdot 25 \cdot 255 \cdot 500$

$= 2709{,}375$ kN

$Pn_1 = c_c + cs_1$

$= 2709{,}375 + 585{,}756$

$= 3295{,}131$ kN

$Mn_1 = c_c \cdot (1/2 \cdot h - 1/2\ a) \cdot 10^{-3} + Cs_1 \cdot (d_2 - d_1 \cdot 10^{-3} + Cs_2 \cdot (d_3 - d_2) \cdot 10^{-3} - cs_3 \cdot (1/2 \cdot b - d_3) \cdot 10^{-3}$

$= 2709{,}375 \cdot (300/2 - 255/2) \cdot 10^{-3} + 585{,}756 \cdot (150 - 44{,}5) \cdot 10^{-3} + 170{,}031 \cdot (255{,}5 - 150) \cdot 10^{-3} - 75{,}663 \cdot (500/2 - 255{,}5) \cdot 10^{-3}$

$= 123{,}173$ kNm

$Pn_2 = 0{,}65 \cdot Pn_1$

$= 0{,}65 \cdot 3295{,}131$

$= 2141{,}835$ kNm

$Mn_2 = 0{,}65 \cdot Mn_1$

$= 0{,}65 \cdot 123{,}173$

$= 80{,}062$. kNm

$e = \frac{Mn_2}{Pn_2}$

$= \frac{80{,}062}{2141{,}835} = 0{,}0375$ kNm

4.6.4. Kontrol Biaksial Kolom

Untuk mengontrol kekuatan biaksial dari kolom maka pada perhitungan ini dignakan metode blesler.

a. Perhtiungan Kapasitas Kolom

Diketahui :

Ukuran kolom : 300 mm x 500 mm

Luas kolom : 150000 mm

Tulangan terpasang : 8 buah D 19

fc : 25 MPa

f_y : 400 MPa

As_1 = 3 D 19 = 850,155 mm^2 ⟶ d_1 = 44,5 mm

As_2 = 2 D 19 = 566,77 mm^2 ⟶ d_2 = 150 mm

As_3 = 3 D 19 = 850,155 mm^2 ⟶ d_3 = 255,5 mm

As total = 2267,08 mm^2

$$cb = \frac{600.d}{600+fy} = \frac{600.255,5}{600+400} = 153,3$$

ab = 0,85 . cb = 0,85 . 153,3 = 130,305 mm

f'_c = 600 . (cb – d_1) / cb

= 600 . (153,3 – 44,5) / 153,3 = 425,831 Mpa > fy = 400 Mpa

Perhitungan pada kondisi c = 153,3 mm

a = 0,85 . c

= 0,85 . 153,3 = 130,305 mm

s_1 = 0,003 . (c – d_1) / c

= 0,003 . (153,3 – 44,5) / 153,3

= 0,00212

s_2 = 0,003 . (c – d_2) /c

= 0,003 . (153,3 – 150) / 153,3

= 0,000064

s_3 = 0,003 . (c –d_3) / c

= 0,003 . (153,3 – 255,5) / 153,3

= - 0,002

$s_1 > 0{,}002$, maka

$c_{s1} = fy \cdot A_{s1}$

$= 400 \cdot 0{,}850155$

$= 340{,}062$ kN

$s_2 < 0{,}002$, maka

$c_{s2} = s_2 \cdot Es \cdot As_2$

$= 0{,}000064 \cdot 200000 \cdot 0{,}56677$

$= 7{,}254$ kN

$s_3 < 0{,}002$, maka

$c_{s3} = s_3 \cdot Es \cdot As_3$

$= -0{,}002 \cdot 200000 \cdot 0{,}850155$

$= -340{,}062$ kN

$c_{si} = cs_1 + cs_2 + cs_3$

$= 340{,}062 + 7{,}254 + -340{,}062$

$= 7{,}254$ kN

$c_c = 0{,}85 \cdot f_c \cdot a \cdot b$

$= 0{,}85 \cdot 25 \cdot 130{,}305 \cdot 500$

$= 1384{,}5$ kN

$Pn_1 = c_c + cs_1$

$= 1384{,}5 + 7{,}254$

$= 1391{,}744$ kN

$Mn_1 = c_c \cdot (1/2 \cdot h - 1/2\ a) \cdot 10^{-3} + cs_1 \cdot (d_2 - d_1) \cdot 10^{-3} + cs_2 \cdot (d_3 - d_2) \cdot 10^{-3} - cs_3 \cdot (1/2 \cdot b - d_3) \cdot 10^{-3}$

$= 1384{,}5 \cdot (300/2 - 130{,}305/2) \cdot 10^{-3} + 340{,}062 \cdot (150 - 44{,}5) \cdot 10^{-3} + 7{,}254 \cdot (255{,}5 - 150) \cdot 10^{-3} - 340{,}062 \cdot (500/2 - 255{,}5) \cdot 10^{-3}$

$= 117{,}71 + 35{,}876 + 0{,}765 + 1{,}87$

$= 155{,}982$ kNm

b. Kontrol kekuatan Kolom dengan Bresler

$P_{nox} = P_{noy} = 1391{,}744$ kN

$M_{nox} = M_{noy} = 155{,}982$ kNm

$P_{no} = 2141{,}835$ kN (tabel interaksi kolom 300 x 500)

P_u (analisis SAP 2000) $= 991{,}67$ kN

M_{ux} (analisis SAP 2000) $= 97{,}3$ kNm

M_{uy} (analisis SAP 2000) $= 6{,}87$ kNm

$$\frac{Pu}{\phi} = \frac{991{,}67}{0{,}65} = 1525{,}6 \text{ kNm}$$

$$\frac{Mux}{\phi} = \frac{97{,}3}{0{,}65} = 149{,}692 \text{ kNm}$$

$$\frac{Muy}{\phi} = \frac{6{,}87}{0{,}65} = 10{,}57 \text{ kNm}$$

$Pn = 0{,}1 \cdot fc \cdot b \cdot h = 0{,}1 \cdot 25 \cdot 500 \cdot 300 = 375$ kN

- **Blesler Restripocal**

$$\frac{1}{Pn} = \frac{1}{Pnox} + \frac{1}{Pnoy} + \frac{1}{Pno} < 1$$

$$\frac{1}{375} = \frac{1}{1391{,}74} + \frac{1}{1391{,}74} + \frac{1}{2141{,}835} \Rightarrow 0{,}002 < 1$$

- **Blesler Load Countour**

$$\left(\frac{Mnx}{Mnox}\right)^2 + \left(\frac{Mny}{Mnoy}\right)^2 < 1$$

$$\left(\frac{149{,}692}{155{,}982}\right)^2 + \left(\frac{10{,}57}{155{,}982}\right)^2 \Rightarrow 0{,}924 < 1$$

- **Farme Load Countour**

$$\left(\frac{Mny}{Mnoy}\right)^2 + \left(\frac{Mnx(1-\beta)}{Mnoy.\beta}\right)^2 < 1$$

$$\left(\frac{10{,}57}{155{,}982}\right)^2 + \left(\frac{149{,}692(1-0{,}35)}{155{,}982.0{,}65}\right)^2 \Rightarrow 0{,}925 < 1$$